Driving Space Commerce Through Effective Spectrum Policy

Recommendations for Improving the Global Competitiveness of the United States Space Sector through Radio Frequency Spectrum Policies, Regulation, and United States Activities at the International Telecommunication Union and Other Multilateral Forums

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EXECUTIVE SUMMARY

On May 24, 2018, President Donald J. Trump issued Space Policy Directive – 2 (SPD-2), Streamlining Regulations on Commercial Use of Space.[1] The section on radio frequency spectrum requires the Secretary of Commerce and the Director of the Office of Science and Technology Policy (OSTP) to provide a report to the President "on improving the global competitiveness of the United States space sector through radio frequency spectrum policies, regulation, and United States activities at the International Telecommunication Union and other multilateral forums."[2] This report responds with a set of recommendations to support the radio frequency needs of the United States space sector.

The Trump Administration recognizes that a healthy satellite industry, equipped with sufficient access to radio frequency spectrum, is essential to the global competitiveness of the United States space sector. This report also considers the need to protect national security assets and balance other economic interests, consistent with the Administration's holistic approach to spectrum management and policy reflected in the recently issued Presidential Memorandum on Developing a Sustainable Spectrum Strategy for America's Future.[3]

In this report, we make thirteen specific recommendations: the first eight relate to spectrum and communications policies; two relate to streamlining the radio frequency licensing process; one relates to improving the United States position in international forums; and the final two procedural recommendations involve strengthening stakeholder input mechanisms and regularly assessing spectrum needs for space operations.[4] The report's specific recommendations, detailed below, are:

1. Allocate and assign radio frequencies domestically in a manner that recognizes satellite operations are essential for space commerce innovation, competitiveness, and economic growth.
2. Spectrum policy must balance in future allocations the rising demand for service with the availability of new technologies that significantly enhance spectral efficiency.
3. Support global harmonization of the radio frequency spectrum for space activities.
4. Improve radio frequency access for commercial space launches in the United States.
5. Protect space operations from harmful radio frequency interference.

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[1] *See* Space Policy Directive-2, Streamlining Regulations on Commercial Use of Space, 83 Fed. Reg. 24901 (May 30, 2018), a*vailable at* https://www.federalregister.gov/documents/2018/05/30/2018-11769/streamlining-regulations-on-commercial-use-of-space ("Space Policy Directive-2" or "SPD-2"). The report is to be prepared in consultation with the Chairman of the Federal Communications Commission and in coordination with the members of the National Space Council. *Id.*

[2] *See id.*

[3] Memorandum for the Heads of Executive Departments and Agencies, Developing a Sustainable Spectrum Strategy for America's Future, 83 Fed. Reg. 54513 (Oct. 30, 2018), *available at* https://www.federalregister.gov/d/2018-23839 ("Spectrum PM").

[4] As the U.S. develops these spectrum-based recommendations, it is important to complement them with both trade advocacy that advances U.S. space commerce issues internationally and multilateral work to alter policies in other nations that discourage U.S. opportunities in the space commerce sector.

6. Examine the impact of quantum satellite communication technologies on the U.S. radio frequency ecosystem.
7. Develop short-term and long-term spectrum policies that ensure deep space communications and navigation capabilities can meet exponentially increasing demand.
8. Support appropriate policies that can help speed the delivery of satellite broadband solutions to global markets in both served and underserved areas.
9. Advance a streamlined U.S. radio frequency licensing process for all satellites.
10. Streamline the U.S. process for authorizing domestic reception of foreign Global Navigation Satellite System signals when found to be in the national interest.
11. Work with like-minded countries to improve the space-related activities and processes of the International Telecommunication Union and other multilateral organizations.
12. Develop a robust process for periodic stakeholder input.
13. Assess spectrum demand for space operation and report on efforts to meet it.

The three annexes provide further background material in connection with the recommendations.

INTRODUCTION

The Trump Administration is committed to advancing commercial space activity and ensuring that the United States remains the flag of choice for space commerce.

On June 30, 2017, President Trump revived the National Space Council, chaired by Vice President Pence, following a twenty-five-year dormancy. Subsequently, the President signed three space policy directives that make evident the Administration's revitalized emphasis on human exploration and discovery.

In signing Space Policy Directive – 1 (SPD-1), President Trump reaffirmed that Americans would lead in space once again on all fronts, and that America would "establish a foundation for an eventual mission to Mars, and perhaps someday, to many worlds beyond."[5] Space Policy Directives 2 and 3 direct the Department of Commerce (Department) to eliminate regulatory burdens on commercial space activity that will unshackle industry and unleash "private enterprise to support the economic success of the United States."[6] To that end, the Department is working with other federal agencies and independent authorities, including the Federal Communications Commission (FCC), to encourage alignment between current and proposed regulations and the President's regulatory priorities to advance space commerce.

The Executive Branch is prioritizing policies that will enable continued United States leadership in space commerce innovation and investment. These include actions that will ensure both present and future commercial and government actors in space have sufficient access to communications networks necessary to execute their missions.

On February 21, 2018, the National Space Council recommended to the President specific action in this regard:

> [National Telecommunications and Information Administration] shall coordinate with the Federal Communications Commission to ensure the protection and stewardship of radio frequency spectrum necessary for commercial space activities, without adversely affecting national security or public safety. The Department of Commerce shall take an active role in working with U.S. industry and members of the National Space Council to develop and advocate, and to the extent possible, implement spectrum management policies that make U.S. space-related industries more competitive globally.[7]

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[5] Space Policy Directive-1, Reinvigorating America's Human Space Exploration Program, 82 Fed. Reg. 59501 (Dec. 11, 2017), *available at* https://www.federalregister.gov/documents/2017/12/14/2017-27160/reinvigorating-americas-human-space-exploration-program.

[6] *See Fact Sheet: President Donald J. Trump is Reforming and Modernizing American Commercial Space Policy*, WHITEHOUSE.GOV (May 24, 2018), https://www.whitehouse.gov/briefings-statements/president-donald-j-trump-reforming-modernizing-american-commercial-space-policy/.

[7] Record of Decision, National Space Council, NSpC ROD-2018-01 at 5 (Feb. 21, 2018).

On May 24, 2018, President Donald J. Trump issued SPD-2, Streamlining Regulations on Commercial Use of Space.[8] Section 1 of the Directive establishes that:

> It is the policy of the executive branch to be prudent and responsible when spending taxpayer funds, and to recognize how government actions, including Federal regulations, affect private resources. It is therefore important that regulations adopted and enforced by the executive branch promote economic growth; minimize uncertainty for taxpayers, investors, and private industry; protect national security, public-safety, and foreign policy interests; and encourage American leadership in space commerce.[9]

In Section 5 of SPD-2, which focuses on radio frequency spectrum, the Department of Commerce, in coordination with OSTP, is directed to work with the FCC to ensure that Federal Government activities related to radio frequency spectrum are, to the extent permitted by law, consistent with that policy.[10] Section 5 of SPD-2 also directs the Secretary and the Director of OSTP to prepare this report "on improving the global competitiveness of the United States space sector through radio frequency spectrum policies, regulation, and United States activities at the International Telecommunication Union and other multilateral forums."[11]

The Trump Administration also recognizes the importance of balanced spectrum management and policy in the context of space traffic management and space situational awareness. The President's recent Space Policy Directive – 3 (SPD-3), the first ever comprehensive National Space Traffic Management Policy, states that the United States should focus on preventing unintentional radio frequency interference and "continue to improve policies, processes, and technologies for spectrum use … to address these challenges and ensure appropriate spectrum use for current and future operations."[12]

In preparing this report, the Department and NTIA took immediate actions to assess the economic environment for American space enterprise; industry needs, capabilities, and plans; and present challenges facing government policy-makers. Accordingly, Secretary Ross and staff engaged in the following:

- Multiple Secretary-led listening sessions and roundtables with the satellite and space commerce sectors;
- NTIA-FCC coordination meetings regarding spectrum management and allocation;
- Assessment of the space commerce economy trends and growth potential;

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[8] *See* SPD-2, *supra* note 1, at 24901.

[9] *Id.* at 24901.

[10] *See id.* at 24902. The Secretary shall assign to the Assistant Secretary and the NTIA responsibility for the performance of the Secretary's communications functions. 47 U.S.C. § 902(b)(1).

