The Heritage Foundation

SPECIAL REPORT

No. 245 | APRIL 27, 2021

Rebuilding America's Military: The United States Space Force

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CENTER FOR NATIONAL DEFENSE

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The Rebuilding America's Military Project

This *Special Report* is the sixth in a series from the *Rebuilding America's Military Project* of The Heritage Foundation's Center for National Defense, which addresses the U.S. military's efforts to prepare for future challenges and rebuild a military depleted after years of conflict in the Middle East and ill-advised reductions in both funding and end strength.

The first paper in this series (Dakota L. Wood, "Rebuilding America's Military: Thinking About the Future," Heritage Foundation *Special Report* No. 203, July 24, 2018) provides a framework for understanding how we should think about the future and principles for future planning.

The second (Dakota L. Wood, "Rebuilding America's Military: The United States Marine Corps," Heritage Foundation *Special Report* No. 211, March 21, 2019) discusses the current status of the U.S. Marine Corps and provides prescriptions for returning the Corps to its focus as a powerful and value-added element of U.S. naval power.

The third (Thomas W. Spoehr, "Rebuilding America's Military: The United States Army," Heritage Foundation *Special Report* No. 215, August 22, 2019) provides context and recommendations on how the U.S. Army should approach planning for future conflicts out to the year 2030.

The fourth (John Venable, "Rebuilding America's Military: The United States Air Force," Heritage Foundation *Special Report* No. 223, March 26, 2020) examines the state, status, and mindset of today's Air Force, evaluates critical aspects of the service, and recommends specific policies and actions that the Air Force needs to pursue to prepare itself for future conflicts out to the year 2040.

The fifth (Brent Sadler, "Rebuilding America's Military: The United States Navy," Heritage Foundation *Special Report* No. 242, February, 18 2021) provides a road map for deployment of a fleet designed for great-power competition with China and Russia. It proposes a balance between readiness and forward presence, peacetime competition and warfighting, over the critical 2021–2035 time frame.

This paper examines the impact of service concepts, doctrine, and plans to provide context for the state, status, and mindset of today's Space Force. It then evaluates critical aspects of the service and recommends specific policies and actions that the Space Force needs to pursue to prepare itself for future conflicts. As an organization, the Space Force is evolving rapidly, and details associated with the number of personnel, active organizational components, and the like that were current at publication will certainly change during the coming months and years.

This paper, in its entirety, can be found at **http://report.heritage.org/sr245**

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Rebuilding America's Military: The United States Space Force

John Venable

The U.S. Space Force should increase its situational awareness platforms, diversify its portfolio of satellites from low earth orbit to geosynchronous equatorial orbit, and expand its military and commercial platforms to increase resilience. The USSF needs to master SmallSat and CubeSat systems' offensive capabilities and develop doctrine for every conceivable counterspace mission. Partnership with civil and commercial organizations has increased capabilities while reducing cost and almost every measure of risk, and development of those ties should continue. The USSF should also complete the transfer of Air Force personnel into its ranks by the end of FY 2021. Congress should grant the USSF the authorities required to transfer and absorb all appropriate DOD space organizations, assets, and personnel to maximize their warfighting potential.

Executive Summary

The U.S. Space Force (USSF) was established on December 20, 2019, when President Donald Trump signed the 2020 National Defense Authorization Act (NDAA) into law. This new service is the second within the Department of the Air Force and reports directly to the Secretary of the Air Force with the mission to organize, train, and equip space forces for joint warfighting commanders.

The importance of the space domain has been recognized by every U.S. President since Dwight Eisenhower, and the lines of organization and governmental space structure that are present today have their origins in his Administration. By the end of 1961, the National Aeronautics and Space Administration (NASA) and the National Reconnaissance Office (NRO) had been established, and the Army, Navy, and Air Force had developed their own independent space programs.

By the end of the Eisenhower Administration, the splintering of space command and control within the Department of Defense (DOD) had taken hold, as had the President's policy of "peaceful uses of outer space." Those two predilections would be sustained by every Administration for the next five decades, effectively preventing DOD from even recognizing this critical arena as a warfighting domain through the early 2010s.

Following early Soviet wins and very public U.S. stumbles in the early 1960s, the U.S. space program began to gain traction. Before the 10th anniversary of John Glenn's historic Mercury 7 flight in 1962, NASA would successfully launch six manned missions to the surface of the moon and begin framing what would become the Space Shuttle program. By 1991, the U.S. civil space program was well ahead of the rest of the world, and while space within DOD was still splintered across multiple lines of effort, it was also thriving.

DOD's space support missions during Operation Desert Storm displayed America's competitive edge. Russia and China recognized both the effectiveness of and the growing U.S. dependence on space through that conflict and began to move against it. In 2000, in an effort to stay one step ahead of their efforts, Congress directed a study of space command and control (C2) within the Defense Department. The Rumsfeld Commission report that followed detailed a splintered, dysfunctional C2 structure and recommended that Congress establish a Space Corps within the Department of the Air Force to fix it. Unfortunately, those efforts were overtaken by the 9/11 terrorist attacks.

In the years since then, China and Russia have developed kinetic anti-satellite weapons (ASATs); high-powered lasers; laser dazzling or blinding; and high-powered microwave systems that now put the U.S. military and civilian satellite constellations at risk. Until very recently, the United States had not taken steps to protect those systems, much less to develop its own warfighting capability in that domain.

In 2017, Congress again studied the issue and found that the space assets within DOD were "led" by six different organizations that managed requirements and eight others that managed acquisition with no single entity or individual in charge of either process. The results of that study coupled with four Space Policy Directives led to the reestablishment of a combatant command (Space Command) and the Space Force in 2019.

The 2020 NDAA limited the new service to the assets and personnel available with the Air Force. As of December 2020, 3,000 airmen, 77 satellites, and five Air Force wings have been transferred from the Air Force to the Space Force. Although these are positive moves, the transfer process is moving too slowly and as currently authorized will still fall well short of streamlining the C2 challenges within DOD.

The Army and Navy have a total of 23 acknowledged satellites and as many as 21,000 space professionals located in organizations at facilities throughout the United States. Those numbers exclude dormant satellites, an estimated 54 classified Navy and NRO systems, and nine National Oceanic and Atmospheric Administration (NOAA) weather satellites. The services and agencies manage their own systems, so most of the bureaucratic weight and C2 issues that the Space Force was designed to solve are still present. Five of the six organizations that managed requirements and all of the eight that managed acquisition before the 2020 NDAA became law are still in place.

Many of those other service satellites are scheduled to transfer to the USSF over the next several years, but the disposition of the remaining systems is unknown, and if those satellites are withheld, many of the C2 challenges the Space Force was created to resolve will persist. While there are mission sets and relationships beyond DOD that will make complete consolidation untenable, other transfers can and should happen expeditiously. The entire portfolio of Army and Navy satellites should transfer to the Space Force along with key facilities and personnel.

The NRO operates under Title 50 of the U.S. Code, and the missions and reporting exemptions enabled by those authorities must be sustained for relevant, highly sensitive, clandestine operations. Air Force personnel account for a significant portion of the NRO's workforce, and many will eventually transfer to the Space Force. Their mission sets and equipment should be reviewed, and those that can be accomplished under Title 10 authorities should be transferred to the Space Force along with the on-orbit systems and personnel that execute those missions.

The operations for systems and satellites that remain in the NRO beyond that review, along with those of NOAA, and NASA should be moved to within the space operations center for military, intelligence, civil, and commercial operations known as National Space Defense Center if they are not already there. This will ensure streamlined command and control of U.S. space assets that reside outside of the Space Force and expedite maneuvers in response to directions from the Commander of U.S. Space Command (USSPACECOM).

Given the limited number of spaceborne systems in DOD's portfolio, losing just a small number of those satellites could significantly impact operational capabilities across the department. Defending those assets begins with space situational awareness (SSA). The USSF has just six dedicated satellites and six dedicated terrestrial-based sites, like the Space Fence located on Kwajalein Atoll in the Pacific, that help to maintain situational awareness on satellites and other objects in space. There also are other land-based tracking sites, but those systems have other primary roles and are not always available. The gaps between the space-based and terrestrial-based sensors are covered by track prediction, which works well until an adversary satellite elects to move.

The number of U.S. military and commercial, as well as allied and adversary, satellites may double over the next three years. Those numbers alone will challenge the current Space Surveillance Network (SSN), but advances in small satellite (SmallSat) propulsion and control will cause announced and unannounced orbital changes to be much more frequent, making it that much more difficult to keep tabs on bad actors.

Two more SSA satellites will be launched in 2021, but the U.S. will still have far too few sensors to monitor the satellites of our increasingly aggressive peers. The Space Force should field a new constellation of less costly surveillance platforms in low earth orbit (LEO) to cover the current gaps in coverage and handle the influx of hostile SmallSats that is on the horizon. At a minimum, a second, strategically located Space Fence should be funded and built as soon as possible.

Defensive measures that the Space Force can take to increase survivability include increasing the number of deployed assets and diversifying their orbital location, as well as defensive maneuvering, and self-protection capabilities.

Shortly before the USSF became an independent service, the Air Force openly stated its desire to build a constellation of thousands of SmallSats weighing less than 500 kilograms (roughly 1,100 pounds) for communications; position, navigation, and timing (PNT); imaging; and collection capabilities in LEO to provide a diversified, redundant portfolio of capabilities. It is has become apparent that those expanding constellations will be comprised of both military and civilian satellites.

Since America's earliest days in space, the efforts of DOD and the civil space exploration program have been closely linked. In more recent years, the growth and influence of commercial space organizations have furthered the efforts of both civil and military space programs to the point that the well-being of each will rely on the health, efforts, and interactions with the other two.

Today, the only U.S. option for getting civilian, commercial, and military payloads into space is a commercial rocket. In 2019, just three U.S. commercial space launch organizations were actively launching satellites into orbit.

That number doubled in 2020, and the inherent competition has driven down the cost per launch, giving DOD greater and more cost-effective access to this domain. The expanding commercial space launch capability will enable the service to deploy new systems in an accelerated fashion to fill shortfalls or replace combat losses with a nearly on-demand capability.

But launch services is just one part of an ever-expanding military–commercial relationship. Commercial communications and remarkably capable collection and imaging satellites, as well as space services (refueling/propulsion) and repair, are being fielded at an incredible pace. Each of those capabilities will fill gaps and reduce risk across the spectrum of Space Force operations.

The Army and Navy now appear to be employing a constellation of 600 LEO-based SpaceX Starlink SmallSats, part of a constellation that will grow to more than 4,500 satellites by the end of 2023. Those satellites likely already provide communications links to tactical units and may eventually provide alternative PNT services in GPS-denied areas. Other U.S. and allied satellite companies are providing DOD with on-demand signals intelligence (SIGINT) imaging, such as Synthetic Aperture Radar (SAR) with incredible 25-centimeter (10-inch) resolution from LEO-based SmallSats.

There is little doubt that the Space Force already relies heavily on the technology and support provided by the civil and commercial space sectors, and that reliance will only grow stronger. The U.S. has fostered relationships with those companies over years of investments and service subscriptions, and while it has already embraced the commercial sector, the USSF should continue to encourage their growth and the strength of what is now a symbiotic relationship. Exceptional capabilities aside, those systems and services deliver resilience and increase the survivability of the space network of satellites available to DOD. There will be a tendency for legacy organizations like Space and Missile Command to maintain their cadence and the business models that fielded big expensive satellites. It will take deliberate ongoing pressure from the leadership both within and beyond the USSF to shift that paradigm to field systems that are more affordable and survivable.

Detecting and being able to attribute attacks is critical to sustaining a viable satellite constellation. The USSF recently fielded a system called Bounty Hunter that can detect, locate, and minimize the effects of threat interference with satellite communications. Having a variety of sensors that can detect, identify, and obtain accurate information on the location of threats is critical to sustaining a viable network of high-value satellites. Fielding a sensor package mounted on satellites that can detect and report hostile engagement to operators who can counter those actions is critical to both satellite defense and threat attribution. Those systems are likely already in place, but if they are not, the Space Force should move to develop and field them on future systems.

Offensive operations seize strategic locations in space, deny adversaries access to their space assets, and prevent them from moving to deny access to your own. War games have proven time and time again that a strategy based solely on defensive measures causes the U.S. to lose a war in this domain. Offensive operations can deliver effects that are temporary or permanent and hard to attribute to an offender or easily determined. The spectrum of permanence and attribution runs in parallel with the progression of deceive, disrupt, degrade, and destroy.

The debris generated by a Chinese ASAT test in 2007 increased the total trackable space object population by an estimated 25 percent, and it is not expected (at least in the near term) that the Space Force will develop kinetic systems that will contribute more debris to the domain. Little else is known about other offensive space-based systems that may already exist in the Space Force, but given recent SmallSat advances in maneuvering and propulsion, there is a great deal that can derived.

The U.S. has a constellation of Geosynchronous Space Situational Awareness Program (GSSAP) satellites that can rejoin with and maneuver around other satellites. These satellites are large enough to carry enough fuel for regular rendezvous proximity operation (RPO) maneuvering, and, while the capability has never been seen, may have the ability to "birth" SmallSats weighing just a couple of pounds on counterspace missions.

Since its inception, NASA's Small Spacecraft Technology Program (SSTP) has focused on developing technologies that include propulsion and navigation systems that allow satellites as small as 10 centimeters cubed (CubeSats) to perform precision RPO operations. When carried to a point of intercept by a larger satellite, these CubeSats can be deployed kilometers away from a target satellite and slow for rendezvous and contact. Once attached, the CubeSat's sensor package can collect and report, alter signals, or go dormant until activated. From there, the offensive potential is limited only by imagination, and the service needs to fully develop those capabilities.

The Space Force of the future must increase its space-based and terrestrial-based situational awareness platforms and diversify its portfolio of satellites from LEO out to the orbital distance of the moon (cislunar). It should also move to increase its resilience and the targeting problem for adversaries by significantly expanding its portfolio of military and commercial platforms. The technological advances that NASA has developed for

SmallSat and CubeSat propulsion and navigation have opened the aperture for offensive counterspace operations, and the service needs not just to field and master the offensive capabilities that these systems offer, but also to develop doctrine for every conceivable counterspace mission.

This new service appears to be on the correct trajectory in each of these areas. Its partnership with civil and commercial organizations has delivered big dividends with respect to increasing USSF capabilities while reducing cost and almost every possible measure of risk. The Space Force must continue to develop and deepen those ties.

At the same time, however, it must be noted that the Space Force has not effectively reduced the command and control challenges that it was formed to streamline. It should accelerate the transfer of Air Force personnel into its ranks by the end of fiscal year 2021, and Congress should grant the USSF the authorities it needs to consolidate all appropriate space organizations and personnel within DOD *and* direct that their transfer be completed by the end of FY 2023.

Introduction

The U.S. Space Force (USSF) was created on December 20, 2019, with enactment of the fiscal year (FY) 2020 National Defense Authorization Act (NDAA).[1] Established as the fifth uniformed service within the Department of Defense (DOD) and the second service within the Department of the Air Force (DAF), the USSF resides under the direction and leadership of the Secretary of the Air Force. The NDAA specifies that a four-star general will serve as Chief of Space Operations (CSO) and as a full member of the Joint Chiefs of Staff.

Space was once considered a sanctuary where the only real threat to systems in orbit was the environment itself.[2] While that has not been true for more than 50 years, many of America's current space assets, including those associated with defense, were designed and fielded within that paradigm. Those systems were believed to be capable of staving off a crippling attack by a peer state not because of U.S. space capabilities, but because of the inability of an adversary to deliver such a blow. Unfortunately, Chinese and Russian military designs have targeted U.S. systems since the late 1960s.[3] The number, types, capabilities, and sophistication of those counterspace systems have only grown over the years.[4]

Both China and Russia have developed doctrine, organizations, and capabilities to challenge U.S. access to and operations in space. Concurrently, their use of this domain is expanding significantly. Both nations regard space access and denial as critical components of their national and military strategies,[5] and both are investing heavily in ground-based anti-satellite (ASAT) missiles and orbital ASAT programs[6] that may deliver a kinetic strike capability[7] as well as co-orbital robotic interference that can alter signals and mask denial efforts or even pull adversary satellites necessary for surveillance, navigation, and targeting out of orbit.[8] These nations have demonstrated the capability to put American space assets at risk, and until very recently, the United States had not taken steps to protect those systems, much less to develop its own warfighting capability in the space domain.

The mission of this newest service is to ensure that America's military is fully prepared to fight and win in that environment. Specifically, the Space Force is tasked to organize, train, and equip forces "to protect U.S. and allied interests in space and to provide space capabilities to the joint force." Its responsibilities include "developing Guardians [Space Force personnel], acquiring military space systems, maturing the military doctrine for space power, and organizing space forces to present to our Combatant Commands."[9]

However, that classic roles-and-missions verbiage does not fully convey the challenge that this new service faces. More directly, the Space Force was formed to unify and streamline command and control for space forces and systems within DOD. While that task is challenging enough, there are organizations and entities outside the military that serve as critical enablers for the nation's space defense program. Since America's earliest days in space, the efforts of DOD and the civil space program have been closely linked. In more recent years, the growth and influence of commercial space organizations have furthered the efforts of both civil and military space programs to the point where the well-being of each will rely on the health, efforts, and interactions with the other two.

The analysis of military services operating in other domains generally focuses on the capacity, capability, and readiness of the equipment and personnel within those specific services. Those categories are not nearly as well defined for the Space Force, as its mission in both peace and war relies heavily on the capabilities within other government and commercial space organizations. Understanding how those capabilities add inseparable depth and resiliency to the Space Force is therefore a critical part of this assessment.

For those who have not studied this domain in depth, the terminology and common descriptions used to describe operations in space can quickly become overwhelming. While this paper is written with that in mind, space expert Dean Cheng's primer "Space 201: Thinking About the Space Domain" provides an excellent overview of the operational challenges, considerations, and common references that will prove useful in fully grasping the following analysis.[10]

I. Background

More than any other nation, America has enjoyed the technological advantages of space, and we now rely on it for nearly every aspect of our lives. Banking, commerce, travel, entertainment, the functions of government, and our military all depend on our assets in space. The importance of this domain has been recognized by every U.S. President since Dwight Eisenhower, and the lines of organization and governmental space structure that are present today were formed during a single decade and solidified during a critical five-year period in the latter part of the 1950s.

A. U.S. Department of Defense

After World War II, the power and military effects offered by nuclear weapons were certainly viewed as the future of the Defense Department, but the sheer weight of a nuclear warhead was beyond the lifting capacity of the rocket engine technology available in the 1940s. Over time, miniaturization of nuclear components began to change that perception, and the U.S. government began to conceptualize a platform that could deliver nuclear weapons.

In the spring of 1950, three years before Eisenhower became President, Secretary of Defense Louis Johnson saw space's potential within the military and assigned the Air Force responsibility for long-range strategic missiles, including ICBMs, and "jurisdiction" for military satellites.[11]

The idea for the Atlas intercontinental ballistic missile (ICBM) was actually formed in 1946 but suffered a cycle of cancellations and programmatic rebirths until it entered the design phase in 1953.[12] In 1954, Air Force Chief of Staff General Nathan Twining assigned Atlas the service's top priority,[13] and following the revelation that the Soviets were working on their own ICBM,[14] it became the top national military program in 1955.[15] An Atlas rocket with a 600-mile range was tested successfully in June 1957, and the ICBM system became operational in 1959.[16]

Pairing military satellite jurisdiction with the requirement to develop rockets for ICBMs that could also place satellites in orbit put the Air Force in prime position to control the U.S. military space program. The Air Force claimed defense-support space missions such as communications, reconnaissance, and navigation as inherent airpower responsibilities. It could see real potential in on-orbit anti-satellite and anti-missile systems and wanted to pursue those capabilities.

Any thought of consolidating the military's space program under one service in the 1950s, however, was waylaid by America's first civil space program. The United States wanted to take the lead in a global competition to launch scientific Earth satellites to research the domain of space in an effort known as the International Geophysical Year (IGY).[17] Being the first to place an IGY satellite on orbit in this civil exploration program was certainly a driver, but the precedent it would set was at least as critical for U.S. national security.

In 1954, President Eisenhower established peacetime strategic reconnaissance as a national priority. Satellite technology was still considered years away, which left only air-breathing options to place a sensor in position to observe the activities of the Soviet Union. Anti-aircraft weapons systems of the day were limited in range and altitude, and even though the unauthorized peacetime overflight of another nation's territory by an aircraft could be construed as a hostile act, the President directed the development of what would become the U-2 high-altitude reconnaissance aircraft.[18]

In the interim, the U.S. would move to develop and launch a scientific satellite through the IGY initiative. The overt goal of that program was to gather technical data on space flight, but by launching a satellite that orbited well above the reach of other nation-states' territorial defenses, that "scientific" IGY satellite would establish a precedent that could be used to ensure unrestricted overflight of other nations and territories for the reconnaissance satellites that would follow.[19]

With the weight of the government behind it, the U.S. National Committee for the IGY pressed the National Science Foundation (NSF) for a scientific satellite. The only capability to launch a satellite resided in the military, so the NSF petitioned DOD for a system that could do just that. All three services provided proposals, but the Navy's Vanguard was selected in 1955 over the Army's Orbiter and the Air Force's Atlas rocket proposals.

B. Five Critical Years: 1957–1961

The pace of and expectations for the U.S. space program changed again on October 4, 1957, when the Union of Soviet Socialist Republics (USSR or Soviet Union) launched its own IGY satellite, Sputnik 1. The Soviets followed that success in November with the launch of Sputnik 2. The Navy's first attempt to launch Vanguard came a month after Sputnik 2, but it failed when Vanguard exploded mere feet above the launch pad.[20] The Soviets' back-to-back successes, coupled with Vanguard's very public failure, drove heightened interest and demands from the White House and both chambers of Congress that America's space program be accelerated.

