U.S. Space Force

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The U.S. Space Force (USSF) was created with enactment of the fiscal year (FY) 2020 National Defense Authorization Act (NDAA) on December 20, 2019.[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 functions under the direction and leadership of the Secretary of the Air Force. The 2019 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.

The mission of this newest service is 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 [military space professionals], acquiring military space systems, maturing the military doctrine for space power, and organizing space forces to present to our Combatant Commands."[2]

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 capabilities that those two sectors bring to the Space Force are critical to an assessment of this new service.[3] The domination of great-power competition in space relies on the interwoven efforts of all three U.S. sectors—military, civil, and commercial space—and that reliance is growing.

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.[4]

Though recognized by every President since Dwight Eisenhower in the mid-1950s, various issues kept the United States from developing a single service charged with managing space assets and capabilities. In 1961, the Air Force was named executive agent for space research and development, but at that point, the Army and Navy already had well-established programs.[5] This splintered approach was sustained by every Administration for the next six decades. Nevertheless, U.S. space capabilities advanced at a stunning pace.

The effectiveness of the DOD's space support missions was put on full display during Operation Desert Storm,[6] 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.

As early as 2001, a congressionally mandated report warned of our growing dependence on space and the vulnerability of U.S. assets in that domain and ultimately recommended establishing a Space Corps within the DAF.[7] Those recommendations were set aside following the terrorist attacks of September 11, 2001, and by the mid-2010s, the command and control of space had fragmented across at least 60 different DOD offices.[8] All the while, U.S. reliance on the Global Positioning System (GPS) for air, land, and sea maneuver, targeting, and

engagement has grown to the point of being nearly universal, exposing a critical vulnerability that our adversaries have moved to exploit.

Both China and Russia have developed doctrine, organizations, and capabilities to challenge U.S. access to and operations in the space domain. Concurrently, their use of space is expanding significantly. These nations have demonstrated the capability to put American space assets at risk, and until very recently, the United States had not taken overt steps to protect those systems, much less to develop its own warfighting capability in that domain.

The 2017 NDAA mandated that DOD conduct a review of the organization and command and control of space assets within the department. Shortly after the NDAA was enacted, President Donald Trump directed that a Space Force be established within the DAF.[9] Congress concurred and created the USSF with the 2020 NDAA.

An important addition to the U.S. warfighting command structure was the reestablishment of U.S. Space Command as the 11th combatant command within the Department of Defense with the mission of conducting "operations in, from, and to space to deter conflict and, if necessary, defeat aggression, deliver space combat power for the Joint/Combined force, and defend U.S. vital interests with allies and partners."[10]

U.S. Space Force 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 its scope to Air Force personnel and assets, equating to a total workforce of approximately 27,300[11] 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.[12]

Those personnel, organizations, and structures have been or 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.

These three commands are leading or 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 final level of command and will fall under Deltas and Garrisons.

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.

Space Systems Command. This command was scheduled to stand up in the summer of 2021[13] 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 $11.3 billion annual budget for research, development, test, and evaluation (RDT&E) and the acquisition of new systems.[14]

At present, DOD's primary space procurement agency is 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, D.C.,[15] and the Air Force Research Laboratory (AFRL) Space Vehicles Directorate based at Kirkland Air Force Base, New Mexico.[16]

Space Training and Readiness (STAR) Command. STARCOM will be the third USSF field organization and will be based at Peterson Air Force Base in Colorado. It will be led by a two-star general and will be responsible for the education and training of space professionals. Until the two-star command stands up, a provisional command and foundational element of STARCOM, STAR Delta (P), which was established in July 2020, will serve as the parent organization for several education, training, test, and evaluation units.[17]

Personnel. The 2020 NDAA specified that only the Air Force was required to provide personnel for the Space Force, and 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.[18] However, most are still wearing the same uniforms they wore before being reassigned, as well as working in the same offices. "Assigned" personnel remain in the Air Force or another service and perform work in support of the USSF. An officer that transfers will be (re)commissioned in the USSF, and enlisted personnel that transfer will execute an enlistment contract with the new service.[19]

The 2021 NDAA authorized 6,434 military personnel, 3,545 civilian personnel, and a total end strength of 9,979 on September 30, 2021.[20] More than 6,400 people have been hand selected to make the transition, and as of the end of April 2021, more than 4,840 had transferred to the new service.[21] Methodically expanding the Space Force to include all DAF military and civilian personnel that the service intends to transfer will probably not be completed until the end of FY 2021.[22]

However, even when combined with the new geographic combatant command for space, a service formed just from Air Force assets will not remedy the dysfunctional oversight or command and control issues that the Space Force initiative was intended to resolve.[23] For that to happen, a significant portion of the approximately 21,200 space professionals that remain in the Army and Navy[24] will need to be incorporated into the Space Force—something that is not likely to happen until FY 2024 or later.

Funding

The President's budget request for FY 2022 lays out a relatively robust level of funding for every aspect of the new service's mission set. The budget for Operations and Maintenance (O&M) is $3.4 billion; the budget for RDT&E is $11.3 billion; and procurement adds another $2.8 billion for a total of $17.4 billion, a 13 percent increase over FY 2021.

Assuming that the President's budget is fully funded, Space Force end strength will be authorized up to 12,764 military and civilian personnel, an increase of 2,785 over FY 2021.[25] The combination of robust funding and manpower levels will allow the CSO to continue to focus on building a strong organizational foundation and filling critical billets with the right people.

Capacity

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. The USSF's position, navigation, and timing (PNT); command and control (C2); communications

TABLE 15

U.S. Space Force Budget

In billions of dollars

	Operation and Maintenance	Military Personnel*	Research, Development, Test, and Evaluation	Procurement	Overseas Contingency Operations	Military Construction	Total
FY 2021	$2.6	0	$10.5	$2.3	0.1	0	$15.4
FY 2022	$3.4	0	$11.3	$2.8	0	0	$17.4

* U.S. Space Force personnel costs were funded by U.S. Air Force Military Personnel, FY 2021 ($800.3 million) and FY 2022 ($929.8 million).
NOTE: Figures may not sum to totals due to rounding.
SOURCES: Extracted from U.S. Air Force budget summaries for fiscal years 2021 and 2022. For example: Table 3, "U.S. Space Force Budget Summary," in U.S. Department of the Air Force, *Department of the Air Force Fiscal Year 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 September 3, 2021).

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(Comm); and weather satellites (referred to collectively as Backbone satellites) and its intelligence, surveillance, and reconnaissance (ISR) satellites are unrivaled and provide extraordinary capabilities. Its space situational awareness (SSA) satellites and terrestrial-based capabilities, while also unrivaled, are limited and require additional resourcing. Each satellite, satellite constellation, and terrestrial space surveillance site has unique characteristics and an expected life span.

The Space Force has a total of 70 Backbone satellites that enable every facet of modern American warfare, to include the collection of real-time intelligence and the ability to communicate, adaptively maneuver, and deliver precision effects almost anywhere on the planet.

