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A SPACE POLICY PRIMER: KEY CONCEPTS, ISSUES, AND ACTORS

SECOND EDITION

JOHN PAUL BYRNE, ROBIN DICKEY, AND MICHAEL P. GLEASON
THE AEROSPACE CORPORATION

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JOHN PAUL BYRNE

John Paul Byrne is an undergraduate at the United States Air Force Academy. He was recently an intern at The Aerospace Corporation, where he supported the work of the Center for Space Policy and Strategy. He is working as the president of the Air Force Academy's International Applied Space Policy and Strategy cadet club, where they focus on developing space-minded officers for the Air and Space Forces. John will earn his bachelor's degree in political science with a focus in international relations, and a minor in German in 2021.

ROBIN DICKEY

Robin Dickey is a space policy and strategy analyst at The Aerospace Corporation's Center for Space Policy and Strategy, focusing on national security space. Her prior experience includes risk analysis, legislative affairs, and international development. She earned her bachelor's and master's degrees in international studies at Johns Hopkins University.

MICHAEL P. GLEASON

Dr. Michael P. Gleason is a national security senior project engineer in The Aerospace Corporation's Center for Space Policy and Strategy and is a well-regarded author on space policy subjects, including international cooperation, space traffic management, national security, and deterrence. He has presented his research on critical space policy issues at conferences in Canada, Europe, Japan, and across the United States. A graduate of the U.S. Air Force Academy, Gleason served 29 years active in the Air Force space career field, including stints in spacecraft operations, on the Air Force Academy faculty, at the Pentagon, and at the Department of State. He holds a Ph.D. in International Relations from George Washington University (GWU) and is an alumnus of the GWU Space Policy Institute. Gleason is the recipient of the Defense Superior Service Medal and the Department of State Superior Honor Award.

ABOUT THE CENTER FOR SPACE POLICY AND STRATEGY

The Center for Space Policy and Strategy is dedicated to shaping the future by providing nonpartisan research and strategic analysis to decisionmakers. The Center is part of The Aerospace Corporation, a nonprofit organization that advises the government on complex space enterprise and systems engineering problems.

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Michael P. Gleason, Ph.D.

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Foreword

Space policy shapes the direction of technological and economic developments that are increasingly integrated with a wide range of human endeavor. While many of the implications of activity in space are understandably invisible to the average person, an astounding range of human activity relies on space capabilities. This is increasingly true around the globe, and especially true in matters affecting national security. However, the diversity of the space community and its technical underpinnings make it challenging for newcomers to receive a holistic understanding of the formulation, implementation, and implications of space policy. Even for scientists and engineers central to space activity, it can be difficult to understand how underlying policy direction fundamentally shapes what is possible. That is why there is great value in a primer that concisely identifies key concepts, issues, and organizational actors involved in space policy.

Simplifying intricate systems and domains, such as space, is not only important to policymakers but also to the average person. Understanding and appreciating how space affects one's daily life will drive further advancements in space that will open up new opportunities for industry and for society in the future. Hopefully this primer contributes to that process in some way.

This primer lays out the essentials on the participants and processes of space policy, with minimal jargon and acronyms. We hope this primer becomes a useful reference document for everyone, from space policy novices to those with extensive experience, with space issues. It should be especially useful as a source of introductory readings for university and professional military education classes on space topics. While the primer is somewhat U.S.-centric, it reflects the global environment and should be useful for non-U.S. observers seeking to understand the complexities of U.S. space policy.

Jamie Morin
Executive Director, Center for Space Policy and Strategy
Vice President, Defense Systems Operations
The Aerospace Corporation

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Introduction

New space policy questions are emerging, affecting both the traditional spacefaring nations and new entrants.

At a time when plans are being made by the United States and others to return humans to the moon and eventually reach Mars while also exploring more distant worlds robotically, what should the overall goals of America's civil space exploration program be, and what strategy is most conducive to achieving them? What role will international partners play in such endeavors? How best can civil and commercial space sectors work together in service of space science and exploration? And how best can the United States provide leadership in space traffic management (STM)?

The rapid transformation of the commercial space sector also drives a number of questions. Governments and their regulatory regimes struggle to keep up with the ever-increasing presence of private reusable rockets, large-scale constellations of satellites in low Earth orbit (LEO), in-space servicing, and potential asteroid mining. What domestic and international governance structures and internationally accepted guidelines, standards, and best practices need to be in place to prevent misunderstanding among nations and to protect the sustainability of the space environment? How can the interests of industry, free markets, and national security best be balanced when they are in opposition?

The United States national security space enterprise also faces numerous challenging questions. The increasing capability of rivals to threaten space assets and to exploit space for military advantage is being used to argue for more rapid development of more survivable space capabilities. Is the United States' current military space acquisition system up to the task? How will the Space Force deter conflict in space and prepare for future wars in space if deterrence fails? And how should U.S. allies and partners share the burden of collective defense in space?

The U.S. military also plays a vital role in tracking space debris and monitoring traffic in space. As malevolent threats to U.S. national security space assets multiply, how will the military, the Department of Commerce, and commercial stakeholders contribute to space situational awareness (SSA) data-sharing and space traffic management (STM)? Will international actors buy into U.S. initiatives? Or will these issues be addressed internationally from a more bottom-up approach?

U.S. policymakers will need to address these questions while working with experts from across many fields, from many different government agencies and from many different countries and commercial enterprises. This primer provides some key concepts for categorizing and understanding space activities, provides an overview of international space law, and explains some common rationales that help justify the significant upfront investments required for space activities. It also provides a brief sketch of how the U.S. government is organized to address these difficult space policy questions. Ideally, this primer will provide the reader with the foundation upon which a comprehensive understanding of the complex issues surrounding U.S. national space policy may be built. More discussions about a variety of space policy topics can be found on the Center for Space Policy and Strategy homepage.[*]

[*] https://aerospace.org/policy

Key Concepts and Nomenclature

This chapter describes several key concepts by introducing common nomenclatures used in thinking about and describing space activities.

Space Activity Categories

Space activities are often divided conceptually into three categories: *human spaceflight*, *space science*, and *spaceflight applications*.

Human spaceflight includes any activity that places humans in space, including the International Space Station, and efforts to send humans to the moon and Mars. Historically, the American public has equated the U.S. space program with human spaceflight since it is the most visible space activity.

Space science involves using spacecraft to make scientific observations of the Earth, celestial bodies, and astronomical phenomena.

Spaceflight applications are practical services performed by spacecraft, including navigation, communications, weather and land monitoring, defense, and intelligence gathering. Although space applications like the global positioning system (GPS) and satellite communications are tightly integrated into the economy and critical for modern society, their association with space is largely invisible to users.

Space Activity Sectors

Space activities are also divided conceptually into three different activity sectors: *civil space*, *commercial space*, and *national security space*.

Civil space consists of activities sponsored and conducted by civilian government entities. This includes a full range of space activities involving agencies like The National Aeronautics and Space Administration (NASA) and the National Oceanographic and Atmospheric Administration (NOAA). Human space exploration, space science, and many space applications like weather monitoring are typically found within the civil space sector.

Commercial space consists of privately financed space activities conducted with profit as the motivating force. This includes satellite manufacturing, launch services, satellite communications, remote sensing, and emerging enterprises such as space tourism. Commercial space has four characteristics: (1) private capital is at risk in development and operation, (2) it requires existing or potential customers, (3) market forces determine viability, and (4) primary responsibility and management reside with the private sector.[1]

National security space, or simply *security space*, refers to military and intelligence space activities which are funded and implemented by the military and intelligence agencies. More specifically, *military space* refers to the operational and tactical level use of space applications for warfighting purposes. *Intelligence space* connotes a more strategic-level use of satellites to provide national security decision makers with strategic information.

These categories are not divided clearly. Even in the earliest days of the Space Age, many civil exploration missions were conducted by military personnel, and various satellites and space stations blended national security and civil missions. Assets, technologies, and satellite data that can be shared between the civil and national security sectors are usually referred to as *dual-use* space capabilities. This blending of missions is done for efficiency reasons. In recent years, however, these categories have blurred even further. Civil and military space actors are purchasing services like launch, communications, and Earth imagery from commercial space actors at an increasing rate. Universities and private laboratories are conducting space science activities previously only possible for governments, and commercial companies have the capacity to independently put humans in space as a service to governments, as an industry for tourism, and for other commercial purposes. Conversely, capabilities developed for military purposes, like GPS, are ever more integrated in commercial activity. As the lines have further blurred, an increasing number of issues have become "cross-cutting" issues rather than remaining siloed in a single sector. Nevertheless, the threefold sectoral division of space activities remains popular, and this conceptual framework provides the organizational backbone for this primer.