President Eisenhower directed the Army to restart Explorer, an IGY line of effort it had cancelled the previous year. Simultaneously, the Navy moved for a second attempt to launch Vanguard, and the Air Force continued to develop both Atlas and the military's first reconnaissance satellite.

Committees were formed in the Senate and House, and their respective hearings highlighted the need to accelerate America's defense and civil space programs. The resulting legislation, the National Aeronautics and Space Act, was signed by President Eisenhower in July 1958, giving birth to the National Aeronautics and Space Administration (NASA).[21]

The last space organization formed during this period was created, at least in part, as a result of the loss of a U-2 over the Soviet Union. Pilot Francis Gary Powers was shot down and taken prisoner by the Soviets on May 1, 1960. Now desperate for non-air-breathing reconnaissance options, President Eisenhower ordered a review of the Air Force Satellite and Missile Observation System (SAMOS) program, the only reconnaissance satellite project within DOD. Originally, it was intended that the program would be operated by Air Force Strategic Air Command (SAC), but the National Security Council (NSC) recommended that both SAMOS and follow-on reconnaissance satellites should fall under the direction and control of DOD rather than a single military service. That recommendation would give birth to the National Reconnaissance Office (NRO) in 1961.[22]

That same year, the Air Force was named executive agent for space research and development, but by that time, the Army and Navy already had their own well-established programs.[23] By the end of the Eisenhower Administration, the splintering of space command and control within DOD had taken hold, as had the President's policy of "peaceful uses of outer space."[24] Those two preferences would be sustained by every Administration for the next five decades, shaping (often unwittingly) every aspect of space policy and effectively preventing DOD from even recognizing this critical arena as a warfighting domain.

On April 12, 1961, just four years after taking the lead in space with Sputnik, the Soviet Union captured another precedent when it launched the first man into space for a single orbit aboard Vostok 1. Although the United States conducted its first manned space mission 23 days later, Alan Shepard's Mercury 3 spacecraft was launched on a suborbital mission—a ballistic shot into space that lasted just 15 minutes.[25]

Four months after Gagarin's inaugural manned mission, the Soviets executed a second, launching Gherman Titov into space for 25 hours and 17 orbits. John Glenn became the third American in space and the first to reach orbit six months after Titov's mission. Glenn's Friendship 7 capsule splashed down in the North Atlantic after five hours and just three revolutions around the Earth.[26] There was no question that the United States was behind in space.

C. Gaining Traction: 1962–1991

Throughout the Cold War, the competition between the United States and the Soviet Union led to great gains across the spectrum of the U.S. civil and military space programs. Following early Soviet wins in the early 1960s, America's space program began to gain traction.

The acceleration began with President Kennedy's 1962 goal of landing U.S. astronauts on the moon and bringing them home by the end of the decade. Before the 10th anniversary of John Glenn's historic Mercury 7 flight, NASA would successfully launch six manned missions to the surface of the moon[27] and begin framing of the Space Transportation System (Space Shuttle) program. By 1991, NASA had launched 44 Shuttle missions[28] and nine deep space probes[29] and had initiated planning for the International Space Station. The U.S. civil space program was well ahead of the rest of the world, and while the space program within the Defense Department was still splintered across multiple lines of effort, it was also thriving.

Also by 1991, DOD and related agencies had successfully launched more than 300 reconnaissance[30] and 68 navigation satellites including the Navy's Transit Navigation System and the Global Positioning System (GPS). Transit was a service-specific and domain-specific geolocation system with a reported accuracy of one-half of a nautical mile when it became operational in 1964.[31] The Navy's system was replaced over time with incremental launches of GPS satellites, and when Operation Desert Storm began in 1991, that constellation held 16 satellites—eight short of the system's designed complement of 24.[32]

D. U.S. Operational Dominance in Space

The effectiveness of DOD's space support missions was put on display during Operation Desert Storm.[33] While GPS-guided munitions were not yet available, the combination of satellite imagery and the precise geolocation capabilities of GPS elevated U.S. targeting to a new level. The ability to find, fix, and engage targets with laser and infrared guided munitions helped to bring that conflict to a quick end, and adversary nations did much more than take note. They recognized the growing U.S. dependence on space and began to position themselves to move against it.

In 1999, a concerned Congress formed an independent team that became known as the Rumsfeld Commission to assess the organization and management of America's national security space program. The commission's report, issued in January 2001, warned that America's growing dependence on space-based systems, coupled with the vulnerability of its assets in that domain, warranted reorganization. The report recommended that Congress consolidate command and control by ultimately establishing a Space Corps within the DAF until the numbers of qualified personnel, mission requirements, and budget were sufficient to consolidate all DOD space resources into a new military department with the primary mission of providing forces for the conduct of both military and intelligence space operations.[34]

The terrorist attacks of September 11, 2001, however, took precedence over all other programmatic issues, and the commission's recommendations were tabled, allowing the splintered efforts of space organizations within DOD to continue to fester. As a result, by the mid-2010s, the splintering of space oversight within the Defense Department had fragmented command and control into 60 different DOD offices.[35] At the same time, U.S. reliance on GPS for air, land, and sea maneuver, targeting, and engagement had grown to the point of being nearly universal, exposing a critical vulnerability that our adversaries moved to exploit.

In the past two decades, both China and Russia have developed doctrine, organizations, and capabilities to challenge U.S. access to and operations in space, and their use of spaceborne systems is expanding significantly. Both nations regard space access and denial as critical components of their national and military strategies[36] and are investing heavily in ground-based anti-satellite (ASAT) missiles and orbital ASAT programs.[37] Those efforts include co-orbital robotic interference that can alter signals and mask denial efforts, or even pull adversary satellites necessary for surveillance, navigation, and targeting out of orbit.[38] These nations have demonstrated the capability to put American space assets at risk, and until very recently, the United States had not taken steps to protect those systems, much less to organize its own warfighting capability in that domain.

II. Reorganization and Recognition of Space as a Warfighting Domain

Almost 17 years after the Rumsfeld Commission detailed the splintered nature of space command and control within the Defense Department, Congress moved once again to study those challenges. The 2017 NDAA mandated that DOD conduct a review of the organization and command and control of space assets within the department. The final report from that study was issued in August 2018 and recommended a two-phase approach for America to retake the lead in space. The first phase outlined three actions the Administration could take using its inherent authority to develop a credible warfighting capability and ultimately form a new uniformed service to sustain it:

- **Establishing** the Space Development Agency (SDA);
- **Identifying** the space professionals in each of the four military services in the Defense Department; and
- **Creating** a new combatant command for space.

Those elements were critical to enabling the second phase in which Congress would ultimately enact legislation to create the new service.

A. Space Development Agency (SDA)

Designing, acquiring, and fielding systems for America's space program have been concerns ever since the program's inception because of the number of and overlapping responsibilities within the organizations that define the requirements and control the acquisition process.[39] Six different organizations managed requirements,[40] and eight other organizations and offices dealt with acquisition[41] with no single entity or individual in charge of either process. The associated dysfunction has contributed to program delays, cost increases, and even system cancellations.[42]

In 2019, the Trump Administration established the SDA to deal with those issues, tasking the organization "to create and sustain lethal, resilient, threat-driven, and affordable military space capabilities that provide persistent, resilient, global, low-latency surveillance to deter or defeat adversaries."[43] Although this was an excellent step toward streamlining the space requirements and acquisition process, an inordinate number of organizations still control those activities in other departments and agencies. The SDA has had a positive effect on DOD space efforts, but its overall effectiveness will be limited until those organizations are moved into this new agency. The SDA currently reports to the Undersecretary of Defense for Research and Engineering but will be realigned under the U.S. Space Force at the beginning of FY 2023.[44]

B. Identifying the Pool of Space Personnel

As a key step in standing up the Space Force, the Administration directed each of the services, the National Guard, and Reserve to identify their military and civilian space professionals for placement in a pool known as the Space Operations Force. The forces would remain in their respective parent organizations, but they have been identified and will be used to build a Space Force cadre capable of dominating this domain.[45]

C. U.S. Space Command (USSPACECOM)

President Trump completed the third step of the first phase on August 29, 2019,[46] by amending the Unified Command Plan (UCP) to reestablish U.S. Space Command[47] as the 11th combatant command within DOD.[48] As a geographic combatant command, USSPACECOM is now responsible for the region from 100 kilometers (60 miles) above sea level and beyond,[49] with a mission to conduct "operations in, from, and to space to deter conflict and, if necessary, defeat aggression."[50] Currently headquartered at Peterson Air Force Base, Colorado, but announced to move to Huntsville, Alabama, USSPACECOM is commanded by a four-star general, currently U.S. Army General James H. Dickinson.[51]

III. USSF Organization

The USSF Headquarters and Office of the Chief of Space Operations are located in the Pentagon. When Congress authorized the Space Force, it limited the scope of the USSF to Air Force personnel and assets, equating to a total workforce of 27,300[52] comprised of personnel and organizations within five Air Force Wings located at five major installations:

- The 21st Space Wing at Peterson Air Force Base, Colorado;
- The 30th Space Wing at Vandenberg Air Force Base, California;

- The 45th Space Wing at Patrick Air Force Base, Florida;
- The 50th Space Wing at Schriever Air Force Base, Colorado; and
- The 460th Space Wing at Buckley Air Force Base, Colorado.[53]

Those personnel, organizations, and structures will be restructured and rolled into three major field commands that fall directly under the CSO:

- Space Operations Command,
- Space Systems Command, and
- Space Training and Readiness Command.

Each of these commands will lead the next tier of organizations, called Deltas and Garrisons. Deltas are equivalent to Air Force Groups, are led by a colonel, and are tasked with and responsible for specific missions and operations. Garrisons are also the equivalent of Air Force Groups and support Deltas with functions similar to those of Air Force "Base" level command. Squadrons are the fourth and final level of command and will fall under Deltas and Garrisons.

A. Space Operations Command

SpOC was established on October 22, 2020, as the first major USSF field command. Currently located at Peterson Air Force Base, Colorado, SpOC is led by a three-star general and is responsible for organizing, training, and equipping space forces assigned to combatant commands. The already standing SpOC at Vandenberg Air Force Base, California, will be redesignated as SpOC West and will continue to conduct operations in support of combatant commanders.

B. Space Systems Command

Space Systems Command is expected to stand up early in 2021[54] to oversee the development, acquisition, and maintenance of satellites and ground systems, the procurement of SATCOM and launch services, and investments in next-generation technologies. Space Systems Command will be headed by a three-star general who will oversee the Space Force's approximately $12.9 billion annual budget for research, development, test, and evaluation (RDT&E) and the acquisition of new systems.

DOD's primary space procurement agency is currently the Space and Missile Systems Center (SMC), located at Los Angeles Air Force Base, California. When Space Systems Command stands up, it will absorb SMC along with two other procurement agencies: the Commercial Satellite Communications Office, based in Washington, DC,[55] and the Air Force Research Laboratory (AFRL) Space Vehicles Directorate, based at Kirkland Air Force Base, New Mexico.[56]

C. Space Training and Readiness (STAR) Command

STARCOM will be the third USSF field organization and will be based at Peterson Air Force Base, Colorado. STARCOM will be led by a two-star general and will be responsible for the education and training of space professionals.[57] In the interim, a provisional command and foundational element of STARCOM, STAR Delta, stood up in July 2020 to serve as the parent organization for several education, training, test and, evaluation units.[58]

D. Deltas and Garrisons

In July 2020, the CSO reformed three Air Force wings into nine Space Force Deltas and two Garrisons.

- Space Delta 2 replaces the 21st Operations Group at Peterson Air Force Base with a mission focus of space domain awareness.

- Space Delta 3 replaces the 721st Operations Group at Peterson Air Force Base with a mission focus of electronic warfare.

- Space Delta 4 replaces the 460th Operations Group at Buckley Air Force Base with a mission focus of missile warning.

- Space Delta 5 replaces the 614th Air Operations Center at Vandenberg Air Force Base with a mission focus of command and control.

- Space Delta 6 replaces the 50th Network Operations Group at Schriever Air Force Base with a mission focus of cyberspace operations.

- Space Delta 7 is aligned with the 544th Intelligence, Surveillance, and Reconnaissance (ISR) Group at Peterson Air Force Base with a mission focus of ISR.

- Space Delta 8 replaces the 50th Operations Group at Schriever Air Force Base with a mission focus of satellite communications and navigation warfare.

- Space Delta 9 replaces the 750th Operations Group at Schriever Air Force Base with a mission focus of orbital warfare.

- Peterson–Schriever Garrison was stood up at Peterson Air Force Base to support operations at Thule, Greenland; Cheyenne Mountain, Colorado; Kaena Point, Hawaii; New Boston, New Hampshire; and 16 other locations around the world.

- Buckley Garrison was stood up at Buckley Air Force Base to support operations at Cape Cod, Massachusetts; Cavalier, North Dakota; Clear, Alaska; and 10 other locations around the world.[59]

The 30th Space Wing at Vandenberg Air Force Base and the 45th Space Wing at Patrick Air Force Base have yet to be reorganized. Collectively, they operate the largest test ranges where NASA, commercial, and military rockets, missiles, and space systems are tested through actual launches and fly-outs. The ground tracks for those missile fly-outs covers thousands of miles, and the ranges include "all stations, sites, ocean areas, and air space necessary to conduct missile and space vehicle test and development."[60] These two wings will be reorganized as the remaining two field commands are activated.[61]

E. Personnel

The 2020 NDAA specified that only the Air Force was required to provide personnel for the Space Force, and more than 6,000 airmen have volunteered to make the transition. The 2021 NDAA authorized 6,434 military personnel, 3,545 civilian personnel, and a total end strength of 9,979 on September 30, 2021, all of which will come from the Air Force.[62] Although legal provisions exist for other services to transfer to the Space Force, the current focus is on transferring the remaining airmen to the Space Force by the middle of FY 2021.[63]

With the redesignation of Air Force Space Command (AFSPC) as Space Operations Command, approximately 16,000 Air Force active duty and civilian personnel were assigned to support the USSF.[64] "Assigned" personnel remain in the Air Force or another service and perform work in support of the USSF. A "transferring" officer will be (re)commissioned in the USSF, and enlisted personnel that transfer will execute an enlistment contract with the new service.

As of December 2020, fewer than 3,000 airmen had transferred to the Space Force.[65] While that process has been methodical, it now needs to be accelerated. The goal is to begin to consolidate space missions and forces from the Army and Navy into the Space Force in FY 2022 and FY 2023. The initial estimate for the total end strength of the Space Force sourced from all services was 15,000,[66] but that number will likely change over time.

F. Acquisition Reform

The FY 2020 NDAA established an Assistant Secretary of the Air Force for Space Acquisition and Integration (ASAF/SP) to serve as the senior space architect within the DAF and directed that the SDA, Space Rapid Capabilities Office, and Space and Missile Systems Center be consolidated under the ASAF/SP's control. On May 20, 2020, the DAF delivered a report to Congress on a new plan for space acquisition, proposing nine specific actions to increase the speed of space acquisition capabilities.[67] Although that report was retracted because of a coordination issue with the Office of Management and Budget (OMB),[68] several of the proposed actions have already been taken.[69]

G. Funding

The Space Force budget for FY 2021 provides a robust level of funding for every aspect of the new service's mission set. The budget for operation and maintenance (O&M) is $2.6 billion; the budget for RDT&E is $10.3 billion; and procurement adds another $2.4 billion for a total of $15.2 billion.[70] That direct funding (which does not include pass-through funding for "other" agencies) will allow the Office of the Chief of Space Operations to continue to focus on building a strong organizational foundation while developing and fielding the space platforms and systems that are required to dominate this domain.

IV. Current Capacity and Capability

The Space Force mission is conducted through a network of satellites, ground-based radar, ground stations, and situational awareness nodes that

TABLE 1

Satellites Controlled by the U.S. Space Force

System	Function	Total in Orbit
GPS	Positioning, Navigation, and Timing	35*
SBIRS	Missile Warning	6
DSP	Missile Warning	5
SBSS	Space Surveillance	1
STSS-ATR	Missile Defense	1
GSSAP	Space Tracking	4
DMSP	Weather	2
Milstar	Communications	5
AEHF	Communications	5
DSCS	Communications	7
WGS	Communications	10
Total in Orbit		**81**

* Four dormant
SOURCE: Satellite types, numbers, and brief descriptions are taken from sources listed in this section as well as Appendix 1.

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cover the gamut of persistent ISR, command and control, communications, weather forecasting, and navigation requirements. The classified nature of deployed space assets makes listing specific capacity levels within the Space Force portfolio, much less attempting to assess the service's capability to execute its mission, a challenging exercise.

There is little question that the constellation of U.S. ISR, navigation, and communication satellites is unrivaled by that of any other nation-state. That array of assets allows the Space Force along with its sister services to find, fix, and target virtually any terrestrial-based or sea-based threat anywhere on the surface of the Earth.

An assessment of Space Force and DOD space capabilities begins with an understanding of the number and types of space platforms under government control. Because many of those systems are classified, determining the number of satellites and their inherent capabilities is difficult.

A database maintained by the Union of Concerned Scientists (UCS) provides a starting point. The UCS states that as of August 1, 2020, just under 1,425 U.S. active satellites were in orbit. Of those, 33 are civil, 208 are military, 173 are "government," and the remaining 1,011 are commercially owned and operated.[71]

UCS's totals differ considerably from the numbers and types of satellites that the United States officially acknowledges. The DAF has stated that the Space Force has 77 satellites, and the Army and Navy acknowledge 12 and 11 service-owned satellites, respectively, for a total of 100 military satellites in orbit. The National Oceanic and Atmospheric Administration (NOAA) has nine satellites[72] and NASA has 26[73] for a total of 35. Those numbers exclude dormant satellites as well as classified systems within the individual military services, the NRO, and National Geospatial Administration (NGA).

The 77 satellites operated by the Space Force (and four others that are maintained in dormant status) provide communications, command and control, missile warning, nuclear detonation detection, weather, and precision position, navigation, and timing (GPS) for National Command Authorities and the joint force.[74] While these USSF systems provide critical capabilities for the nation, they equate roughly to the number of satellites that are believed to be owned and controlled by other services and agencies within the Defense Department.

The unclassified capacity and capability of the Space Force can be broken down into Backbone (Communication, Navigation/Timing and Weather); ISR; Offensive; and Defensive areas of capability.

A. Backbone Satellite Constellations

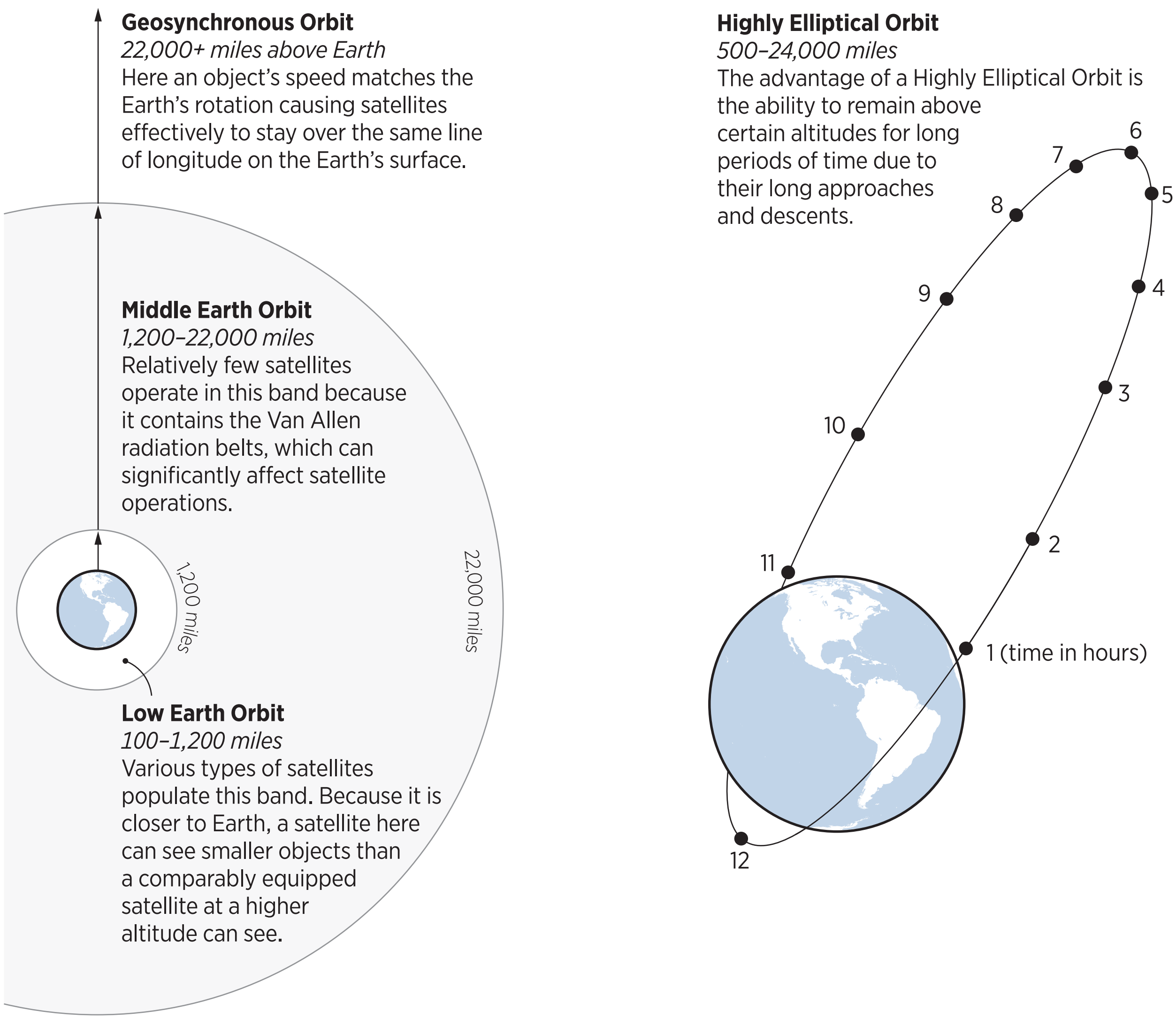
The Space Force has 67 total navigation and timing, command and control, communications, and weather satellites that enable every facet of modern American warfare to include collecting real-time intelligence, the ability to communicate, adaptively maneuver, and deliver precision effects almost anywhere on the planet.[75]

B. ISR Satellites

The Space Force has 17 acknowledged ISR and space situational awareness satellites. While there likely are more classified systems in the portfolio, these satellites provide exceptional missile warning and intercept cues for intercontinental, regional, and submarine launched ballistic missiles (SLBMs) as well as an ability to track man-made objects in space out to the bounds of geosynchronous equatorial orbit (GEO).