[11] *See id* at 24902.

[12] *See* Space Policy Directive-3 (SPD-3) Section 4(g), National Space Traffic Management Policy, 83 Fed. Reg. 28969, 28971 (Jun. 18, 2018), *available at* https://www.federalregister.gov/documents/2018/06/21/2018-13521/national-space-traffic-management-policy.

- Multiple staff briefings and listening sessions with commercial space industry, including companies focused on satellite remote sensing, telecommunications, on-orbit servicing, tourism, space situational awareness, prospecting, and venture capital firms, among others;
- Meetings with private equity, venture capital, and lending institutions to discuss economic and investment trends in space;
- Discussions with Federally Funded Research and Development Centers (FFRDCs), including MITRE Corp. and Aerospace Corp., working to evaluate technical aspects of space-related spectrum use, protections, and challenges;
- Review of industry white papers and reports; and
- Engagement with other Executive Branch departments and agencies, including the Department of Defense (DoD), Air Force, National Aeronautics and Space Administration (NASA), the National Institute of Standards and Technology (NIST), and the National Oceanic and Atmospheric Administration (NOAA), regarding potential radio frequency interference concerns and challenges facing current and planned mission-critical space operations.

The research and analyses performed for this report make clear that U.S. commercial industry, in addition to the federal government, envisions far-reaching missions in space that will require vital communications to achieve success—both space-to-space communications and communications between Earth and objects in space. These missions will also depend on spectrum for other purposes, such as navigation and sensing. The United States needs strong and innovative space industries. Government action and policy must ensure that spectrum is available for important and rapidly advancing commercial—and Administration—envisioned space initiatives.

At the same time, radio frequency spectrum is limited and the ability to access spectrum is critical to many important commercial, personal, government, and scientific applications. As a relevant example, access to spectrum for space commerce at times competes with access for terrestrial wireless services including emerging 5G communications, which is an Administration priority that will provide tremendous benefits to U.S. consumers and the U.S. economy. Further, the nature of space communications, often involving exceptionally long distances, generate their own requirements in how radio frequency spectrum is allocated and managed. Because of the significant implications of how we as a nation manage our spectrum resources now, and especially for the future, President Trump has directed the Department, working through NTIA, to lead development of a national spectrum strategy.[13] As we consider the importance of satellite and space commerce to Americans, we must understand how these services factor into our broader economic picture and the protection of national security and public safety.

As President Trump has recognized, no country in the world is more reliant on space for its security, economy, and international status. Key to continued U.S. global leadership is our

[13] *See Spectrum PM*, *supra* note 3.

ability to continue expanding America's preeminence in space through civil, commercial, and military activity.[14] For Americans today, many common household and business functions, means of transportation, and fundamental services rely on satellite technology. The Department of Commerce and NTIA recognize that "the world as we know it today literally would not exist without [] satellites."[15] In that vein, the world of tomorrow will likely depend on a stable spectrum environment that appropriately protects vital satellite operations from harmful interference and supports U.S. goals in the global spectrum policy arena.

ANALYSIS

In preparing the recommendations in this report, the Department first considered the state of the space economy and the importance of space-related communications to U.S. business and consumers. Second, staff reviewed industry feedback, planned activities, and related concerns. Finally, the Department, through NTIA, evaluated potential government actions and recommendations related to spectrum management that will help advance American space commerce.

The Space Economy

Recent data make evident that the global space economy, though difficult to fully quantify, is rapidly growing. By one account, it now totals more than $383.5 billion worldwide.[16] Last year, seven countries spent more than $1 billion on space, orbital launches increased by over 7 percent, and the total number of deployed spacecraft doubled.[17] Data show that, under the Trump Administration, the United States continues to solidify its leadership role within the burgeoning economy. The U.S. totals approximately 57 percent of global space spending, accounts for one-third of all orbital launch activities, and the U.S. share of global spacecraft deployed is roughly 65 percent.[18]

The U.S. satellite industry is a key component of the growing space economy. The Satellite Industry Association (SIA) reports that the U.S. satellite industry generated over $110 billion in revenues and supported over 210,000 American jobs in 2016.[19] Currently, there are over 800 operational American satellites in orbit, and by 2024, that number could exceed 15,000. In

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[14] *See generally*, Michael Pence, Vice President, Remarks at 34th Space Symposium (Apr. 16, 2018), https://www.whitehouse.gov/briefings-statements/remarks-vice-president-pence-34th-space-symposium-colorado-springs-co.

[15] *See* David J. Redl, Assistant Secretary of Commerce for Communications and Information, Remarks at Satellite 2018: Affirming Our Partnership for Growth and Innovation in Space, Washington DC (Mar. 14, 2018), https://www.ntia.doc.gov/speechtestimony/2018/remarks-assistant-secretary-redl-satellite-2018.

[16] *See The Space Report 2018: The Authoritative Guide to Global Space Activity*, SPACE FOUNDATION (Jul. 19, 2018).

[17] *Id.*

[18] *Id.*

[19] *See 2017 State of the Satellite Industry Report*, SATELLITE INDUSTRY ASSOCIATION 6 (June 2017), https://www.sia.org/wp-content/uploads/2017/07/SIA-SSIR-2017.pdf.

addition, companies already are selling tickets for human flights into suborbit at $250,000 each.[20] Today's satellites have capacities of up to 260 Gbps which will increase to 1000 Gbps by the end of the decade.[21]

The American investment community recognizes the economic opportunity of space. In 2015, more than 50 venture capital firms began investing in space. That year, more capital ventured into the space market than in the prior 15 years combined.[22] The trend is likely to continue as America enters a new space age, with $3 billion in equity investments in 2018 alone.[23] Recent estimates show that by 2040 global space revenue will grow to over $1.1 trillion as more than 70 countries begin operating in space.[24]

One does not have to look far to identify the significant benefits of our assets in space. The Global Positioning System (GPS) continues to be crucial to the everyday lives of Americans. This satellite technology enables systems and modern applications for precise geographic position, navigation, and timing that are essential to modern business, public safety and more. The totality of the GPS economy is difficult to capture, as modern applications and uses rapidly develop (e.g., cell phone mapping and location-based applications; smart watches; public safety announcements and warnings) and overlap with other space functions like communications. A preliminary study conservatively estimated the GPS economy at $55.8 billion in 2013, benefitting multiple sectors and industries including precision agriculture, construction, surveying, rail and air transportation, maritime, and consumer vehicles.[25] Undoubtedly, GPS technology and uses have rapidly expanded in the last six years. This and other estimates likely do not fully take into consideration the broad indirect applications of GPS value related to increased human productivity, improved efficiency, and information data collection and analysis, to name a few.

GPS is driving innovative business technologies that are changing the modern world. Farmers plant seeds through auto-steering machinery that relies on GPS guidance. Private automobile ride service providers, valued at over a combined $1 trillion, use GPS to locate customers, save people commuting time and expense, and create thousands of jobs. GPS technology provides improved air transportation routes that enable fewer carbon emissions, fewer flight delays, fuel savings and other implications that lead to an estimated $1.3 trillion in annual

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[20] Wilbur Ross, Opinion, *That Moon Colony Will Be a Reality Sooner Than You Think*, N. Y. TIMES (May 24, 2018).

[21] *See* Realizing the Benefits of Rural Broadband: Challenges and Solutions: Hearing before the Subcomm. on Communications & Technology of the H. Comm. Energy and Commerce Subcommittee on Communications & Technology (Jul. 17, 2018) (statement of Tom Stroup, President, Satellite Industry Association).

[22] Lauren Thomas, *In a new space age, Goldman suggests investors make it big in asteroids*, CNBC (April 6, 2017), https://www.cnbc.com/2017/04/06/goldman-sachs-tells-investors-to-consider-new-space-age.html.

[23] *See Space Investment Quarterly Q4 2018,* SPACE ANGELS (Jan 2019), https://spaceangels.docsend.com/view/imudzjd.

[24] *See Space: Investing in the Final Frontier*, MORGAN STANLEY (Nov. 13, 2017), https://www.morganstanley.com/ideas/investing-in-space.