Satellite Constellations

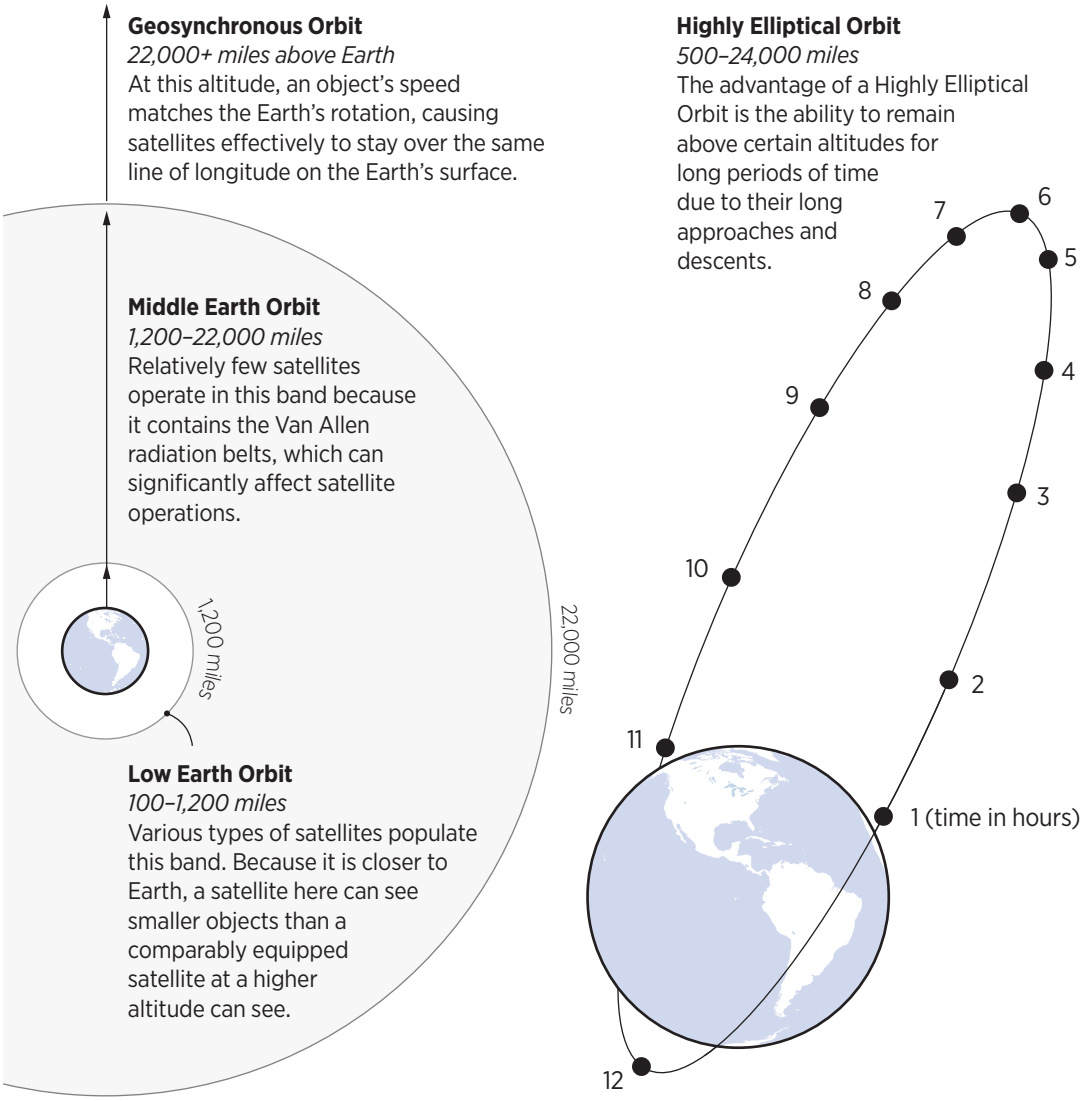
The Space Force mission is conducted through a network of satellites, ground-based radar, ground stations, and situational awareness nodes. In 2018, the Secretary of the Air Force stated that the service operates 77 satellites vital to national security that provide communications, command and control, missile warning, nuclear detonation detection, weather, and GPS for the world.[26] An estimated 90 satellites in that portfolio now reside within the Space Force. (See Table 17).

Global Positioning System (38 Satellites). Perhaps the best-known constellation of satellites under Space Force control is the Global Positioning System (GPS), which provides PNT for millions of simultaneous users around the world. It takes 24 of these satellites to provide seamless global coverage, and 31 are currently operational.[27] Approximately seven additional satellites that have been decommissioned and serve as on-orbit spares bring the total to 38.

GPS III is the latest upgrade to the platform and incorporates a more robust anti-jamming capability. The fifth GPS III[28] satellite was launched into orbit on June 17, and the scheduled launch of the sixth in September 2021 will increase the number in orbit to 39.[29] Interoperability with other Global Navigation Satellite Systems (GNSS) such as the European Galileo network and the Japanese Quazi-Zenith Satellite System adds an impressive level of resiliency.[30]

FIGURE 4

Types of Earth Orbits



SOURCE: Heritage Foundation research.

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Weather (Four Satellites). Defense weather satellites have been collecting weather data and providing forecasts for U.S. military operations since 1962 through the Defense Meteorological Satellite Program (DMSP).[31] Currently, four operational DMSP satellites are in polar low-Earth orbits (LEOs).[32]

The main sensors for these weather satellites are optical, and each provides continuous visual and infrared imagery of cloud cover over an area approximately 1,600 nautical miles wide and provide complete global coverage of weather features every 14 hours.[33] Launched between 1999 and 2009 with a life expectancy

of just five years, they have continued to deliver exceptional data well beyond their expected lifetimes.[34]

Communications (28 Satellites). Milstar is a satellite communications (SATCOM) system designed in the 1980s to provide the National Command Authorities assured, survivable global communications with a low probability of intercept or detection. The technology built into this five-satellite constellation was crafted to overcome enemy jamming and nuclear effects and was considered the DOD's most robust and reliable SATCOM system when it was fielded.

The follow-on to Milstar is the Advanced Extremely High Frequency System (AEHF). This system is a network of satellites operated by the Space Force for the Joint Force that allows the DOD to sustain secure, jam-resistant communications and C2 for high-priority military ground, sea, and air assets located anywhere in the world. The AEHF Constellation includes six satellites[35] in GEO.[36]

The Defense Satellite Communications System (DSCS) has seven operational satellites that provide nuclear-hardened, global communications to the Defense Department, the Department of State, and the National Command Authorities. The system is capable of high data rates and provides anti-jamming capabilities.

Wideband Global SATCOM (10 Satellites). Wideband Global SATCOM (WGS) is a joint-service program funded by the U.S. Air Force and U.S. Army, along with international partners Australia and Canada, and is used by all DOD services as well as National Command Authorities. Once known as the Wideband Gapfiller Satellite,[37] WGS provides Super High Frequency (SHF) wideband communications, using direct broadcast satellite technology to provide C2 for U.S. and allied forces. With solid capabilities that include phased array antennas and digital signal processing technology, this system delivers a flexible architecture with a satellite life span of up to 14 years.

Space-Based Infra-Red System (Six Satellites).[38] The Space-based Infrared System (SBIRS) is an integrated constellation of satellites designed to deliver early missile warning and provide intercept cues for missile defenses. This surveillance network was designed to incorporate three satellites in high elliptical orbit (HEO) and eight others in geosynchronous orbit (GEO), each working in concert with ground-based data processing and command and control centers. Because SBIRS HEO is a retaskable orbit, these satellites can be moved to more optimum orbits/viewpoints as mission requirements dictate. Five SBIRS GEO satellites have been placed in orbit, and it is expected that the final vehicle, GEO-6, will launch sometime in 2022.[39]

The funding that was removed from SBIRS shifted to a new program, Next-Generation Overhead Persistent Infrared (Next-Gen OPIR), which will include a new ground-control system. The program is intended to deliver resilient detection and tracking capability through a contested environment that includes emerging advances in adversary rocket propulsion technology. It is expected that fielding of a strategically survivable constellation of satellites to provide missile warning will begin sometime in FY 2023.[40]

Defense Support Program (Five Satellites). Defense Support Program (DSP) satellites were designed to detect launches of ICBMs or Sea Launched Ballistic Missiles (SLBMs) against the U.S. and its allies. Its secondary missions include 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 and booster plumes against the Earth's background. Phase 1 placed four satellites in orbit from 1970 through 1973[41] and was followed by Phase 2, which placed six satellites in orbit from 1979–1987.[42] Phase 3 consisted of 10 DSP satellites that were launched from 1989–2007.[43]

Although Phase 3 DSP satellites have long exceeded their design lifetimes, reliability has exceeded expectations, and at least five[44] and as many as eight are still providing reliable data and are now integrated with and controlled by the SBIRS program ground station.[45]

Space Situational Awareness Systems

Knowledge of hostile systems—their locations, their positional history, and how those satellites are maneuvering in real time—conveys intent and collectively shapes the protocols and counterspace decisions that follow. Space situational awareness is therefore critical to every aspect of defensive and offensive counterspace operations and forms the foundation for DOD counterspace activities.[46]

In addition to adversary systems, other significant threats are in orbit. The National Aeronautics and Space Administration (NASA) estimates that as many as a half-million objects with diameters between 0.4 inches and four inches are circling the Earth,[47] and the Australian Space Academy says that objects in LEO are traveling between 15,600 and 17,900 miles an hour.[48]

Maintaining a high level of situational awareness of satellites and debris 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 six dedicated and 17 collateral or contributing 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 ground-based sensors but without their weather-related and sunlight-related limitations.