FIGURE 1

Types of Earth Orbits



SOURCE: Heritage Foundation research.

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- The **Defense Support Program (DSP, 5 satellites)** was designed to detect ICBM and SLBM launches and to have secondary missions including the detection of space launch missions or nuclear weapons testing and detonations. The DSP constellation is in GEO and uses infrared sensors to pick up the heat from booster plumes against the Earth's background. Ten Phase 3 DSP satellites were launched from 1989–2007[76] and have demonstrated exceptional reliability with at least five[77] and as many as eight still providing reliable data.[78]

- The **Space-Based Infra-Red System (SBIRS, 6 satellites)** provides early missile warning and intercept cues for missile defenses. The SBIRS constellation was designed to hold 11 satellites: three in high elliptical orbit (HEO) and eight in GEO.[79] All three HEO satellites were placed in orbit from 2006–2008, but the number of GEO satellites has since been reduced to six. Four GEO satellites have been fielded to date, and the remaining two are scheduled to be placed in orbit in 2021 and 2022, respectively.[80] SBIRS HEO platforms include a scanning sensor array composed of short-wave and mid-wave infrared radars that can detect infrared activity close to the ground. These satellites are retaskable and can be moved to more optimum orbits as mission requirements dictate.

- Operational details of any strategic **Reconnaissance and Imaging** systems, even though Air Force history is steeped in these reconnaissance systems, are classified. The number of satellites the Space Force has dedicated to those missions would exceed the 77 that the DAF has publicly acknowledged and the 81 that it possesses. High-end reconnaissance and imaging capabilities, however, exist within the space situational awareness satellites in the Space Force's portfolio.

C. Space Situational Awareness Systems

Space situational awareness (SSA) is critical to every aspect of U.S. civil, commercial, and defense space operations. NASA estimates that up to a half-million objects with a diameter between 0.4 inches and four inches are circling the Earth.[81] Objects in low earth orbit (LEO) are traveling between 15,600 and 17,900 miles an hour.[82] Providing their location to civil and commercial users for deconfliction is critical to all aspects of U.S. space operations, and the capability is a key part of the U.S. space program.

From a military standpoint, SSA information enables defensive and offensive counterspace operations and forms the foundation for DOD counterspace activities.[83] Knowing the locations of hostile systems, their positional history, and how those satellites are maneuvering in real time conveys intent and collectively shapes the protocols and counterspace decisions that follow.

Maintaining a high level of situational awareness on satellites orbiting across the depth and vast dimensions of potential Earth orbits requires a robust and seamless network of space-based and terrestrial-based sensors. Understanding the capabilities and limitations of that network naturally begins with understanding the numbers and types of space-based and ground-based systems.

Six acknowledged satellites and 23 terrestrial-based sensors help to maintain situational awareness of satellites and other objects in space. The satellites, collectively known as the space-based surveillance system (SBSS), operate in concert with but without the limitations of ground-based sensors that are constrained by weather, time of day, and atmospheric conditions.

- The **Space Based Surveillance System (SBSS-1, 1 satellite)** tracks man-made objects and debris fields in orbit from LEO.[84] SBSS sensors include a Space Infrared Imaging Telescope (SPIRIT); Ultraviolet and Visible Imagers and Spectrographic Imagers (UVISI); Space-Based Visible instrument (SBV); and an On-board Signal and Data Processor (OSDP).[85]

- **Space Tracking and Surveillance System Advanced Technology Risk Reduction (STSS-ATR, 1 satellite)** is an RDT&E satellite placed in orbit on May 5, 2009, by the Missile Defense Agency (MDA). This satellite was built to explore different capabilities and technology for the MDA.[86] It was transferred to the Air Force in 2011 for the SSA mission.[87]

- The **Geosynchronous Space Situational Awareness Program (GSSAP, 4 satellites)** is a classified surveillance constellation that can accurately track and characterize objects in orbit[88] and employs electro-optical and emissions sensors to that end.[89] Operating near GEO, GSSAP satellites are maneuverable, which allows them to perform rendezvous and proximity operations (RPO) on objects of interest in space.[90] RPO-capable systems can "rejoin" with other satellites to observe, inspect, and collect emissions from those systems, opening the opportunity to conduct offensive operations against another nation's assets. Launched in pairs, the first two GSSAP spacecraft were put in orbit on July 28, 2014, followed by the second two on August 19, 2016.[91]

D. Ground-Based Space Surveillance Systems

The U.S. Space Surveillance Network (SSN) is comprised of 23 ground-based radar and optical tracking sites (six dedicated, seven collateral, and 10 contributing) that have the ability to detect, track, identify, and catalog all man-made objects orbiting the Earth. Dedicated sensors are operationally controlled by U.S. Space Command, and their primary mission is space surveillance. Collateral sensors are also under the operational control of SPACECOM, but their primary mission is to detect and track ICBMs and SLBMs and to test and evaluate other systems. Contributing sensors are controlled by other organizations or agencies and provide space surveillance support upon request from the National Space Defense Center (NSDC).

The SSN's limitations include optical (weather) interference, geographic location, and the lateral/vertical area and depth that the sensor is capable of covering. Until recently, the majority of the dedicated terrestrial-based space sensors were based almost exclusively in the Northern Hemisphere.

Dedicated Sensors. Each of the three Ground-based Electro-Optical Deep Space Surveillance (GEODSS) sites is equipped with three powerful telescopes that operate in conjunction with low-light television and high-speed computers capable of detecting, tracking, and collecting information on objects as small as a basketball more than 20,000 miles in space.[92] The three sites are located in New Mexico, on the island of Diego Garcia, and in Hawaii. They operate only at night and can be impaired by cloud cover and local weather conditions.[93]

An additional optical system known as the Moron Optical Space Surveillance (MOSS) is located in Moron, Spain. MOSS operates in conjunction with the GEODSS network to provide uninterrupted geosynchronous coverage. MOSS has a single high-resolution electro-optical telescope.

The Air Force Space Surveillance System (AFSSS), also known as the Space Fence, was constructed on Kwajalein Atoll in the Marshall Islands and became operational on March 27, 2020. It has a coverage area that is reportedly wider than the continental United States and is capable of detecting and tracking objects with diameters as small as 0.4 inches through the depth of GEO orbits.[94] It can detect new, uncatalogued[95] objects like foreign launches, maneuvering systems, and those conducting operations in proximity to other satellites.

AN/FPS-85 Phased-Array Radar, located at Eglin Air Force Base, Florida, can track a basketball-sized object up to 22,000 nautical miles from Earth.[96] It is the only dedicated phased-array radar in the space surveillance system.

Collateral Sensors. Five Phased Array Warning System (PAVE PAWS) sites[97] located in Greenland, Alaska, the United Kingdom, Massachusetts, and California were built for and have a primary mission of detecting and tracking ICBM and SLBM launches. Tracking man-made satellites and debris is a secondary mission for all five sites.[98] The Greenland, Alaska, and U.K. sites have Upgraded Early Warning Radars (UEWR) that also provide missile tracking data to the U.S. Ground-based Midcourse Defense Fire Control Center as part of their primary mission. The UEWR sites reach approximately 2,900 nautical miles into space, and the Massachusetts and California sites can range approximately 3,300 nautical miles into space.[99]

The Perimeter Acquisition Radar Attack Characterization System (PARCS) site is located near North Dakota's border with Canada and has the same primary mission set and fundamental capabilities as the PAVE PAWS sites.[100]

The Ascension Range Radar located between South America and Africa provides radar point tracking in support of operational test and evaluation (OT&E) for ICBMs, space launch vehicles, and launch test range systems. It can also be used to track and characterize objects in space.[101]

Contributing Sensors. Two Millstone and Haystack radars are owned and operated by the Massachusetts Institute of Technology and MIT's Lincoln Laboratory. Millstone is a deep-space radar built in the late 1950s as a ballistic missile and satellite tracking prototype.[102] Haystack is a 120-foot-diameter deep-space imaging radar billed as the world's highest-resolution long-range sensor for imaging space objects in support of space situational awareness.[103] Given the right conditions, both MIT radars can track objects as small as a few millimeters in size, but as contributing sensors, they collect only a few hundred hours of data each year.[104]

ALTAIR is a long-range tracking and instrumentation radar for near-Earth and deep-space tracking located on Kwajalein Atoll in the Marshall Islands. The system is used by the U.S. Army for operational testing and can independently track as many as 32 targets up to an altitude of 24,000 nautical miles.[105] Due to its proximity to the equator, it can monitor approximately one-third of the geosynchronous belt.

Coverage Restrictions and Limitations. An orbital period is the time it takes a satellite to complete a single orbit around the Earth, and it correlates with a satellite's orbital altitude. A satellite in GEO sits at an altitude of 22,236 miles and has an orbital period of exactly 24 hours, which means that GEO satellites orbiting over the equator (zero inclination) do not move in relation to terrestrial-based observers or sensors.[106] A sensor that can track targets up to an altitude of 24,000 miles can track GEO satellites in close lateral proximity, but monitoring those that are laterally displaced by thousands of miles is more difficult.

The orbital period for a satellite in medium earth orbit (MEO) is approximately 12 hours, and the period for those in LEO varies between roughly 90 minutes and two hours.[107] Assuming that their orbit tracks fly within the range of ground-based sensors, those periods equate directly with the

TABLE 2

Satellites by Weight

Group Name	Weight	Size
Large Satellite	1,000+ kilograms (kg)	Large
Medium Satellite	500–1,000 kg	Medium
Mini Satellite	100–500 kg	Small
Micro Satellite	10–100 kg	Small
Nano Satellite (CubeSats)	1–10 kg	Small
Pico Satellite	0.1–1 kg	Small
Femto Satellite	<100 grams	Small

SOURCE: Chalie Galliand, "Study of the Small: Potential for Operational Military Use of CubeSats," 24th Annual American Institute of Aeronautics and Astronautics/Utah State University Conference on Small Satellites, August 10, 2010, p. 1 https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1199&context=smallsat (accessed February 23, 2021).

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windows those ground-based sensors (like the Space Fence) have to identify those systems.

The gaps in coverage between the space-based and terrestrial-based sensors are addressed by prediction, which works well—until a satellite elects to move when it is out of coverage. Every time a satellite maneuvers, the process of discovery, creation of a tracking file, and refinement of the associated data must be repeated.[108] Satellite operators will often provide scheduled maneuver times and post-maneuver orbital data that assist in the tracking of friendly and cooperative systems, but the operators of adversarial satellites can time their maneuvers to take advantage of those gaps.

With the influx of SmallSats (See Table 2), the potential for the number of U.S. military satellites in orbit to grow from a few hundred to several thousand over the next three years is very real. Add new commercial, allied, and adversary SmallSats to the mix and it is highly likely that the number of operational satellites in orbit will double over that same period. While increasing numbers alone will challenge the current Space Surveillance Network, the number of announced and unannounced orbital changes among those satellites will make it more difficult to keep tabs on bad actors.

A second, strategically located Space Fence like the one on Kwajalein Atoll would help to handle that load. The U.S. had announced plans to build one in Western Australia in 2021, but that site has yet to be funded. Even if a second Space Fence does eventually materialize, however, the Space Force will still need more satellites that are dedicated to this mission.[109]

E. Defensive Space Systems

[F]or countries that can never win a war with the United States by using the method of tanks and planes, attacking the U.S. space system may be an irresistible and most tempting choice.

—Wang Hucheng, Chinese strategist[110]

Defensive systems and operations are designed to protect friendly space capabilities against kinetic anti-satellite weapons, high-powered lasers, laser dazzling or blinding, and high-powered microwave systems.[111] Protective measures can be separated into active and passive systems and actions. An active defense is really offensive in nature and includes engagements to destroy, nullify, or reduce enemy systems that put U.S. and allied systems and capabilities at risk. Passive defense measures increase survivability through asset diversification, including the deployment of more space systems in different orbits, as well as real-time satellite maneuverability and self-protection.[112]

Portfolio Diversification. With just 81 satellites in the USSF, the loss of even a small number could significantly impact operational capabilities across DOD. On the other hand, a constellation of hundreds or even thousands of satellites in diverse orbits could be quite resilient to attack.

Shortly before the USSF became an independent service, the Air Force openly stated its desire to build a constellation of thousands of SmallSats in low earth orbit to provide a redundant, diversified portfolio of capabilities.[113] The idea appeared to be that DOD would field a vast array of satellites that would deliver backup communications and position, navigation, and timing (PNT) as well as overhead persistent infrared (OPIR) and other imaging capabilities currently found on strategic satellites. Over time, it is has become apparent that those expanding constellations will be comprised of both military and civilian satellites.

In 2018, the Air Force signed a $28 million contract with SpaceX to evaluate Starlink, a network of satellites designed to provide Internet service to remote locations,[114] for its potential to service warfighter needs. The Army has been in discussions with SpaceX since 2019, and while service engagements beyond that have been somewhat opaque, it appears that both the Space Force and the Army are now employing Starlink services.[115]

The Air Force began to test SpaceX compatibility and communications linkages with airborne service aircraft and other spaceborne systems in its Global Lightning program in 2019,[116] and the Army tapped into a constellation of 600 satellites in LEO during an exercise known as Project Convergence in the summer of 2020. Participants expressed the expectation that the constellation would grow to some 4,500 satellites—numbers that mirror the current and projected state of SpaceX's Starlink constellation—by the end of 2023.[117]

The exact number and composition of DOD's growing LEO-based network of satellites is unknown, but it appears to be in place and growing at a rate of as many as 60 satellites a month.[118] Assuming that it continues, this relationship will bode well for the resilience and survivability of the network of satellites available to DOD.

Maneuverability. Satellites generally consist of at least one sensor that collects raw data and a satellite bus that carries that mission sensor and provides it with power, thermal control, and communications. Enemy systems can use lasers or electronic measures to deny, degrade, or destroy sensors and kinetic ASAT weapons to target and destroy the satellite bus.[119] One of the best ways to counter many of those engagements is through maneuver.

The U.S. has demonstrated the ability to maneuver large satellites like those within the GSSAP constellation both actively and regularly.[120] Almost all satellites including CubeSats have at least some ability to maneuver while in orbit, but their propulsion systems are limited by available thrust and total onboard fuel.

Most larger satellites were fielded before the need for active defensive maneuvering was built into their designed fuel capacity, limiting the number of times they can be maneuvered out of the path of a threat and then back into an operational orbit. Just sustaining an orbit requires fuel, and when its fuel reserves approach exhaustion, a satellite is either moved into a satellite graveyard or back into the Earth's atmosphere where it burns up. Developmental efforts are underway to refuel satellites, but for now, most satellites can be maneuvered to counter a threat only as long as the threat is detected and operators are in place to move them in a timely fashion.

There is a host of sensors that can detect a terrestrial-based ASAT launch. With a robust network of space situational awareness assets, the USSF could determine an ASAT's trajectory and identify the targeted satellite and alert operators in time to take evasive action with those systems. Unfortunately, the gaps in that network that were highlighted earlier make the timely assessment of and response to such an attack on a specific U.S. satellite problematic.

Detecting a laser or electronic attack on a satellite's sensors is even more challenging. While they most certainly exist, the degree to which those capabilities have been fielded is unknown as is the sensitivity of those systems. Much as happened in the recent SolarWinds cyberattack, a delay in recognizing that a laser or non-reversible (permanently debilitating) electronic attack is underway can render a satellite's sensors unusable before protective measures can be implemented and therefore make attribution much more challenging.

Detecting attacks meant to deceive, disrupt, deny, or degrade satellite communications is another challenge that was recently addressed through the fielding of the Bounty Hunter system. These ground-based units are designed to detect satellite communications interference by monitoring electromagnetic interference across multiple frequency bands, allowing operators to locate sources of both intentional and unintentional interference and minimize them.[121] Bounty Hunter achieved initial operational capability (IOC) in the summer of 2020.

Fielding Bounty Hunter is an excellent move; however, some hostile actions can be confused with or explained away by solar activity and other naturally occurring phenomena.[122] Having a variety of terrestrial and spaceborne sensors that can detect hostile action is critical to sustaining a viable network of satellites. Modern combat aircraft like the F-35 have sensor packages that allow them to detect, identify, and obtain accurate information on the location of threats. Fielding a sensor package that allows high-value satellites to self-detect hostile system engagement and report it to operators who are positioned to take defensive actions is critical to defending those assets and attributing the associated attacks.

Cyberattacks present a different challenge to space-based systems. Like other kinetic and non-kinetic attacks, cyber intrusions can cause service disruptions, sensor interference, or the permanent loss of satellite capabilities. Additionally, an effective cyberattack could corrupt the satellite's data stream to reliant elements or systems—or even allow an adversary to seize control of a satellite.[123]

A recent Royal Institute of International Affairs report states that the U.S. is well behind its peer competitors in this area and should assume that its satellite constellations have already been penetrated and compromised. The U.S. must make a concerted effort to focus on this threat and develop techniques to identify current weaknesses and penetrations and counter these cyberattacks.[124]

There is no place to hide in classic Earth orbits, and this makes protecting a targeted satellite against a determined adversary more difficult. However, many of the passive protection measures employed on airbreathing assets like deception and stealth are also viable in space.

Deploying clandestine satellites alongside unclassified systems can readily be accomplished, and coating those classified satellites with black paint makes visual tracking of those deployments and their moves to follow-on orbits challenging. Stealth coatings can counter radar tracking of deployed satellite systems, and incorporating low probability of intercept (LPI) telemetry and communications emissions into those satellites will further mask their presence. Beaming those LPI transmissions to other relay satellites[125] would further complicate an adversary's ability to find, fix, track, and target one of these systems. Those passive measures, coupled with the moves to create a much larger network of satellites in different orbits, will prove to be an effective defensive approach to mitigating the operational impact of a concerted enemy attack on U.S. satellite constellations.

F. Offensive Systems

Our almost complete reliance on space-based systems, coupled with the debris-generating effects of kinetic ASAT systems, cause many to believe that the only rational U.S. approach to a war in space is a strong defensive posture. After more than five decades of one Administration after another carrying forward President Eisenhower's policy of "peaceful uses of outer space," that mindset is especially hard to shake. The associated approach involves building resilience into our constellations and maneuvering to evade hostile ASAT forays—but not threatening enemy systems in kind. While both are an important part of today's defensive posture, they ignore the fact that China and Russia have already militarized space and that modern war games have proven time and time again that a strategy based solely on defensive measures results in the U.S. losing a war in this domain.[126]

Offensive operations deny adversaries' access to their space assets and/or prevent them from moving to deny access to your own. The efforts can be ground-based, sea-based, air-based, or space-based and may involve taking the initiative to deceive, disrupt, deny, degrade, or destroy enemy satellites or elements of their supporting space infrastructure. The effects of those operations can be temporary or permanent, hard to attribute to an offender, and difficult to determine.

Generally speaking, the spectrum of permanence and attribution runs in parallel with the deceive-disrupt-degrade-destroy progression. Deception can be hard to detect and typically has short-term effects. Destruction, on the other hand, is permanent, and it is easier to determine the specific actor who caused that system's destruction.

In 1958, with the unveiling of bomber-launched ASATs, the U.S. became the first nation to initiate an anti-satellite weapons program.[127] The first successful U.S. test was conducted in September 1985 when an F-15 fired an ASM-135A missile at a failing satellite in LEO and destroyed it.[128] In the years since then, Russia, China, and India have demonstrated the ability to destroy orbiting satellites.[129] Today, peer competitors' ASAT capabilities include ground-launched and air-launched missiles as well as possible space-based, dual-use "killer satellites."

The debris generated by the 2007 Chinese ASAT test increased the population of trackable space objects by 25 percent.[130] In 2016, the Commander of Air Force Space Command, General John Hyten, stated that the Air Force would not develop systems that would kinetically destroy enemy satellites and create debris.[131] Even though the Space Force was established to regain the upper hand in this domain, debris-generating counterspace systems are not likely to become part of the Space Force's portfolio of systems.

Little is known about other offensive space-based systems that may already exist in the Space Force, but the potential offensive capacity that the GSSAP constellation offers is certainly intriguing. Each of those satellites can track,[132] monitor, and rendezvous with other objects of interest in space.[133] It is estimated that each of the four satellites within the constellation weighs between 1,430 and 1,540 pounds,[134] offering the physical dimensions and capacity to possess many of the capabilities that similar Russian systems have demonstrated over the past four years. Those capabilities include fuel for regular RPO maneuvering and, while the capability has never been seen, may also include the ability to "birth" micro or Nano satellites with a counterspace mission set.