[25] Irv Leveson, *The Economic Benefits of GPS*, GPS WORLD (Sep. 1, 2015) ("Leveson Report"), *available at* https://www.gpsworld.com/the-economic-benefits-of-gps/.

economic activity generating more than 10 million jobs.[26] Meanwhile, the maritime industry will see valuable benefits from new space technologies as ports and ships use satellite imaging and GPS positioning services to more effectively navigate ships, avoid weather, and implement automated steering and robotics into operations.[27]

Satellite technology will also support many terrestrial communications advancements in the coming years, including support for, and integration with, 5G communications platforms. For example, satellites can help bring 5G and other next-generation services to rural and other areas where it is not economically feasible for terrestrial companies to lay fiber-optic cables, benefiting ranchers, farmers, pilots, sailors, and others.[28]

Finally, environmental observation and data collection generate billions in economic value. Weather analysis, prediction, and forecasting present are just a few examples. In 2014, the Department found that the aggregate annual valuation of weather forecasts totals approximately $31.5 billion.[29] The total of private and public spending on weather forecasting exceeds $5 billion, and re-packaged government data is currently used to produce over 15 million weather products relating to tornado and flood warnings, air quality alerts, tourism and farming applications, and more.[30] Studies show that many people refer to weather forecasts an average of 3.8 times a day—an estimated 301 billion forecasts consumed per year—to plan their daily lives. The economic benefit of weather forecasts to businesses, consumers, and government is especially apparent preceding and during extreme weather and natural disasters.[31] Accurate data and precise forecasting enable prompt evacuations and preparations that have saved lives and led to trillions of dollars in savings.

Space activities and their commercial applications are vital to the lives of Americans and our economic growth, national security, public safety, innovation, and achievement. As entrepreneurs and companies expand upon the business opportunities of space and embark upon new applications relating to remote sensing, GPS, environmental observation, manufacturing, tourism, pharmaceuticals, space situational awareness, and many other activities, addressing future

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[26] *Guiding Profits, Eight Ways the Global Positioning System Drives Billions in Economic Activity,* RAYTHEON (Dec. 13, 2017), www.raytheon.com/news/feature/guiding-profits.

[27] *See When Shipping Meets Satellite Technology*, PORT TECHNOLOGY (Mar. 1, 2016), https://www.porttechnology.org/news/when_shipping_meets_satellite_technology; *see also* Joseph Bennington Castro, *Robot Ships Will Bring Big Benefits – and Put Captains on Shore*, NBCNEWS (Nov. 8, 2017), https://www.nbcnews.com/mach/science/robot-ships-will-bring-big-benefits-put-captains-shore-ncna818941.

[28] Caleb Henry, *5 Q's for 5G, What the satellite industry needs to know about where it stands,* SPACENEWS (Aug. 27, 2018), https://spacenews.com/what-the-satellite-industry-needs-to-know-about-where-5g-stands/.

[29] Jane Callen, *The Value of Government Weather and Climate Data*, U.S. DEPARTMENT OF COMMERCE (Sept. 2, 2014), https://www.commerce.gov/news/blog/2014/09/value-government-weather-and-climate-data.

[30] *Id.*

[31] *Id.*

space communications requirements including spectrum access must be a priority for the federal government.

Planned Space Commerce Activities

The Trump Administration seeks to ensure that the United States remains the flag of choice for commercial space activities as technology progresses and companies realize novel concepts in space. Industry plans for new space businesses and deep space exploration are advancing quickly. Commercial activities in space will escalate as the Administration and NASA envision a renewed American presence on the Moon. NASA's Deep Space Gateway program could provide an anchor, like the International Space Station (ISS), for outward expansion.[32] Communication needs will be of upmost importance to these endeavors. Numerous companies have briefed the Department on the forward-thinking business plans they are beginning to execute, including:

- Spacecraft aiming to create a sustainable economy in low-Earth orbit for commercial crew transportation and future expansion outward towards the Moon;
- Missions to send humans to the Moon as early as 2023;
- Advance cargo missions to Mars in 2022 to confirm water resources, identify hazards, and support infrastructure;
- Formation of space habitations;
- Inflatable space stations to be used as space hotels;
- Establishment of a permanent operating presence on the Moon and sophisticated Moon infrastructure to enable prospecting of precious resources that could bring enormous benefits to Earth, including water, which could provide an accessible source for in-space rocket fuel;
- Development of an all-optical, global satellite communications network;[33]
- Development of a commercial architecture docking station for spacecraft transporting to and from the moon.
- A next generation shift from ground-based air traffic control to a satellite-based system of air traffic management.
- Mega-constellations of lower cost-satellites to provide low-latency, high-speed broadband access across the globe.

These are representative examples of commercial and public-private partnership activities—many conducted in support of government agencies—to pursue expanded operations in space. One thing is clear: these difficult challenges will require increasingly data-heavy, reliable communications with Earth and within space.

Complementing private industry efforts, President Trump has also made clear the Administration's intent to expand the American presence and infrastructure in space. Large-scale

[32] Sarah Lewin, *Humanity's Expansion into Deep Space Is Inevitable, Industry Experts Say,* SPACE.COM (Dec. 13, 2017), https://www.space.com/39076-humanity-heads-toward-deep-space-expansion.html.

[33] Optical communications systems are in experimental phases; these systems could provide space communications without the current need for spectrum access.

state-sponsored programs look toward the Moon and beyond. NASA's next-generation missions will depend on commercial support and lead to continued economic growth as they provide an anchor for space development and technology:

- New U.S. commercial spacecraft and rockets are assisting with cargo deliveries to ISS and are planning to launch NASA astronauts from U.S. soil in the near future;
- ISS is providing an ideal laboratory setting for wide-ranging scientific research including advanced life support systems and human/robotic interfaces;
- New NASA-piloted aircraft designs could lead to supersonic flight over land;
- NASA's Space Launch System (SLS) rocket will carry astronauts aboard its ORION spacecraft back to the moon, where the astronauts will begin developing the systems needed for subsequent missions into deep space;
- NASA will continue building up its deep space capabilities in preparation for human trips to Mars;
- Two new NASA missions, ICESat-2 and GRACE Follow-On, will entail new satellite Earth observation technologies critical to environmental planning and understanding of changes to national resources; and
- Development of new technologies and techniques for solving problems in preparation for longer-duration missions far from Earth.[34]

Trends in the Use of Space-related Spectrum

It is critical that all stakeholders—regulators, service providers, users—understand and consider the detailed technical characteristics of each use of radio spectrum in any regulatory decision. Regulatory instability is bad for business and internationally harmonized regulations are critical for satellites since their signals do not stop at borders and offer global and regional coverage. Satellite regulation requires a global and regional approach—most importantly at the International Telecommunications Union.

Prudent spectrum allocation and management, incorporating spectrum sharing when appropriate, is critical due to congested radio spectrum. In light of the disparate radio spectrum uses, a "one size fits all" approach to spectrum sharing is not possible or even necessarily desirable because, for example, it could detract from optimizing spectrum use intensity through more advanced sharing techniques.

Commercial terrestrial users are pushing into higher millimeter-wave frequency bands. These higher frequencies appear attractive to those market entrants interested in launching high capacity, high-speed, low-latency wireless networks. In 2016, the FCC adopted new rules for wireless broadband operations in frequencies above 24 GHz, making the U.S. the first country in the world to make this spectrum available for next-generation wireless services. The rules balance different spectrum access approaches, including exclusive use licensing, shared access, and unlicensed access in order to meet a variety of different needs and use cases. The FCC also adopted other

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[34] *What's Next for NASA*, NASA (April 24, 2018), https://www.nasa.gov/about/whats_next.html. For a current description of NASA exploration plans, please refer to www.NASA.gov.

flexible service and technical rules to allow new technologies and innovations to evolve and flourish without needlessly prescriptive regulations. Some of these bands are currently used by the space community, and the impact of sharing on sensitive satellite receivers needs to be considered.

The newer technology of software-defined radios presents even more policy issues. Some satellites (today, mostly small lower Earth orbit (LEO) satellites) are designed with software-defined radios, which can adapt frequency usage dynamically and which may open the door over time to new regulatory approaches to spectrum sharing. However, many legacy satellites without the ability to adapt to different areas of spectrum will be on orbit for decades to come. Transmitters capable of operating across wide frequency bands are certainly attractive for their flexibility, but these same transmitters could be sources of interference or jamming if allowed to operate across spectrum used for space services. Carefully thought out regulatory implementation of these new spectrum access technologies and techniques is imperative.