Table 1: Space Sectors of 2020

Sector	Examples of Activities	Examples of Actors
Civil Space	International Space Station, Hubble Telescope, Apollo Program, Artemis Human Lander Program	NASA, NOAA, FAA, FCC
Commercial Space	Launch industry, Earth observation, communications, broadband.	SpaceX, ULA, Iridium, Maxar, Lockheed Martin, Boeing, Blue Origin
National Security: Military	GPS, communication, missile attack warning satellites	Space Force, Air Force, Army, Navy, Coast Guard
National Security: Intelligence	Signals intelligence, reconnaissance	Intelligence agencies

European Space Agency

As a point of comparison with the U.S.-centric frameworks offered above, the European Space Agency's (ESA) intergovernmental organization provides a different setup. ESA has 22 member states, with Germany, France, Italy, and the United Kingdom contributing the most resources, in addition to multiple cooperating states that contribute to research and development.[2] ESA divides its space missions and assets into four categories: (1) science and exploration, (2) safety and security, (3) applications, and (4) enabling and support. This ESA framework is the default for many of the ESA member states.

Science and exploration includes all manned and unmanned science missions. These missions include the ExoMars Trace Gas Orbiter, Solar Orbiter, and the proposed European Large Logistics Lander (EL3).[3]

Safety and security describes topics such as space weather, planetary defense, orbital debris, and cybersecurity. The European Gateway will orbit the moon and monitor radiation from solar rays. ClearSpace-1 focuses on active removal of space debris from LEO. ESA plans to launch this mission by 2025.[4]

Applications covers Earth science, navigation, and telecommunications. PhiSat-1 was just one of these applications used within the last year to improve the efficiency of sending vast quantities of data back to Earth. Specifically, PhiSat-1 is an artificial intelligence Earth observer satellite.[5]

Enabling and support comprises launch vehicles, ground stations, and infrastructure. These components are ever important to mission success, as they provide the means for communication, payload delivery, and connectivity.

Satellite Orbital Characteristics

Space policy issues and key concepts are tightly intertwined with the mechanics of space flight, meaning that even an introductory policy overview must contain some background on the nomenclature used to describe the nature of satellite orbits.

Low Earth orbit (LEO) satellites operate from about 200 kilometers to 2,000 kilometers altitude. Medium Earth orbit (MEO) is generally considered to range from about 2,000 kilometers to GEO altitude. Geosynchronous/geostationary (GEO) satellites circle the equator at 35,785 kilometers altitude. (See Table 2.)

Table 2: Satellite Orbital Characteristics

<table>
<tr><th colspan="2">Orbit</th><th colspan="2">Altitude (km)</th><th>Typical Mission</th></tr>
<tr><td colspan="2">Low Earth Orbit (LEO)</td><td colspan="2">200–2,000;
nominal: 500–1,000</td><td>Remote sensing, communications, weather</td></tr>
<tr><td colspan="2">Medium Earth Orbit (MEO)</td><td colspan="2">2,000–GEO;
nominal: 10,000–20,000</td><td>Positioning, navigation, and timing (PNT)</td></tr>
<tr><td colspan="2">Geostationary Earth Orbit (GEO)</td><td colspan="2">35,785</td><td>Missile warning, communications, weather, remote sensing</td></tr>
<tr><td rowspan="2">Highly Elliptical Orbit (HEO)</td><td>Molniya (12h)</td><td>~500</td><td>~40,000</td><td rowspan="2">Missile warning, communications, remote sensing</td></tr>
<tr><td>Tundra (24h)</td><td>~24,000</td><td>~40,000</td></tr>
</table>

A satellite's "inclination" is also often used to classify satellites. If a spacecraft circles the Earth directly above the equator for its entire orbit, it has an inclination of zero degrees. The terms "geosynchronous Earth orbit" and "geostationary Earth orbit" (GEO) describe an orbit that has zero degrees inclination and an altitude of 35,785 kilometers. "Polar orbits" circle the Earth from pole to pole, with a 90-degree inclination. The International Space Station is at an inclination of 51.6 degrees, which is a "high-inclination" orbit greater than 45 degrees but much less than 90 degrees. "Sun-synchronous" orbits are near-polar in inclination; they assist overhead observation by allowing spacecraft to view specific latitudes on Earth at the same local time on each pass, producing images with the same sun angles.

Another classification is the shape of a spacecraft's orbit. Circular orbits, elliptical orbits, and highly elliptical (Tundra and Molniya) orbits are the most common. Figure 1 helps to visualize the different types of orbits.

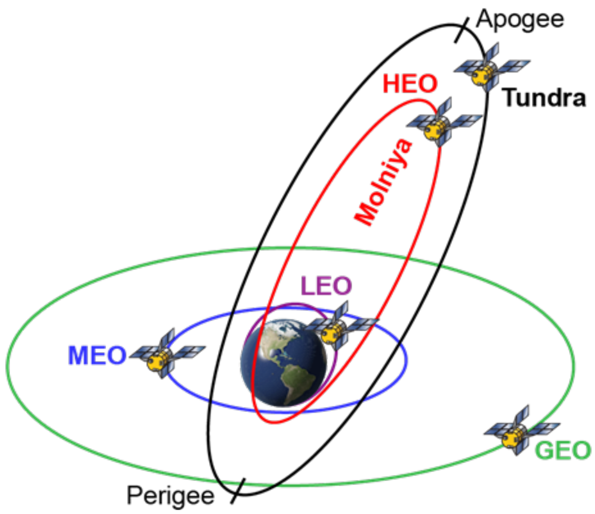

Figure 1: Orbital characteristics.[6]

Rationales for Spaceflight

NASA historian Roger Launius identified five general rationales for spaceflight: (1) human destiny, (2) geopolitics/prestige, (3) national security, (4) economic competitiveness, and (5) scientific discovery.[7]

Human destiny rationales invoke the history of exploration found in human societies around the world. In the United States, there is a belief that the "frontier" shaped our national character, and the opening of the final frontier, space, is vital to our country's continued success. Related rationales include the drive to understand "the heavens" and the desire to preserve the human species from threats on Earth by building new settlements in space or other planets. Advocates for human space exploration often employ this rationale to help justify the immense investments required for such space activities.

Geopolitics/prestige rationales relate to perceptions of a country in the wider world. During the Cold War, space exploration became a tool of foreign policy for the United States and the USSR, with each success seen as a vindication of each country's political and economic system. The Apollo 11 moon landing was hailed as a victory for democracy and capitalism on an interplanetary stage. A nation's perception of its own leadership in space plays a key role in its space policy, as when President Nixon approved the space shuttle for fear of being seen as ceding the United States' leadership role.[8] Today, for many countries the prestige of having a space program is a significant driver to help justify the high costs of such an endeavor.

National security rationales focus on the unique opportunities that space provides for defense and intelligence purposes. International space law guarantees the right to fly in space over any nation, allowing states to maintain strategic, global, situational awareness, monitor their rivals, identify threats, ensure compliance with international treaty agreements, and thereby enhance deterrence and strategic stability. Space also enables long-distance communication, precision navigation, and weather forecasting that are critical for many different uses. As a result, some theorists consider space to be the new "high ground," analogous to strategic territory, control of the seas, or aerial superiority, giving significant advantages to those with access to space. While this analogy is imperfect, given the differences between a terrestrial hill and the orbital environment, the importance of space capabilities for national security is clear. Indeed, more and more countries are increasing their investments in dedicated military space capabilities and dual-use space capabilities.

Scientific discovery rationales emphasize the value of science both for its own sake and for potential applications it can create. Noting that the vast majority of the universe has yet to be explored, these rationales point to space as a limitless source of undiscovered knowledge. Scientific discovery as a rationale has also been applied in the context of using space to better understand and solve problems on Earth, particularly in the area of climate science and mitigating the effects of climate change.

Economic competitiveness rationales point to the concrete benefits that space programs bring to societies on Earth. Economically useful space applications, the development of a high-tech industrial workforce, and the creation of new industries motivate space activities in many countries. The 2010 U.S. space policy holds as a fundamental principle that "A robust and competitive commercial space sector is vital to continued progress in space. The United States is committed to encouraging and facilitating the growth of a

U.S. commercial space sector that supports U.S. needs, is globally competitive, and advances U.S. leadership in the generation of new markets and innovation-driven entrepreneurship."[9] Commercial space activities are thus vital for maintaining the *economic competitiveness* of a spacefaring country. As well, a strong commercial space sector is critical to maintaining national security. Commercial space ensures the survival of a strong, skilled industrial base, which allows the U.S. government access to advanced technologies and satellite services that can be used for defense.

U.S. National Space Policy

Current National Policy Documents

The National Space Policy of the United States of America, released in December 2020 by the Trump administration, describes current U.S. national space policy.[9] The document follows and largely includes themes from the seven major space policy directives also released by the Trump administration (SPD-1, SPD-2, SPD-3, SPD-4, SPD-5, SPD-6, and SPD-7).

Key U.S. national space policy documents are identified below.