Some satellites track objects and debris fields from LEO. Others operate from a much higher orbital position (GEO) and are capable of maneuvering to perform detailed inspections of orbiting items of especially high interest.

Space-Based Surveillance System (Six Satellites). The Geosynchronous Space Situational Awareness Program (GSSAP) is a classified surveillance constellation of four satellites that can accurately track and characterize objects in orbit.[49] Operating near GEO, GSSAP satellites are maneuverable and therefore able to perform rendezvous and proximity operations (RPO) on objects of interest in space.[50] Launched in pairs, the first two GSSAP satellites were put in orbit on July 28, 2014, followed by the second two on August 19, 2016, and each has a life span of up to seven years.[51]

The first of the two remaining satellites, Space-Based Surveillance System-1 (SBSS-1), was launched to LEO in 2010 with a seven-year life expectancy.[52] The second, Space Tracking and Surveillance System Advanced Technology Risk Reduction (STSS-ATR), is an RDT&E satellite placed in a polar LEO on May 5, 2009, with an unknown life expectancy. It was placed in orbit by the Missile Defense Agency (MDA) but is now part of the USSF portfolio.[53]

Space Surveillance Network (Six Dedicated Ground-Based Sensors). The U.S. Space Surveillance Network (SSN) is comprised of 23 ground-based radar and optical tracking sites that have the ability to detect, track, identify, and catalog all man-made objects orbiting the Earth. Of the 23 sites, six are dedicated sensors with a primary mission of space surveillance.

Seven collateral sensors are part of the network, but their primary mission is to detect and track ICBMs and SLBMs and to test and evaluate other systems. Another 10 contributing SSN sensors controlled by other organizations or agencies provide space surveillance support upon request from the National Space Defense Center (NSDC).

Reconnaissance and Imaging Satellites (Unknown). Although the history of the Air Force is steeped in these reconnaissance systems, the operational details of each constellation are classified. In the late 1990s and early 2000s, the Air Force moved to develop and field a constellation of space-based radar satellites. That program (known as Lacrosse/Onyx) launched five satellites, each carrying a synthetic aperture radar (SAR) as its prime imaging sensor. Because SAR systems can see through clouds with high resolution, they offer the potential to provide a capability from which it is hard to hide.[54]

TABLE 16

Space Launches by Country Since 2010

	U.S.	China	Russia	India
2010	17	16	16	3
2011	19	19	20	3
2012	12	19	12	2
2013	19	15	18	3
2014	21	15	22	4
2015	19	19	14	3
2016	24	22	13	7
2017	29	18	13	4
2018	29	39	13	7
2019	20	34	14	6
2020	53	19	21	14
2021	66	22	26	7
Total	**328**	**257**	**202**	**63**

SOURCE: Space Launch Schedule, https://www.spacelaunchschedule.com/ (accessed September 8, 2021).

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Space Launch Capacity

The Space Force manages the National Security Space Launch (NSSL) program, 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 (ULA) 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 ULA and SpaceX, and those two vendors will provide space launch services for the Space Force through 2027.[55]

In 2010, four organizations, including NASA, were involved in launching manned and unmanned systems into space. Today, nine private corporations—twice the number that had launched systems into orbit in 2019—are engaged in placing satellites into orbit.[56] In 2021, U.S. companies are scheduled to launch 66 missions into space, and China and Russia are scheduled to conduct 22 and 26 launches, respectively.[57] America has turned the corner on this vital capability, and the access to space that these private companies provide will be a major factor in determining whether the United States is able to prevail in the great-power competition that lies ahead.

Capability

With an estimated 90 satellites in its portfolio, the USSF can meet much of the communications, collection, and imagery demand placed on it by the National Command Authorities and the strategic-level intelligence requirements of the Defense Department. However,

TABLE 17

U.S. Satellites in Orbit

System	Function	Satellites
GPS	Positioning, Navigation, and Timing	38
SBIRS	Missile Warning	9
DSP	Missile Warning	5
SBSS	Space Surveillance	1
STSS-ATR	Missile Defense	1
GSSAP	Space Tracking	4
DMSP	Weather	4
Milstar	Communications	5
AEHF	Communications	6
DSCS	Communications	7
WGS	Communications	10
Total		**90**

NOTE: Data are current as of May 20, 2021.
SOURCES:

- Union of Concerned Scientists, "UCS Satellite Database," updated May 1, 2021, https://www.ucsusa.org/resources satellite-database (accessed September 3, 2021).
- 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 September 3, 2021).
- 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 September 3, 2021).
- 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 September 3, 2021).
- 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 September 3, 2021).
- Gunter's Space Page, "Trumpet 6, 7 / SBIRS HEO-3, 4," last update April 29, 2021, https://space.skyrocket.de/doc_sdat/trumpet-fo-2. htm (accessed September 3, 2021).
- 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 September 3, 2021).
- Fact Sheet, "Space Based Space Surveillance," U.S. Air Force, Air Force Space Command (Archived), current as of July 2019, https://www.afspc.af.mil/About-Us/Fact-Sheets/Article/249017/space- based-space-surveillance-sbss/ (accessed September 3, 2021).
- Gunter's Space Page, "STSS-ATRR," last update July 21, 2019, https://space.skyrocket.de/doc_sdat/stss-atrr.htm (accessed September 3, 2021).
- 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 26, 2011, https://www.mda.mil/news/11news0004.html (accessed September 3, 2021).
- 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 September 3, 2021).

TABLE 18

U.S. Space Launches by Organization

Organization	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total
Space X	2	0	2	3	5	7	10	18	20	13	31	36	147
United Launch Alliance	10	12	9	11	14	12	12	8	7	4	13	12	124
Northrup Grumman	2	4	1	5	2	0	2	3	2	3	5	2	31
Rocket Lab, Ltd	0	0	0	0	0	0	0	0	0	0	2	6	8
NASA	3	3	0	0	0	0	0	0	0	0	0	2	8
Virgin Orbit	0	0	0	0	0	0	0	0	0	0	0	3	3
Firefly Aerospace	0	0	0	0	0	0	0	0	0	0	1	1	2
Blue Origin	0	0	0	0	0	0	0	0	0	0	0	2	2
Astra Space Launch Co.	0	0	0	0	0	0	0	0	0	0	1	0	1
Relativity Space	0	0	0	0	0	0	0	0	0	0	0	1	1
USAF	0	0	0	0	0	0	0	0	0	0	0	1	1
Total	**17**	**19**	**12**	**19**	**21**	**19**	**24**	**29**	**29**	**20**	**53**	**66**	**328**

SOURCE: Space Launch Schedule, "USA Launch Schedule," https://www.spacelaunchschedule.com/category/usa/ (accessed September 8, 2021).