Between 2016 and mid-2018, GSSAP satellites reportedly maneuvered within 15 kilometers of eight different foreign satellites in GEO, including Russian, Pakistani, Chinese, and Nigerian satellites. One of those satellites was Russia's Luch-Olymp spy satellite, which also has demonstrated RPO capabilities[135] and is assessed to have advanced sensors that collect communications and electronic intelligence emissions (collectively known as Signals Intelligence or SIGINT) from other platforms.[136]

The Air Force's 2017 budget included $158 million to develop offensive space capabilities over a period of five years.[137] That funding, coupled with research and development efforts that have taken place in U.S. civil and commercial arenas, offers excellent insights into the systems that may be on the horizon. Together, GSSAP's RPO capabilities and NASA's advances in CubeSat technology will offer extraordinary opportunities for every segment of military counterspace operations in the coming years.

There is just one U.S. offensive space system of record in open-source literature: a terrestrial- based counter communications system (CCS) known as Meadowlands. Meadowlands is a mobile offensive system that delivers effects to thwart adversary SATCOM in a given area of responsibility (AOR). The effects of Meadowlands are reversible: When the system is turned off, the systems and sensors it was targeting return to their original functionality.[138]

Other offensive systems are undoubtedly being developed (if they have not already been fielded), and doctrine will be required to frame their employment and prepare warfighters for the range situations they are likely to face in their respective roles.

V. Space Doctrine

There is a tendency in our planning to confuse the unfamiliar with the improbable. The contingency we have not considered looks strange; what looks strange is thought improbable; what is improbable need not be considered seriously.

—Thomas Schelling[139]

Before the Space Force was formed, Air Force doctrine provided operational guidelines for servicemembers and assets in the space domain. It was relatively robust in length but dwelled on what space forces would do at an operational level to support a Joint Air Force Component Commander during a conflict. It discussed hostile systems and broadly described their offensive capabilities but offered little with regard to U.S. offensive capabilities. Nor did it touch on associated standards for tactics, techniques, or procedures (TTPs). It did not address how space forces support all instruments of national power (diplomacy, information, military, and economic) around the globe continually in peacetime and in conflict. Finally, that doctrine applied only to the Air Force.

Concepts of operation (CONOPS), on the other hand, spell out how the joint force plans to fight in the future and generally drive acquisition decisions across DOD. In 2017, Air Force Space Command announced that it had developed a CONOPS for fighting in space, but like Air Force doctrine, it applied only to the Air Force.[140] In the summer of 2020, SPACECOM (the joint combatant command for space) announced that it was writing a joint space concept and that, while it had yet to be completed, the principals had agreed to the plan's operational tenets.[141]

U.S. Space Force Doctrine is broken down into three levels.

- At the top is the space capstone publication, *Spacepower: Doctrine for Space Forces*. Published in June 2020, it conveys the service's theory of space power and defines its purpose, identity, and values.

- The intermediate level of doctrine is operational.[142] While not yet published, it will define the organizational support needed for effective military effort and will add further detail to the core competencies spelled out in USSF capstone doctrine.

- The final level of doctrine is tactical and also has not yet been published.

Spacepower specifies that tactical commanders who are responsible for specific missions must have both the situational awareness and the span of control needed to operate in accordance with guidance and intent.[143] This is undoubtedly due to the speed at which threating situations can develop in space and the need for operators to take immediate action. Tactical doctrine and mission orders will spell out those standard actions, known as Tactical Standard Operations Procedures (TACSOPs). While not as directive as a checklist, TACSOPs will convey both the range of options based on lessons learned and historic best practices for how to respond to a host of situations.[144]

The formation of strategic and operational doctrine relies on detailed national security guidance and defense policy. Developing and updating that guidance and policy is an iterative process that will lean heavily on the advice and counsel of Space Force senior leaders. That dialogue will also be critical to forming concepts of operations and alternatives for crisis action response—and impressing a full understanding of the nation's space capabilities and limitations on the National Command Authorities.[145]

While each tier of space doctrine certainly begets the next, the most critical of the three levels may very well be the tactical level. The TTPs that guide tactical operations for services in other domains are generally escalatory in nature. The risk to personnel and systems grows incrementally as those assets move from basing locations through deployment and ultimately to contact with the enemy. Decisions on when to put those assets at risk and when to retrograde them out of harm's way can be made deliberately, and the guiding principles for those moves can span all three levels of doctrine, particularly when they involve high-value platforms. If a strategic system is threatened or lost due to hostile action in one of those other domains, the response can be equally deliberate and thought through over time.[146]

With terrestrial forces, a commander can withdraw a battalion of soldiers or a squadron of ships, but once launched, every satellite placed in orbit is continually at risk, and there is no way to retrograde even strategic systems completely out of harm's way. Known threats to U.S. spaceborne assets are already significant and run the gamut from acts of rogue nations to shadowing and escalatory moves by peer competitors to wartime targeting of the space systems. The cascading effects any of those scenarios can hobble DOD's network of space systems that give U.S. warfighters an edge over our peers. To protect those systems, Space Force TACSOPs should enable tactical operators to employ their systems without hesitation. The service's plan to develop and amend TACSOPs through a collaborative online process and approve those changes rapidly may be novel, but the tactical doctrine that evolves from that process should go well beyond the likely.

As technology progresses, threats may manifest themselves in ways and at speeds that are not currently palatable. The Rumsfeld Commission warned that "[s]urprise is most often not a lack of warning, but the result of a tendency to dismiss as reckless what we consider improbable."[147] Developing doctrine that encompasses that potential must be shaped by operators and strategists, as well as space futurists, and because many of the recommendations that come out of that process will not be based on a record of actions or a portfolio of best practices, they should be run through a gauntlet of war games and operational simulations before they are incorporated into tactical doctrine. The products of each of those forays should inform strategic and operational doctrine updates, as well as the space requirements and acquisition processes.

VI. Spaceborne Assets in Other Services and Agencies

The development and fielding of space systems by the Army, Navy, and National Reconnaissance Office that began in the 1950s have continued for more than 60 years. The satellites fielded through those independent efforts were designed to meet the operational challenges within service-centric domains and specific agency intelligence requirements, but almost every system within those constellations can serve the collection needs of the others.

While the actual numbers, types, and ownership of operational systems that are in orbit will likely remain classified and never be made public, several public sources offer details on unclassified U.S. operational systems. The Army[148] and Navy[149] have acknowledged a total of 23 unclassified systems in orbit, NOAA has nine,[150] and NASA currently has 26 operational satellites.[151]

TABLE 3

Satellites Not in the U.S. Space Force Portfolio

U.S. Army Satellites	
SMDC-ONE (Communications)	4
SNaP (BLOS Communications)	4
TacSat 6 (Communications)	1
Kestrel Eye II (Imaging)	1
ICEYE-X3 (Synthetic-Aperture Radar/Optical)	1
ACES RED 1 (Classified)	1
Total in Orbit	**12**

U.S. Navy Satellites	
FLTSAT (Communications)	1
UFO (Communications)	5
MUOS (Communications)	5
Total in Orbit	**11**

National Reconnaissance Office System Satellites	
Topaz FIA (Radar Imaging)	5
Orion (Signals Intelligence)	8
SHARP 1 (Electronic Intelligence/Signals Intelligence)	1
Nemesis (Communications Intelligence)	2
STPSat4 (Synthetic-Aperture Radar Experimental)	1
Onyx/Lacrosse (Radar Imaging)	3
Kennen/Crystal	5
RPP	1
RASR (Unknown)	3
Quasar (Data Relay)	9
Intruder (Radar/Optical Imaging)	16
Total in Orbit	**54**

SOURCE: Satellite types, numbers, and brief descriptions are taken from sources listed in this section as well as Appendices 2, 3, and 4.

SR245 heritage.org

Sorting through the unacknowledged systems that have been fielded by the services and DOD agencies is another matter entirely. From 2010–2020, there were more than 31 published National Reconnaissance Office launches (NROLs), and several of those missions carried multiple payloads into space.[152] The UCS database maintains details on the numbers and types of systems that have been fielded through NROLs. Collectively, those sources will provide insights into the current command and control of U.S. space assets, how they are programmed to evolve, and how their organization needs to change in order to prepare the U.S. more effectively for a conflict that bleeds into space.

A. U.S. Army

The Army has 12 acknowledged satellites.[153] Eleven of these are CubeSats, which are a growing feature of the LEO constellation. These Nano-class satellites are based on the standard dimensions of 10 centimeters (cm) x 10 cm x 10 cm and one kilogram (2.2 pounds) in weight, equating to one unit, or 1U. Individual CubeSats can be designed in multiples of a single unit (2U, 3U, etc.) and are carried aloft in dispensers known as Poly-Picosat Orbital Deployers, or P-Pods; 154 Multiple P-Pods can be fitted as secondary or auxiliary payloads[155] mounted directly to the launch vehicle underneath the primary payload, considerably reducing the cost of placing them in orbit.[156]

Each of the Army's CubeSats is designed to evaluate imaging, communications, and communications relay capabilities that can be fielded on these incredibly small systems to serve warfighters more effectively at the tactical level.[157] The Army also has three ongoing satellite testbed programs: Gunsmoke, Lonestar, and Polaris. Each is designed to further develop and evaluate aspects of a large constellation of SmallSats and their ability to provide three critical enablers in direct support of frontline tactical units on the ground: reconnaissance; communications, and navigation and timing.

The technologies under development include a Synthetic Aperture Radar (SAR) to provide all-weather/all-lighting imaging; advanced communications links for accurate and reliable information in degraded environments; and Sensor-to-Shooter (S2S) mission targeting systems to enable on-demand, multi-layer capabilities for long-range fires.[158] As technology matures, multispectral and hyperspectral imaging, along with full-motion video, will be added to CubeSat payloads.[159] As those systems move toward fruition, the Army is continuing with other novel approaches including the use of commercial services to reduce risk.

In recent exchanges, the Commander of the Army's Space and Missile Defense Command (SMDC) has stated that the service is getting out of the satellite ownership business. This necessarily implies that these systems and/or the technology derived from them will be transferred to the Space Force over the next several years.

B. U.S. Navy

The Navy has a fleet of 11 acknowledged communication satellites that are scheduled to be transferred to the USSF in 2022.[160] These satellites were undoubtedly designed and fielded to serve the service's domain-specific requirements, but they can also provide critical information to warfighters in other domains.

A service formed just from Air Force assets and those that other services and agencies are willing to transfer voluntarily will not remedy the dysfunctional oversight or command and control issues that the Space Force was intended to resolve.[161] For that to happen, the entire portfolio of Army and Navy satellites should transfer to the Space Force, along with key personnel within the remaining pool of 21,200 space professionals in the Army and Navy.[162] Portions of the Army Space and Missile Defense Headquarters at Redstone Arsenal, Alabama, should be reviewed, and select components should be rolled into the Space Force,[163] as should components of the Naval Warfare Systems Command in San Diego, California,[164] and the Navy Satellite Operations Center at Point Mugu, California.[165]

C. National Reconnaissance Office

Comparing the numbers and types of acknowledged U.S. military and government satellites with those that remain unaccounted for in the UCS database likely means that the NRO has at least 54 operational satellites in orbit.[166] While the capabilities within the NRO are not completely known, they undoubtedly include a network of high-resolution imaging and sensitive SIGINT platforms that provide critical information to departments and agencies spanning the breadth of the federal government, to include U.S. warfighters based around the world.

The rationale for assigning satellite assets to a hybrid DOD/Intelligence Community organization is well founded and has as much to do with differing priorities as it does with authorities. DOD's collection requirements are all but insatiable, and if every spaceborne intelligence platform was controlled by that department, little time would be spent meeting the markedly different requirements of other departments, intelligence organizations, and agencies whose collection requirements, not unlike DOD's, run the gamut.

In its early years, the NRO was a small, agile organization that led the development of advanced reconnaissance technologies. Formed to meet the strategic reconnaissance requirements of DOD and the Intelligence Community, it had a reputation for delivering novel, first-of-its-kind systems to meet America's most difficult collection challenges.

Until recently, the systems and day-to-day operational demands of NRO satellites were significantly different from those of DOD satellites. With the exception of station keeping and occasional repositioning, operations of Air Force (now Space Force) satellites were generally routine. Operators would monitor but by and large did not go hands-on to move or interact with these satellites unless there was a problem. NRO satellite operations, on the other hand, were tasked to move frequently, causing operators to shift orbits regularly to meet constantly changing collection requirements.[167]

TABLE 4

National Reconnaissance Office (NRO) Satellites

System	Function	Total in Orbit
Topaz FIA	Radar Imaging	5
Orion	Signals Intelligence	8
SHARP 1	Electronic Intelligence/Signals Intelligence	1
Nemesis	Communications Intelligence	2
STPSat4	Synthetic-Aperture Radar Experimental	1
Onyx/Lacrosse	Radar Imaging	3
Kennen/Crystal	—	5
RPP	—	1
RASR	Unknown	3
Quasar	Data Relay	9
Intruder	Radar/Optical Imaging	16
Total in Orbit		**54**

SOURCE: Satellite types, numbers, and brief descriptions are taken from sources listed in this section as well as Appendices 2, 3, and 4.

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But times have changed, and the chasm between Space Force and NRO mission demands, mindsets, and risk tolerance is narrowing. The NRO's customer base has grown from the NSC and a tightly focused Intelligence Community to the Departments of State, Justice, and Treasury, an expanded Intelligence Community, and other civil agencies.[168] As far back as 2001, the Rumsfeld Commission found that this expanded customer base, coupled with the accompanying, relentless demand for timely and reliable products, generated several adverse impacts.[169]

Those support requirements have forced the NRO to spend more time operating and maintaining legacy satellite reconnaissance programs. The need to minimize the risk of a service disruption and the funding required to sustain legacy systems forced the organization to adopt a more bureaucratic mindset. At the very least, balancing the funding required to sustain a growing list of legacy satellites with the funding made available for advanced system development means that less is available for the latter. The combination makes the spiral and evolutionary development of new technologies much more palatable and affordable than attempting to develop revolutionary advances would be.[170] While still formidable in its capabilities, the NRO has become less nimble.

In the meantime, the potential threats to and mission demands of USSF constellations like SBIRS and DSP cause them to be maneuvered and handled more as clandestine NRO systems are maneuvered and handled. Moreover, the Space Force that operates those systems has assumed a much more aggressive posture than the Air Force had with everything from acquisition to counterspace operations. Left unchecked, the burdens, mannerisms, and philosophies of the NRO and the USSF will grow increasingly similar over time, and while there are obvious benefits for the new service, that progression is unhealthy for the NRO.

The NRO operates under Title 50 of the U.S. Code, which gives it the authority to collect and execute foreign intelligence or counterintelligence programs while exempting the organization from Freedom of Information Act[171] disclosure requirements.[172] The missions those authorities and exemptions enable must be sustained for relevant, highly sensitive clandestine operations.

However, a significant portion of the workforce within the NRO is made up of Air Force personnel, many of whom will eventually transfer to the Space Force. The systems and personnel currently resident within the NRO should therefore be reviewed for mission sets that can be accomplished under U.S.C. Title 10 authorities.[173] Those that can be accomplished by a uniformed service, along with the on-orbit systems and select personnel that execute those missions, should be transferred to and consolidated under the command and control of the Space Force.

VII. Civil and Commercial Space

A 2001 RAND study estimated that 95 percent of all civilian and commercial space technologies have direct applicability to military systems or are of dual use. That fact and the additive capabilities that those two sectors bring to DOD make it critical that America's space program be viewed through a holistic lens.[174] Dominating great-power competition in this domain relies on the interwoven efforts from all three U.S. sectors—military, civil, and commercial space—and that reliance is growing.

The two U.S. civil agencies with space assets are the National Oceanic and Atmospheric Administration and the National Aeronautics and Space Administration, and both are already playing critical national security roles.

A. National Oceanic and Atmospheric Administration

The primary mission of NOAA's nine satellites is to understand and predict changes in climate, weather, oceans, and coastlines, and the organization uses its spaceborne assets to that end.[175] This agency has operational control of every sensor and spaceborne platform that provides weather imaging and data used by all U.S. civil and military forecasting agencies. Although the Space Force has responsibility for funding and maintains Satellite Control Authority[176] over the DMSP constellation, operational control of those satellites was transferred to NOAA in 1998.[177]

B. National Aeronautics and Space Administration

NASA's 24 satellites[178] serve 18 Earth science missions that measure aspects of the environment that include everything from rain and snowfall to crop growth and natural disasters.[179] Most people are aware of NASA because of its role in exploring space, but exploration, both manned and unmanned, is just one of its several areas of concentration.

NASA's mission is to drive advances in science, technology, aeronautics, and space exploration and developmental efforts.[180] Since its inception, NASA's Small Spacecraft Technology Program (SSTP) has focused on developing transformative space technologies to enable future missions to Mars.[181] Just one of the many efforts within SSTP's portfolio is designed to advance CubeSat subsystems to include nanosatellite propulsion and navigation systems that are critical for precision RPO missions. Those developmental efforts are poised to deliver several significant capabilities that will migrate into counterspace operations.

Because of size limits, each CubeSat asset will have less capability, but as a whole, a constellation of CubeSats may eventually be able to meet warfighter needs in a much more resilient package.[182] CubeSats can be placed in orbit as the vehicle moves to the requirements of the primary payload, allowing them to be dispensed and placed somewhat inconspicuously. While the detection, tracking, and latency capabilities of peer or adversary satellite tracking systems are not well known, tracking the deployment and subsequent movement of these systems can be problematic even for the U.S.[183]

NASA/SSTP funding enabled the design, construction, and operational testing of a series of CubeSats, the most recent of which flew in December 2020. That mission's two CubeSats contained GPS receivers that could pinpoint the satellites' location to within single-digit meters, a propulsion system that controlled CubeSat changes in velocity as small as four-thousandths of an inch per second, and a satellite control system that could point system sensors and satellite velocity vectors to within fractions of a degree.[184] Those capabilities are fundamental to flying close to, inspecting, latching onto, or docking with another satellite.

NASA's SSTP program is on track to launch a CubeSat Proximity Operations Demonstration (CPOD) mission in 2021. During this mission, a pair of nanosatellites will test a battery of maneuvering challenges at distances from 25 kilometers down to controlled contact and docking.[185] The potential that this development offers for every facet of counterspace operations is boundless.

As noted, NASA was formed shortly after the United States attempted (and failed) to launch the world's first exploration satellite in a competition known as the International Geophysical Year. One of the major drivers in that competition was the overflight precedent that the civil program would deliver for the U.S. reconnaissance satellites to follow.[186] That mutually furthering connection between the defense and civil sectors of space has since expanded broadly into the commercial sector.

C. Commercial Space

At least through the formative years of the U.S. space program, government requirements for satellite construction and rocket design were met almost exclusively by the commercial sector. That paradigm was transformed by three changes in U.S. law over a 30-year period.

- The Commercial Space Launch Act of 1984 freed commercial organizations from the restriction of launching satellites *only* on the Space Shuttle, allowing them to pursue private, expendable launch systems.[187]

- The National Aeronautics and Space Administration Multiyear Authorization Act of 1990 directed NASA to purchase primary payload launch services from commercial venders.[188]

- The Commercial Space Launch Amendments Act of 2004 paved the way for SpaceX and other budding commercial space carriers to take the reins for innovation, exploration, and the commercial use of space.[189]

Collectively, these three acts upended the supported–supporting paradigm that had been serving NASA since the 1960s, and the commercial sector now leads all others.

Commercial growth in the space industry has skyrocketed over the past decade. In 2010, just three U.S. commercial space organizations were involved, and collectively, they launched 14 missions into space.[190] Deregulation during the Trump Administration fostered more competition, and today, six private corporations are actively engaged in placing satellites into orbit—twice the number that had launched systems into orbit in 2019.[191]

Thirty-six years ago, the only way commercial satellites made it into space was aboard a very limited number of NASA Space Shuttle missions. Today, the only U.S. option for getting civilian, commercial, and military payloads into space is aboard a commercial rocket. In 2020, SpaceX alone launched 26 Falcon 9 missions into space,[192] including two manned missions, the first from U.S. soil since 2011.[193] All told, U.S. companies launched 53 missions into space in 2020, while China launched 22 and Russia launched 21.[194] The inherent competition has driven down the cost per launch, giving DOD greater and more cost-effective access to this domain. America has turned the corner on this vital capability, and the access that commercial space organizations give the U.S. will be critical to dominating great-power competition in the coming years.

The Space Force manages the National Security Space Launch (NSSL) program, which is a Major Defense Acquisition Program that acquires launch services from private companies to deliver national security satellites into orbit. Currently, the NSSL uses the Atlas V and Delta IV Heavy launch vehicles from United Launch Alliance and the Falcon 9 and Falcon Heavy from SpaceX to launch national security payloads. In 2018, the Air Force awarded three launch services agreements to space launch companies to develop their launch vehicles for a second phase of the NSSL. In 2020, the Space Force awarded two launch services procurement contracts to United Launch Alliance (ULA) and SpaceX, and those two vendors will provide space launch services for the Space Force through 2027.[195]

The expanding commercial space launch capability will enable the service to deploy new systems in an accelerated fashion and fill shortfalls or replace combat losses with a nearly on-demand capability, but launch services is just one part of an ever-expanding military–commercial relationship. The fielding of commercial communications and remarkably capable collection and imaging satellites, along with space services and repair, is growing at an incredible pace. Each of those capabilities will fill gaps and reduce risk across the spectrum of Space Force operations.

The Army's Project Convergence 2020 (PC20) concentrated on providing warfighters in the Army's "close fight" with seamless communications by integrating 600 commercial SpaceX Starlink satellites in LEO.[196] PC20 tested enabling technologies to provide communications and other potential capabilities to Brigade Combat Teams (BCTs), Combat Aviation

Brigades (CABs), and Expeditionary Signal Battalion-Enhanced (ESB-E) to facilitate faster decisions. Ideally, the high bandwidth–low latency communications Starlink SmallSats will provide the connectivity required for nearly real-time intelligence and independent sensor-to-shooter solutions.