Table 3: National Space Policy Documents

Policy	Year	Subject
Space Policy Directive 7, The United States Space-Based Positioning, Navigation, and Timing Policy	2021	GPS
National Space Policy	2020	Overall policy
Presidential Executive Order on Encouraging International Support for the Recovery and Use of Space Resources	2020	Commercial exploration
Space Policy Directive 6, National Strategy for Space Nuclear Power and Propulsion	2020	Space nuclear power and propulsion
Space Policy Directive 5, Cybersecurity Principles for Space Systems	2020	Cybersecurity
Space Policy Directive 4, Establishment of the United States Space Force	2019	Military use of space
Space Policy Directive 3, National Space Traffic Management Policy	2018	Space traffic management
Space Policy Directive 2, Streamlining Regulations on Commercial Use of Space	2018	Commercial regulation
Space Policy Directive 1, Presidential Memorandum on Reinvigorating America's Human Space Exploration Program	2017	Human exploration
Presidential Executive Order on Reviving the National Space Council	2017	Space Council
National Space Transportation Policy	2013	Space transportation
U.S. Commercial Remote Sensing Space Policy	2003	Remote sensing

Policy Goals

In the 2020 space policy, the Trump administration identified eight goals for U.S. space policy:

1. *Promote and incentivize private industry* concerns the advancement of the satellite manufacturing, space launch, and space applications industries in the United States. Efforts associated with this goal include U.S. government support for new commercial launch providers[10] and increased utilization of

rideshare and hosted payload capabilities where commercial and NASA spacecraft hitch rides to space together.[11]

2. *Encourage and uphold the rights of nations to use space responsibly and peacefully* focuses on diplomatic, economic, and security capabilities and strategies aimed at identifying and responding to threats to the rights of nations in space.

3. *Lead, encourage, and expand international cooperation* involves sharing data and promoting the peaceful use of space. This goal is manifested in the creation of SSA data-sharing agreements, increasing allied and partner contributions to military space activities, and international efforts to establish norms of behavior for outer space activity.

4. *Create a safe, stable, secure, and sustainable environment* focuses on domestic policy and international cooperation to mitigate the dangers of orbital collisions and debris, as well as protecting space systems and ground infrastructure more generally. This goal contributes to ongoing U.S. efforts to promote responsible behaviors and build international and interagency partnerships to share data and analyze threats to space and space-related assets.

5. *Increase assurance of national critical functions* consists of protecting spacecraft from all forms of disruption, including space weather, orbital debris, and hostile action. This goal reflects U.S. military efforts to increase the survivability of its space capabilities in the face of growing Chinese and Russian ASAT capabilities.

6. *Extend human economic activity into deep space* comprises an addition from the previous 2010 policy, calling for the establishment of a permanent human presence on the moon and human missions to Mars in cooperation with private industry and international partners.

7. *Increase the quality of life for all humanity* relates to improving space-enabled capabilities for activities such as space and Earth resource discovery and utilization, monitoring of weather and land use, and other critical data. This goal applies to programs such as NOAA's meteorological satellite program and the United States Geological Survey (USGS) Landsat program.

8. *Preserve and expand U.S. leadership* focuses on the development of innovative space technologies, services, and operations in cooperation with commercial and international partners while also preventing the transfer of sensitive space technologies to potential adversaries.

Many of these goals directly parallel goals from the Obama administration's 2010 National Space Policy, with most of the change between the two policies coming from new emphasis on human exploration of the moon and Mars; formal acknowledgment of the role of the U.S. Space Force and space as a warfighting domain; heightened focus on commercial partnerships and the space industrial base; the removal of mentions of climate change research; and incorporation of previous guidance on cybersecurity, space situational awareness, and orbital debris.

The seven Trump administration space policy directives followed similar themes, calling for long-term exploration of the moon before reaching for Mars,[12] streamlining the application process for commercial spaceflight activities,[13] recommending the creation of a civilian space traffic management authority lead by the Department of Commerce,[14] forming the newest branch of the armed services: the U.S. Space Force,[15] establishing cybersecurity principles and practices for space systems,[16] developing space nuclear power and propulsion,[17] and maintaining and protecting space-based PNT.[18]

Actors that Generate U.S. Space Policy

Executive Branch. The President determines overall national space policy as well as civil, commercial, and national security space policy. Within the White House, since 2017, space policy is coordinated by the National Space Council, which is chaired by the Vice President and consists of the Secretaries of State, Defense, Commerce, Transportation, and Homeland Security along with the Director of National Intelligence, Director of the Office of Management and Budget, National Security Advisor, Assistant to the President for Economic Policy, Assistant to the President for Domestic Policy, Administrator of NASA, the Director of the Office of Science and Technology Policy, and the Chairman of the Joint Chiefs of Staff.[19]

In addition to the collaborative work of the National Space Council, the National Security Council (NSC), National Science and Technology Council (NSTC), the Office of Science and Technology Policy (OSTP), the Office of Management and Budget (OMB), and the National Economic Council (NEC) draft policy for the President. The Administrator of NASA reports directly to the President as well.[20] The relative importance of various space policy actors varies by administration. The National Space Council, for example, was dormant under all previous presidencies other than John F. Kennedy and George H. W. Bush, while OSTP has had less influence during the Trump administration because a director was not appointed until 2019.

Legislative Branch. Designated Senate and House subcommittees deal with civil space issues. *Authorizing* subcommittees provide a policy framework for space activities and oversee their implementation. *Appropriations* subcommittees review civil space funding requests and appropriate funds to agency budgets.[21]

Table 3 shows the primary Senate and House subcommittees that deal with space issues. The Senate authorizes civil space activities through two subcommittees within a single committee, the Committee on Commerce, Science, and Transportation. The Subcommittee on Space, Science, and Competitiveness handles issues concerning such organizations as NASA, the National Oceanographic and Atmospheric Administration (NOAA), the National Science Foundation (NSF), and OSTP. The House, on the other hand, has two authorizing committees involving civil space: the Committee on Science, Space, and Technology and, to a lesser extent, the Committee on Energy and Commerce. Military and intelligence space issues are primarily handled through the Armed Services and Select Intelligence committees in their respective houses.

In addition to the primary authorization and appropriations committees for civil and military space, there are a variety of other committees in the House and Senate that periodically make laws related to space. Special interest groups, lobbyists, and citizens also provide policy input to the elected and appointed decision makers that act in the organizations noted above.

Table 4: Congressional Space Authorization and Appropriations Committees

Authorization	
House	**Senate**
• Committee on Science, Space, and Technology – Subcommittee on Space and Aeronautics • Committee on Armed Services (HASC) – Subcommittee on Strategic Forces • Committee on Energy and Commerce – Subcommittee on Communications and Technology • Permanent Select Committee on Intelligence (HPSCI) – Subcommittee on DOD Intelligence and Overhead Architecture	• Committee on Commerce, Science, and Transportation – Subcommittee on Space, Science, and Competitiveness – Subcommittee on Communications, Technology, Innovation, and the Internet • Committee on Armed Services (SASC) – Subcommittee on Strategic Forces • Select Committee on Intelligence (SSCI)
Appropriations	
House	**Senate**
• Committee on Appropriations – Subcommittee on Commerce, Justice, Science, and Related Agencies – Subcommittee on Defense (HAC-D)	• Committee on Appropriations – Subcommittee on Commerce, Justice, Science, and Related Agencies – Subcommittee on Defense (SAC-D)

Civil Space Sector

Civil Space includes aspects of spaceflight funded and directed by non-military government entities. This includes human spaceflight, space science, and many space application activities. Examples include human spaceflight programs like Apollo and the International Space Station, robotic exploration missions like Curiosity and Hubble, and Earth observation programs like Landsat and geostationary operational environmental satellites (GOES).

U.S. Civil Space Implementers

National Aeronautics and Space Administration (NASA).[†] NASA is an independent agency that reports directly to the White House. NASA headquarters is located in Washington D.C., and much of the organization's internal activities are conducted at nine "field centers," located around the United States, plus the Jet Propulsion Laboratory, which is managed for NASA by the California Institute of Technology (see Appendix A). The NASA workforce fluctuates around 19,000 civil service employees. NASA grants and contracts also support a large workforce in the aerospace industry and in universities across the United States. NASA's FY 2021 budget request was $25 billion, with $22.6 billion appropriated for FY 2020.[22][23]

National Oceanic and Atmospheric Administration (NOAA) National Environmental Satellite, Data and Information Service (NESDIS).[‡] NOAA's NESDIS program is the nation's primary source of space-based meteorological and climate data and is a leading source of such data for the world at large. NOAA-NESDIS spacecraft produce the satellite weather photos the public associates with television weather forecasts and Internet satellite weather maps. NESDIS headquarters is in Silver Spring, Maryland. The NESDIS appropriation for FY2020 was $1.51 billion, and the budget request for FY2021 was $1.50 billion.[24]

U.S. Geological Survey (USGS). [§] USGS is an agency of the Department of the Interior (DOI). It is responsible for the Landsat program, currently consisting of the Landsat-7 and Landsat-8 Earth observation satellites. NASA originally built and operated the Landsat satellites, but today the USGS operates the satellites and manages the data the satellites provide. Contractors operate Landsat spacecraft for USGS at its Earth Resources Observation and Science Center (EROS) in Sioux Falls, South Dakota, and at the NASA Goddard Space Flight Center.