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getting real-time satellite intelligence to warfighters at the operational and tactical levels is still problematic. The loss of even a small number of those 90 satellites could significantly impact operational capabilities across the DOD.

Backbone Satellites. In spite of an ever-growing demand, the USSF can meet a significant amount of the strategic demand for collection, imagery, and communications placed on it by the National Command Authorities and the Defense Department. The PNT services offered by GPS are unrivaled in both capacity and capability. With 31 operational GPS satellites in orbit and seven spaceborne (dormant) spares, the system has enough redundancy and resiliency to handle losses associated with normal (not-combat-related) space operations.

The current and growing DOD demands for imagery and collection are another thing entirely. The shortfall is projected to be so great that the Departments of the Air Force and Army, the National Reconnaissance Office, and other agencies have invested in and are employing the services of commercial organizations to provide collection and imagery on demand.[58]

In the summer of 2020, the U. S. Army conducted an exercise called Project Convergence 2020 (PC20), which was designed to test the capability of commercial spaceborne systems to provide the intelligence, imagery, and communications linkages for warfighters in the service's "close fight." Brigade Combat Teams (BCTs), Combat Aviation Brigades (CABs), and Expeditionary Signal Battalion-Enhanced (ESB-E) were given access to 600 commercial SpaceX Starlink satellites in LEO to facilitate faster decisions.[59]

When combined with other small satellites (SmallSats), the sensors on Starlink's rapidly

TABLE 19

Satellites by Weight

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

SOURCE: Table 1, "Satellites by Mass," in 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. 1, https:// digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1199&context=smallsat (accessed September 3, 2021).

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expanding constellation, which numbered 1,440 satellites as of May 2021,[60] will enable the Army's concept for a Multi-Domain Operations (MDO)–Capable Force by 2028 and an MDO-Ready Force by 2035.[61] The capabilities demonstrated in PC20 are similar in nature to those sought in the Air Force's Advanced Battle Management System (ABMS) and the Navy's Overmatch C2 development programs.[62] Starlink reportedly also has the ability to provide a very accurate PNT backup for GPS, which will become increasingly important for all of the services as the competition in space intensifies.[63]

Intelligence, Surveillance, and Reconnaissance. The USSF has 14 satellites dedicated to missile launch warning. While the SBIRS constellation is two GEO satellites short of design, its nine satellites, coupled with the five DSP satellites, provide global coverage and generally excellent response times.

As noted above, the current portfolio of reconnaissance satellites, while highly classified, meets many of the essential strategic requirements of the NCA and the Defense Department. However, Space Force capabilities fall well short of the needs of the services. The Department of the Air Force is therefore investing in and employing the services of commercial organizations to meet the "on demand" collection and imagery needs of USSF customers.[64]

Space Situational Awareness. The Space Force's six acknowledged SSA satellites and the six dedicated and 17 collateral contributing ground-based sensors within the space-based surveillance system help to maintain situational awareness of satellites and other objects in space. However, the limited number and inherent limitations of the sensors within the SBSS leave significant gaps in coverage. Those gaps are addressed by prediction, and every time a satellite maneuvers, "the process of initial discovery by a sensor, creation of an initial element set, and refinement of that element set needs to be repeated."[65]

The Backbone and ISR assets within the USSF are critically important; however, the focus of the *Index of U.S. Military Strength* is primarily on assessing the classic "hard combat power" found in defensive and offensive systems.

Defensive Capabilities

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.[66]

The first challenge in defense is detecting an attack, and a host of sensors exist that can detect the launch of terrestrial-based anti-satellite (ASAT) weapons. With 14 satellites dedicated to detecting missile launches, it is possible for the USSF to determine an ASAT's trajectory, identify the targeted satellite, and alert operators in time for them to take evasive action with those systems. Unfortunately, the gaps in the SSA network highlighted earlier make the timely assessment of and response to such an attack on a specific U.S. satellite difficult.

Detecting other (non-missile) attacks presents another problem, and the Space Force has fielded a system that can deal with one part of that challenge. Operated by ground-based units, Bounty Hunter can detect an adversary's attempts to deceive, disrupt, deny, or degrade satellite communications by monitoring electromagnetic interference across multiple frequency bands. Operators can locate sources of intentional and unintentional interference and minimize them.[67] Bounty Hunter achieved initial operational capability (IOC) in the summer of 2020. While this system is a significant improvement, it has no known capability to detect or counter laser.

USSF satellites need a sensor package that allows them to self-detect hostile system engagement and report it to operators who are positioned to take defensive actions. That capability is currently not known to exist.

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.[68] 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.[69]

In spite of its current limitations, protective measures that the service can take now to safeguard its spaceborne systems can be separated into two categories of systems and actions: active and passive.

- 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.[70]

Shortly before the USSF became an independent service, the Air Force made clear that it wanted to build a constellation of thousands of SmallSats in low-Earth orbit to provide a redundant, diversified portfolio of capabilities. Over time, it is has become apparent that those expanding constellations will be comprised of both military and civilian satellites.[71]

In 2018, the Air Force signed a $28 million contract with SpaceX to evaluate its LEO-based Starlink constellation of satellites that provide broadband services. In 2019, the service tested Starlink's ability to provide communications linkages with airborne service aircraft and other spaceborne systems during its Global Lightning program.[72]

Starlink had 1,440 satellites in orbit as of May 2021, but while significant in number, that constellation would be unable to provide seamless global coverage. Ultimately, however, Starlink is on track to field some 4,500 satellites by the end of 2023, which will lift that limitation.[73] Continuing this relationship with Starlink will bode well for the USSF and its

ability to support U.S. forces with satellite access, resilience, and the overall survivability of the network of satellites available to the DOD.

Offensive Systems

The Air Force's FY 2017 budget included $158 million to develop offensive space capabilities over a period of five years.[74] The only offensive space system of record within the USSF that can be found in open-source literature is a system called Meadowlands.

Meadowlands is a mobile, terrestrial-based, counter-communications system (CCS) 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 communications linkages it was targeting return to their original functionality.[75]

Readiness

The Space Force was born of a congressionally mandated study that included a plan for the incremental transition of operational Air Force space assets and personnel to the new service. Throughout the plan's execution, the USSF has been deliberate in its hiring and is on a path to developing a solid cadre of personnel and a strong organizational culture.

The operations assumed by the USSF to support strategic and high-end operational-level support have proceeded uninterrupted, and to that end, readiness has remained high, but those operations were primarily supportive in nature and did not include robust, nearly real-time support to tactical units. While the service is undoubtedly moving forward on credible defensive and offensive readiness, there is little evidence that it is ready for the threat envisioned by Congress when it formed the Space Force.

Available government and commercial systems have the capability and capacity to meet the imagery, collection, and communication linkage demands and throughput requirements of warfighters at the operational and tactical levels. However, the entities driving to fill the gaps in capability, capacity, and the readiness levels required to infuse that intelligence to the operational and tactical levels is coming from the other services.

The Space Force needs to take the reins of this challenge in every dimension (capacity, capability, and readiness) to further the efforts of warfighters at all levels in the other domains, and it should move aggressively to fill the gaps that exist in the readiness that is required to defend our assets and threaten those of our adversaries.

Scoring the U.S. Space Force

Capacity Score: Weak

The number and types of Backbone and ISR assets are sufficient to support global PNT requirements and the majority of strategic-level communications, imagery, and collection requirements of the National Command Authorities and the Department of Defense. However, the Space Force is not capable of meeting current—much less future—on-demand, operational, and tactical-level warfighter requirements.

As noted in the readiness section, the gaps in the SBSS are covered by prediction, and operators of adversarial satellites can time their maneuvers to take advantage of those gaps.