The sensors on these small satellites also have the capability to provide a very accurate PNT backup for GPS,[197] and when combined with other SmallSats, they will help to enable the Army's concept for a Multi-Domain Operations (MDO)-Capable Force by 2028 and an MDO-Ready Force by 2035.[198]

The Army's PC program is similar in nature to the Air Force's Advanced Battle Management System (ABMS) and the Navy's Overmatch C2 development programs.[199] Although the programs are under separate developmental paths, the potential for interface issues will likely be reduced through their respective interface with and collective reliance on the Starlink constellation. This rapidly expanding commercial constellation will offer DOD prudent redundancy and increased resilience and will reflect a healthy bond between the defense and civil sectors.

Collection and Imagery. Increasingly, the Department of the Air Force,[200] the NRO, and other departments and agencies have invested in and are employing the services of commercial organizations to provide collection and imagery on demand. Hawkeye360 is a U.S. commercial organization that collects electronic signals using clusters of three satellites flown in formation to detect and then triangulate electronic emissions. The clusters' sensors collect and store signals from a spectrum of frequencies that spans from VHF to Ku frequency band signals,[201] and their signals library will expand to include future threats.[202] These clusters are based in LEO, so their target dwell time and revisit rate (every seven hours) do not provide the persistence of satellites in GEO, but their capabilities offer incredible fidelity on demand and provide a backup layer of resilience that makes the network of Space Force systems much more survivable.

What is perhaps even more impressive are the commercial radar images being produced by small commercial satellites. Even in 2002, commercial satellites were licensed to provide imagery with one-half meter resolution (roughly 20 inches), offering detail that allows analysts to differentiate between classes of military vehicles.[203]

In March 2020, ICEYE, a Finnish Synthetic Aperture Radar (SAR) satellite company, began to offer customers direct access to SAR imagery with 25-centimeter resolution (roughly 10 inches). The satellites that produce those images are SmallSats weighing less than 100 kilograms (220 pounds). At least one of this company's satellites is part of the Army's portfolio of assets, but the company will provide on-demand services with its growing constellation of on-orbit assets.

Servicing and Repair. Satellite lifetimes are often limited by the onboard fuel required to stay in orbit, maneuver to capture a specific image, or enhance the collection capabilities of onboard sensors. As fuel states approach empty, otherwise fully capable systems are either moved into a satellite graveyard or maneuvered into the Earth's atmosphere where they burn up. The outlook for those satellites began to change in February 2020 when a SpaceLogistics' service satellite known as Mission Extension Vehicle-1 (MEV-1) docked with an Intelsat satellite. The fuel and propulsion offered by MEV-1 enabled it to return to service. MEV-1 will remain with the Intelsat satellite for the next five years before taking it to a decommissioning orbit and, incredibly, moving on to its next client.[204]

Other technology on the horizon will enable actual repairs of on-orbit systems. The Defense Advanced Research Projects Agency (DARPA) is developing a payload with robotic arms and partnering with commercial organizations to develop the capability to use those systems to service satellites in GEO. The program, known as Robotic Servicing of Geosynchronous Satellites (RSGS), will eventually enable servicing satellites to install new sensor payloads on dated satellites, delivering state-of-the-art capabilities without the cost of a new satellite.[205]

There is little doubt that the Space Force already relies heavily on the technology and support provided by the civil and commercial space sectors, and that reliance will only grow stronger. The opportunity for commercial space organizations to provide services to adversaries is certainly present, but the relationship the U.S. has fostered with those companies over years of investments and subscriptions will likely help them shape when those services are available to other customers and when they are not. The Space Force has already embraced the commercial sector, and it should continue to foster both its growth and the strength of what is now a symbiotic relationship.

VIII. Requirements and Acquisition

Equipping America's military for space operations has been a challenge for several decades because of the fragmentation and overlap in the organizations that define the requirements and control the acquisition process.[206] In fact, one of the many reasons for creation of the U.S. Space Force was the disaggregated nature of almost every aspect of DOD's space program at the time.

The Trump Administration established the Space Development Agency to deal with the dysfunction associated with those disparate organizations and the resultant program delays, cost increases, and occasional system cancellations.[207] Since its founding on March 12, 2019, the SDA has made significant progress in setting the strategic direction for America's defense capabilities in space. It has framed and appears to be orchestrating successfully the development of the National Defense Space Architecture (NDSA), which is designed around seven novel layers of functionality with systems based primarily in LEO. These are the NDSA's:

- **Transport Layer**, which provides or "transports" low-latency data to warfighters worldwide;[208]
- **Battle Management Layer**, which provides automated space-based battle management C2, tasking, mission processing, and dissemination supporting a time-sensitive kill chain;[209]
- **Tracking Layer**, which provides indications, warning, tracking, and targeting of advanced missile threats, including hypersonics, globally;[210]
- **Custody Layer**, which tracks and keeps positional "custody" of mobile surface targets to support targeting with advanced weapons;[211]
- **Emerging Capabilities (Deterrence) Layer**, which develops future concepts with an initial focus on deterring hostile action from beyond GEO up to a distance at or equal to the Moon;[212]
- **Navigation Layer**, which provides alternative for PNT in GPS-denied environments;[213] and
- **Support Layer**, which provides terrestrial-based support infrastructure that enables space-based layer capabilities to transmit, receive, process, exploit, and disseminate data.[214]

The NDSA is comprehensive, and the Army demonstrated one of the most novel and compelling aspects of that layering when it employed SpaceX's Starlink constellation of 600 SmallSats in Project Convergence 2020 (PC20). The number of additional developmental efforts in the Battle Management Layer alone will give insights into the redundant efforts and weight of the programs just within the uniformed services. The Air Force is pouring significant funding and work into its Advanced Battle Management System (ABMS), and the Navy is doing the same thing with its Overmatch program. While there is good work being done in all three of those lanes,[215] there undoubtedly are service-centric efforts buried in each that have the potential to marginalize the capabilities of the whole—particularly if those systems run down independent lanes of acquisition.

The amount of money the Defense Department spends every year on space is nothing short of an enigma. In 2021, the Space Force was allocated $12.9 billion for procurement and RDT&E. However, classified space funding for all the services and DOD agencies is buried in the DAF's pass-through budget, which totaled $39.1 billion in FY 2021,[216] and no single individual or entity is in charge of establishing the requirements for or the systems acquired through that process.[217]

As indicated above, equipping America's military for space operations has been challenged by the fragmentation, overlap, and blurred lines that began in 1950s and still exist within DOD.[218] The Space Force, and more specifically the SDA, was formed to take charge and streamline that process: to minimize the redundancy, overlap, and potential for wasted time and capital within multiple streams of effort. Yet five different organizations still manage requirements,[219] eight others still deal with acquisition,[220] and no single individual or entity is in charge of either process.

DOD needs to move immediately to fix the dysfunction that remains within the requirements and acquisition process by implementing the strategy it devised in 2017. The Secretary of Defense needs to move as rapidly as possible to actualize that plan by moving the SDA under the USSF and giving the new service the lead in formulating the requirements and fielding of space systems for all DOD services and agencies.[221]

IX. Requirements for the Future

The advances in miniaturization and propulsion and the proliferation of space technologies have put a host of counterspace capabilities on the edge of fruition. The future of small, lightweight, inexpensive, and highly capable systems is at hand, and the United States must move to ensure that it maintains a sizable lead over peer competitors with these systems.

NASA-funded CubeSat experiments that will fly in 2021 are designed to enable space exploration, satellite inspection, and inexpensive imaging. The application of the technologies that evolve out of those CubeSat tests is limited only by imagination and will certainly change the way military powers approach the counterspace mission.

CubeSats certainly offer a variety of capabilities for reconnaissance, many of which have already been touched on in this paper. The Space Force is likely already refreshing their engagements with both NASA and the CubeSat manufacturers to refine requirements for propulsion and maneuvering to meet a host of potential missions. The game-changing potential of these systems was identified by the Rumsfeld Commission back in 2002—but only now is the required technology at hand.[222]

Multiple, mission-specific P-Pods could be, will be, and potentially already are being mounted on host RPO platforms like the current constellation of GSSAP satellites. The hosts need only maneuver to dispense a CubeSat on an intercept course and at a speed that allows its propulsion system to slow the CubeSat for RPO with its target. The velocity of a CubeSat at ejection/deployment from a P-Pod can be as high as two meters per second, which could allow a CubeSat to be deployed dozens if not hundreds of kilometers away from a target satellite and slow for rendezvous and contact.[223] Once attached, the parasite's sensor package can go to work to collect, report, and alter signals; alternatively, the CubeSat could go dormant until activated.[224]

While the idea of *space mine* that physically destroys a target has sensibly been ruled out,[225] there are any number of ways an attached or "parasite" CubeSat could effectively deceive, degrade, or permanently disable any satellite in orbit.

The concept of CubeSats deploying solar sails—10 x 10-meter expanses of material that capture solar particles[226]—that can slow and actually pull satellites out of LEO proved effective during orbital testing in 2011 and 2015.[227] The sails successfully deorbited two U.S. CubeSats, but they could just as easily be used to pull a hostile system out of orbit. An offensive CubeSat could rendezvous and attach itself as a parasite, deploy a solar sail, and begin to slow a hostile system. With no onboard ability to detect the presence of the parasite, the system would be lost without the adversary knowing why or how the loss took place. In higher orbits, similar material could be deployed to blind imaging sensors or deny the collection, reception, or transmission of mission data.

CubeSats could be designed with a variety of payloads, depending on the mission. Some could capture, alter, and/or disrupt signals; others could hold electromagnetic pulse (EMP) packages to render a target's electronics useless. Parasite CubeSats could even carry low-power lasers capable of burning out sensors and solar panels to destroy a target satellite without creating space debris. Or a parasite could merely be activated to fire its engine and "spin" its host in a manner from which the target satellite was not designed to recover.[228]

The technological advances that NASA has developed for SmallSat and CubeSat propulsion and navigation have opened the aperture for offensive counterspace operations, and the service needs not just to master the offensive capabilities that these systems offer, but also to develop doctrine for every conceivable counterspace mission. Given current space situational awareness limitations, detecting the approach of one of these systems, much less defending against it, will prove difficult even for our own satellites.[229] This increases the urgency of the need to develop systems that can detect an adversary's hostile moves.

X. Summary of Recommendations

A. Organization

Congress should grant the USSF the authorities required to transfer key personnel, facilities, and terrestrial-based and space-based systems across the whole of the Defense Department to maximize U.S. warfighting capabilities in the space domain.

The growing LEO constellation of SmallSats being developed and fielded by the different services will eventually provide global ISR, communications, and a PNT backup for GPS for warfighters in all branches. Additionally, all Army and Navy satellites (both acknowledged and unacknowledged) can provide critical information to warfighters in other domains. Once authorized by Congress, the Secretary of Defense should therefore transfer all Army and Navy spaceborne systems to the Space Force.

Once authorized by Congress, the Secretary of Defense should also transfer select Army and Navy personnel and facilities that support their satellites to the Space Force. The facilities and personnel that should be transferred include those on or within the Army Space and Missile Defense Headquarters at Redstone Arsenal, Alabama, as well as the Naval Warfare Systems Command in San Diego, California,[230] and the Navy Satellite Operations Center, Point Mugu, California.

The National Reconnaissance Office operates under Title 50 of the U.S. Code, and the missions and reporting exemptions enabled by those authorities must be sustained for relevant, highly sensitive clandestine operations. Air Force personnel account for a significant portion of the workforce within the NRO, and many will eventually transfer to the Space Force. The NRO mission sets and equipment that involve those personnel should be reviewed, and those missions that can be accomplished under U.S.C. Title 10 authorities should be transferred to the

Space Force along with the on-orbit systems and personnel that execute those missions.

B. Space Situational Awareness

Even when the last two GSSAP satellites are launched to join the space-based surveillance system in 2021, the U.S. will have far too few sensors to keep track of the satellites of our growingly aggressive peer competitors. The Space Force should therefore field a new constellation of less costly surveillance platforms in LEO to cover the current gaps in coverage and should act in anticipation of the influx of hostile SmallSat systems that is on the horizon.

The limited number of dedicated terrestrial-based space surveillance systems means that there are significant gaps in the U.S. Space Surveillance Network. Even when combined with the constellation of SSA satellites, the number of hostile satellites likely already outnumbers the collective network's sensor capacity. The gaps between the space-based and terrestrial-based sensors are covered by prediction, which works well until a satellite elects to move. With the influx of maneuverable CubeSats, the potential for the number of operational satellites in orbit to double over the next three years is real, and the potential number of their orbital changes will make keeping tabs on bad actors that much more difficult. The Space Force should immediately field a second Space Fence in Western Australia to help handle that load.

C. Defensive Systems

To increase defensive and attribution capabilities, the USSF should develop and field a sensor package that allows high-value satellites to self-detect hostile system engagement and either report it to operators who can take appropriate actions or cause the satellite to take automatic protective measures.

To mitigate the operational impact of a concerted enemy attack on U.S. satellite constellations, the Space Force should create and employ a much larger network of satellites in different orbits. This should include the expansion of commercial satellite services and the fielding of more government-owned and government-operated satellites of all types in LEO.

D. Doctrine

The USSF should develop TACSOPs through consultation with operators, strategists, space futurists, and close allies, and it should refine those

TACSOPs through war games and operational simulations before incorporating them into tactical doctrine. Changes in tactical doctrine should inform the revision process for strategic and operational doctrine, as well as the space requirements and acquisition processes.

E. Requirements Development and Systems Acquisition

The number of stovepiped requirements and acquisition organizations and entities within the Defense Department is still inordinately high, continuing the dysfunction that the SDA was formed to solve. The Secretary of Defense needs to move as rapidly as possible to move the SDA under the USSF and give the new service the lead in formulating the requirements and the fielding of space systems for all DOD services and agencies.

There is little doubt that the Space Force already relies heavily on the technology and support provided by the civil and commercial space sectors, and that reliance will only grow stronger. The U.S. has fostered relationships with those companies over years of investments and service subscriptions. Those relationships will also further a tendency for legacy organizations like Space and Missile Command to maintain their cadence and the business models that fielded big expensive satellites. The leadership within and beyond the USSF must work relentlessly to shift that paradigm so the U.S. fields systems that are more affordable and survivable.

The offensive potential that CubeSats offer is limited only by imagination, and the service needs to fully develop those capabilities. The Space Force should engage with both NASA and CubeSat manufacturers to refine RPO propulsion and maneuvering requirements and develop a host of compatible offensive systems.

XI. Conclusion

The Space Force of the future must increase its space-based and terrestrial-based situational awareness platforms and diversify its portfolio of satellites from LEO to GEO. It should also move to increase its resilience and the targeting problem for adversaries by significantly expanding its portfolio of military and commercial platforms. The technological advances that NASA has developed for SmallSat and CubeSat propulsion and navigation have opened the aperture for offensive counterspace operations, and the service needs both to master the offensive capabilities that these systems offer and to develop doctrine for every conceivable counterspace mission.

To all appearances, this new service is on the correct trajectory in each of those areas. Its partnership with civil and commercial organizations has delivered big dividends for increasing USSF capabilities while reducing cost and almost every possible measure of risk. The Space Force must continue to develop and deepen those ties.

Effective command and control of space operations depends on clearly defined authorities, roles, and relationships. As stated in the USSF's *Spacepower* capstone doctrine, a tactical commander tasked with a specific mission must have the situational awareness and span of control required to fully execute that mission's guidance and intent.[231] Having those same pillars of situational awareness and span of control is an absolute necessity for the Space Force leadership.

No one better suited to understanding the nation's military strategy and its priorities for space deterrence and space warfighting—or how to develop and maintain the space assets to meet those ends—than the Chief of Space Operations and the USSF.[232] The Space Force should accelerate the transfer of Air Force personnel into its ranks and complete it by the end of FY 2021, and Congress should not only grant the USSF the authorities it needs to unify the command and control of all DOD space organizations and personnel, but also direct that their transfer be completed by the end of FY 2023.

Appendix I: Space Force Backbone Satellite Constellations

There are very few individual military weapons systems that do not rely wholly on the following backbone constellation of position, navigation, timing, communications, and weather satellites. This means in turn that the success of any military operation depends on the communications linkages, weather, navigation, and timing that these platforms provide. In addition, although the collective constellations are very capable, the size, cost, limited number, and vulnerability of these satellites is a risk that must be mitigated through the fielding of more spaceborne systems.

USSF Navigation and Timing

The **Global Positioning System (GPS, 35 satellites)** provides timing, velocity, and precise navigation for millions of simultaneous users around the world. It takes 24 of these satellites to provide seamless global coverage, and 27 are currently in operation,[233] four more are in ready reserve, and an additional four have been retired but could be returned to service.[234] GPS III is the latest upgrade, and the four satellites currently in orbit incorporate a more robust anti-jamming capability and are interoperable with other Global Navigation Satellite Systems (GLONASS) such as the European Galileo network and the Japanese Quazi-Zenith Satellite System (QZSS), adding to system resiliency.[235] Two more GPS III satellites are scheduled for launch in 2021.[236]

USSF Communications

Milstar (5 satellites) is a SATCOM system that provides the National Command Authorities with assured, survivable global communications with a low probability of intercept or detection. These satellites were designed to overcome enemy jamming and nuclear effects.

The **Advanced Extremely High Frequency System (AEHF, 6 satellites)** is the follow-on to Milstar in GEO that provides DOD with sustained secure, jam-resistant communications and command and control (C2) for high-priority defense assets anywhere in the world.[237]

The **Defense Satellite Communications System (DSCS, 7 satellites)** provides nuclear-hardened, high-data-rate, and jam-resistant communications globally for DOD, the Department of State, and the National Command Authority (NCA).[238]

Wideband Global SATCOM (WGS, 10 satellites) provides Super High Frequency (SHF) wideband communications for all DOD services, National Command Authorities, and allied forces. The constellation as a whole can serve warfighters roughly anywhere between the Arctic and Antarctic Circles.[239]

USSF Weather

The main sensors for the LEO weather satellites in the **Defense Meteorological Satellite Program (DMSP, 4 satellites)** are optical, and each provides continuous visual and infrared imagery over an area approximately 1,600 nautical miles wide.[240] DMSP operations were transferred from DOD to the Department of Commerce and National Oceanographic and Atmospheric Administration in June 1998, but the U.S. Space Force has responsibility for funding and Satellite Control Authority.[241]

Appendix II: Army Satellites

The satellites of **Space Missile Defense Command–Operational Nanosatellite Effect (SMDC-ONE, 4 satellites)** were the first operational military CubeSats and were launched in 2012. Designed as communications technology demonstrators, they successfully relayed voice communications through an LEO-based NanoSat using military standard radios—something that had never been done before.[242]

The satellites in the **SMDC Nanosatellite Program (SNaP 1, 4 satellites)** are Beyond-Line-of Sight (BLOS) communications technology demonstrators designed to provide BLOS communications to "disadvantaged" users at the squad level utilizing existing fielded low-power, hand-held squad radios with no in-theater infrastructure.[243] The program also successfully demonstrated the ability of NanoSats to encrypt and decrypt those communications.

Tactical Satellite-6 (TacSat 6, 1 satellite) is a 3U CubeSat[244] communications technology demonstrator that is part of the Government Experimental Multi-Satellite (GEMSat) mission.

Kestrel Eye Block II (1 satellite) is a NanoSat optical imaging communications technology demonstrator designed to provide warfighters with direct access to satellite imagery. It has successfully demonstrated that a satellite can be tasked to take an image and downlink it back to the warfighter in a single pass[245] with a 1.5 meter resolution. The Army originally planned to orbit a constellation of roughly 30 satellites with the capability to provide persistent theater imagery coverage.[246]

Army Cost-Efficient Spaceflight (ACES) Research Experiments and Demonstrations (RED) (ACES RED 1 or AR1, 1 satellite) is estimated to be a 3-U CubeSat deployed from the International Space Station (ISS) on June 5, 2019, as a technology demonstrator. The mission set and sensor package associated with this satellite are classified. ACES RED 2 is currently in the development phase and is scheduled to launch in November 2021, The program was developed to lower costs for future Army space programs by identifying commercial off-the-shelf (COTS) technologies that are suitable for use in future Army satellite buses containing several experimental payloads.

ICEYE-X3 (Harbinger, 1 satellite) is a radar-imaging technology demonstrator that was launched successfully in May 2019 aboard a Rocket Lab Electron launch vehicle from Mahia, New Zealand. ICEYE-X3 is a 150 kilogram-class satellite carrying a low-resolution optical camera and an SAR payload. This satellite employs an easy-to-use interface application for smart phones, tablets, and computers and demonstrated real-time satellite tasking and return of state-of-health data from remote locations.