Stakeholder Feedback

The Department recognizes that access to spectrum is critical for the U.S. satellite industry's ability to innovate. Consumer-focused satellite communications services include direct broadcast television, satellite radio, satellite broadband access, mobile satellite phones and terminals, and navigation or location-based applications. In addition to growth in these areas, as industry and government operations progress further into deep space missions satellite communications and navigation will be essential to mission success.

In preparation of this report, Department staff conducted numerous meetings and briefings with industry, nonprofit organizations, military and civil government officials and engineers, and other interested stakeholders. Space stakeholders expressed concerns and provided input pertaining to radio frequency spectrum including:

1. The Administration's efforts to establish the U.S. as first in 5G must support its concurrent efforts to ensure that foreign influence, including that of China, does not leverage international spectrum policies to the detriment of the U.S. satellite industry globally and prevent satellite services from competing with nationalized terrestrial systems. Satellite systems need a stable and predictable spectrum environment given their long-lasting, often mission-critical uses and their far-reaching scientific and economic benefits.
2. Some services are inherently incompatible unless separated—sometimes widely separated—in frequency. Space systems have unique spectrum needs that may be incompatible with terrestrial systems, particularly those that are widely deployed and operate at power levels that are orders of magnitude above that of received satellite signals.
3. Once satellites are in orbit and operational, these systems need sufficient protection from harmful interference. For example, GPS satellites and receivers require protection from harmful interference, especially if future systems, such as the NextGen satellite-driven air traffic management network, are to effectively enable safe transportation. Meanwhile,

upfront capital is not likely to flow to new entrants in the satellite market in the presence of excessive uncertainty or lack of predictability for fear that future operations will be compromised.

4. Interference protection criteria should be based on widely accepted spectrum engineering principles and practices (including additional protections for safety applications).
5. Industry seeks assured spectrum allocations in the U.S. and harmonized international allocations in light of the international nature of satellite operations.
6. Future spectrum management and policies should consider that deep space missions are quickly becoming a reality. They will require reliable spectrum access for mission success and, in some cases, to protect lives.
7. Satellite systems in the L-band currently need a stable spectrum environment given their long-lasting and mission-critical uses.
8. The composite effect of terrestrial systems, if not considered carefully, could negatively affect the noise floor in space-based receiving systems, depending on the specific case. This could in turn harm important science missions conducted by NASA and other space agencies.
9. Protection of the existing S, X, Ku, and Ka DSN frequency band allocations from out-of-band or disproportionately high-powered terrestrial uses in satellite bands must be a priority if moon and mars missions are to be a reality. Certain emissions of sufficient power level from operational systems in LEO, highly elliptical orbit (HEO), and geosynchronous Earth orbit (GEO) in immediately adjacent frequency bands will likely cause harmful interference to deep space communications, as deep space signals are usually received on the ground at much lower power levels than LEO, HEO, and GEO satellite systems.

As noted above, in preparing this Report, the Department assessed the state of the satellite industry, the impact of spectrum policy, and management decisions and actions. Our engagement with stakeholders inside and outside of the government also provided us with significant inputs on how spectrum policies could help advance U.S. space commerce. However, this report must be viewed as an initial effort—a launching pad for further study, stakeholder input, and ultimately decision-making. For example, as the space industry is rapidly expanding and innovating, we need a much deeper understanding of the specific spectrum demands for the near- and longer-term across a wide range of mission needs. At the same time, we need to understand whether industry is investing in more spectrally efficient technologies that will support co-existence with other space-based as well as terrestrial systems, or, in the case of some emerging technologies, perhaps even alleviate the need for access to radio frequency spectrum.[35] Moreover, a strategy for addressing the spectrum implications of an expanding U.S. space industry must not occur in a vacuum. Therefore, although the federal government must continue to review the spectrum

[35] For example, to minimize launch-based spectrum demand, launch ranges transitioning to GPS metric tracking and automatic flight termination systems can reduce, if not eliminate, the need for dedicated spectrum for flight termination command and control.

requirements and technology developments associated with space operations, NTIA must incorporate this activity into the development of the President's national spectrum strategy.

RECOMMENDATIONS

The President's recent Spectrum PM calls for "a balanced, forward-looking, flexible, and sustainable approach to spectrum management," recognizing that valuable demand for future spectrum is needed due to American industry technological advancements, including the expansion of commercial space operations.[36] The President directs the Secretary to develop recommendations for a long-term spectrum strategy that, among other things, would "improve the global competitiveness of United States terrestrial and space-related industries and augment the mission capabilities of Federal entities through spectrum policies, domestic regulations, and leadership in international forums."[37]

To embrace the Administration's priority of maintaining and expanding the U.S. position in space exploration, innovation, and economic growth, the U.S. Government must ensure that U.S. spectrum use and related regulatory and licensing policies balance all our national priorities, including support for a robust satellite industry. This report outlines the need for rapidly advancing such policies through stakeholder engagement, collaboration across the federal government, and sound scientific study and analysis. It also makes clear that spectrum policy and planning in the context of space must be part of the Administration's broader spectrum management strategy. By embracing the recommendations in this report, the Administration will take decisive steps to make U.S. space commerce a dominant economic force for the benefit of all Americans.

I. Spectrum Policies.

1. **Allocate and assign radio frequencies domestically in a manner that recognizes satellite operations as essential for space commerce innovation and economic growth**. A healthy satellite industry is essential to enhance the global competitiveness of the United States space sector. The Department, through NTIA and in collaboration with the FCC, must ensure that U.S. spectrum policies consider the needs of space-based technologies. To this end, the government should assess current satellite technical characteristics, future space technologies, and associated spectrum demand in order to inform national forward-looking spectrum policies. The Spectrum PM requires the Director of the White House Office of Science and Technology Policy to submit a report to the President on emerging technologies and their expected impact on non-Federal spectrum demand. It also directs Federal departments and agencies to report to NTIA on their anticipated future spectrum requirements. Both of these examinations must take into full account space-based systems. Meanwhile, the FCC is encouraged to continue considering innovative spectrum assignment approaches, including those that account for geographical characteristics (e.g.,

[36] *See Spectrum PM, supra* note 3.

[37] *Id.*

urban areas versus rural areas) and that recognize the roles of both terrestrial and space systems in serving the public interest and advancing U.S. priorities.

2. **Spectrum policy must balance in future allocations the rising demand for service with the availability of new technologies that significantly enhance spectral efficiency.** It is inevitable that, as wireless and satellite services expand commercial and personal capabilities, demand will continue to grow. In a static spectral efficiency environment, it would be appropriate for spectrum allocations to track that demand and exclusively provide greater spectrum access for the services that are experiencing the greatest demand. However, according to one study, wireless network bandwidth capacity, and the capacity of other modalities, increase approximately 100% every ten years.[38] Current and emerging technologies hold significant promise in this regard for both terrestrial and satellite services.

   For example, quadrature amplitude modulation (QAM) technology deployed in many wireless operations is a method of combining two amplitude-modulated signals into a single channel, thereby doubling the effective bandwidth.[39] Additionally, beamforming is significantly increasing the capacity of its allocated spectrum and reducing the number of cell sites required for service.[40] Moreover, 5G technology is projected to provide 50% more spectral efficiency than LTE.[41]

   Similarly, satellite technology advancements are enhancing bandwidth capacity and broadband service provision with enabling spectrum allocations. High Efficiency Video Coding (HEVC) is an emerging video compression standard that can make ultra-high definition video via satellite cost effective.[42] High-throughput satellite (HTS) have increased satellite spectral capacity by approximately two orders of magnitude since 2011.[43]

   Taken together, and considering other developments such as the FCC's currently under consideration proposals with regard to C-Band reallocation,[44] it may be that

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[38] *See The Spectrum Handbook 2018*, SUMMIT RIDGE GROUP (Oct. 2018, 31), https://ssrn.com/abstract=3259782.

[39] *See id.*

[40] *See id.* at 36.

[41] *See id.* at 44.

[42] *See id.* at 34.

[43] *See id.* at 36.