With the influx of small satellites (see Table 19), 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. Although increasing numbers alone will challenge the current Space Surveillance Network, the number of unannounced orbital changes among those satellites will make it markedly more difficult to keep track of bad actors.

The U.S. had announced plans to build a second, strategically located Space Fence like the

one on Kwajalein Atoll in Western Australia in 2021, but that site has yet to be funded. Even if a second Space Fence does eventually materialize, the Space Force will still need more satellites that are dedicated to this mission.[76]

The service's two counterspace weapons systems (Meadowlands and Bounty Hunter, respectively) cover only a fraction of the offensive and defensive capabilities required to win a conflict in space. Other counterspace systems are likely being developed or, like cyber, are already in play. Nevertheless, the current visible capacity of the Space Force is not sufficient to support, fight, or weather a war with a peer competitor.

Capability Score: Weak

The current space asset modernization plan that is visible to the public follows the same incremental replacement and fielding design that has been in practice for decades. The vast majority of Backbone and ISR assets have exceeded their designed life spans and the DAF's willingness to delay and/or defer the acquisition of replacement systems remains a legacy of that department.

The capability of Backbone and ISR satellites is marginal, but it is more than offset by the gaps in SSA and the apparent lack of defensive and offensive capabilities ("very weak"). The capability score is therefore "weak," the result of being scored "weak" in "Size of Modernization Program," "weak" for "Age of Equipment" and "Health of Modernization Programs," and "weak" for "Capability of Equipment."

Readiness Score: Weak

The mission sets, space assets, and personnel that transitioned to the Space Force and those that have been assigned to support the USSF from the other services have not missed an operational beat since the Space Force stood up in 2019. Throughout that period, the readiness levels have seamlessly sustained backbone and ISR support to the NCA, DOD, combatant commanders, and warfighters around the world.

However, there is little evidence that the USSF has improved its readiness to provide nearly real-time support to the operational and tactical levels ("marginal") or that it is ready in any way to execute defensive and offensive counterspace operations to the degree envisioned by Congress when it formed the Space Force ("very weak").

Overall U.S. Space Force Score: Weak

This is an unweighted average of the USSF's capacity score of "weak," capability score of "weak," and readiness score of "marginal."

U.S. Military Power: Space

	VERY WEAK	WEAK	MARGINAL	STRONG	VERY STRONG
Capacity		✓			
Capability		✓			
Readiness		✓			
OVERALL		✓			

SPACE FORCE SCORES

1 2 3 4 5
Weakest ⟷ Strongest

Procurement and Spending ■ Through FY 2021 ■ Pending

Navigation

PLATFORM	Age Score	Capability Score	REPLACEMENT PROGRAM	Size Score	Health Score
Global Positioning System (GPS) Inventory: **38** Fleet age: **14.5** Date: **1997** GPS satellites provide timing, velocity, and precise navigation for millions of simultaneous users around the world. It takes 24 GPS satellites to provide seamless global coverage; currently, 32 are operational with an additional four decommissioned satellites serving as on-orbit spares.	5	4	**GPS III** Timeline: **2019–TBD** GPS III is the latest upgrade to the GPS platform and incorporates more robust anti-jamming capabilities. It is interoperable with other countries' Global Navigation Satellite systems, and this interoperability adds resilience to the GPS system. **PROCUREMENT** 2 2 **SPENDING** *($ millions)* $598 $601	5	5

Missile Warning

PLATFORM	Age Score	Capability Score	REPLACEMENT PROGRAM	Size Score	Health Score
Space Based Infrared System (SBIRS) Inventory: **9** Fleet age: **7.5** Date: **2006** An integrated constellation of satellites, SBIRS is designed to deliver early missile warning and provide intercept cues for missile defenses. The satellites are retaskable, which means they can be moved to more optimum or viewpoints as mission requirements dictate. The program was ended early because of cost, schedule, and performance issues.	4	4	**Next Generation Persistent Infrared (Next-Gen OPIR)** Timeline: **TBD**		
Defense Support Program (DSP) Inventory: **5** Fleet age: **32.5** Date: **1970** These satellites were designed to detect intercontinental ballistic missile and sea-launched ballistic missile launches against the U.S. and its allies. They can also detect space launch missions and nuclear weapons testing and detonations. Phase 3 satellites were launched from 1989 to 2007 and have long exceeded their designed lifetimes, but they are still providing reliable data and are integrated with the SBIRS program.	1	3			

NOTE: See page 500 for details on fleet ages, dates, timelines, and procurement spending.

SPACE FORCE SCORES

1 2 3 4 5
Weakest ⟷ Strongest

Procurement and Spending ■ Through FY 2021 ■ Pending

Space Surveillance

PLATFORM	Age Score	Capability Score	REPLACEMENT PROGRAM	Size Score	Health Score
Space Based Surveillance System (SBSS) Inventory: **1** Fleet age: **11** Date: **2010** This system uses multiple types of sensors to track man-made objects and debris fields in orbit.	3	3	None		

Missile Defense

PLATFORM	Age Score	Capability Score	REPLACEMENT PROGRAM	Size Score	Health Score
Space Tracking and Surveillance System Advanced Technology Risk Reduction (STSS-ATR) Inventory: **1** Fleet age: **12** Date: **2009** This research, development, testing, and evaluation (RDT&E) satellite was originally launched by the Missile Defense Agency to explore different capabilities and technology but was transferred to the Air Force in 2011.	3	4	None		

Space Object Tracking

PLATFORM	Age Score	Capability Score	REPLACEMENT PROGRAM	Size Score	Health Score
Geosynchronous Space Situational Awareness Program (GSSAP) Inventory: **4** Fleet age: **6** Date: **2014** This classified surveillance satellite constellation can accurately track and characterize objects in orbit using electro-optical and emissions sensors. Their maneuverability allows these satellites to conduct rendezvous and proximity operations (RPO) on space objects, enabling them to conduct offensive operations against other nations' assets.	5	5	None		

NOTE: See page 500 for details on fleet ages, dates, timelines, and procurement spending.

SPACE FORCE SCORES

1 2 3 4 5
Weakest ⟷ Strongest

Procurement and Spending ■ Through FY 2021 ■ Pending

Weather

PLATFORM	Age Score	Capability Score	REPLACEMENT PROGRAM	Size Score	Health Score
Defense Meteorological Satellite Program (DMSP) Inventory: **4** Fleet age: **17** Date: **1999** Since 1962, defense weather satellites in the DMSP have been collecting weather data and providing forecasts for U.S. military operations. The current four satellites were launched between 1999 and 2009 with only a five-year life expectancy, but they have continued to provide accurate meteorological data well beyond that timeframe and are still in use today.	1	4	**Weather System Follow-on Microwave Satellite (WSF-M)** Timeline: **TBD**		

Communications

PLATFORM	Age Score	Capability Score	REPLACEMENT PROGRAM	Size Score	Health Score
Milstar Inventory: **5** Fleet age: **22.5** Date: **1994** Milstar is a satellite communications system designed in the 1980s to provide the National Command Authorities with global communications that were assured and survivable and carried low probability of interception or detection. Designed to overcome nuclear effects and enemy jamming, it was considered the most robust and reliable DOD SATCOM system at the time of fielding.	1	3	**Advanced Extremely High Frequency System (AEHF)** Timeline: **2010–2021** **PROCUREMENT** **SPENDING** *($ millions)* $8 $0	**TBD**	**TBD**
Advanced Extremely High Frequency System (AEHF) Inventory: **6** Fleet age: **6** Date: **2010** The AEHF system is a network of six satellites that provides DOD with secure, jam-resistant communications and command and control for military ground, sea, and air assets located anywhere in the world.	5	5			

NOTE: See page 500 for details on fleet ages, dates, timelines, and procurement spending.

Communications (Cont.)