Appendix III: Navy Satellites

Fleet Satellite (FLTSAT, 1 satellite) was originally a constellation of five operational communications satellites used by the Navy, the Air Force, and the NCA as a secure communications link. This last remaining satellite was launched into GEO in 1989 with a design life of 12 years. The satellite has 23 channels in the ultra-high and super-high frequency bands. The Navy was assigned 10 channels, the Air Force uses 12 for command and control of its nuclear-capable forces, and a single channel is reserved for the NCA.[247] FLTSAT is scheduled to transfer to the USSF in 2022.[248]

Ultra-High Frequency Follow-on (UFO, 5 satellites) supports the Navy's global communications network, serving ships at sea and other U.S. military fixed and mobile terminals. These satellites replaced the Fleet Satellite Communications (FLTSATCOM) and were placed in GEO between 1996 and 2003 with a programmed life of 14 years. The system is compatible with sea-based and ground terminals that were already in service.[249] These five satellites are scheduled to be transferred to the USSF in 2022.[250]

Mobile User Objective System (MUOS, 5 satellites) is a next-generation narrowband tactical satellite communications system. Launched between 2012 and 2016, this constellation was designed for U.S. forces on the move. The system is not limited by weather or foliage and can handle a volume of information 10 times greater than legacy UFO satellites can handle. The constellation is ideal for troops located in the most remote locations or in urban environments and buildings with no satellite access.[251] All five MUOS satellites are scheduled to be transferred to the USSF in 2022.[252]

Appendix IV: Other Agency Satellites

National Reconnaissance Office Satellites

The **TOPAZ Future Imagery Architecture (FIA, 5 satellites)** is believed to be composed of advanced radar imaging satellites, the follow-on to the Onyx radar imaging satellites. These systems were to be fielded alongside FIA optical systems, but those satellites were cancelled because of cost overruns.[253]

Orion (also known as Mentor, 8 satellites) is composed of signals intelligence satellites in GEO that were designed to intercept missile telemetry from Russia and China. These satellites carry very large dish antennas (upwards of 100 meters in diameter) and are believed to have significant COMINT capabilities that allow them to tap into satellite mobile phone communications.[254]

The **SIGINT High Altitude Replenishment Program (SHARP, 1 satellite)** is likely a series of ELINT/SIGINT satellites in GEO with large dish antennas based in GEO.[255]

Nemesis (2 satellites) are COMINT satellites in GEO that are believed to target commercial satellite uplinks by collocating themselves with the target satellite and therefore must possess RPO capabilities.[256]

Space Test Program Satellite 4 (STPSat4, 1 satellite) carries several test sensors and components that include RF Modular Tiles for phased array technology (synthetic aperture radar).

Onyx/Lacrosse (3 satellites) is composed of satellites that reportedly include very large synthetic aperture radar arrays for imaging terrestrial-based targeting.[257]

Kennen/Crystal (5 satellites) is composed of digital electro-optical imaging satellites that provide real-time optical observation with an estimated 15 centimeter (six inch) resolution.[258]

Rapid Pathfinder Program (RPP, 3 satellites) is part of a science and technology development program run by the NRO.[259]

Rapid Acquisition Small Rocket (RASR, 3 satellites) is an unknown payload that was launched as part of the NRO's program to streamline commercial launch opportunities for small satellites.[260]

Quasar (9 satellites) are "satellite data system" (SDS) spacecraft that relay communications and transmit real-time data between U.S. reconnaissance satellites, aircraft, and ground stations.[261]

Intruder (unacknowledged, estimated at 16 satellites)[262] is likely composed of Ocean Surveillance (ISR) platforms designed to track ships and aircraft. These satellites were launched into LEO between 2001 and 2020 and include radar and/or optical sensors.[263] Two Intruder satellites were carried into orbit with every launch, enabling them to maneuver and keep station relative to each other. Each satellite has an estimated weight of 7,150 pounds, allowing for the inclusion of very capable sensor packages along with a considerable amount of additional fuel and the potential for other expendables. The functionality of these satellites is similar to that of Air Force GSSAP satellites, which at the very least opens up the potential for RPO operations with other on-orbit platforms.[264]

NOAA Satellites

Geostationary Operational Environmental Satellites (GOES, 4 satellites) observe terrestrial and space weather for North, Central, and South America as well as the Atlantic and Pacific Oceans.[265] GOES-16 and GOES-17 are currently in full operation, while GOES-14 and GOES-15 have been placed in a storage mode.[266]

Polar-Orbiting Operational Environmental Satellites (POES, 4 satellites) provide short-term and long-term global weather forecasting.[267]

Deep Space Climate Observatory (DSCOVR, 1 satellite) is the primary warning system for geomagnetic storms and provides solar wind data.[268]

Endnotes

1. S. 1790, National Defense Authorization Act for Fiscal Year 2020, Public Law 116-92, 116th Cong., December 20, 2019, Title IX, Subtitle D, https://www.congress.gov/bill/116th-congress/senate-bill/1790 (accessed February 23, 2021).
2. Tyrone Marshall Jr., "Officials: Space No Longer a Sanctuary; Sequester a Threat," U.S. Department of Defense, March 26, 2015, https://www.defense.gov/Explore/News/Article/Article/604366/ (accessed March 10, 2021).
3. The first successful anti-satellite system was tested by the Soviet Union in 1968 and entered service in 1973. Anatoly Zak, "The Hidden History of the Soviet Satellite-Killer," *Popular Mechanics*, November 1, 2013, https://www.popularmechanics.com/space/satellites/a9620/the-hidden-history-of-the-soviet-satellite-killer-16108970/ (accessed March 10, 2021).
4. Douglas L. Loverro, former Secretary of Defense for Space Policy, statement on "Space Warfighting Readiness: Policies, Authorities, and Capabilities" before the Committee on Armed Services, U.S. House of Representatives, March 14, 2018, p. 4, https://docs.house.gov/meetings/AS/AS00/20180314/107973/HHRG-115-AS00-Wstate-LoverroD-20180314.pdf (accessed February 23, 2021).
5. U.S. Department of Defense, *Defense Space Strategy Summary*, June 2020, p. 3, https://media.defense.gov/2020/Jun/17/2002317391/-1/-1/1/2020_DEFENSE_SPACE_STRATEGY_SUMMARY.PDF (accessed February 23, 2021).
6. U.S. Defense Intelligence Agency, *Challenges to Security in Space*, 2019, p. 21, https://www.dia.mil/Portals/27/Documents/News/Military%20Power%20Publications/Space_Threat_V14_020119_sm.pdf (accessed February 23, 2021).
7. Weston Williams, "Russia Launches Anti-Satellite Weapon: A New Warfront in Space?" *The Christian Science Monitor*, December 22, 2016, http://www.csmonitor.com/USA/Military/2016/1222/Russia-launches-anti-satellite-weapon-A-new-warfront-in-space (accessed February 23, 2021).
8. Bill Gertz, "China Tests Anti-Satellite Missile," *The Washington Free Beacon*, November 9, 2015, http://freebeacon.com/national-security/china-tests-anti-satellite-missile/ (accessed February 23, 2021).
9. U.S. Space Force, "About United States Space Force: Mission," https://www.spaceforce.mil/About-Us/About-Space-Force/Mission/ (accessed February 23, 2021).
10. Dean Cheng, "Space 201: Thinking About the Space Domain," in *2018 Index of U.S. Military Strength*, ed. Dakota L. Wood (Washington: The Heritage Foundation, 2018), pp. 73–82, https://www.heritage.org/sites/default/files/2017-10/2018_IndexOfUSMilitaryStrength-2.pdf.
11. R. Cargill Hall, "Civil–Military Relations in America's Early Space Program," in R. Cargill Hall and Jacob Neufeld, eds., *The U.S. Air Force in Space: 1945 to the 21st Century*, Proceedings, Air Force Historical Foundation Symposium, Andrews Air Force Base, Maryland, September 21–22, 1995, p. 21, https://media.defense.gov/2010/Oct/01/2001329745/-1/-1/0/AFD-101001-060.pdf (accessed February 23, 2021).
12. Center for Strategic and International Studies, Missile Defense Project, "SM-65 Atlas," *Missile Threat*, last modified June 15, 2018, https://missilethreat.csis.org/missile/atlas/ (accessed February 23, 2021).
13. General Bernard A. Schriever, USAF (Ret.), "Military Space Activities: Recollections and Observations," in Hall and Neufeld, eds., *The U.S. Air Force in Space: 1945 to the 21st Century*, p. 14.
14. U.S. Department of State, Office of the Historian, *Foreign Relations of the United States, 1955–1957, National Security Policy*, Volume XIX, Document 9, "Report by the Technological Capabilities Panel of the Science Advisory Committee," February 14, 1955, https://history.state.gov/historicaldocuments/frus1955-57v19/d9 (accessed February 23, 2021).
15. Schriever, "Military Space Activities: Recollections and Observations," p. 14.
16. U.S. Department of the Interior, National Park Service, Minuteman Missile National Historic Site, "Intercontinental Ballistic Missiles: The Atlas Missile," last updated October 20, 2020, https://www.nps.gov/articles/atlas-icbm.htm (accessed February 23, 2021).
17. Hall, "Civil–Military Relations in America's Early Space Program," pp. 21–23.
18. The U-2 is a manned jet aircraft that carries cameras and other sensors at altitudes in excess of 70,000 feet. In an effort to enforce future arms control agreements, President Eisenhower unveiled an "Open Skies" proposal to the Soviet Union, calling for aerial surveillance of the other's military installation through strategic reconnaissance flights—an idea that was rejected by Soviet leader Nikita Khrushchev. Editors of Encyclopaedia Britannica, "U-2, United States Aircraft," *Encyclopaedia Britannica*, https://www.britannica.com/technology/U-2 (accessed February 23, 2021), and History.com Editors, "President Eisenhower Presents His 'Open Skies' Plan," This Day in History: July 21, 1955, last updated July 20, 2020, https://www.history.com/this-day-in-history/eisenhower-presents-his-open-skies-plan (accessed February 23, 2021).
19. Hall, "Civil–Military Relations in America's Early Space Program," p. 23.
20. Smithsonian Institution, National Air and Space Museum, "Satellite, Vanguard TV 3," https://airandspace.si.edu/collection-objects/satellite-vanguard-tv-3/nasm_A19761857000 (accessed February 23, 2021).
21. National Aeronautics and Space Administration, "60 Years Ago: The U.S. Response to Sputnik," last updated November 27, 2017, https://www.nasa.gov/feature/60-years-ago-the-us-response-to-sputnik/ (accessed February 24, 2021).
22. Hall, "Civil–Military Relations in America's Early Space Program," p. 29.

23. R. Cargill Hall and Jacob Neufeld, "Preface," in *The U.S. Air Force in Space: 1945 to the 21st Century*, p. iii.

24. "Address by President Dwight Eisenhower to the UN General Assembly," September 22, 1960, https://2009-2017.state.gov/p/io/potusunga/207330.htm (accessed March 2, 2021).

25. Biography.com Editors, "Alan Shepard," updated August 27, 2020, https://www.biography.com/astronaut/alan-shepard (accessed March 10, 2021).

26. Sarah Pruitt, "What Really Happened to Yuri Gagarin, the First Man in Space?" History.com, updated August 22, 2018, https://www.history.com/news/what-really-happened-to-yuri-gagarin-the-first-man-in-space (accessed February 23, 2021).

27. HistoryLists.org, "Events: List of 6 Manned Moon Landings," https://historylists.org/events/list-of-6-manned-moon-landings.html (accessed February 23, 2021).

28. National Aeronautics and Space Administration, "Space Shuttle: Mission Information," last updated August 29, 2011, https://www.nasa.gov/mission_pages/shuttle/shuttlemissions/index.html (accessed February 23, 2021). One of the missions, STS 51-L (Challenger), was lost on January 28, 1986. National Aeronautics and Space Administration, "Space Shuttle: Mission Archives: Shuttle Missions—1986," last updated November 23, 2007, https://www.nasa.gov/mission_pages/shuttle/shuttlemissions/list_1986.html (accessed February 23, 2021).

29. Voyager 1 and 2 and Mariner 2, 4, 5, 6, 7, 9, and 10. California Institute of Technology, Jet Propulsion Laboratory, "NASA's Voyager 2 Probe Enters Interstellar Space," December 10, 2018, https://www.jpl.nasa.gov/news/news.php?feature=7301 (accessed February 23, 2021), and National Aeronautics and Space Administration, "Mariner Space Probes," last updated October 27, 2009, https://history.nasa.gov/mariner.html (accessed February 23, 2021).

30. Reconnaissance Satellites likely exceed 299 in number and include photo reconnaissance, electronic, signals, and communications intelligence as well as radar birds. See Gunter's Space Page, "Military Spacecraft—USA," "Reconnaissance, Optical," "Reconnaissance, Radar," and "SIGINT/COMIN/ELINT," last update February 22, 2021, https://space.skyrocket.de/directories/sat_mil_usa.htm (accessed February 23, 2021).

31. European Space Agency Earth Observation Portal (eoPortal), eoPortal Directory, "Satellite Missions: Transit: Transit—US Navy Navigational Satellite System (NNSS)," https://directory.eoportal.org/web/eoportal/satellite-missions/t/transit (accessed February 24, 2021).

32. Larry Greenemeier, "GPS and the World's First 'Space War,'" *Scientific American*, February 8, 2016, https://www.scientificamerican.com/article/gps-and-the-world-s-first-space-war/ (accessed February 23, 2021).

33. For examples of retrospectives of this pivotal moment in war, see ibid. and Sharon Watkins Lang, "SMDC History: 25 Years Since First 'Space War,'" U.S. Army, January 20, 2016, https://www.army.mil/article/161173/smdc_history_25_years_since_first_space_war (accessed February 23, 2021).

34. Commission to Assess United States National Security Space Management and Organization, *Report of the Commission to Assess United States National Security Space Management and Organization*, January 11, 2001, pp. 52 and 80–81, https://aerospace.csis.org/wp-content/uploads/2018/09/RumsfeldCommission.pdf (accessed February 24, 2021).

35. John Venable, "Done Right, Trump's Space Force Would Put the U.S. on Top," Heritage Foundation *Commentary*, June 21, 2018, https://www.heritage.org/defense/commentary/done-right-trumps-space-force-would-put-the-us-top.

36. U.S. Department of Defense, *Defense Space Strategy Summary*, p. 3.

37. Williams, "Russia Launches Anti-Satellite Weapon: A New Warfront in Space?"

38. Gertz, "China Tests Anti-Satellite Missile."

39. Mike Gruss, "Does the Pentagon Need a Space Acquisition Agency?" *SpaceNews*, July 28, 2016, https://spacenews.com/does-the-pentagon-need-a-space-acquisition-agency/ (accessed February 23, 2021).

40. U.S. Space Force, U.S. Army Space and Missile Defense Command, Chief of Naval Operations, Commandant of the Marine Corps, Joint Chiefs of Staff, and Joint Requirements Oversight Council.

41. Assistant Secretary of the Air Force for Space Acquisition and Integration; Assistant Secretary of Defense for Space Policy; Chief of Space (Force) Operations; Commander, U.S. Space Command (SPACECOM/CC); National Reconnaissance Office; Space Development Agency (SDA); Army Space and Missile Defense Command (SMDC)/Army Forces Strategic Command (ARSTRAT); and Assistant Secretary for the Navy for Research Development and Acquisition.

42. U.S. Government Accountability Office, "Defense Space Acquisitions: Too Early to Determine If Recent Changes Will Resolve Persistent Fragmentations in Management and Oversight," GAO-16-592R, July 27, 2016, p. 1, https://www.gao.gov/assets/680/678697.pdf (accessed February 24, 2021). See also ibid., Enclosure 1, "DOD Space Acquisition Management and Oversight: Information Presented to Congressional Committees," May 17, 2016, pp. 3 and 14.

43. U.S. Department of Defense, Office of the Under Secretary of Defense, Research and Engineering, Space Development Agency, "About Us," https://www.sda.mil/home/about-us/ (accessed February 24, 2021).

44. U.S. Department of Defense, Office of the Under Secretary of Defense, Research and Engineering, Space Development Agency, "Frequently Asked Questions: When Will SDA Transition to Be a Part of the U.S. Space Force?" https://www.sda.mil/home/about-us/faq/ (accessed February 24, 2021).

45. U.S. Department of Defense, "Report to Congressional Defense Committees: Final Report on Organizational and Management Structure for the National Security Space Components of the Department of Defense," August 9, 2018, p. 4, https://media.defense.gov/2018/Aug/09/2001952764/-1/-1/1/ORGANIZATIONAL-MANAGEMENT-STRUCTURE-DOD-NATIONAL-SECURITY-SPACE-COMPONENTS.PDF (accessed February 24, 2021)

46. News release, "Department of Defense Establishes U.S. Space Command," U.S. Department of Defense, August 29, 2019, https://www.defense.gov/Newsroom/Releases/Release/Article/1948288/department-of-defense-establishes-us-space-command/ (accessed February 24, 2021).
47. Space Command was first established in 1987 but was disestablished in 2001 following the terrorist attacks on September 11, 2001, because of the need to establish Special Operations Command (SOCOM) and President Bush's desire to limit the number of combatant commands to 10. Space Command was subsequently made a subunified command under STRATCOM.
48. This is the second time USSPACECOM has been on the roster of combatant commands within the UCP. It was established in 1986 as a *functional* combatant command designed to unify command and control of the space forces within the Army, Navy, and Air Force and support the development of a shield against Soviet ballistic missiles that was known as the Strategic Defense Initiative (SDI). In 2002, the UCP was amended to place the USSPACECOM mission for space operations, as well as warning and assessment of space attack, under U.S. Strategic Command as a subordinate unified command. Edward J. Drea, Ronald H. Cole, Walter S. Poole, James F. Schnabel, Robert J. Watson, and Willard J. Webb, *History of the Unified Command Plan 1946–2012*, Office of the Chairman of the Joint Chiefs of Staff, Joint History Office, 2013, pp. 55 and 86, https://www.jcs.mil/Portals/36/Documents/History/Institutional/Command_Plan.pdf (accessed February 24, 2021).
49. Theresa Hitchens, "SPACECOM to Write New Ops War Plan: 100km and Up," *Breaking Defense*, September 16, 2019, https://breakingdefense.com/2019/09/spacecom-to-write-new-ops-war-plan-100km-and-up (accessed February 24, 2021).
50. U.S. Space Force, "About United States Space Force: Mission."
51. U.S. Department of Defense, United States Space Command, "Organizational Fact Sheet," https://www.spacecom.mil/Portals/32/USSPACECOM%20Fact%20Sheet%2018Jun20.pdf?ver=2020-06-18-155219-363 (accessed February 24, 2021).
52. This number is an estimate based on the fact that approximately 12,100 active-duty, 1,600 reserve-component, and 11,900 civilians are part of 14th Air Force. Todd Harrison, "How Much Will the Space Force Cost?" Center for Strategic and International Studies *Brief*, November 2018, https://csis-website-prod.s3.amazonaws.com/s3fs-public/publication/181119_Harrison_SpaceForce_layout_FINAL.pdf (accessed February 24, 2021).
53. Fact Sheet, "Fourteenth Air Force," U.S. Air Force, Air Force Space Command, current as of October 2019, https://www.afspc.af.mil/About-Us/Fact-Sheets/Display/Article/1604750/fourteenth-air-force/ (accessed July 1, 2020).
54. Sandra Erwin, "Space Force Stands up Operations Command in Colorado Springs," *SpaceNews*, October 21, 2020, https://spacenews.com/space-force-stands-up-operations-command-in-colorado-springs/ (accessed February 24, 2021).
55. The Commercial Satellite Communications Office manages the procurement of commercial SATCOM for DOD. The Space Vehicles Directorate develops and transitions space technologies to provide space-based ISR, space domain awareness, communications, global position, navigation and timing, and defensive space control (space defense) capabilities. U.S. Air Force, Kirtland Air Force Base, "AFRL Space Vehicles Directorate," https://www.kirtland.af.mil/Units/AFRL-Space-Vehicles-Directorate/ (accessed February 24, 2021).
56. Sandra Erwin, "U.S. Space Force Creates Acquisition Command to Build Culture of Innovation," *SpaceNews*, July 18, 2020, https://spacenews.com/u-s-space-force-creates-acquisition-command-to-build-culture-of-innovation/ (accessed February 24, 2021).
57. Erwin, "Space Force Stands Up Operations Command in Colorado Springs."
58. Captain Christopher Merian, "U.S. Space Force Stands up STAR Delta Provisional," U.S. Space Force, July 24, 2020, https://www.spaceforce.mil/News/Article/2287104/us-space-force-stands-up-star-delta-provisional/ (accessed February 24, 2021).
59. Sandra Erwin, "Space Force Reorganizes Former Air Force Space Wings into 'Deltas' and 'Garrisons,'" *SpaceNews*, July 24, 2020, https://spacenews.com/space-force-reorganizes-former-air-force-space-wings-into-deltas-and-garrisons/ (accessed February 24, 2021).
60. Captain Bruce E. Cone, USAF, *The United States Air Force Eastern Test Range: Range Instrumentation Handbook*, AFETR-TR-76-04, Patrick Air Force Base, Florida, July 1, 1976, Report Documentation Page: Abstract, https://apps.dtic.mil/dtic/tr/fulltext/u2/a029237.pdf (accessed February 24, 2021).
61. Erwin, "Space Force Reorganizes Former Air Force Space Wings into 'Deltas' and 'Garrisons.'"
62. Table 3, "U.S. Space Force Budget Summary," in U.S. Department of Defense, Secretary of the Air Force, Office of Financial Management and Budget (SAF/FMB), *Department of the Air Force FY 2021 Budget Overview*, p. 8, https://www.saffm.hq.af.mil/Portals/84/documents/FY21/SUPPORT_/FY21%20Budget%20Overview_1.pdf?ver=2020-02-10-152806-743 (accessed February 24, 2021).
63. U.S. Space Force, "Transfer FAQs: Transferring to the U.S. Space Force FAQS," https://www.spaceforce.mil/Transfer/ (accessed February 24, 2021).
64. Transcript, "Space Force Briefing," U.S. Department of Defense, December 20, 2019, https://www.defense.gov/Newsroom/Transcripts/Transcript/Article/2045979/space-force-briefing/ (accessed February 24, 2021).
65. Lynn Kirby, "2.4k Airmen to Transfer into Space Force Beginning Sept. 1," U.S. Space Force, September 1, 2020, https://www.spaceforce.mil/News/Article/2332258/24k-airmen-to-transfer-into-space-force-beginning-sept-1/ (accessed February 24, 2021).
66. Hope Hodge Seck, "Here's Who Will Get the First Chance to Transfer into Space Force," Military.com, March 5, 2020, https://www.military.com/daily-news/2020/03/05/heres-who-will-get-first-chance-transfer-space-force.html (accessed February 24, 2021).
67. U.S. Department of the Air Force, "Report to Congressional Committees: Alternative Acquisition System for the United States Space Force," May 2020, https://acqnotes.com/wp-content/uploads/2020/05/Alternative-Acquisition-System-for-the-US-Space-Force.pdf (accessed February 24, 2021).
68. Justin Johnson, former Acting Assistant Secretary of Defense for Space Policy, written response to query, February 12, 2021.