[44] "The FCC has unanimously voted to find ways to open up the C-band spectrum (3.7-4.2 Ghz) for terrestrial wireless use, either all of the 500 Mhz or some portion of it, and through either an incentive or capacity auctions, a market mechanism where incumbents voluntarily strike deals to reduce their footprint, or some other means." John Eggerton, *FCC Votes to Open C-Band for Wireless Broadband,* BROADCASTINGCABLE.COM (Jul. 12, 2018), https://www.broadcastingcable.com/news/fcc-votes-to-open-c-band-for-wireless-broadband.

the U.S. will be able to minimize the oft-repeated concerns of a looming "Spectrum Crunch." Accordingly, U.S. spectrum policy and spectrum allocation decisions should take into serious consideration significant spectral efficiency enhancement technologies that will help meet wireless and satellite service demand. Moreover, spectrum policy should assess how advancements in technology for satellite and other services will provide new methods to meet consumer demand – provided these modalities have the spectrum they need to provide service.

3. **Support global harmonization of the radio frequency spectrum for space-related activities.** U.S. space activities, which operate over much of the globe, will benefit significantly from internationally harmonized spectrum. Operation of a satellite system in different spectrum bands in different regions increases operational challenges and costs while decreasing U.S. investment, threatening the growth of U.S.-based space commerce. NTIA must continue to strive to understand fully the specific harmonization needs, challenges to global harmonization, and technically and economically feasible alternatives in specific bands (if any). This policy positions the U.S. delegation to pursue globally harmonized spectrum allocations where feasible at the upcoming 2019 World Radiocommunication Conference (WRC-19).

   The ITU has made clear through several recent actions that, amidst a search for spectrum to advance terrestrial wireless broadband, or "IMT-2020" in ITU parlance, reserving spectrum for satellite services is also of paramount importance. The 2015 WRC identified over 33 GHz of millimeter wave spectrum for study for possible identification for IMT-2020 at WRC-19. On the other hand, the 28 GHz (Ka) band was not included in this list, with the resolution noting the importance of the Ka band in providing mission critical satellite broadband services in the U.S. and other nations.[45] Moreover, the ITU protected satellite use in the of 3.6-4.2 GHz band (C Band) in Region 2, covering the Americas, but that same band was identified as available for wireless service in other regions.[46]

   Additionally, the subsequent 2016 edition of the ITU Radio Regulations includes several requirements designed to protect space communications from terrestrial operations above 1 GHz. The ITU's basis for these requirements was in the premise that, "all stations, whatever their purpose, must be established and operated in such a manner as not to cause harmful interference to the radio

[45] *See, e.g.,* The World Radiocommunication Conf. Res. 238-1, (WRC-15) (2015).

[46] *See,* The World Radiocommunication Conf. FINAL ACTS, (WRC-15) (2015) (identifying the lower 200MHz of C-band downlink frequencies—3400-3600MHz—for mobile telecommunication use in ITU Regions 1 and 2, covering most of the world except East Asia.) In Region 2 – EMEA and Russia – a footnote identified the 3600-3700MHz band for mobile use in a few countries. *Id*.

services or communications of other Members or of recognized operating agencies, or of other duly authorized operating agencies which carry on a radio service, and which operate in accordance with the provisions of these Regulations."[47] Specifically, ITU Radio Regulations Article 21 establishes detailed technical parameters on power limits and separation angles for terrestrial, earth, and space stations operating above 1 GHz to mitigate interference upon and from space communications.[48]

Further, the ITU recently stated that access to spectrum for satellite technology is crucial for broadband services and applications. In its Plenipotentiary Conference 2018, the ITU stated, "In recognition of satellite's unique capability to extend broadband connectivity, the ITU's 2018 Plenipotentiary Conference modified its resolution on connectivity to broadband networks to specifically include satellite technology."[49] That resolution now invites Member States "to facilitate connectivity to satellite and terrestrial broadband networks, including enabling access to spectrum, as appropriate, as one important component of access to broadband services and applications, including to remote, underserved and unserved areas."[50]

To ensure continued investment in essential satellite services, it is critical that the U.S. Government strive to align international activities, including in preparation for WRC-19, with current and future U.S. spectrum regulations and decisions that advance President Trump's space and economic priorities.

4. **Improve radio frequency access for commercial space launches in the United States.** In the past, spectrum needed to support the tracking and commanding of space launches was largely within the domain of the federal government. This was due to the way the U.S. manages spectrum, with access to all spectrum bands supporting launch allocated exclusively for federal government use. Today, the U.S. provides spectrum for commercial space launches through an ad hoc process of special temporary authority grants or experimental licenses. In addition, our policies have evolved, encouraging the federal government to use commercial space-related systems to meet its satellite needs through commercial leasing, which can include investment in federal earth stations. However, the U.S. does not protect federal earth station investments through federal allocations when they are built to connect to commercial satellites. The U.S. must protect such infrastructure as it represents significant taxpayer investment. NTIA has

[47] ITU Radio Regulations, Preamble 0.4 (2016).

[48] *See id.* at Art. 21.

[49] *See* ITU Plenipotentiary, Res. 293 (Rev. Dubai 2018).

[50] *Id.*

collaborated with the FCC on these issues for many years and it is imperative we act. This will be especially important as the opportunities for smaller commercial launch vehicles, and expected growth in the number of launches, grow substantially.

5. **Protect space operations from harmful interference.** SPD-3 directs federal agencies to "coordinate to mitigate the risk of harmful interference and promptly address any harmful interference that may occur."[51] The U.S. must work to protect the reception and transmission of space-related operations against harmful interference through U.S. and international regulations. Satellite systems such as GPS and others rely on reception of low power signals from space. Reception of these signals can be difficult in the presence of signals from other communication services (either terrestrial or space) operating in the same or adjacent spectrum. Conversely, satellite systems in space seek to receive low power signals from the earth for a wide variety of purposes that can be constrained by high levels of noise observed in space caused by other communication services (terrestrial or space) as well as natural events such as space weather.

   NTIA should gather information from stakeholders on specific interference concerns for space operations and actions that could mitigate harmful interference, including best practices that would encourage innovation and deployment of next-generation space operations. At the same time, space systems should leverage innovative technologies, to the extent feasible, to tolerate certain levels of interference, increasing resiliency and maximizing the potential for spectrum sharing with other communications services.

   Interference is of particular and immediate concern regarding the Global Positioning System (GPS) satellite constellation, which provides critical, precise geographic location on the Earth. GPS applications are driving innovation and creating major economic growth in farming, aviation, weather forecasting, construction, mining, banking systems, financial markets, power grids, and a host of other markets.[52] GPS contributes between $37.1 and $74.5 billion to the U.S. economy each year[53] and provides vital information to first responders across the nation.[54]

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[51] *See* SPD-3 Section 6(g), *supra* note 12.

[52] *See GPS Applications*, GPS.GOV, *available at* https://www.gps.gov/applications (last visited Sept. 12, 2018).

[53] *See Leveson Report*, *supra* note 25.

[54] *See GPS Applications – Public Safety and Disaster Relief*, GPS.GOV, *available at* https://www.gps.gov/applications/safety/.

Critical federal stakeholders—including the U.S. Air Force[55]—support the adoption of the International Telecommunications Union-recommended 1 dB interference protection criterion (IPC) for radio navigation services, including GPS.[56] Disruption to GPS could have significant impact to U.S. industry, safety, and economy. Beyond losing life-saving, mission-critical communications, GPS disruption could result in costs to U.S. GPS users and manufacturers of as much as $96 billion per year.[57]

In order to advance our national interests in both GPS and other spectrum-based services, NTIA will gather data from stakeholders on interference protection needs for space communications, potential mitigating technologies against harmful interference, and best practices that would encourage innovation and deployment of next generation space communications and report to the Secretary no later than June 1, 2019. The NTIA report will include recommendations and analysis that address, *inter alia*, the ITU-R M.1903 recommendation and the U.S. Air Force's proposal for a 1 dB IPC[58] and prior work done within NTIA and the U.S. government on this and related issues.[59]

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[55] Memorandum from Air Force IRAC Representative to the IRAC Chairman, re: Doc. 43501/1 OET Public Notice on TAC Spectrum Policy Recommendations, ET Docket No. 17-430 (Dec. 29, 2017); s*ee also Background Paper on Use of A 1-Db Decrease In C/N0 As GPS Interference Protection Criterion*, GPS.GOV, https://www.gps.gov/spectrum/ABC/1dB-background-paper.pdf (last visited Sept. 12, 2018).