PLATFORM	Age Score	Capability Score	REPLACEMENT PROGRAM	Size Score	Health Score
Defense Satellite Communications System (DSCS) Inventory: **7** Fleet age: **28.5** Date: **1982** This system of seven satellites provides nuclear-hardened, global communications with anti-jamming capabilities to the Defense Department, State Department, and National Command Authorities.	1	2	**Advanced Extremely High Frequency System (AEHF)** Timeline: **2010–2021** **PROCUREMENT** **SPENDING** *($ millions)* $8 $0	**TBD**	**TBD**
Wideband Global SATCOM (WGS) Inventory: **10** Fleet age: **8** Date: **2007** WGS, formerly known as the Wideband Gapfiller Satellite, is a joint-service program funded by the U.S. Air Force and U.S. Army along with international partners Australia and Canada. It uses direct broadcast satellite technology to provide command and control for U.S. and allied forces. Satellites have a life span of as many as 14 years.	4	5			

NOTES: See Methodology for descriptions of scores. Fleet age is the average between the last year of procurement and the first year of initial operational capability. The date is when the platform achieved initial operational capability. The timeline is from the start of the platform's program to its budgetary conclusion. Spending does not include advanced procurement or research, development, test, and evaluation (RDT&E).

U.S. Space Force Modernization Table Citations

GENERAL SOURCES

- U.S. Department of the Air Force, *Department of Defense Fiscal Year (FY) 2022 Budget Estimates, Air Force, Justification Book Volume 1 of 1: Procurement, Space Force*, May 2021, https://www.saffm.hq.af.mil/Portals/84/documents/FY22/PROCUREMENT_/FY22%20DAF%20J-Book%20-%203022%20-%20SF%20Proc.pdf?ver=NEFQ6zdjfeGcJFeAdv_97g%3d%3d (accessed August 20, 2021).

PROGRAM SOURCES

GPS

- GPS.gov, "Space Segment: Current and Future Satellite Generations," last modified July 12, 20021, https://www.gps.gov/systems/gps/space/ (accessed August 20, 2021).
- Fact Sheet, "GPS III," U.S. Air Force, Los Angeles Air Force Base, current as of April 2018, https://www.losangeles.af.mil/About-Us/Fact-Sheets/Article/343728/gps-iii/ (accessed August 20, 2021). Fact Sheet, "Global Positioning System," United States Space Force, current as of October 2020, https://www.spaceforce.mil/About-Us/Fact-Sheets/Article/2197765/global-positioning-system/ (accessed August 20, 2021).

SBIRS

- 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 August 20, 2021).
- GlobalSecurity.org, "SBIRS HEO–High Earth Orbit," last modified August 26, 2018, https://www.globalsecurity.org/space/systems/sbirs-heo.htm (accessed August 20, 2021).
- Gunter's Space Page, "Trumpet 6, 7 / SBIRS HEO-3, 4," last update April 29, 2021, https://space.skyrocket.de/doc_sdat/trumpet-fo-2.htm (accessed August 20, 2021).
- William Harwood, "Space Force Launches Billion-Dollar Satellite to Warn of Missile Launches," CBS News, May 18, 2021, https://www.cbsnews.com/news/space-force-launches-missile-early-warning-satellite/ (accessed August 20, 2021).
- Sandra Erwin, "The End of SBIRS: Air Force Says It's Time to Move on," *SpaceNews*, February 19, 2018, https://spacenews.com/the-end-of-sbirs-air-force-says-its-time-to-move-on/ (accessed August 20, 2021).

DSP

- Gunter's Space Page, "DSP 1,2,3,4 (Phase 1)," last update March 19, 2020,
- https://space.skyrocket.de/doc_sdat/dsp-1.htm (accessed August 20, 2021).
- Gunter's Space Page, "DSP 5, 6, 7 (Phase 2)," last update March 19, 2020, https://space.skyrocket.de/doc_sdat/dsp-2.htm (accessed August 20, 2021).
- 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 August 20, 2021).
- Table, "Spacecraft in Service over Time," in "Air Force & Space Force Almanac," *Air Force Magazine*, Vol. 103, No. 6 (June 2020), p. 67, https://www.airforcemag.com/app/uploads/2020/06/June2020_Fullissue5.pdf (accessed August 20, 2021).

SBSS

- Fact Sheet, "Space Based Space Surveillance," U.S. Air Force, Air Force Space Command (Archived), current as of July 2019, https://www.afspc.af.mil/About-Us/Fact-Sheets/Article/249017/space-based-space-surveillance-sbss/ (accessed August 20, 2021).
- Gunter's Space Page, "MSX," last update December 11, 2017, https://space.skyrocket.de/doc_sdat/msx.htm (accessed August 20, 2021).
- Gunter's Space Page, "SBSS-1," last update December 11, 2017, https://space.skyrocket.de/doc_sdat/sbss-1.htm (accessed August 20, 2021).

STSS-ATR

- Center for Strategic and International Studies, Missile Defense Project, "Space Tracking and Surveillance System (STSS)," *Missile Threat*, last updated July 19, 2021, https://missilethreat.csis.org/defsys/stss/ (accessed August 20, 2021).
- Gunter's Space Page, "STSS-ATRR," last update July 21, 2019, https://space.skyrocket.de/doc_sdat/stss-atrr.htm (accessed August 20, 2021).
- 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 26, 2011, https://www.mda.mil/news/11news0004.html (accessed August 20, 2021).

GSSAP

- 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 August 20, 2021).
- Spaceflight101, "GSSAP Satellite Overview," https://spaceflight101.com/spacecraft/gssap/ (accessed August 20, 2021).
- Fact Sheet, "Geosynchronous Space Situational Awareness Program," U.S. Air Force, Air Force Space Command (Archived), current as of September 2019, https://www.afspc.af.mil/About-Us/Fact-Sheets/Article/730802/geosynchronous-space-situational-awareness-program-gssap/ (accessed August 20, 2021).

DMSP

- Fact Sheet, "Defense Meteorological Satellite Program," U.S. Air Force, Air Force Space Command (Archived), current as of July 2019, https://www.afspc.af.mil/About-Us/Fact-Sheets/Article/249019/defense-meteorological-satellite-program/ (accessed August 20, 2021).
- William McCormick, "DOD Plans to Replace DMSP Weather Satellites Within Five Years; Gen. David Thompson Quoted," ExecutiveGov, May 24, 2021, https://www.executivegov.com/2021/05/dod-plans-to-replace-dmsp-weather-satellites-within-five-years-gen-david-thompson-quoted/ (accessed August 20, 2021).

WSF-M

- Gunter's Space Page, "WSF-M 1, 2," last update May 25, 2021, https://space.skyrocket.de/doc_sdat/wsf-m.htm (accessed August 20, 2021).
- Debra Werner, "Are Small Satellites the Solution for Space Weather Monitoring?" *SpaceNews*, March 6, 2019, https://spacenews.com/are-small-satellites-the-solution-for-space-weather-monitoring/ (accessed August 20, 2021).

Milstar

- U.S. Air Force, Air Force Space Command (Archived), "Milstar Satellite Communications System," current as of July 2019, https://www.afspc.af.mil/About-Us/Fact-Sheets/Display/Article/1012622/milstar-satellite-communications-system/ (accessed August 20, 2021).

AEHF

- Airman 1st Class Jonathan Whitely, "AEHF-6 Satellite Completes Protected Satellite Constellation," United States Space Force, March 27, 2020, https://www.spaceforce.mil/News/Article/2129221/aehf-6-satellite-completes-protected-satellite-constellation/ (accessed August 20, 2021).
- U.S. Air Force, Air Force Space Command (Archived), "Advanced Extremely High Frequency System," current as of July 2019, https://www.afspc.af.mil/About-Us/Fact-Sheets/Display/Article/249024/advanced-extremely-high-frequency-system/ (accessed August 20, 2021).