Department of State, Bureau of Oceans and International Environmental and Scientific Affairs, Office of Space and Advanced Technology (OES/SAT).[**] OES/SAT handles international space issues and represents the United States in the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS). This UN committee developed the Outer Space Treaty and the other space-related conventions. The OES/SAT office also maintains the official United States registry of objects launched

[†]Further information on NASA can be found at its website, www.NASA.gov.
[‡]Further information on NESDIS can be found at its website, www.NESDIS.NOAA.gov.
[§]Further information about the Landsat program can be found at www.Landsat.USGS.gov.
[**]Further information about SAT can be found at www.state.gov/e/oes/sat/.

into outer space, oversees implementation of the Intergovernmental Agreement on the International Space Station, and supports U.S. civil space entities in upholding international agreements.

Department of State, Bureau of Arms Control, Verification, and Compliance (AVC), Office of Emerging Security Challenges (AVC/ESC).[25] AVC/ESC handles security issues relating to space, cyberspace, and the polar regions. In space, AVC/ESC pursues transparency and confidence building measures (TCBMs) meant to reduce tensions and enhance cooperation in space. AVC/ESC also participates in the formulation of military and intelligence-related space policy.

Key Civil Space Policy Issues

Commercialization of Low Earth Orbit (LEO). President Trump's FY2019 budget proposal called for an end to direct federal funding for the International Space Station by 2025, and the FY2020 budget proposal called for cancellation of three NASA science missions: the Wide-Field Infrared Survey Telescope (WFIRST) and two Earth science missions.[26] The extra funding is allocated to developing a commercial alternative for low Earth orbit research in the interim.[27] Congress has expressed opposition to the proposed timeline,[28] but the ISS's hardware is expected to expire by 2030, and continued presence in LEO will require a replacement. What will that replacement look like? Who will fund it? The models of commercialization demonstrated by the Commercial Crew and Cargo Programs, where NASA pays for services provided, show some ways forward. Purely public and purely private models can also be envisioned, as well as many combinations in between.

International Cooperation. Starting with the International Geophysical Year in 1957-58 that spurred the launches of Sputnik 1 and Explorer 1, space exploration became an international affair. The United States, specifically NASA through the NASA Act of 1958, has cooperated with a wide array of countries to study the Earth, explore planets, and advance human spaceflight through projects like Apollo-Soyuz and the International Space Station. This act mandates that NASA will use support and cooperation from scientists and engineers from other countries and international organizations after consultation with the Secretary of State.[29] As the civil space goals and capabilities of the United States and partner nations evolve into the future, what shape will that cooperation take? How will cooperation with established and rising space powers like ESA, Russia, China, and India develop in the future? Will proposed international norms of behavior in outer space be adopted? How will the ISS partners fit into commercial models for LEO research? What role will other countries have in missions to the moon or Mars? The nature of international cooperation will play a key role in determining what the future of space science and exploration will look like.

Commercial Space Sector

Commercial Spaceflight can be defined in many ways. Some definitions consider commercial space to be any space activity conducted for profit, including for-profit activities conducted by government agencies. Definitions also differ as to whether ground systems like GPS receivers should be considered commercial space products.[30] For the purposes of this primer, commercial space refers to space activities with four characteristics: (1) private capital is at risk in development and operation, (2) there are existing or potential non-governmental customers, (3) market forces determine viability, and (4) the primary responsibility and management resides with the private sector.[31] The aerospace industry builds and sells satellites and launch vehicles and provides launch services for the civil space sector, the national security space sector, telecommunications companies, and remote sensing companies. The industry has grown significantly in recent decades: by 2018, commercial space activities accounted for 76 percent of total space spending.[32]

Commercial Space Landscape

Affordable Launch. Two key trends have enabled reductions in the cost of space launch. First, companies like SpaceX and Blue Origin have pioneered techniques to re-use launch vehicles, which has the potential for significant savings.[33] Several companies like Rocket Lab have also begun introducing small launch vehicles enabled by new technologies such as additive manufacturing. These small vehicles do not demonstrate the scale economies of larger rockets (e.g., cost per pound to orbit), but their lower total cost makes them attractive to some users.[34]

Smallsats. Partially enabled by reduced launch costs, and partially by the ever-shrinking size of computer components, small satellites have paved the way for more diverse uses of space. Countries without significant space history like Mongolia and Ghana have been able to field satellites,[35] as have universities, high schools, and even middle schools through programs like NASA's Educational Launch of Nanosatellites (ELaNa).[36] Small satellites, specifically CubeSats, have also enabled a number of commercial ventures, including Earth imaging and communications services provided by huge fleets of cheap spacecraft in LEO.[37] Despite their applications, small satellites and large constellations also pose the risk of significantly increasing the quantity of debris in orbit.

Large Constellations. The idea of large constellations has changed over time as it has become cheaper and easier to launch large numbers of small satellites, and the FCC currently defines a large constellation as one that includes 1,000 spacecraft.[38] In 2019 and 2020, a growing number of companies such as SpaceX, Telesat, and OneWeb began planning or launching satellites to contribute to planned large constellations or "mega-constellations," with other companies and countries planning large constellations for a wide range of applications.[39] Large constellations can be particularly useful for lower-latency satellite communications and for expanding Internet of Things (IoT) applications, but they come with risks such as increased light pollution and an order-of-magnitude increase to objects in orbit leading to higher potential for collisions and debris.

New Space Applications. Recent years have seen serious proposals by commercial companies to undertake novel activities in space. *Space tourism*, which began in the early 2000s with a limited number of passengers paying high prices for a flight to the ISS, has continued to develop, with plans for private customers on suborbital flights by at least two well-financed companies.[40] Other activities include *satellite servicing* with specialized spacecraft, which repair or refuel existing satellites to extend their mission lifetimes, and *commercial lunar and asteroid missions*, which could provide data to space agencies and universities or even prospect for useful resources.

U.S. Commercial Space Governance Actors

Three key government organizations facilitate the commercial space sector:

1. **Federal Communications Commission (FCC).** The FCC regulates interstate and international communications by radio, television, wire, satellite, and cable. As such, the FCC is concerned with in-flight satellite operations, not launch and reentry. Within the FCC, the primary organization responsible for space-related issues is the Satellite Division of the International Bureau.[††]

2. **Office of Space Commerce (OSC).** OSC is an office under the Department of Commerce and is tasked with fostering an economic and policy environment that ensures growth and international competitiveness of the U.S. commercial space industry.

3. **Federal Aviation Administration, Associate Administrator for Commercial Space Transportation (AST).** This office is part of the Department of Transportation. Its mission is to protect public property and the national security and foreign policy interests of the United States during a commercial launch or reentry activity.[‡‡] AST is responsible for issuing commercial launch licenses, licensing the operations of nonfederal launch sites, or "spaceports," and regulating key aspects of space tourism.

Table 5: Examples of Past and Current Commercial Space Activities

Activity Type	Example Companies
Satellite manufacturing	Northrop Grumman, Lockheed Martin, Boeing, Maxar
Launch vehicle subsystem manufacturing	Aerojet Rocketdyne
Launch services	Arianespace, SpaceX, ULA, Northrop Grumman, Blue Origin
Telecommunication	Iridium, Intelsat, Eutelsat, DirectTV, Sirius XM
Earth observation	Planet, Maxar
Space tourism	Virgin Galactic, Blue Origin
Satellite servicing	MDA, Northrop Grumman
Space station logistics	SpaceX, Sierra Nevada, Boeing, Northrop Grumman
Space stations	Axiom, NanoRacks, Bigelow Aerospace
Smallsat manifesting	Spaceflight Industries, NanoRacks
Lunar delivery and space resources	Astrobotic, Moon Express, ConsenSys

[††]More information on the FCC's International Bureau Satellite Division can be found on its website, https://www.fcc.gov/general/international-bureau-satellite-division.
[‡‡]Further information on AST can be found on its website, https://www.faa.gov/about/office_org/headquarters_offices/ast/.

Key Commercial Space Policy Issues

Continuing Supervision. The Outer Space Treaty requires countries to continually supervise the activities of their citizens and organizations in space.[41] Until recently, those activities solely involved Earth-orbiting satellites that rarely changed orbits: licenses for launch, communications, and Earth observations covered all potential use cases. With the advent of spacecraft servicing and deep space commercial operations licensing has become more complicated. How will governments balance the need to maintain treaty obligations with the goal of supporting innovative uses of space, and which government agencies will be responsible for which activities?

U.S. Launch Range Capacity. Launch ranges in the United States are limited in number and capacity, which hinders growth in the number of future launches the United States can accommodate for growing commercial, civil, and military launch demand. The two main U.S.-based launch facilities are located in Cape Canaveral Air Force Station, Florida, and Vandenberg Air Force Base, California. However, the United States has also launched from Wallops Island, Kwajalein Atoll, and Kodiak Island.[42]

With more commercial space launches, there is decreased launch site availability. Range infrastructure modernization efforts will increase launch capacity, although there is a limit. Another solution to this problem includes ride-sharing opportunities, which put multiple satellites onto a single launch vehicle.[43] This cooperative approach will decrease launch costs in addition to providing more launch opportunities for commercial, civil, and military payloads. Nevertheless, a lack of range capacity may drive U.S. commercial companies to launch from other countries—a loss for the United States.