[56] *See* ITU-R Recommendation M.1903 at 9 (2012), *available at* https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.1903-0-201201-I!!PDF-E.pdf ("[T]he accepted approach is to define the aggregate interference power density threshold at a level that will not raise the total noise floor by more than 1 dB above the environmental noise floor.").

[57] *See* Nam D. Pham, *The Economic Benefits of Commercial GPS Use in the U.S. and The Costs of Potential Disruption*, NDP CONSULTING 2 (June 2011), https://static1.squarespace.com/static/52850a5ce4b068394a270176/t/52d84e86e4b042903508ec47/1389907590034/GPS|Report|June|21|2011.pdf (last visited Sept. 19, 2018).

[58] *See supra* notes 56 and 57.

[59] *See Final Report*, GPS TECHNICAL WORKING GROUP (June 30, 2011), *available at* https://ecfsapi.fcc.gov/file/7021690471.pdf; Letter from Lawrence E. Strickling, Assistant Secretary for Communications and Information, U.S. Department of Commerce, to Julius Genachowski, Chairman, Federal Communications Commission (Feb. 14, 2012), *available at* https://www.ntia.doc.gov/files/ntia/publiations/lightsquared_letter_to_chairman_genachowski_feb_14_2012.pdf; Tom Powell, *Adjacent Band Interference to Consumer Receivers*, THE AEROSPACE CORPORATION 4, 5 (May 7, 2013), *available at* https://www.gps.gov/governance/advisory/meetings/2013-05/powell.pdf (last visited Sept. 12, 2018); W. Young et al., *NIST Technical Note 1952: LTE Impacts on GPS – Final Report*, NASCTN (Feb. 2017), *available at* https://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.1952.pdf; *Final Report: Assessment to Identify Gaps in Testing of Adjacent Band Interference to the Global Positioning System (GPS) L1 Frequency Band*, NATIONAL SPACE-BASED POSITIONING, NAVIGATION, AND TIMING SYSTEMS ENGINEERING FORUM (Mar. 2018), *available at* https://go.usa.gov/xPQE8; *Global Positioning System (GPS) Adjacent Band Compatibility Assessment: Final Report*, U.S. DEP'T OF TRANSPORTATION (Apr. 2018), *available at* https://go.usa.gov/xPQPt.

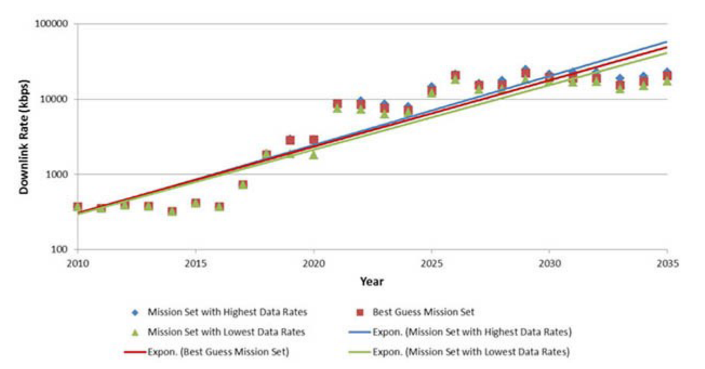
6. **Examine the impact of quantum satellite communication technologies on the U.S. radio frequency ecosystem.** The use of quantum technologies could lead to ultra-fast, ultra-secure communications networks. Some countries have already initiated experiments related to space-to-ground quantum communication. With the use of satellites for space-to-ground quantum communications, the effects of quantum communication on the spectrum ecosystem need to be understood, including whether the spectrum requirements of these networks would differ from traditional communications networks. To develop policies that might leverage quantum technologies, NTIA and OSTP should seek stakeholder data on future applications, how they would affect spectrum needs for space operations, and how quantum communications networks will interact with legacy networks. In addition to the reports mentioned in the first recommendation, the Spectrum PM directs OSTP to submit a report on recommendations for research and development priorities that advance spectrum access and efficiency; consideration of quantum communications may be ripe for inclusion.

7. **Develop short-term and long-term spectrum policies that ensure deep space communications and navigation capabilities will meet demand.**

   As it develops recommendations to ensure spectrum policies encourage space innovation and activity, the Department must examine future demands for deep space communications and navigation and consider near-term and longer-term technical requirements and solutions to meet those demands. The data capacity requirements for deep space communications systems are projected to increase by almost a factor of ten in each of the next three decades.[60] The expectation is that increasingly complex inquiries and advanced imaging technologies will require transmission of significantly more data.[61] *See* Figure 1.

[60] *See Deep Space Communications*, JET PROPULSION LABORATORY, *available at* https://scienceandtechnology.jpl.nasa.gov/research/research-topics-list/communications-computing-software/deep-space-communications ("JPL: Deep Space Comms") (last visited Oct. 2, 2018).

[61] *See id.*



High communication rates are dictated by future science data requirements.

Figure 1. Source: *Deep Space Communications,* JET PROPULSION LABORATORY, https://scienceandtechnology.jpl.nasa.gov/research/research-topics-list/communications-computing-software/deep-space-communications.

Federal researchers currently regard deep space optical communications (DSOC) as the technology likely to meet the deep space communications demand in the future given present challenges with the use of radio frequency. DSOC will enable streaming of high definition imagery and data over interplanetary distances and boost surface asset-to-orbiter performance by 20 dB (a factor of 100) over current state-of-the-art spectrum technology.[62] Moreover, if successfully implemented, DSOC would not experience the growing spectral congestion, regulatory burdens, and potential for harmful interference inherent in radio frequency use.[63] Private sector space innovators also identify these long-term benefits of DSOC and some are collaborating with federal agencies to optimize communications through optics for commercial deep space missions.

Space innovators, however, would not reap the benefits of DSOC, as an end-to-end solution for deep space activity, for many years. For example, NASA's Jet Propulsion Laboratory (JPL) as part of a technology demonstration mission is currently developing DSOC technologies.[64] A DSOC payload will undergo validation testing in 2019 and will launch in 2022.[65] This DSOC payload will be

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[62] *See id.*

[63] *See id.*

[64] *See Deep Space Optical Communications (DSOC)*, JET PROPULSION LABORATORY, *available at* https://www.nasa.gov/mission_pages/tdm/dsoc/index.html (last visited Oct. 2, 2018). DSOC technologies being developed include: a low-mass spacecraft disturbance isolation and pointing assembly; a high-efficiency flight laser transmitter; and a pair of high-efficiency photon counting detector arrays for the flight optical transceiver and the ground-based receiver.

[65] *See id.*

a part of NASA's robotic Psyche mission and will not begin transmission as a demonstration technology until 2026.[66]

While DSOC promises to provide superior deep space communications without the regulatory and interference concerns of transmissions, near-term deep space activity will need to rely on radio frequency technologies. Given current radio frequency technology shortcomings for deep space operations, JPL's Deep Space network (DSN) uses specific equipment and radio frequencies for Moon and Mars operations.[67] Further, JPL is investigating new radio frequency-based technologies that would allow current radio systems to accommodate the increasing need to move more data between deep space and Earth.[68]

Given the growing need for spectrum to accommodate radio frequency transmissions to and from deep space, the Department, NTIA, and other federal stakeholders should work with the private sector to develop policies that will enable deep space radio frequency communications near-term. Considerations of power levels, methods to encourage new spectrally efficient technologies, and other policies could help drive efficient and effective deep space communications. Moreover, the Department, NTIA, and other federal stakeholders should work with the private sector to consider establishing a roadmap for DSOC deployments. Ultimately, this could lead to future repurposing of spectrum currently used for deep space communications for other uses.

8. **Support appropriate policies that can help speed the delivery of satellite broadband solutions to market.** Informed by stakeholders, NTIA should work to facilitate and advance policies that hold promise to speed delivery of satellite broadband systems to unserved areas in the United States and globally. Satellite broadband represents an important U.S. competitive advantage that complement terrestrial services to ensure U.S. leadership in 5G.