DSCS

- Fact Sheet, "Defense Satellite Communications System," U.S. Air Force, Air Force Space Command (Archived), current as of July 2019, https://www.afspc.af.mil/About-Us/Fact-Sheets/Display/Article/1012656/defense-satellite-communications-system/ (accessed August 20, 2021).

WGS

- Gunter's Space Page, "WGS 1, 2, 3 (WGS Block 1)," last update November 4, 2020, https://space.skyrocket.de/doc_sdat/wgs-1.htm (accessed August 20, 2021).

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 June 13, 2021).
2. United States Space Force, "About the United States Space Force: USSF Mission," https://www.spaceforce.mil/About-Us/About-Space-Force (accessed June 13, 2021).
3. Roger Cliff, *The Military Potential of China's Commercial Technology*, RAND Corporation, Project Air Force, 2001, p. 27, https://www.rand.org/pubs/monograph_reports/MR1292.html (accessed June 13, 2021).
4. For a more in-depth understanding of this domain and how much the United States depends on it, see 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.
5. R. Cargill Hall and Jacob Neufeld, Preface, in *The U.S. Air Force in Space: 1945 to the Twenty-first Century*, ed. R. Cargill Hall and Jacob Neufeld, Proceedings, Air Force Historical Foundation Symposium, Andrews Air Force Base, Maryland, September 21–22, 1995, p. iii, https://media.defense.gov/2010/Oct/01/2001329745/-1/-1/0/AFD-101001-060.pdf (accessed June 13, 2021).
6. For examples of retrospectives of this pivotal moment in war, see 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 June 13, 2021), 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 June 13, 2021).
7. 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 June 13, 2021).
8. 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.
9. Donald J. Trump, Space Policy Directive–4, "Establishment of the United States Space Force," February 19, 2019, *Federal Register*, Vol. 84, No. 37 (February 25, 2019), pp. 6049–6052, https://www.govinfo.gov/content/pkg/FR-2019-02-25/pdf/2019-03345.pdf (accessed June 13, 2021).
10. U.S. Department of Defense, United States Space Command, "Mission," https://www.spacecom.mil/Mission/#:~:text=United%20States%20Space%20Command%20(USSPACECOM,interests%20with%20allies%20and%20partners (accessed June 17, 2021). This is the second time USSPACECOM has been on the roster of combatant commands within the Unified Command Plan (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 June 13, 2021).
11. This number is an estimate based on the fact that "approximately 12,100 active duty, 1,600 guard and reserve, and 11,900 civilian personnel" are part of 14th Air Force. Todd Harrison, "How Much Will the Space Force Cost?" Center for Strategic and International Studies *Brief*, November 2018, p. 2, https://csis-website-prod.s3.amazonaws.com/s3fs-public/publication/181119_Harrison_SpaceForce_layout_FINAL.pdf (accessed June 13, 2021).
12. Fact Sheet, "Fourteenth Air Force," U.S. Air Force, Air Force Space Command (Archived), current as of October 2019, https://www.afspc.af.mil/About-Us/Fact-Sheets/Display/Article/1604750/fourteenth-air-force/ (accessed June 13, 2021).
13. Satnews, "Space & Missile Systems Center to Be Re-Designated as the USAF's New Space Systems Command," April 11, 2021, https://news.satnews.com/2021/04/11/space-missile-systems-center-to-be-re-designated-as-the-usafs-new-space-systems-command/ (accessed June 13, 2021).
14. Table 3, "U.S. Space Force Budget Summary," in U.S. Department of the Air Force, *Department of the Air Force FY 2022 Budget Overview*, generated May 28, 2021, p. 14, https://www.saffm.hq.af.mil/Portals/84/documents/FY22/SUPPORT_/FY22%20Budget%20Overview%20Book.pdf?ver=Reck2JzBUzoZmGByI9Zm-Q%3d%3d (accessed June 15, 2021).
15. 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, Air Force Research Laboratory, "Technology Directorates: Space Vehicles (RV)," https:// www.afrl.af.mil/RV/ (accessed June 14, 2021).

16. 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 June 14, 2021).
17. Capt. Christopher Merian, "U.S. Space Force Stands up STAR Delta Provisional," United States Space Force, Space Force News, July 24, 2020, https://www.spaceforce.mil/News/Article/2287104/us-space-force-stands-up-star-delta-provisional/ (accessed June 22, 2021).
18. 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 June 14, 2021). The briefing was provided by Barbara Barrett, Secretary of the U.S. Air Force; General John "Jay" Raymond, Commander, U.S. Space Command, and Commander, Air Force Space Command, and Commander, Joint Force Space Component; Stephen Kitay, Deputy Assistant Secretary of Defense for Space Policy.
19. Lynn Kirby, "2.4k Airmen to Transfer into Space Force Beginning Sept. 1," United States Space Force, Space Force News, September 1, 2020, https://www.spaceforce.mil/News/Article/2332258/24k-airmen-to-transfer-into-space-force-beginning-sept-1/ (accessed June 14, 2021).
20. Table 3, "U.S. Space Force Budget Summary," in U.S. Department of the Air Force, *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 June 14, 2021).
21. Theodore Bunker, "Space Force Reports Thousands of Applications Received from Other Military Branches," Newsmax, April 20, 2021, https://www.newsmax.com/newsfront/spaceforce-military-transfer-applications/2021/04/20/id/1018377/ (accessed June 14, 2021).
22. United States Space Force, "Transfer FAQs," https://www.spaceforce.mil/Transfer/ (accessed June 14, 2021).
23. Venable, "Done Right, Trump's Space Force Would Put the U.S. on Top."
24. Harrison, "How Much Will the Space Force Cost?"
25. Table 3, "U.S. Space Force Budget Summary," in U.S. Department of the Air Force, *Department of the Air Force FY 2022 Budget Overview*, p. 14.
26. Air Force News Service, "AF Plans to Accelerate Defendable Space with Next-Gen OPIR," U.S. Air Force, May 4, 2018, https://www.af.mil/News/Article-Display/Article/1512949/af-plans-to-accelerate-defendable-space-with-next-gen-opir/ (accessed June 14, 2021).
27. U.S. Department of Homeland Security, U.S. Coast Guard Navigation Center, "GPS Constellation Status for 06/014/2021," last updated June 14, 2021, https://www.navcen.uscg.gov/?Do=constellationStatus (accessed June 14, 2021).
28. Nathan Strout, "Space Force Launches Fifth GPS III Satellite for More Secure Positioning," C4ISRNET, June 18, 2021, https://www.c4isrnet.com/battlefield-tech/space/2021/06/18/space-force-launches-fifth-gps-iii-satellite/?utm_source=Sailthru&utm_medium=email&utm_campaign=EBB%206.21&utm_term=Editorial%20-%20Early%20Bird%20Brief (accessed June 23, 2021).
29. Ben Evans, "Next GPS Block III Satellite Arrives in Florida, Targets Mid-June Launch," AmericaSpace, April 22, 2021, https://www.americaspace.com/2021/04/22/next-gps-block-iii-satellite-arrives-in-florida-targets-mid-june-launch/ (accessed June 14, 2021), and RocketLaunch.Live, "Launch Schedule," https://www.rocketlaunch.live (accessed June 14, 2021).
30. GPS.gov, "New Civil Signals: Fourth Civil Signal: L1C," last modified August 10, 2020, https://www.gps.gov/systems/gps/modernization/civilsignals/#L1C (accessed June 23, 2021).
31. Fact Sheet, "Defense Meteorological Satellite Program," U.S. Air Force, Air Force Space Command (Archived), current as of July 2019, https://www.afspc.af.mil/About-Us/Fact-Sheets/Article/249019/defense-meteorological-satellite-program/ (accessed June 14, 2021).
32. William McCormick, "DOD Plans to Replace DMSP Weather Satellites Within Five Years; Gen. David Thompson Quoted," ExecutiveGov, May 24, 2021, https://www.executivegov.com/2021/05/dod-plans-to-replace-dmsp-weather-satellites-within-five-years-gen-david-thompson-quoted/ (accessed June 14, 2021).
33. Fact Sheet, "Defense Meteorological Satellite Program."
34. McCormick, "DOD Plans to Replace DMSP Weather Satellites Within Five Years; Gen. David Thompson Quoted."
35. Airman 1st Class Jonathan Whitely, "AEHF-6 Satellite Completes Protected Satellite Constellation," United States Space Force, Space Force News, March 27, 2020, https://www.spaceforce.mil/News/Article/2129221/aehf-6-satellite-completes-protected-satellite-constellation/ (accessed June 14, 2021).
36. Fact Sheet, "Advanced Extremely High Frequency System," U.S. Air Force, Air Force Space Command (Archived), current as of July 2019, https://www.afspc.af.mil/About-Us/Fact-Sheets/Display/Article/249024/advanced-extremely-high-frequency-system/ (accessed June 14, 2021).