Evolving Foreign Competition. Many areas of the commercial space industry such as satellite manufacturing, space-rated components, and satellite imagery sales are developing increasingly competitive global markets. New technological developments are enabling new commercial actors or helping existing actors to compete in new ways. As alluded to above, a particularly visible example of this can be found in the launch market. Following years of declining international sales, the rise of affordable launch vehicles has improved U.S. competitiveness on the global market. Nevertheless, the international context is complex. Europe, Russia, China, and India continue to offer commercial launch services on the international market, at times at rates that competitors argue are subsidized.[44] How will foreign competitors respond to U.S. efforts to increase market share? What must the United States do to prepare itself for a changing market?

National Security Sector

National security space refers to military and intelligence space application activities funded and implemented by national security sector actors, including the military and intelligence agencies. Traditionally, *military space* referred to the operational- and tactical-level use of satellite information for battlefield purposes. A few examples include military telecommunication satellites, enemy missile launch detection and warning satellites, and GPS satellites. In recent years, however, this definition has expanded to include offensive and defensive operations in space itself in order to protect freedom of action and valuable space assets. *Intelligence space* refers to the gathering of data—through Earth observation, signal interception, and other space-based techniques—to inform national security decisions.

Key U.S. National Security Space Actors

United States Space Force (USSF). The USSF, set forth by SPD-4 and established by Title 10, focuses on organizing, training, and equipping space forces to protect national interests in the space domain and to provide space capabilities to the joint force. The new space cadre will develop military space professionals, acquire new space systems, develop new space power doctrine, and present forces to U.S. Combatant Commands. The USSF comprises three components: The Space Operations Command (SPOC), Space Systems Command (SSC), and Space Training and Readiness Command (STARCOM).[45]

U.S. Space Command (USSPACECOM). USSPACECOM, being the newest combatant command in the armed forces, is distinctly different from the USSF. It employs forces from each of the military services to accomplish missions within the space domain. This combatant command has four areas of focus: (1) deter aggression/conflict, (2) defend U.S./allied interests, (3) deliver space combat power, and (4) develop ready and lethal joint warfighters. USSPACECOM has two subordinate commands, the Combined Force Space Component Command (CFSCC) and the Joint Task Force Space Defense (JTF-SD), who manage the Combined Space Operations Center (CSpOC) and the National Space Defense Center (NSDC), respectively.[46]

Combined Space Operations Center (CSpOC). CSpOC uses space assets to accomplish the operational command and control for theater and global objectives. Its main role is to support other combatant commanders in accomplishing national security objectives. It also incorporates international allies through the presence such as Australia, Canada, France, Germany, New Zealand, and the United Kingdom and includes a Commercial Integration Cell to enhance cooperation with commercial partners. CSpOC is currently based out of Vandenberg Air Force Base (AFB).[47]

National Space Defense Center (NSDC) is an interagency operations center located at Schriever AFB composed of DOD staff, members of the intelligence community, and contractors. The NSDC is tasked with sharing information gathered by interagency partners about threats to satellites and coordinating responses to those threats.[48]

Space Development Agency (SDA). SDA focuses on the development and use of technology that will aid in developing the future threat-driven National Defense Space Architecture. These technological advances will provide a military space advantage for national defense. It will transfer from DOD to the USSF by 2022 and is currently located in northern Virginia.[49]

U.S. Space Force Space and Missile Systems Center (SMC).[§§] SMC is located at Los Angeles AFB, California, and is the Space Force's premier space acquisition center. SMC develops, acquires, fields, and sustains space and missile systems for the DOD. Programs focus on communications, navigation and tracking satellites, launch systems, and satellite control networks.

Space Rapid Capabilities Office (Space RCO). Space RCO, an office formed from the former Operationally Responsive Space office (ORS), is tasked with rapidly developing new space capabilities to support the warfighter.[50] Space RCO is based at Kirtland AFB in Albuquerque, New Mexico.[51]

U.S. Army Space and Missile Defense Command (SMDC). SMDC, located in Huntsville, Alabama, is the Army command that supports the missions of USSTRATCOM and USSPACECOM. It uses data collected from space by the Air Force, intelligence community, and commercial partners to enable its ground forces. The U.S. Army also provides a firm nexus between space and its missile defense mission. U.S. Army SMDC conducts space and missile defense operations and provides planning, integration, control and coordination of U.S. Army forces and capabilities in support of USSPACECOM and USSTRATCOM for space and missile defense missions, respectively.[52]

Naval Network Warfare Command (NETWARCOM). NETWARCOM has been the naval operational agent for space. Its responsibilities have included acting as the U.S. Navy Functional Component for Space to U.S. Strategic Command; equipping, manning, and training the U.S. Navy for space; developing a U.S. Navy space cadre; and supporting space situational awareness activities.[53] With the stand-up of USSPACECOM, the Navy component to the new combatant command will be called NAVSPACE.

Marine Corps Forces Space Command (MARFORSPACE). The Commandant of the Marine Corps directed the activation of the Marine Corps forces command on November 13, 2020. MARFORSPACE will provide space operational support to the Fleet Marine Force while subordinate to USSPACECOM and will initially be located at Offutt Air Force Base, Nebraska.[54]

Service (Army, Navy, Air Force, Marines) Program Offices. Service program offices are responsible for developing, building, and deploying end-user equipment for the warfighter. There are multiple service program offices, each with their own authority and budget that coordinate schedule, risks, and other interface requirements with their counterpart space segment program office.

U.S. Coast Guard Research, Development, Test, and Evaluation Program (RDT&E). The USCG launched two CubeSats in 2018 in support of the Department of Homeland Security Science and Technology Polar Scout project. Its role was to support the Arctic search and rescue missions, which have increased due to opening waterways in the Arctic.[55]

[§§]Further information on SMC can be found on the LA AFB website, www.losangeles.af.mil/.

U.S. Service Academies (USAFA, USMA, USNA). The service academies provide unique, hands-on training for developing and operating satellites. From FalconSAT at the U.S. Air Force Academy (USAFA), to Black Knight-1 at the U.S. Military Academy (USMA), and the QIKCOM-1 at the U.S. Naval Academy (USNA), each service academy is investing in developing new officers that will appreciate the challenges, opportunities, and value of space. The USAFA was the first commissioning source to send 2nd Lieutenants into the Space Force, which occurred in April 2020.

Key National Security Space Policy Issues

Department of Defense (DOD) Space Governance. Many entities within the DOD have an important stake in military space activities. The services, the Joint Staff, the intelligence community, and the Office of the Secretary of Defense all play significant roles in the acquisition, operation, and governance of military space. For decades, the DOD has grappled with designing the best organizational structure for maximizing U.S. military space activities for the warfighter and across these many stakeholders. The creation of the Space Force delivers education and training structures that aid the United States in the new space age. However, how will the Space Force collaborate with their partners from the intelligence, civil, and commercial space sectors? Will U.S. Space Command deliver capabilities to the warfighter better or worse than prior to becoming a Combatant Command? Emerging threats have created a new sense of urgency for resolving DOD space governance issues, and these questions will play an important role in space policy discussions in the coming years.

Threats, Deterrence, and Resilience. Dr. Christopher Ford, Assistant Secretary of State, remarked in a CSIS webinar, "Space has long been important *to* warfighting… however, outer space has more recently become an alarming potential location *for* warfighting."[56] How should the United States address these threats? The 2020 Defense Space Strategy states, "Space is vital to our Nation's security, prosperity, and scientific achievement. Space-based capabilities are integral to modern life in the United States and around the world and are an indispensable component of U.S. military power. China and Russia each have weaponized space as a means to reduce U.S. and allied military effectiveness and challenge our freedom of operation in space."[57] How should the U.S. respond to these encroaching powers and deter any harmful interference against our space assets?

In this regard, military planners have begun examining ways to achieve "Space Domain Mission Assurance."[58] Space domain mission assurance activities are divided into three categories: (1) defensive operations that stop or deter an enemy's attack, (2) reconstitution to restore a capability after it has been damaged, and (3) resilience or the ability of a capability to withstand the effects of an attack. Resilience activities include concepts like disaggregation, where capabilities that have traditionally been bundled onto monolithic satellites are split onto separate satellites in order to limit single points of failure. Other concepts involved in achieving resilience are distribution, diversification, protection, proliferation, and deception.

These ideas will be incorporated into mission architectures, where strategies to achieve them and the relative costs and benefits of those strategies can be weighed and reviewed against each other in a deliberate and thoughtful way.[59] What balance of strategies is most useful for each mission? How will success in achieving mission assurance goals be measured? These questions will play an important role in determining what the national security space sector looks like in the years to come.