69. Sandra Erwin, "Space Force Proposes 'Alternative Acquisition System' with Less Red Tape," *SpaceNews*, May 21, 2020, https://spacenews.com/space-force-proposes-alternative-acquisition-system-with-less-red-tape/ (accessed February 24, 2021).
70. Table 6-6, "Inyears DOA TOA, Budget Authority and Outlays by Appropriation Account (Discretionary and Mandatory), Current Dollars," in U.S. Department of Defense, Office of the Under Secretary of Defense (Comptroller), *National Defense Budget Estimates for FY 2021*, April 2020, pp. 109–110, https://comptroller.defense.gov/Portals/45/Documents/defbudget/fy2021/FY21_Green_Book.pdf (accessed February 24, 2021).
71. Union of Concerned Scientists, "UCS Satellite Database," updated January 1, 2021, http://web.archive.org/web/20201217120442/https://www.ucsusa.org/resources/satellite-database (accessed March 10, 2021).
72. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Environmental Satellite Data and Information Service, "Currently Flying," https://www.nesdis.noaa.gov/content/currently-flying (accessed March 10, 2021).
73. National Aeronautics and Space Administration, "NASA'S Fleet of Satellites Keep an Eye on Earth," last updated August 6, 2017, https://www.nasa.gov/image-feature/nasas-fleet-of-satellites-keep-an-eye-on-earth (accessed February 24, 2021), and National Aeronautics and Space Administration, "NASA'S Vantage Point over Earth," April 19, 2017, https://www.youtube.com/watch?v=iWKZ0_1f6hw (accessed February 24, 2021).
74. Air Force News Service, "AF Plans to Accelerate Defendable Space with Next-Gen OPIR," May 4, 2018, https://www.af.mil/News/Article-Display/Article/1512949/af-plans-to-accelerate-defendable-space-with-next-gen-opir/ (accessed February 24, 2021).
75. For details on these satellites, see Appendix I, *infra*.
76. Gunter's Space Page, "DSP 14, 15, 16, 17, 18, 19, 20, 21, 22, 23 (Phase 3)," last update March 19, 2020, https://space.skyrocket.de/doc_sdat/dsp-3.htm (accessed February 24, 2021).
77. Table, "Spacecraft in Service over Time (As of Sept. 30, 2019)," in "Air Force & Space Force Almanac 2020," *Air Force Magazine*, Vol. 103, No. 6 (June 2020), p. 67, https://www.airforcemag.com/app/uploads/2020/06/June2020_Fullissue5.pdf (accessed February 24, 2021).
78. Gunter's Space Page, "DSP 14, 15, 16, 17, 18, 19, 20, 21, 22, 23 (Phase 3)."
79. Gunter's Space Page, "Trumpet 4, 5 / SBIRS HEO-1, 2," last update November 4, 2020, https://space.skyrocket.de/doc_sdat/trumpet-fo.htm (accessed February 24, 2021), and "Trumpet 6, 7 / SBIRS HEO-3, 4," last update November 4, 2020, https://space.skyrocket.de/doc_sdat/trumpet-fo-2.htm (accessed February 24, 2021.
80. Gunter's Space Page, "SBIRS-GEO 1, 2, 3, 4" last update November 4, 2020, https://space.skyrocket.de/doc_sdat/sbirs-geo-1.htm (accessed February 24, 2021).
81. Kyle Mizokami, "The U.S. Space Force Is Ready to Turn on Its All-Seeing 'Space Fence,'" *Popular Science*, February 7, 2020, https://www.popularmechanics.com/military/weapons/a30798053/us-space-force-space-fence/ (accessed February 24, 2021).
82. Australian Space Academy, "An Overview of Space Situational Awareness," https://www.spaceacademy.net.au/intell/ssa.htm (accessed February 24, 2021). Speed converted from kilometers per second to miles per hour (mph).
83. Chalie L. Galliand, "Study of the Small: Potential for Operational Military Use of CubeSats," 24th Annual AIAA/USU [American Institute of Aeronautics and Astronautics/Utah State University] Conference on Small Satellites, August 10, 2010, p. 8, https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1199&context=smallsat (accessed February 24, 2021).
84. Fact Sheet, "Space Based Space Surveillance," U.S. Air Force, Air Force Space Command, current as of July 2019, https://www.afspc.af.mil/About-Us/Fact-Sheets/Article/249017/space-based-space-surveillance-sbss/ (accessed February 24, 2021).
85. Gunter's Space Page, "MSX," last update December 11, 2017, https://space.skyrocket.de/doc_sdat/msx.htm (accessed February 24, 2021), and "SBSS-1," last update December 11, 2017, https://space.skyrocket.de/doc_sdat/sbss-1.htm (accessed February 24, 2021).
86. Gunter's Space Page, "STSS-ATRR," last modified July 21, 2019, https://space.skyrocket.de/doc_sdat/stss-atrr.htm (accessed February 24, 2021), and news release, "Missile Defense Agency Space Tracking and Surveillance System Advanced Technology Risk Reduction Satellite Transfers to Air Force Space Command," U.S. Department of Defense, Missile Defense Agency, February 25, 2011, https://www.mda.mil/news/11news0004.html (accessed February 24, 2021).
87. News release, "Missile Defense Agency Space Tracking and Surveillance System Advanced Technology Risk Reduction Satellite transfers to Air Force Space Command."
88. Gunter's Space Page, "GSSAP 1, 2, 3, 4, 5, 6 (Hornet 1, 2, 3, 4, 5, 6)," last update November 4, 2020, https://space.skyrocket.de/doc_sdat/gssap-1.htm (accessed February 24, 2021).
89. Spaceflight101.com, "GSSAP Satellite Overview," https://spaceflight101.com/spacecraft/gssap/ (accessed February 24, 2021).
90. Fact Sheet, "Geosynchronous Space Situational Awareness Program," U.S. Air Force, Air Force Space Command, current as of September 2019, https://www.afspc.af.mil/About-Us/Fact-Sheets/Article/730802/geosynchronous-space-situational-awareness-program-gssap/ (accessed February 24, 2021).
91. Gunter's Space Page, "GSSAP 1, 2, 3, 4, 5, 6 (Hornet 1, 2, 3, 4, 5, 6)."
92. Air Command and Staff College, Space Research Electives Seminars, *AU-18 Space Primer* (Maxwell Air Force Base, AL: Air University Press, September 2009), p. 252, https://www.airuniversity.af.edu/Portals/10/AUPress/Books/AU-18.PDF (accessed February 24, 2021).

93. Ibid., p. 249.
94. Kristen Shimkus, "USSF Announces Initial Operational Capability and Operational Acceptance of Space Fence," United States Space Force, March 27, 2020, https://www.spaceforce.mil/News/Article/2129325/ussf-announces-initial-operational-capability-and-operational-acceptance-of-spa/ (accessed February 24, 2021).
95. The Department of Defense maintains a "space object catalog," also known as a SATCAT or SATC, for all tracked objects in space.
96. GlobalSecurity.org, "AN/FPS-85 Spacetrack Radar," last modified April 21, 2016, https://www.globalsecurity.org/space/systems/an-fps-85.htm (accessed February 24, 2021).
97. Fact Sheet, "Pave Paws Radar System," U.S. Air Force, current as of November 2015, https://www.af.mil/About-Us/Fact-Sheets/Display/Article/104593/pave-paws-radar-system/ (accessed February 24, 2021).
98. Air Command and Staff College, Space Research Electives Seminars, *AU-18 Space Primer*, p. 254.
99. Ibid.
100. Ibid., p. 255.
101. Ibid.
102. Massachusetts Institute of Technology, Haystack Observatory, "Millstone Hill Geospace Facility," https://www.haystack.mit.edu/the-millstone-hill-geospace-facility/ (accessed February 24, 2021).
103. Massachusetts Institute of Technology, Lincoln Laboratory, "Haystack Ultrawideband Satellite Imaging Radar," https://www.ll.mit.edu/r-d/projects/haystack-ultrawideband-satellite-imaging-radar (accessed February 24, 2021).
104. Brian Weeden, "The Numbers Game: What's in Earth Orbit and How Do We Know?" *The Space Review*, July 13, 2009, https://www.thespacereview.com/article/1417/1 (accessed February 24, 2021).
105. Radartutorial.eu, "Card Index of Radar Sets—Strategic Radar Systems: Altair," https://www.radartutorial.eu/19.kartei/01.oth/karte005.en.html (accessed February 24, 2021).
106. Center for Strategic and International Studies, Aerospace Security Project, "Polar Orbits 101," last updated October 26, 2020, https://aerospace.csis.org/aerospace101/popular-orbits-101/ (accessed February 24, 2021).
107. Ibid.
108. Weeden, "The Numbers Game: What's in Earth Orbit and How Do We Know?"
109. Debra Werner, "Indian Anti-Satellite Test Proves Early Test for Space Fence," *SpaceNews*, April 11, 2019, https://spacenews.com/indian-anti-satellite-test-proves-early-test-for-space-fence/ (accessed February 24, 2021).
110. Quoted in Loverro, statement on "Space Warfighting Readiness: Policies, Authorities, and Capabilities," March 14, 2018, pp. 2–3.
111 Todd Harrison, Kaitlyn Johnson, Thomas G. Roberts, Tyler Way, and Makena Young, Space Threat Assessment 2020, Center for Strategic and International Studies, Aerospace Security Project, March 2020, p. 6, https://csis-website-prod.s3.amazonaws.com/s3fs-public/publication/200330_SpaceThreatAssessment20_WEB_FINAL1.pdf (accessed February 24, 2021).
112. These measures also include "communication, transmission, and emissions security; camouflage, concealment, and deception; and system hardening" across the entire portfolio of space assets. U.S. Space Force, *Spacepower: Doctrine for Space Forces*, Space Capstone Publication, June 2020, p. 36, https://www.spaceforce.mil/Portals/1/Space%20Capstone%20Publication_10%20Aug%202020.pdf (accessed February 24, 2021).
113. Nathan Strout, "What Will the Space Development Agency Really Do?" C4ISRNET, July 24, 2019, https://www.c4isrnet.com/battlefield-tech/space/2019/07/24/what-will-the-space-development-agency-really-do/ (accessed February 24, 2021).
114. Adam Mann, "Starlink: SpaceX's Satellite Internet Project," Space.com, January 17, 2020, https://www.space.com/spacex-starlink-satellites.html (accessed February 24, 2021).
115. Gillian Rich, "SpaceX Doubles Starlink Internet Satellites in Orbit, Eyes Critical Mass," *Investor's Business Daily*, November 11, 2019, https://www.investors.com/news/spacex-launch-double-starlink-satellites-2020-surge/ (accessed February 24, 2021).
116. Joey Roulette, "Musk's Satellite Project Testing Encrypted Internet with Military Planes," Reuters, October 22, 2019, https://www.reuters.com/article/us-spacex-starlink-airforce/musks-satellite-project-testing-encrypted-internet-with-military-planes-idUSKBN1X12KM (accessed February 24, 2021).
117. Kris Osborn, "Army Seeks Thousands of High-Speed, Low Earth Orbit Satellites for Ground Attack," Warrior Maven, September 29, 2020, https://defensemaven.io/warriormaven/land/army-seeks-thousands-of-high-speed-low-earth-orbit-satellites-for-ground-attack-N0ghFfguE0uakOTOcufTJQ (accessed February 25, 2021).
118. Ibid.
119. U.S. Air Force, Air University, Curtis E. LeMay Center for Doctrine Development and Education, "Annex 3-14 Space Operations: Offensive Space Control," last updated June 19, 2012, https://fas.org/irp/doddir/usaf/3-14-annex-osc.pdf (accessed February 27, 2021).
120. Fact Sheet, "Geosynchronous Space Situational Awareness Program."

121. Frank Wolfe, "Space Force Developing Non-Kinetic Counterspace Systems," *Defense Daily*, November 9, 2020, https://www.defensedaily.com/space-force-developing-non-kinetic-counterspace-systems/space/ (accessed February 25, 2021).
122. Commission to Assess United States National Security Space Management and Organization, *Report of the Commission to Assess United States National Security Space Management and Organization*, p. 23.
123. Lawrence Sellin, "The US Is Unprepared for Space Cyberwarfare," *Military Times*, September 4, 2019, https://www.militarytimes.com/opinion/commentary/2019/09/04/the-us-is-unprepared-for-space-cyberwarfare/ (accessed February 25, 2021).
124. Ibid.
125. See Section VIII, "Requirements and Acquisition, Transport Layer" *infra*.
126. Telephone interview with Dean Cheng, Senior Research Fellow, The Heritage Foundation, December 16, 2020.
127. Wolfe, "Space Force Developing Non-Kinetic Counterspace Systems."
128. Peter Suciu, "Back in 1985, a U.S. Air Force F-15 Fighter 'Killed' a Satellite with a Missile," *The National Interest*, The Buzz Blog, June 1, 2020, https://nationalinterest.org/blog/buzz/back-1985-us-air-force-f-15-fighter-killed-satellite-missile-159271 (accessed February 25, 2021).
129. Wolfe, "Space Force Developing Non-Kinetic Counterspace Systems."
130. European Space Agency, "About Space Debris," http://www.esa.int/Safety_Security/Space_Debris/About_space_debris (accessed February 25, 2021).
131. Mike Gruss, "Hyten Tells Senate DoD Needs to Focus on Space Control Battle Management System," *SpaceNews*, September 20, 2016, https://spacenews.com/hyten-tells-senate-dod-needs-to-focus-on-space-control-battle-management-system/ (accessed February 25, 2021).
132. Gunter's Space Page, "GSSAP 1, 2, 3, 4, 5, 6 (Hornet 1, 2, 3, 4, 5, 6)."
133. Fact Sheet, "Geosynchronous Space Situational Awareness Program."
134. Spaceflight101.com, "GSSAP Satellite Overview."
135. Theresa Hitchens, "The Stellar Dance: US, Russia Satellites Make Potentially Risky Close Approaches," *Breaking Defense*, April 10, 2019, https://breakingdefense.com/2019/04/the-stellar-dance-us-russia-satellites-make-potentially-risky-close-approaches/ (accessed February 25, 2021).
136. Angelique Chrisafis, "'Act of Espionage': France Accuses Russia of Trying to Spy on Satellite Data," *The Guardian*, September 7, 2018, https://www.theguardian.com/world/2018/sep/07/france-accuses-russia-spying-satellite-communications-espionage (accessed January 8, 2021).
137. Mike Gruss, "DoD Will Spend $2 Billion on Space Control This Year," *SpaceNews*, March 23, 2016, https://spacenews.com/dod-will-spend-2-billion-on-space-control-this-year/ (accessed February 25, 2021).
138. Wolfe, "Space Force Developing Non-Kinetic Counterspace Systems."
139. Quoted in Theresa Shafer, "Thomas Schelling on Strategic Surprise," SKMurphy, September 11, 2018, https://www.skmurphy.com/blog/2018/09/11/thomas-schelling-on-strategic-surprise/ (accessed February 25, 2021).
140. Mike Fabey, "U.S. Space Command Develops Operational Concepts for Waging War in Orbit," *SpaceNews*, August 8, 2017, https://spacenews.com/u-s-space-command-develops-operational-concepts-for-fighting-war/ (accessed February 25, 2021).
141. Theresa Hitchens, "Exclusive: NRO, SPACECOM Craft CONOPS for War in Space," *Breaking Defense*, May 4, 2020, https://breakingdefense.com/2020/05/exclusive-nro-spacecom-craft-conops-for-war-in-space/ (accessed February 25, 2021).
142. U.S. Space Force, *Spacepower: Doctrine for Space Forces*, p. 42.
143. Ibid., p. xvi.
144. Ibid., p. 42, https://www.spaceforce.mil/Portals/1/Space%20Capstone%20Publication_10%20Aug%202020.pdf (accessed January 15, 2020).
145. Commission to Assess United States National Security Space Management and Organization, *Report of the Commission to Assess United States National Security Space Management and Organization*, p. xvi.
146. On June 20, 2019, Iran used a surface-to-air missile belonging to the Islamic Revolutionary Guard Corps to shoot down a Global Hawk. The decision on the U.S. response was made over time by the President of the United States.
147. Commission to Assess United States National Security Space Management and Organization, *Report of the Commission to Assess United States National Security Space Management and Organization*, pp. xv and 25.
148. Lieutenant General Daniel Karbler, Commander, U.S. Army Space and Missile Defense Command, e-mail response to query, December 11, 2020.
149. Office of Deputy Chief of Naval Operations for Information Warfare/Director of Naval Intelligence (N2N6 Strategic Engagements), e-mail response to request for information on Navy satellite systems, December 18, 2020.
150. NOAA operates but does not own seven additional satellites including one Suomi NPP satellite, one Jason-3 satellite, four DMSP satellites, and the EWS-G1 satellite. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Environmental Satellite Data and Information Service, "Currently Flying."

151. National Aeronautics and Space Administration, "NASA'S Fleet of Satellites Keep an Eye on Earth," and National Aeronautics and Space Administration, "NASA'S Vantage Point over Earth."
152. Rocket launch schedules from 2010 through 2020 in Space Launch Schedule, "Year," https://www.spacelaunchschedule.com/ (accessed February 25, 2021). See, for example, Space Launch Schedule, "2010 Launch Schedule," https://www.spacelaunchschedule.com/2010-launch-schedule/ (accessed February 25, 2021).
153. Karbler, e-mail response to query, December 11, 2020.
154. Isaac Nason, Michelle Creedon, and Nick Johansen, "CubeSat P-Pod Deployer Requirements," May 2002, p. [2], http://www.oh1sa.net/data/satellite/cubesat/P-POD-mk1/ppod_mk1_icd.pdf (accessed February 25, 2021). "The CubeSat program is a joint effort between Cal Poly and Stanford Universities to develop a new class of picosatellites, which lend themselves to the educational side of space development." Ibid.
155. Richard P. Welle, "The CubeSat Paradigm: An Evolutionary Approach to Satellite Design," presented at the 32nd Space Symposium, Technical Track, Colorado Springs, Colorado, April 11–12, 2016, p. 3, http://2019.spacesymposium.org/wp-content/uploads/2017/10/Welle-Richard-THE-CUBESAT-PARADIGM%EF%80%A2-AN-EVOLUTIONARY-APPROACH-TO-SATELLITE-DESIGN.pdf (accessed February 25, 2021).
156. National Aeronautics and Space Administration, NASA CubeSat Launch Initiative, *CubeSat 101: Basic Concepts and Processes for First-Time CubeSat Developers*, revision dated October 2017, p. 38, https://www.nasa.gov/sites/default/files/atoms/files/nasa_csli_cubesat_101_508.pdf (accessed February 25, 2021).
157. For descriptions of each of these satellites, see Appendix II, *infra*.
158. Matthew A. Anderson, Christopher M. Duron, Timothy A. Farmer, Matthew A. Hitt, Melanie G. Klinner, Gerald E. Lanz, John R. London III, Mark E. Ray, Molly E. Riebling, Sierra L. Smith, Davis J. Weeks, Ryan T. Wolff, "Army Decade in Space" 34th Annual AIAA/USU [American Institute of Aeronautics and Astronautics/Utah State University] Conference on Small Satellites, August 16, 2020, p. 6, https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=4712&context=smallsat (accessed February 25, 2021).
159. Galliand, "Study of the Small: Potential for Operational Military Use of CubeSats," p. 11.
160. Office of Deputy Chief of Naval Operations for Information Warfare/Director of Naval Intelligence (N2N6 Strategic Engagements), e-mail response to request for information on Navy Satellite Systems, December 18, 2020. For descriptions of those unclassified systems, see Appendix III, *infra*.
161. Venable, "Done Right, Trump's Space Force Would Put the U.S. on Top."
162. Harrison, "How Much Will the Space Force Cost?"
163. U.S. Army Space and Missile Defense Command, "U.S. Army Space & Missile Defense Command: SMDC Organization," https://www.smdc.army.mil/ABOUT/ (accessed July 1, 2020).
164. Barry Rosenberg, "Why Is SPAWAR Now NAVWAR? Networks & Cyber Warfare," *Breaking Defense*, June 5, 2019, https://breakingdefense.com/2019/06/why-is-spawar-now-navwar-networks-cyber-warfare/ (accessed February 26, 2021).
165. "US Naval Satellite Operations Center Takes Control of Fifth MUOS Satellite," *Naval Today*, November 17, 2017, https://navaltoday.com/2017/11/17/us-naval-satellite-operations-center-takes-control-of-fifth-muos-satellite/ (accessed February 26, 2021).
166. For general descriptions of those satellites, see Appendix IV, *infra*.
167. Commission to Assess United States National Security Space Management and Organization, *Report of the Commission to Assess United States National Security Space Management and Organization*, pp. 67–68.
168. National Reconnaissance Office, "What We Do," https://www.nro.gov/About-NRO/The-National-/Reconnaissance-Office/What-We-Do/ (accessed February 26, 2021).
169. Commission to Assess United States National Security Space Management and Organization, *Report of the Commission to Assess United States National Security Space Management and Organization*, pp. 59–60.
170. Ibid.
171. 5 U.S.C. § 522, https://www.law.cornell.edu/uscode/text/5/552 (accessed February 26, 2021).
172. 50 U.S.C. § 3142, https://www.law.cornell.edu/uscode/text/50/3142 (accessed February 26, 2021).
173. 10 U.S.C., Armed Forces, https://www.law.cornell.edu/uscode/text/10 (accessed March 5, 2021).
174. Roger Cliff, *The Military Potential of China's Commercial Technology*, RAND Corporation, Project Air Force, 2001, p. 27, https://www.rand.org/content/dam/rand/pubs/monograph_reports/2001/MR1292.pdf (accessed February 26, 2021).
175. See note 150, *supra*.
176. SCA is defined as "[a] transferable authority and ability to provide Telemetry, Tracking and Commanding (TT&C) of a satellite's bus and to provide control and management of a satellite's payload unless PCA is assigned to another organization." U.S. Air Force, Air Force Space Command, Instruction 10-1204, "Satellite Operations," May 15, 2014, p. 32, https://static.e-publishing.af.mil/production/1/afspc/publication/afspci10-1204/afspci10-1204.pdf (accessed February 26, 2021).