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[66] *See id.*

[67] DSN uses cryogenically cooled HEMT receivers that would be able to support missions to both the Moon and Mars. For Moon operations, DSN's uplink bands are 2025-2110 MHz, 7190-7235 MHz, 22.55-23.15 GHz, and the downlink bands are 2200-2290 MHz, 8450-8500 MHz, 25.5-27 GHz. For Mars operations, DSN uses 2110-2120 MHz (with restriction in Spain), 7145-7190 MHz, 34.2-34.7 GHz for uplink and 2290-2300 MHz, 8400-8450 MHz, 31.8-32.3 GHz for downlink.

[68] *See JPL: Deep Space Comms*, *supra* note 63 (noting that JPL is examining "spectral-efficient technologies that increase the data rate that can be reliably transmitted within a given spectral band; power-efficient technologies that reduce the amount of energy needed to transmit a given number of bits; propagation effects, to better understand atmospheric modeling and allocate frequency bands; improved flight and ground transceivers that enable future radio systems; antennas, both flight and ground, that enable NASA's move to higher radio frequencies such as Ka-band (26 to 40 GHz), and deployable and arraying antenna technology.").

II. Radio frequency Licensing Policies

9. **Advance a streamlined U.S. radio frequency licensing process for satellites of all sizes.** The FCC designed its current satellite licensing process around international requirements and procedures for large and expensive satellites. Innovative small satellites are becoming more prevalent. However, they are often developed and funded by small businesses or academia with limited resources and little knowledge of or experience with the regulatory process for gaining authority to access spectrum.[69] Further, even for larger satellite companies, complex licensing frameworks increase cost, slow deployment, and provide disincentives for using the United States as a base for their space commerce activities. Collectively, these processes can discourage innovators from using the United States as a flag nation for space operations.[70] Additionally, under certain circumstances, the regulatory process involving federal and non-federal missions necessitates working with various federal agencies including the FCC.

   The Department of Commerce, through NTIA and in consultation with the FCC and Executive Branch agencies, should continue collaborating with the FCC to develop a licensing framework for commercial small satellite missions, and NTIA and the FCC together should streamline and improve inter-agency processes that facilitate deployment of nascent small satellites and alleviate burdens on the U.S. satellite and space industry. This should be accomplished in a manner that ensures protection of incumbent systems. The Federal government should base its streamlining and other improvements to processes and policies on data and on other input from small satellite innovators and all other space commerce stakeholders, to include determining if a combined licensing process to address missions that have both Federal and non-Federal payloads is possible. Additional Federal support (including outreach and education) to universities, research institutions and small businesses may be necessary in order to improve knowledge and experience concerning domestic and international satellite regulatory processes. Specific attention should also be paid to ways to reduce the licensing costs on smaller satellite operators or those with experimental design.

10. **Streamline the U.S. process for authorizing use of radio frequencies for international satellite Positioning, Navigation and Timing systems**. Foreign-

[69] The FCC has initiated a rulemaking to streamline the licensing process for commercial small satellites, seeking to reduce the burdens and costs for licensees. *See Streamlining Licensing Procedures for Small Satellites*, Notice of Proposed Rulemaking in IB Docket No. 18-86, FCC 18-44 (Apr. 17, 2018), a*vailable at* https://transition.fcc.gov/Daily_Releases/Daily_Business/2018/db0417/FCC-18-44A1.pdf. NTIA urges the FCC to complete this process.

[70] *See*, *e.g.*, *White Paper on Encouraging the United States as the Flag Country for Commercial Space Stations*, ECHOSTAR & HUGHES (Sept. 5, 2018) (citing federal regulations that inhibit streamlined space station filings at the ITU, require high bonding fees for ITU filings advanced through federal agencies, and mandate overly prescriptive milestones which have, collectively, decreased the number of United States flagged commercial space stations).

based positioning, navigation, and timing (PNT) systems require a waiver from the FCC of its own rules and interagency coordination to allow signal reception in the United States. The recent approval of one such system took many years.[71] Additionally, there is widespread confusion regarding the U.S. approval process; this results in equipment manufacturers often building devices to receive PNT signals from foreign systems without regard to the authorization process. NTIA, in consultation with the FCC, should expedite input from PNT stakeholders, including federal agencies, and clarify the process and objectives of the review to enhance GPS services domestically. Especially as allies and other countries create independent or supplementary capabilities, such delays impede collaboration, create international friction, and especially create business uncertainty for commercial satellite operators and their partners.

III. International Spectrum Policies Impacting Space Operations

11. **Improve the space-related activities and processes of the International Telecommunications Union and other multilateral organizations.** The current international satellite coordination and related processes are cumbersome, costly, and time-consuming. Efforts should be made to encourage a regulatory environment internationally that is conducive to promoting spectrum harmonization, innovation, and investment in spectrally efficient next-generation space technologies.

IV. Stakeholder Input

12. **Develop a robust, periodic process for stakeholder input**. Implementing these recommendations will require input from and collaboration with key stakeholders, within the U.S. Government, in the U.S. space commerce sector and in other sectors potentially impacted by any new policies and regulations. Importantly, as our national spectrum decisions and policies do not occur in a vacuum, these efforts must include non-space users of spectrum on a routine basis as we work to address ever-escalating and widespread demand for spectrum access. These efforts should align with NTIA's work to implement the Spectrum PM and develop a national spectrum strategy.

13. **Assess spectrum demand for space operation and report on efforts to meet it.** Stakeholder input will provide federal policymakers with data to support future spectrum policy recommendations to help drive U.S. space commerce today and in the coming years. To this end, NTIA's efforts to work with the White House, executive branch departments and agencies, and the FCC to implement the Spectrum PM will be critical. Areas for assessment could include: 1) current spectrum allocations for space communications and other space services; 2) the anticipated growth of space service demand over the next 15 years; 3) whether

[71] *See, e.g.*, *Waiver of Part 25 Licensing Requirements for Receive-Only Earth Stations Operating with the Galileo Radionavigation-Satellite Service*, Order, FCC 18-158 (Nov. 2018) (approving a waiver sought in 2013).

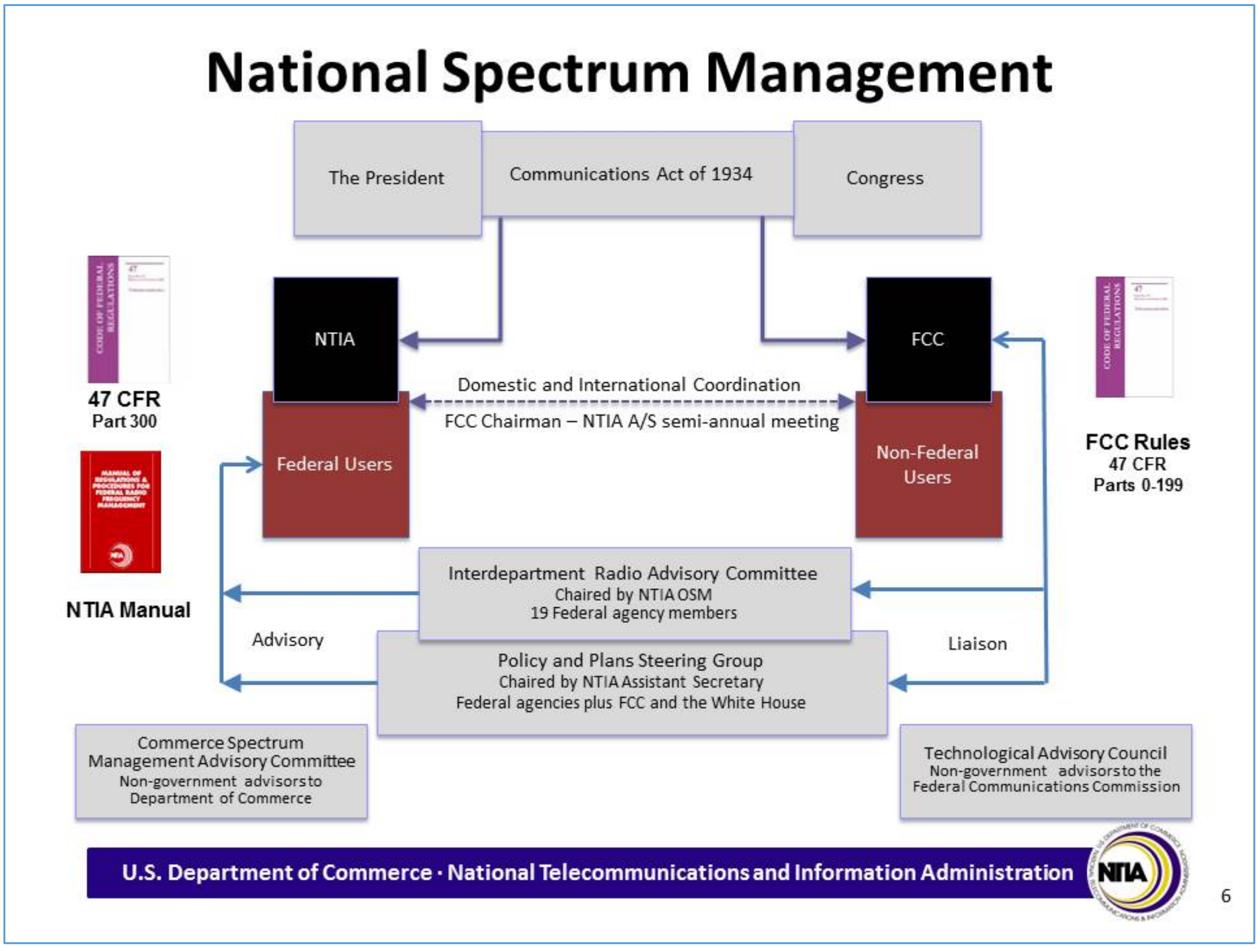
current and anticipated spectrum allocations in the United States and internationally will meet those demands; and 4) how new technologies, including quantum mechanics and optical communications, may mitigate spectrum requirements for U.S. space commerce over time. In addition to informing the national spectrum strategy, NTIA will include applicable actions that address space spectrum requirements in annual reporting the Spectrum PM requires.