Commercial Earth Imaging. In recent years, commercial Earth imaging systems have become more widespread and more capable. While the national security community has been able to take advantage of these advances in some ways, the national security and commercial sectors sometimes come into conflict. Current policy places restrictions on the resolution of imagery commercial operators may offer to customers for fear that detailed images of some targets could pose a security threat. However, commercial operators in other countries may be less limited, making U.S. restrictions an impediment to economic competitiveness without providing a benefit to national security.[60]

On July 20, 2020, a new NOAA rule on licensing of private remote sensing space systems came into effect. This rule overhauled the previous licensing system by moving from imposed conditions on certain types of imagery to a categorization of applicants based on the availability of their unenhanced data from sources outside the control of the U.S. government. This means that systems receive the bare minimum of licensing conditions so long as the system is only capable of producing unenhanced data similar to data available from sources not regulated by the Department of Commerce, such as foreign sources. The rationale behind this change was the notion that, "Commerce cannot prevent the harm that such systems might cause to national security, regardless of how strictly they are regulated," because substantially the same unenhanced data is available elsewhere.[61]

Even with these recent changes, several questions remain regarding commercial remote sensing. How can the United States balance security needs with the realities of the international market? What is the appropriate role for commercial imagery in the national security space community? How will the U.S. military adapt to the arrival of high-resolution, persistent, global commercial imaging of the Earth, which will reveal the location and activities of U.S. military forces on a near realtime, global scale?

International Space Law and International Organizations

Foundational Documents

International Space Law is based upon four main agreements: the 1967 Outer Space Treaty, the 1968 Rescue and Return Agreement, the 1972 Liability Convention, and the 1975 Registration Convention.

The Outer Space Treaty (OST). The Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, commonly known as the Outer Space Treaty, is the foundation of international space law. It provides several guiding principles for the use of outer space, the moon, and other celestial bodies. The common interest principle (Article I), the freedom principle (Article I), and the non-appropriation principle (Article II) establish that everyone is equally free to use outer space and no country can claim sovereignty over any part of it. The OST also acknowledges that the United Nations (UN) Charter and international law apply in outer space (Article III).[62]

The OST formally establishes the right of freedom of access to space for all nations, including the right of satellites to fly over any part of the Earth. Sovereign states maintain control of airspace over their territory and territorial waters but since the OST went into effect, that control does not legally extend upward into space.

The OST limits the military uses of space in only two respects:

1. Nuclear weapons or other weapons of mass destruction cannot be placed in orbit, on the moon or any other celestial body, or in outer space

2. The moon and other celestial bodies will be used exclusively for peaceful purposes; establishing military bases, testing weapons of any kind, or conducting military maneuvers on the moon and other celestial bodies is forbidden.[63]

The OST prohibits placing weapons of mass destruction in space, but it does not specifically prohibit other types of weapons in space. Furthermore, the OST does not prohibit anti-satellite weapons (ASATs). However, the OST also states "[i]n the exploration and use … Parties … shall conduct all their activities … with due regard to the corresponding interests of all other states."

With regard to the exploration of outer space (including the moon and celestial bodies), the OST makes clear that states must "avoid harmful contamination." Furthermore, if a state's space activity could potentially cause harmful interference with the space activities of other states (Article IX), the offending state is required to consult with the affected states.[64]

Rescue and Return Agreement. The Rescue and Return Agreement requires the rescue and prompt return of spacecraft personnel who land in international waters and in foreign countries. The agreement also requires states to return spacecraft parts that land in their territory if requested by the launching state.

Liability Convention. The Liability Convention and the OST make *states* responsible and liable for all activities that occur in outer space, even those conducted by civilians and private entities.[65] States therefore impose licensing and insurance requirements on commercial and private entities in order to provide authorization and continuing supervision as required in Article VI of the OST, and prevent potential costly liability expenses to the government.

The Registration Convention. The Registration Convention established a UN registry for space objects. It also requires states to establish national registries. However, the Registration Convention does not require very detailed or timely information, so its usefulness is often questioned.[66] The Registration Convention and the other treaties are sometimes criticized for their ambiguity on how the responsible state is to be identified. As commercial activities flourish, satellite and launch agreements are increasingly multinational, and it is more difficult to determine which government is required to register and/or is to be held liable for damages.[67]

Other Treaties. Other treaties also affect the use of outer space.

The 1963 Limited Test Ban Treaty prohibits nuclear explosions in outer space as well as in the atmosphere or underwater.[68]

The 1980 Environmental Modification Convention forbids hostile modification of the environment that might cause long lasting, severe, or widespread environmental changes in outer space or the atmosphere.[69]

The New Strategic Arms Reduction Treaty (New START) between the United States and Russia prohibits interference with early warning systems and "national technical means" (NTMs); i.e., a reference to reconnaissance satellites but the term has never been officially defined. The purpose of these prohibitions is to facilitate the monitoring of treaty compliance and thereby reduce the risk of nuclear war.

The Hague Code of Conduct commits subscribing states to provide pre-launch notification of space launch vehicles launches and ballistic missile launches.

Key International Organizations

International Telecommunication Union (ITU). The ITU is a UN agency that governs the use of the radio frequency spectrum. The United States is an ITU member state. Additionally, the ITU assigns physical satellite orbital slots in geostationary orbit. The United States applies ITU rules to the U.S. military.[70]

United Nations Committee on the Peaceful Uses of Outer Space (COPUOS). COPUOS was established in 1959 as a forum for discussing international governance of outer space. The major space treaties listed previously were negotiated under the aegis of COPUOS, along with the Moon Agreement (which did not see widespread acceptance).[71] In recent years, COPUOS members have discussed issues like space debris management, creating guidelines for the long-term sustainability of space, and determining if more concrete solutions are necessary or possible.[72]

Conference on Disarmament. The Conference on Disarmament is an international forum outside of the United Nations dedicated to disarmament. Members have negotiated a variety of treaties limiting the use of nuclear, chemical, and biological weapons.[73] In recent years, Russia and China have proposed a draft Treaty on the Prevention of the Placement of Weapons in Outer Space, the Threat or Use of Force against Outer Space Objects (PPWT). In short, the PPWT would ban the placement of weapons in outer space. The United States has resisted this effort, calling the treaty "fundamentally flawed" for ignoring ground-based ASATs that China has tested repeatedly, as well as arguing that it is unverifiable.[74]

Inter-Agency Space Debris Coordination Committee (IADC). The IADC is an international committee composed of national space agencies. The IADC's goals are to facilitate research on space debris and enable international cooperation on responses and mitigation techniques.[75]

Committee on Space Research (COSPAR). COSPAR provides a forum for the international sharing of knowledge gained through space exploration. It also serves as a venue for discussing issues relating to the practice of space exploration, including the development of rules to prevent cross contamination of Earth and other celestial objects.[76]

International Organization for Standardization (ISO). ISO provides voluntary, consensus-based international standards for spaceflight to improve space situational awareness (SSA) and space traffic management (STM). ISO 24113, which outlines space debris mitigation requirements, has been adopted by the European Cooperation for Space Standardization (ECSS), and, through ECSS, the European Commission for Standardization included it as a European standard. It has also been adopted by the European Space Agency and is used by the Japanese government as a requirement for their industry as well as by China and, to some extent, Russia.[77] Even though ISO 24113 standards are more measurable, these standards and best practices are near enough replicates of the IADC standards that some in the international community who have not adopted the ISO standards choose to follow the IADC standards instead.

International Cross-Cutting Issues

While space activities are typically categorized into three distinct activity sectors—civil, commercial, and national security—many issues affect all three, in addition to the international level. Resolving these key issues requires effort from stakeholders from each group.

Export Control

Many space objects, no matter their intended purpose, are inherently "dual-use" and could be used for both civil and security needs. As a result, many U.S. space technologies are subject to U.S. export control regimes for national security reasons. The most notable of these are the International Traffic in Arms Regulations (ITAR). Though seen as necessary for ensuring national security, many in the field of commercial space feel that obsolete or overly restrictive rules impede American competitiveness internationally. Significant reforms were undertaken in 2014 and SPD-2 in 2018 called for a review of export licensing conditions, but security and commercial actors differ on the path forward to resolve conflicts between the desire to boost commerce by easing regulatory burdens and the desire to preserve national security through export control.[78]

Space Situational Awareness and Space Traffic Management

As activity in space continues to grow, so too does the number of objects in orbit. Traveling at over 17,000 miles per hour at low Earth orbit (LEO) altitudes, impacts between spacecraft would cause catastrophic damage. The threats posed by space debris, congestion, and possible attacks in orbit were made more apparent when a 2007 test of an anti-satellite weapon by the People's Liberation Army of China created thousands of pieces of debris,[79] and in 2009 when an operational Iridium telecommunications satellite was destroyed in a collision with a defunct Russian military spacecraft.[80] Managing the risks posed by this increasingly congested space environment is critical to ensuring the safety and sustainability of space operations. In order to address these threats, it is necessary to first identify and track spacecraft and debris. This allows satellites an opportunity to maneuver away from danger as well as making it possible to attribute attacks or acts of negligence to particular actors and construct an appropriate response.