177. Fact Sheet, "Defense Meteorological Satellite Program," U.S. Space Force, current as of October 2020, https://www.spaceforce.mil/About-Us/Fact-Sheets/Article/2197779/defense-meteorological-satellite-program/ (accessed February 26, 2021).

178. National Aeronautics and Space Administration, NASA Science, "Solar System Exploration," updated June 6, 2019, https://solarsystem.nasa.gov/missions/?order=launch_date+desc&per_page=50&page=0&search=&fs=&fc=33&ft=&dp=&category=33 (accessed February 26, 2021).

179. National Aeronautics and Space Administration, "NASA's Fleet of Satellites Keep an Eye on Earth," last updated August 6, 2017, https://www.nasa.gov/image-feature/nasas-fleet-of-satellites-keep-an-eye-on-earth (accessed February 26, 2021).

180. National Aeronautics and Space Administration, "Our Missions and Values," last updated August 17, 2020, https://www.nasa.gov/careers/our-mission-and-values (accessed February 26, 2021).

181. National Aeronautics and Space Administration, Space Technology Mission Directorate, "About Us," last updated August 5, 2020, https://www.nasa.gov/directorates/spacetech/about_us/index.html (accessed February 26, 2021).

182. Strout, "What Will the Space Development Agency Really Do?"

183. Files on objects in space are produced/updated once or twice a day by the Space Surveillance Network, during which time CubeSats can be released in relative proximity to other satellites - and those with propulsion systems can move relatively significant distances to be masked by, close on and ultimately attach to other satellites. Michael L Umbricht, "Tracking 'Flocks' of CubeSats," Brown University, Ladd Observatory Curator Blog, October 7, 2018, https://blogs.brown.edu/umbricht/2018/10/07/flocking_cubesats/ (accessed February 26, 2021).

184. Aerospace Corporation, "CubeSats Get Close: Proximity Operation with Interesting Implications," July 22, 2020, https://aerospace.org/article/cubesats-get-close-proximity-operation-interesting-implications (accessed February 26, 2021).

185. Safe contact implies one satellite grasping another, vice two birds executing a controlled docking procedure. Gunter's Space Page, "CPOD A, B (PONSFD A, B)," last updated January 24, 2021, https://space.skyrocket.de/doc_sdat/cpod.htm (accessed February 26, 2021).

186. Hall, "Civil–Military Relations in America's Early Space Program," p. 23.

187. H.R. 3942, Commercial Space Launch Act, Public Law 98-575, 98th Cong., October 30, 1984, https://www.congress.gov/bill/98th-congress/house-bill/3942 (accessed February 26, 2021).

188. S. 916, National Aeronautics and Space Administration Multiyear Authorization Act of 1990, 101st Cong., introduced May 3, 1989, https://www.congress.gov/bill/101st-congress/senate-bill/916 (accessed February 26, 2021), and H.R. 5649, National Aeronautics and Space Administration Multiyear Authorization Act of 1990, 101st Cong., introduced September 18, 1990, https://www.congress.gov/bill/101st-congress/house-bill/5649?s=1&r=60 (accessed February 26, 2021).

189. H.R. 5382, Commercial Space Launch Amendments Act of 2004, Public Law 108-492, 108th Cong., December 23, 2004, https://www.congress.gov/bill/108th-congress/house-bill/5382 (accessed February 26, 2021).

190. Space Launch Schedule, "2010 Launch Schedule."

191. SpaceX, Northrup Grumman, and the United Launch Alliance have been launching systems into space throughout the past decade. In July 2020, Rocket Lab Ltd., Astra Space, and Firefly Aerospace were scheduled to launch their first systems into space. Space Launch Schedule, "2020 Launch Schedule," https://www.spacelaunchschedule.com/2020-launch-schedule/ (accessed February 26, 2021).

192. Eric Ralph, "SpaceX Falcon 9 Ends Year as the Most-Launched Rocket of 2020," Teslarati, December 20, 2020, https://www.teslarati.com/spacex-falcon-9-most-launched-rocket-2020/ (accessed January 29, 2021).

193. Space Launch Schedule, "2020 Launch Schedule."

194. Ibid.

195. News release, "Space Force Awards National Security Space Launch Phase 2 Launch Service Contracts to United Launch Alliance, LLC (ULA) and Space Exploration Technologies Corporation (SpaceX)," U.S. Space Force, August 7, 2020, https://www.spaceforce.mil/News/Article/2305278/space-force-awards-national-security-space-launch-phase-2-launch-service-contra/ (accessed February 26, 2021).

196. Kris Osborn, "Army Seeks Thousands of High-Speed, Low Earth Orbit Satellites for Ground Attack."

197. Brian Wang, "SpaceX Starlink Can Provide Super GPS with a Software Modification," Nextbigfuture Blog, September 28, 2020, https://www.nextbigfuture.com/2020/09/spacex-starlink-can-be-tweaked-to-provide-super-gps.html (accessed February 26, 2021).

198. Anderson et al., "Army Decade in Space" p. 12.

199. Theresa Hitchens, "Exclusive: J6 Says JADC2 Is a Strategy; Service Posture Reviews Coming," *Breaking Defense*, January 4, 2021, https://breakingdefense.com/2021/01/exclusive-j6-says-jadc2-is-a-strategy-service-posture-reviews-coming/ (accessed February 26, 2021).

200. The Air Force's AFWERX program invests in U.S. and global tech companies and organizations and uses military problems to accelerate commercial technologies. As an early-stage investor, it can then use private capital to develop and field commercial systems to solve military problems. AFWERX, "What Is AFWERX?" https://www.afwerx.af.mil/faq.html (accessed February 26, 2021).

201. That band includes VHF push-to-talk radios, radar system cell towers, Very Small Aperture (VSAT) terminals associated with satellite Internet service, and even aircrew and nautical rescue emergency locator beacons. HawkEye 360, "Technology: Unique Source of Advanced RF Analytics," https://www.he360.com/technology/ (accessed February 26, 2021).

202. HawkEye 360, "AFWERX Announces HawkEye 360 Among Top Teams Selected to Revolutionize the Space Ecosystem," Cision PR Newswire, October 15, 2020, https://www.prnewswire.com/news-releases/afwerx-announces-hawkeye-360-among-top-teams-selected-to-revolutionize-the-space-ecosystem-301153300.html (accessed February 26, 2021).
203. Commission to Assess United States National Security Space Management and Organization, *Report of the Commission to Assess United States National Security Space Management and Organization*, p. 35.
204. Nathan Strout, "Intelsat Satellite Returns to Service After First Commercial Life Extension Mission," C4ISRNET, April 17. 2020, https://www.c4isrnet.com/battlefield-tech/space/2020/04/17/intelsat-satellite-returns-to-service-after-first-commercial-life-extension-mission/ (accessed February 26, 2021).
205. Joseph Parrish, "Robotic Servicing of Geosynchronous Satellites (RSGS)," U.S. Department of Defense, Defense Advanced Research Projects Agency, https://www.darpa.mil/program/robotic-servicing-of-geosynchronous-satellites (accessed February 26, 2021).
206. Gruss, "Does the Pentagon Need a Space Acquisition Agency?"
207. U.S. Government Accountability Office, "Defense Space Acquisitions: Too Early to Determine If Recent Changes Will Resolve Persistent Fragmentations in Management and Oversight," p. 1, and ibid., Enclosure 1, "DOD Space Acquisition Management and Oversight: Information Presented to Congressional Committees," pp. 3 and 14.
208. U.S. Department of Defense, Office of the Under Secretary of Defense, Research and Engineering, Space Development Agency, "Transport," https://www.sda.mil/transport/ (accessed February 26, 2020).
209. U.S. Department of Defense, Office of the Under Secretary of Defense, Research and Engineering, Space Development Agency, "Battle Management Command, Control, and Communication (BMC3)," https://www.sda.mil/battle-management/ (accessed February 26, 2020).
210. U.S. Department of Defense, Office of the Under Secretary of Defense, Research and Engineering, Space Development Agency, "Tracking," https://www.sda.mil/tracking/ (accessed February 26, 2020).
211. U.S. Department of Defense, Office of the Under Secretary of Defense, Research and Engineering, Space Development Agency, "Custody," https://www.sda.mil/custody/ (accessed February 26, 2020).
212. U.S. Department of Defense, Office of the Under Secretary of Defense, Research and Engineering, Space Development Agency, "Emerging Capabilities (Deterrence Layer)," https://www.sda.mil/emerging-capabilities/ (accessed January 21, 2020).
213. U.S. Department of Defense, Office of the Under Secretary of Defense, Research and Engineering, Space Development Agency, "Navigation," https://www.sda.mil/navigation/ (accessed February 26, 2020).
214. U.S. Department of Defense, Office of the Under Secretary of Defense, Research and Engineering, Space Development Agency, "Support," https://www.sda.mil/support/ (accessed February 26, 2020).
215. Hitchens, "Exclusive: J6 Says JADC2 Is a Strategy; Service Posture Reviews Coming."
216. The DAF's non-pass-through budget was $169.0 billion in 2021. The budget for the DAF within DOD's "Greenbook" includes the pass-through and totaled $208.9 billion. The difference equates to pass-through funding that totaled $39.9 billion. Table 6-24, "Air Force Outlays by Public Law Title," in U.S. Department of Defense, Office of the Under Secretary of Defense (Comptroller), *National Defense Budget Estimates for FY 2021*, p. 259, and Table 3, "U.S. Space Force Budget Summary," in U.S. Department of Defense, Secretary of the Air Force, Office of Financial Management and Budget (SAF/FMB), *Department of the Air Force FY 2021 Budget Overview*, p. 8.
217. Theresa Hitchens, "Space Force Nears Year Mark, Acquisition Remains a Quagmire," *Breaking Defense*, October 2, 2020, https://breakingdefense.com/2020/10/as-space-force-nears-one-year-mark-acquisition-remains-a-quagmire/ (accessed February 26, 2021).
218. Gruss, "Does the Pentagon Need a Space Acquisition Agency?"
219. See note 40, *supra*.
220. See note 41, *supra*.
221. U.S. Government Accountability Office, "Defense Space Acquisitions: Too Early to Determine If Recent Changes will Resolve Persistent Fragmentations in Management and Oversight," p. 1, and ibid., Enclosure 1, "DOD Space Acquisition Management and Oversight: Information Presented to Congressional Committees," pp. 3 and 14.
222. Galliand, "Study of the Small: Potential for Operational Military Use of CubeSats," p. 14.
223. Stack Exchange, Space Exploration Beta, "CubeSat Dispenser Operation for Fleet Deployment," edited January 23, 2016, https://space.stackexchange.com/questions/13661/cubesat-dispenser-operation-for-fleet-deployment (accessed February 26, 2021).
224. Galliand, "Study of the Small: Potential for Operational Military Use of CubeSats," pp. 12–13.
225. Gruss, "Hyten Tells Senate DoD Needs to Focus on Space Control Battle Management System."
226. National Aeronautics and Space Administration, George C. Marshall Space Flight Center, "NanoSail-D," *NASA Facts*, https://www.nasa.gov/centers/marshall/pdf/484314main_NASAfactsNanoSail-D.pdf (accessed February 26, 2021).
227. Janet L. Anderson, "NASA's Nanosail-D 'Sails' Home—Mission Complete," National Aeronautics and Space Administration, Small Satellite Missions, last updated November 29, 2011, https://www.nasa.gov/mission_pages/smallsats/11-148.html (accessed February 26, 2021), and Gunter's Space Page, "LightSail 1, 2," last modified October 7, 2019, https://space.skyrocket.de/doc_sdat/lightsail-1.htm (accessed February 26, 2021).

228. Telephone interview with Dr. Everett Dolman, Professor of Comparative Military Studies, Department of Space Power and Schriever Space Scholars, USAF Air Command and Staff College, February 19, 2021.

229. Commission to Assess United States National Security Space Management and Organization, *Report of the Commission to Assess United States National Security Space Management and Organization*, p. 20.

230. Rosenberg, "Why Is SPAWAR Now NAVWAR? Networks & Cyber Warfare."

231. U.S. Space Force, *Spacepower: Doctrine for Space Forces*, p. 42.

232. Loverro, statement on "Space Warfighting Readiness: Policies, Authorities, and Capabilities," March 14, 2018, p. 14.

233. Table, "GPS Constellation Status for 2/27/21," in U.S. Department of Homeland Security, U.S. Coast Guard Navigation Center, last updated February 27, 2021, https://www.navcen.uscg.gov/?Do=constellationStatus&srt=SVN&dir=Asc (accessed February 27, 2021); GPS.gov, "Space Segment, Current and Future Satellite Generations," last modified January 12, 2021, https://www.gps.gov/systems/gps/space/ (accessed February 27, 2021); and Space Launch Schedule, "SpaceX Launch Schedule," https://www.spacelaunchschedule.com/category/spacex/ (accessed February 26, 2021).

234. Gunter's Space Page, "GPS-2R (Navstar-2R)," last update March 19, 2020, https://space.skyrocket.de/doc_sdat/navstar-2r.htm (accessed February 26, 2021); "GPS-2RM (Navstar-2RM)," last update March 19, 2020, https://space.skyrocket.de/doc_sdat/navstar-2rm.htm (accessed February 26, 2021); "GPS-2F (Navstar-2F)," last update July 21, 2020, https://space.skyrocket.de/doc_sdat/navstar-2f.htm (accessed February 26, 2021); "GPS-3 (Navstar-3)," last update November 19, 2020, https://space.skyrocket.de/doc_sdat/navstar-3.htm (accessed February 26, 2021); and Space Launch Schedule, "2020 Launch Schedule."

235. GPS.gov, "Space Segment: Current and Future Satellite Generations," and U.S. Air Force, "GPS Modernization Fact Sheet," https://www.gps.gov/systems/gps/modernization/2006-fact-sheet.pdf (accessed March 10, 2021).

236. Space Launch Schedule, "SpaceX Launch Schedule."

237. Fact Sheet, "Advanced Extremely High Frequency System," U.S. Air Force, Air Force Space Command, current as of July 2019, https://www.afspc.af.mil/About-Us/Fact-Sheets/Display/Article/249024/advanced-extremely-high-frequency-system/ (accessed February 26, 2021), and Christine Lunsford, "In photos: Atlas V Launches AEHF-6 Military Satellite for US Space Force," Space.com, May 15, 2020, https://www.space.com/space-force-atlas-v-rocket-aehf-6-satellite-launch-photos.html (accessed February 26, 2021).

238. Fact Sheet, "Defense Satellite Communications System," U.S. Air Force, current as of November 2015, https://www.af.mil/About-Us/Fact-Sheets/Display/Article/104555/defense-satellite-communications-system/ (accessed February 26, 2021).

239. Gunter's Space Page, "WGS 1, 2, 3 (WGS Block 1)," Gunter's Space Page, last update March 19, 2020, https://space.skyrocket.de/doc_sdat/wgs-1.htm\ (accessed February 26, 2021).

240. Fact Sheet, "Defense Meteorological Satellite Program," U.S. Air Force, Air Force Space Command, current as of July 2019, https://www.afspc.af.mil/About-Us/Fact-Sheets/Article/249019/defense-meteorological-satellite-program/ (accessed February 26, 2021).

241. Fact Sheet, "Defense Meteorological Satellite Program," U.S. Space Force, current as of October 2020.

242. Anderson et al., "Army Decade in Space," p. 3.

243. Ibid., p. 5.

244. Gunter's Space Page, "TacSat 6," last update December 11, 2020, https://space.skyrocket.de/doc_sdat/tacsat-6.htm (accessed February 26, 2021).

245. Anderson et al., "Army Decade in Space," p. 6.

246. Galliand, "Study of the Small: Potential for Operational Military Use of CubeSats," p. 9.

247. Gunter's Space Page, "MUOS 1, 2, 3, 4, 5," last update November 4, 2020, https://space.skyrocket.de/doc_sdat/muos-1.htm (accessed February 26, 2021).

248. Office of Deputy Chief of Naval Operations for Information Warfare/Director of Naval Intelligence (N2N6 Strategic Engagements), e-mail response to request for information on Navy satellite systems, December 18, 2020.

249. Gunter's Space Page, "FLTSATCOM 6, 7, 8 (Block 2)," last update December 11, 2017, https://space.skyrocket.de/doc_sdat/fltsatcom-2.htm (accessed February 26, 2021), and Office of Deputy Chief of Naval Operations for Information Warfare/Director of Naval Intelligence (N2N6 Strategic Engagements), e-mail response to request for information on Navy satellite systems, December 18, 2020.

250. Office of Deputy Chief of Naval Operations for Information Warfare/Director of Naval Intelligence (N2N6 Strategic Engagements), e-mail response to request for information on Navy satellite systems, December 18, 2020.

251. Gunter's Space Page, "UFO 4, 5, 6, 7 (UHF-FO Block 2)," last update December 11, 2017, https://space.skyrocket.de/doc_sdat/ufo-4.htm (accessed February 26, 2021); "UFO 8, 9, 10 (UHF-FO Block 3)," last update December 11, 2017, https://space.skyrocket.de/doc_sdat/ufo-8.htm (accessed February 26, 2021); and "UFO 11 (UHF-FO Block 4)," last update December 11, 2017, https://space.skyrocket.de/doc_sdat/ufo-11.htm (accessed February 26, 2021).

252. Office of Deputy Chief of Naval Operations for Information Warfare/Director of Naval Intelligence (N2N6 Strategic Engagements), e-mail response to request for information on Navy satellite systems, December 18, 2020.

253. Gunter's Space Page, "Topaz 1, 2, 3, 4, 5 (FIA-Radar 1, 2, 3, 4, 5)," last update December 11, 2020), https://space.skyrocket.de/doc_sdat/topaz-1.htm (accessed February 26, 2021).
254. Gunter's Space Page, "Orion 5, 6, 7, 8, 9, 10, 11, 12," last update December 12, 2020, https://space.skyrocket.de/doc_sdat/orion-5_nro.htm (accessed February 26, 2021).
255. Gunter's Space Page, "SHARP 1 ?," last update November 4, 2020, https://space.skyrocket.de/doc_sdat/sharp.htm (accessed February 26, 2021). Question mark in original.
256. Gunter's Space Page, "Nemesis 1, 2 (PAN, CLIO / P360)," last update April 12, 2019, https://space.skyrocket.de/doc_sdat/nemesis-1.htm (accessed February 26, 2021).
257. Gunter's Space Page, "Onyx 1, 2, 3, 4, 5 (Lacrosse 1, 2, 3, 4, 5)" last update February 9, 2021, https://space.skyrocket.de/doc_sdat/onyx.htm (accessed February 26, 2021).
258. Gunter's Space Page, "KH-11 / Kennen / Crystal," last update December 11, 2020), https://space.skyrocket.de/doc_sdat/kh-11.htm (accessed February 26, 2021).
259. Gunter's Space Page, "RPP," last update February 4, 2020, https://space.skyrocket.de/doc_sdat/rpp.htm (accessed February 26, 2021), and Union of Concerned Scientists, "UCS Satellite Database," Excel format.
260. Gunter's Space Page, "USA 294 (NROL 151)," last update December 20, 2020, https://space.skyrocket.de/doc_sdat/usa-294.htm (accessed February 26, 2021).
261. Gunter's Space Page, "Quasar 20, 21 (SDS-4 1, 2), last update December 11, 2020, https://space.skyrocket.de/doc_sdat/sds-4.htm (accessed February 26, 2021), and "Quasar 12, 13, 14, 15, 16, 17, 18, 19 (SDS-3 1, 2, 3, 4, 5, 6, 7, 8)," last update December 11, 2020, https://space.skyrocket.de/doc_sdat/sds-3.htm (accessed February 26, 2021).
262. Union of Concerned Scientists, "UCS Satellite Database," Excel format.
263. GlobalSecurity.org, "SB-WASS—Consolidated Program," last modified March 31, 2017, https://www.globalsecurity.org/space/systems/sbwass_c.htm (accessed February 26, 2021).
264. Gunter's Space Page, "Intruder 5, ..., 12 (NOSS-3 1, ..., 8)," last update November 4, 2020, https://space.skyrocket.de/doc_sdat/noss-3.htm (accessed February 26, 2021). Ellipses in original.
265. European Space Agency Earth Observation Portal (eoPortal), eoPortal Directory, "GOESR (Geostationary Operational Environmental Satellite-R)," https://directory.eoportal.org/web/eoportal/satellite-missions/content/-/article/goes-r (accessed February 25, 2021).
266. National Oceanic and Atmospheric Administration, National Weather Service, National Centers for Environmental Prediction, Space Weather Prediction Center, "GOES-14 & 15 Are Now in Storage Mode," March 11, 2020, https://www.swpc.noaa.gov/news/goes-14-15-are-now-storage-mode (accessed February 26, 2021).
267. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Environmental Satellite Data and Information Service, "Currently Flying."
268. Ibid.

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