37. Gunter's Space Page, "WGS 1, 2, 3 (WGS Block 1)," last update November 4, 2020, https://space.skyrocket.de/doc_sdat/wgs-1.htm (accessed June 14, 2021).
38. The *2021 Index of U.S. Military Strength* stated erroneously that there were seven SBIRS satellites in orbit. This was an error in computation. There actually were eight in orbit, and a ninth satellite joined the constellation (GEO) in May 2021.
39. SIBRS GEO5 was placed in orbit on May 18, 2021. William Harwood, "Space Force Launches Billion-Dollar Satellite to Warn of Missile Launches," CBS News, May 18, 2021, https://www.cbsnews.com/news/space-force-launches-missile-early-warning-satellite/ (accessed June 14, 2021), and Center for Strategic and International Studies, Missile Defense Project, "Space Tracking and Surveillance System (STSS)," *Missile Threat*, last updated June 15, 2018, https://missilethreat.csis.org/defsys/stss/ (accessed June 14, 2021).
40. Sandra Erwin, "The End of SBIRS: Air Force Says It's Time to Move on," *SpaceNews*, February 19, 2018, https://spacenews.com/the-end-of-sbirs-air-force-says-its-time-to-move-on/ (accessed June 14, 2021).
41. Gunter's Space Page, "DSP 1,2,3,4 (Phase 1)," last update March 19, 2020, https://space.skyrocket.de/doc_sdat/dsp-1.htm (accessed June 14, 2021).
42. Gunter's Space Page, "DSP 5, 6, 7 (Phase 2)," last update March 19, 2020, https://space.skyrocket.de/doc_sdat/dsp-2.htm (accessed June 14, 2021).
43. 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 June 14, 2021).
44. 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 June 23, 2021).
45. Gunter's Space Page, "DSP 14, 15, 16, 17, 18, 19, 20, 21, 22, 23 (Phase 3)."
46. 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 June 17, 2021).
47. 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 June 17, 2021).
48. Australian Space Academy, "An Overview of Space Situational Awareness," https://www.spaceacademy.net.au/intell/ssa.htm (accessed June 17, 2021). Speed converted from kilometers per second to miles per hour (mph).
49. 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 June 14, 2021).
50. Fact Sheet, "Geosynchronous Space Situational Awareness Program," U.S. Air Force, Air Force Space Command (Archived), current as of September 2019, https:// www.afspc.af.mil/About-Us/Fact-Sheets/Article/730802/geosynchronous-space-situational-awareness-program-gssap/ (accessed June 14, 2021).
51. Gunter's Space Page, "GSSAP 1, 2, 3, 4, 5, 6 (Hornet 1, 2, 3, 4, 5, 6)," and Craig Covault, "AFSPC-6 Launch Helps Form Extraordinary New US Space Defense Foundation," AmericaSpace, August 19, 2016, https://www.americaspace.com/2016/08/19/afspc-6-launch-helps-form-extraordinary-new-u-s-space-defense-foundation/ (accessed June 17, 2021).
52. Gunter's Space Page, "SBSS 1," last update December 11, 2017, https://space.skyrocket.de/doc_sdat/sbss-1.htm (accessed June 14, 2021), and Fact Sheet, "Space Based Space Surveillance," U.S. Air Force, Air Force Space Command (Archived), current as of July 2019, https://www.afspc.af.mil/About-Us/Fact-Sheets/Article/249017/space-based-space-surveillance-sbss/ (accessed June 14, 2021).
53. Gunter's Space Page, "STSS-ATRR," last update July 21, 2019, https://space.skyrocket.de/doc_sdat/stss-atrr.htm (accessed June 14, 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 26, 2011, https://www.mda.mil/news/11news0004.html (accessed June 14, 2021).
54. Dwayne A. Day, "Radar Love: The Tortured History of American Space Radar Programs," *The Space Review*, January 22, 2007, https://thespacereview.com/article/790/1 (accessed June 14, 2021).
55. Air Force News Service, "Space Force Awards National Security Space Launch Phase 2 Launch Service Contracts to United Launch Alliance, LLC (ULA) and Space Exploration Technologies Corporation (SpaceX)," United States Space Force, Space Force News, August 7, 2020, https://www.spaceforce.mil/News/Article/2305278/space-force-awards-national-security-space-launch-phase-2-launch-service-contra/ (accessed June 14, 2021).

56. 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. The compiling of corporate and national space launch numbers was accomplished by reviewing the global space launch schedules by year at "Space Launch Schedule," https://www.spacelaunchschedule.com (accessed June 21, 2021).
57. Space Launch Schedule, "2021 Launch Schedule," https://Spacelaunchschedule.com/2021-launch-schedule/ (accessed June 21, 2020).
58. John Venable, "Rebuilding America's Military: The United States Space Force," Heritage Foundation *Special Report* No. 245, April 27, 2021, p. 44, https://www.heritage.org/defense/report/rebuilding-americas-military-the-united-states-space-force, and 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 June 13, 2021).
59. Osborn, "Army Seeks Thousands of High-Speed, Low Earth Orbit Satellites for Ground Attack."
60. Amy Thompson, "SpaceX Launches 60 Starlink Satellites in Record 10th Liftoff (and Landing) of Reused Rocket, Space.com, May 9, 2021, https://www.space.com/spacex-starlink-27-10th-falcon-9-rocket-launch-landing-success (accessed June 14, 2021).
61. 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, and 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. 12, https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=4712&context=smallsat (accessed June 17, 2021).
62. 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 June 14, 2021).
63. 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 June 14, 2021).
64. The Air Force's AFWERX program invests in U.S. and global technology 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 June 14, 2021).
65. 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 June 17, 2021).
66. 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 June 14, 2021).
67. 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 June 13, 2021).
68. 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 June 23, 2021).
69. Ibid. and Beyza Unal, "Cybersecurity of NATO's Space-Based Strategic Assets," Chatham House: The Royal Institute of International Affairs *Research Paper*, July 2019, https://www.chathamhouse.org/sites/default/files/2019-06-27-Space-Cybersecurity-2.pdf (accessed June 23, 2021).
70. 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 June 13, 2021).
71. Adam Mann, "Starlink: SpaceX's Satellite Internet Project," Space.com, updated May 28, 2021, https://www.space.com/spacex-starlink-satellites.html (accessed June 14, 2021).
72. 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 June 13, 2021).
73. Osborn, "Army Seeks Thousands of High-Speed, Low Earth Orbit Satellites for Ground Attack."
74. 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 June 14, 2021).

75. Wolfe, "Space Force Developing Non-Kinetic Counterspace Systems."
76. 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 June 14, 2021).