As part of the ongoing mission to protect their space assets, both NASA and the Department of Defense (DOD) maintain well-developed space situational awareness (SSA) capabilities. As an effort to minimize the risk from space debris caused by others, the DOD and Department of Commerce play increasingly important roles for space traffic management (STM), issuing conjunction warnings to satellite owners on a collision course with debris or other satellites.[81]

Another approach to mitigating the negative effects of a more congested space environment in the long term is the push for international norms, standards, and best practices for space sustainability. These initiatives consist of unilateral efforts to demonstrate responsible behavior, multilateral discussions on shaping potential norms, and agreements and resolutions developed by international organizations. For example, in June 2019, COPUOS adopted 21 guidelines for the long-term sustainability of outer space activities, a voluntary set of recommendations for policy and regulatory frameworks involving space.[82]

Because the activity of one can affect the safety of all in space, cooperation between different companies, countries, and organizations will likely continue to be a central facet of space sustainability.

Radio Frequency Spectrum Management

Connectivity, fueled by the transmission of data over radiofrequency (RF) waves, is an increasingly important part of our daily lives. The RF spectrum is a limited resource, however, and new users like 5G networks and large satellite constellations threaten to overwhelm it. Solutions to the problem have been suggested, including techniques for spectrum-sharing between space and terrestrial users,[83] but agreeing on and implementing a particular solution will be a challenge.

Accommodating new and legacy users of spectrum to build a more connected world will require the cooperation of commercial companies and civil and military agencies who all utilize RF spectrum. As electromagnetism does not recognize political boundaries, solutions will also need to be international or regional in nature.

The COVID-19 Pandemic

The coronavirus heavily affected the space industrial base during FY2020, especially among the smaller businesses. Governments have attempted to provide aid for these businesses, but resources are limited. In the United States, the Space and Missile Systems Center (SMC) announced that it would award six companies with rideshare contracts.[84] However, these awards were later rescinded. Long-term effects of the coronavirus on the space industrial base are still unknown, but governments are attempting to alleviate the pressure on the small launch market.

Conclusion

The purpose of this primer has been to provide some key concepts and common nomenclature for thinking about space, provide an overview of international space law, and outline the key questions confronting the United States and other countries today. It also has provided a brief sketch of how the U.S. government is organized to address these difficult space policy questions and touched upon the rationales for investing in space activities. While this primer by no means touched upon every important concept, rationale, actor, or issue, it will hopefully make a small contribution to the discussion on how the United States, and the world, moves ahead in space. The Aerospace Corporation's Center for Space Policy and Strategy also produces a number of papers and other resources to aid further understanding of developments in space policy. These resources may be found on its website.[***]

[***]Further space policy resources can be found at the Center for Space Policy and Strategy's website: https://aerospace.org/policy.

Acknowledgments

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Acronyms

AFB	Air Force Base
AFRC	Armstrong Flight Research Center
AFSPC	Air Force Space Command
ARC	Ames Research Center
ASAT	anti-satellite weapon
AST	FAA Office of the Associate Administrator for Commercial Space Transportation
AVC/ESC	Department of State, Bureau of Arms Control, Verification, and Compliance (AVC), Office of Emerging Security Challenges
C2	command and control
CFSCC	Combined Force Space Component Command
COPUOS	United Nations Committee on the Peaceful Uses of Outer Space
CSpOC	Combined Space Operations Center
COSPAR	Committee on Space Research
DHS	Department of Homeland Security
DNI	Director of National Intelligence
DOD	Department of Defense
DOI	Department of the Interior
ECSS	European Cooperation for Space Standardization
ELaNa	Educational Launch of Nanosatellites
EROS	Earth Resources Observation and Science Center
ESA	European Space Agency
EU	European Union
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
FY	fiscal year
GEO	geostationary Earth orbit; *also* geosynchronous Earth orbit
GOES	geostationary operational environmental satellite
GPS	global positioning system
GRC	Glenn Research Center
GSFC	Goddard Spaceflight Center
HEO	high Earth orbit; *also* highly elliptical orbit
IADC	Inter-Agency Space Debris Coordination Committee
IGY	international geophysical year

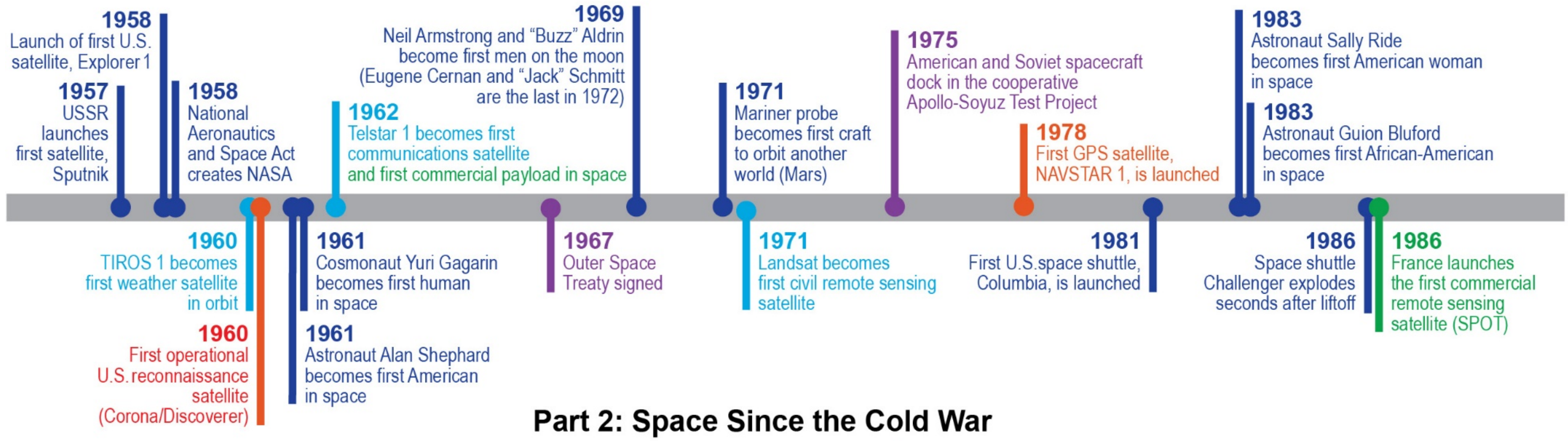
IoT	Internet of Things
ISO	International Organization for Standardization
ISS	International Space Station
ITAR	International Traffic in Arms Regulations
ITU	International Telecommunication Union
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
JTF-SD	Joint Task Force Space Defense
KSC	Kennedy Space Center
LARC	Langley Research Center
LEO	low Earth orbit
MARFORSPACE	Marine Corps Forces Space Command
MDA	MacDonald, Dettwiler and Associates, a division of Maxar; *also* Missile Defense Agency
MEO	medium Earth orbit
MSFC	Marshall Spaceflight Center
NASA	National Aeronautics and Space Administration
NEC	National Economic Council
NESDIS	National Environmental Satellite, Data and Information Service
NETWARCOM	Naval Network Warfare Command
New START	New Strategic Arms Reduction Treaty
NOAA	National Oceanic and Atmospheric Administration
NORAD	North American Aerospace Defense Command
NSC	National Security Council
NSDC	National Space Defense Center
NSF	National Science Foundation
NTM	National Technical Means, reconnaissance satellites
OES/SAT	Office of Science and Advanced Technology
OMB	Office of Management and Budget
OSC	Office of Space Commerce
OST	Outer Space Treaty/Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies
OSTP	Office of Science and Technology Policy
PAROS	prevention of an arms race in outer space

PLA	Chinese People's Liberation Army
PNT	position, navigation, timing
RDT&E	Research, Development, Test, and Evaluation Program
RF	radiofrequency
SDA	Space Development Agency
SIGINT	signals intelligence
SLS	space launch system
SMC	Space Force Space and Missile Systems Center
SMDC	U.S. Army Space and Missile Defense Command
Space RCO	Space Force Space Rapid Capabilities Office
SpaceX	Space Exploration Technologies Corporation
SPD	space policy directive
SPOC	Space Operations Command
SSA	space situational awareness
SSC	Stennis Space Center; *also* Space Systems Command
SSL	Space Systems Loral, a division of Maxar
STARCOM	Space Training and Readiness Command
STM	space traffic management
SW	space wing
TCBMs	Transparency and Confidence Building Measures
ULA	United Launch Alliance
UN	United Nations
U.S.	United States
USAFA	United States Air Force Academy
USCG	United States Coast Guard
USGS	U.S. Geological Survey
USMA	United States Military Academy
USNA	United States Naval Academy
USSF	United States Space Force
USSPACECOM	United States Space Command
USSR	Union of Soviet Socialist Republics
USSTRATCOM	United States Strategic Command

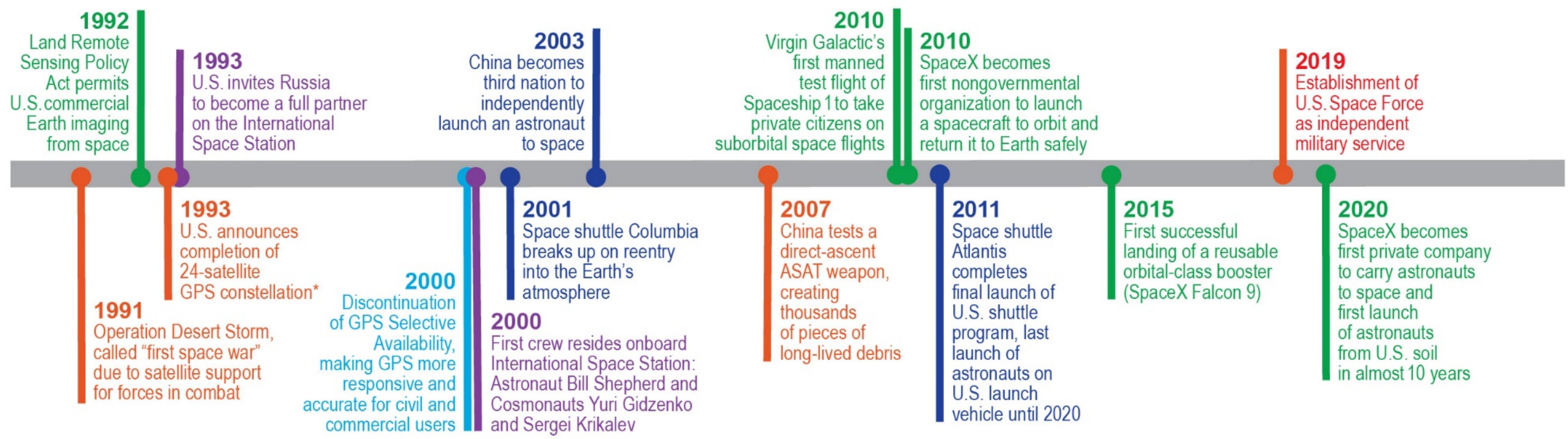
Appendix A: Overview of Space Policy History

This timeline is not meant to be comprehensive for all significant happenings in space but to highlight the progression of several space developments and activities across such areas as civil space exploration, national security space, commercial space, international space cooperation, and the expansion of services provided from space.[85]

Part 1: The Cold War and the First Space Age



Part 2: Space Since the Cold War



■ National Security ■ International Cooperation ■ Space Exploration ■ Space Services ■ Commercial Space

*Although the 24-satellite GPS constellation was not declared formally operational until 1993, GPS satellites were used for military and civil applications throughout the late 1980s and during Operation Desert Storm.
For further reading see Michael P. Gleason, *Galileo: Power, Pride, and Profit* (2009).

Appendix B: NASA Field Centers

There are five mission directorates within NASA headquarters: Human Exploration and Operations, Space Technology, Mission Support, Science, and Aeronautics Research. The Trump Administration's 2019 budget proposed eliminating Space Technology as a separate directorate and moving its activities into Human Exploration and Operations with a small number of projects being transferred to Science.[86] NASA Headquarters is responsible for liaison with the White House, other Executive Branch agencies, Congress, NASA's international partners, the media, and the general public. Through its mission directorates, it develops the projects and programs and associated budgets that NASA's field centers are responsible for implementing.

NASA Field Centers

Johnson Space Center (JSC); Houston, Texas: JSC is the lead center for all NASA human spaceflight, including ISS activities, and bears responsibility for astronaut training. The mission control center (MCC) manages activity onboard the International Space Station. JSC is managing the development of the Orion spacecraft intended to send astronauts beyond LEO and collaborates with commercial partners developing the vehicles that will soon send crew to the ISS.

Kennedy Space Center (KSC); near Titusville and Cocoa Beach (the "Space Coast"), Florida: KSC hosts launch facilities for the space launch system (SLS) intended to send humans beyond LEO as well as commercial rockets. KSC also coordinates launch vehicles carrying NASA payloads at Cape Canaveral Air Force Station in Florida, Vandenberg Air Force Base in California, and elsewhere. KSC also hosts facilities for the development of commercial crew and cargo spacecraft.

Marshall Space Flight Center (MSFC); Huntsville, Alabama: MSFC is responsible for key space launch and propulsion system development, including work on the space launch system.

Stennis Space Center (SSC); near Bay St. Louis in southern Mississippi: SSC is NASA's primary center for rocket engine testing and is the United States' largest rocket test complex.

Ames Research Center (ARC); Mountain View, California: ARC leads NASA research in information technology, nanotechnology, space biology, biotechnology, aerospace and thermal protection systems, and human factors. ARC also conducts research on the effects of gravity on living things and the nature and distribution of stars, planets, and life in the universe.

Goddard Space Flight Center (GSFC); Greenbelt, Maryland, a suburb of Washington D.C.: GSFC operates numerous scientific spacecraft including the Hubble Space Telescope, making GFSC the largest organization in the United States engaged in researching the Earth, the solar system, and the universe through satellite-based observations. GSFC also manages the operational space and ground network that supports the Human Spaceflight Program, as well as Earth orbiting missions, international, commercial, and classified and unclassified national missions.

Jet Propulsion Laboratory (JPL); California Institute of Technology, Pasadena, California: JPL is a federally funded research and development center managed and staffed by Caltech for NASA. JPL is responsible for interplanetary, deep space scientific and exploratory missions. Recent JPL missions include the Mars Science Laboratory rover, Curiosity; the Cassini mission to Saturn; and the Juno spacecraft orbiting Jupiter. JPL is also responsible for management of NASA's Deep Space Network, a global network of antenna complexes for controlling deep space spacecraft and retrieving data from them.

Armstrong Flight Research Center (AFRC); Edwards Air Force Base, California: AFRC, formerly Dryden Flight Research Center, is NASA's primary installation for flight research. In carrying out this mission, AFRC operates some of the most advanced research aircraft in the nation.

Glenn Research Center (GRC); Cleveland, Ohio: GRC is engaged in research, technology, and systems development programs in aeronautical propulsion, space propulsion, space power, space communications, and microgravity sciences in combustion and fluid physics.

Langley Research Center (LARC); Hampton, Virginia: Founded in 1917, LARC was the nation's first civilian aeronautical research facility. LARC leads NASA initiatives in aviation safety, small aircraft transportation, and aerospace vehicles system technology.

Appendix C: U.S. Space Force Field Commands[†††]

Space Training and Readiness Command (STARCOM)

STARCOM heads the education and training of all Space Force members. While it is currently located at Peterson Air Force Base in Colorado, the final location has not yet been decided. STARCOM will be similar to the Air Education and Training Command and will begin training in 2021.[87]

Space Systems Command (SSC)

SSC is tasked with acquiring and sustaining space weapons systems for USSPACECOM and USSF.[88] The Space and Missiles Systems Center (SMC), the service's current space acquisition organization will transition into SSC, in addition to certain functions from the Air Force Research Laboratory (AFRL), Space Rapid Capabilities Office (RCO), and the Space Development Agency (SDA).[89] SSC will also be responsible for launch, developmental testing, on-orbit checkout, and sustainment and maintenance for space systems.[90]

Space Operations Command (SpOC)

Headquartered at Peterson Air Force Base in Colorado, SpOC will operate military satellites, to include GPS, missile warning constellations, and satellite communications.[91] This organization is merely a name change, shifting Air Force Space Command (AFSPC) to SpOC.

Transitioned and Transitioning Wings and Units

The U.S. Space Force transitioned five Air Force wings to the Space Force upon its formation. These wings included the 21st, 30th, 45th, 50th, and 460th Space Wings.[92] In addition to the Wing transitions, 23 units have been designated for transfer. These include Test, Intel, and Weapons Squadrons, as well as AFRL divisions.[93] The locations of these units will not change so that the expertise and infrastructure already present may be used effectively.[94]

Activated Mission Deltas

On June 30, 2020, the U.S. Space Force executed several organizational changes as part of its transition to a flatter field organizational structure. This included the activation of the Space Training and Readiness (STAR) Delta Provisional (the precursor to STARCOM), two garrison commands, and eight mission deltas as well as the deactivation of three space wings and eight lower echelon commands from the previous Air Force structure. The two activated garrison commands are the Peterson-Schriever Garrison, replacing the 21st Space Wing and the 50th Space Wing, and the Buckley Garrison, replacing the 460th Space Wing.

The eight other mission deltas are designed to focus on specific, complex missions, and each has its own functional emphasis. The deltas, starting with Space Delta 2, are categorized as (2) space domain awareness; (3) space electronic warfare; (4) missile warning; (5) command and control; (6) cyberspace

[†††] This appendix was most recently updated in August 2020. Given the frequent updates to the structure of the new U.S. Space Force, the organization of the service is subject to chance.

operations; (7) intelligence, surveillance, and reconnaissance; (8) satellite communications/navigation warfare; and (9) orbital warfare.[95]

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