ANNEX A

Spectrum Policies Background

Congress has divided spectrum management in the United States between the FCC, which manages radio frequency spectrum use by all non-federal systems, and NTIA, which manages the use of the radio frequency spectrum by all federal government systems. Together the two agencies manage the allocation and assignment of spectrum among various types of uses. The figure below shows the structural framework for this effort.

Figure A-1



ANNEX B

FCC Space Systems Licensing Policies and Procedures

I. Introduction

The Communications Act of 1934 and the implementing regulations of the Federal Communications Commission (FCC or Commission) require licensing of the use of the radio frequency spectrum in the United States. This includes all non-federal geostationary and non-geostationary satellite systems (both the space segment and the ground segment) that provide service to or from the United States. The FCC is also able to license the space segment of satellite systems that operate outside the United States if their operators want their system to be flagged as a U.S. system for purposes of international frequency coordination through the International Telecommunication Union (ITU) processes for such coordination.

In order to facilitate operation of earth stations located in the United States with satellites licensed by other countries, the FCC has a process for granting requests for access to the U.S. market by satellites licensed by other countries.[72] The information requirements for such requests, and the substantive criteria applied in reviewing these requests, are the same as those for entities seeking authority to operate a U.S. satellite.

The FCC reviews applications for commercial satellites under the rules contained in 47 CFR Part 25. In the last several years, the FCC has authorized numerous small satellites for experimental operations — including scientific and research missions for purposes of experimentation, product development, and market trials — in non-geostationary orbit (NGSO) under Part 5 of the Commission's rules. Some amateur small satellite operations have also been authorized under Part 97 of the Commission's rules.

Because of the increasingly commercial nature of small satellite missions, many of these satellites are not suitable for licensing under the Commission's Part 5 experimental licensing process. Obtaining a regular commercial authorization under Part 25 for an NGSO system, however, can be challenging for some small satellite applicants because of the costs and timelines involved. In view of that, the Commission has recently proposed a streamlined authorization process within Part 25 that is tailored to small satellites.[73]

This document focuses on the licensing process for commercial operations under Part 25 and does not address the licensing process for experimental and amateur operations under Parts 5 and 97, unless specifically indicated otherwise.

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[72] 47 C.F.R. § 25.137.

[73] *Streamlining Licensing Procedures for Small Satellites*, Notice of Proposed Rulemaking, FCC 18-44 (Apr. 17, 2018).

II. Licensing Process for Commercial Satellites

For applications for new geostationary-like (GSO-like) satellite operation, the FCC uses a "first-come, first-served" procedure to process applications.[74] Under this procedure, applications are placed in a queue and considered in the order that they are filed. The FCC reviews the first application in the queue and if it is found to be acceptable for filing, it is placed on public notice. After conclusion of a 30-day comment period, the application may be granted. The FCC will grant the application if it finds that the applicant is legally, technically and otherwise qualified and that the proposed operations are compatible with previously authorized operations. In several frequency bands compatibility is established by compliance with the "two-degree rules"[75] or coordination agreements with affected previously authorized systems in case of any violation of these rules.

A place in the processing queue for geostationary satellite space stations can also be established by submitting to the FCC a request for coordination of frequencies under the auspices of the ITU. An application that follows this "two-step process" will be considered complete if all required application information is submitted within two years of the date of submission of the initial materials.[76]

The process for NGSO-like satellite operations is different. An application for NGSO-like operations may trigger a "processing round" if it conflicts with a previously-authorized satellite system or a previously filed-application.[77] Additional applications can then be filed until a deadline the FCC sets in the same public notice that accepts for filing the "leading application."[78] If the systems use non-directional earth station antennas and are unable to avoid co-frequency interference, available spectrum will be divided equally among qualified applicants.[79] On the other hand, if the systems use directional earth station antennas and co-frequency interference can be avoided, authorized systems must coordinate their operations. In case two or more satellite systems cannot agree on coordination, then, during any period of time in which a certain

[74] 47 C.F.R. § 25.158(b). "GSO-like satellite operation" means operation of a GSO satellite to communicate with earth stations with directional antennas. *Id.* at § 25.158(a)(1).

[75] *See* 45 C.F.R. § 25.103. These rules set power limits that, if met, will ensure compatible operations at two-degree spacing on the geostationary orbit. *Id.*

[76] 47 C.F.R. § 25.110(b)(3)(iii).

[77] 47 C.F.R. § 25.157. "NGSO-like satellite operation" means operation of a NGSO satellite system or of a GSO MSS satellite to communicate with earth stations with non-directional antennas. *Id.* at § 25.157(a).

[78] 47 C.F.R. § 25.157(c)(2).

[79] 47 C.F.R. § 25.157(e).

interference threshold is exceeded in a commonly-authorized frequency band, such band will be divided among the affected satellite systems.[80]

To prevent warehousing spectrum, licenses for GSO and NGSO systems are conditioned on the licensee meeting certain milestones.[81] GSO satellites must be deployed and operational within five years of the grant. For an NGSO constellation, the milestone is launch and operation of 50% of the satellites within six years of the grant. In addition, all licensees and recipients of grants of U.S. market access must post a surety bond in order to discourage warehousing of scarce resources.[82] The bond must be posted within 30 days of the grant of a license or U.S. market access. The required bond amount escalates from $1 million to $3 million over five years for a GSO space station and escalates from $1 million to $5 million over six years for a NGSO constellation. If a license or market access grant is surrendered or revoked prior to achieving the requisite milestone, the licensee is liable only for the pro rata amount of the bond on the date of the surrender. For an application following the "two-step process" described above, a surety bond of $500,000 is also required for the first step of the process to establish a place in the licensing queue.

Milestones and bond requirements apply only to commercial satellites licensed under Part 25 and do not apply to experimental and amateur satellites. For some types of satellites that do not seek to use spectrum as intensively as typical fixed satellite and mobile satellite service communications satellites, the FCC has either not applied or has waived portions of these milestone requirement. This is the case for many satellites operating in the earth exploration satellite service.

The FCC also has adopted rules to mitigate orbital debris, applicable to commercial satellite operations under Part 25, as well as experimental and amateur satellite operations under Parts 5 and 97.[83] These rules require applicants for a satellite license or a grant of U.S. market access to describe what steps it will take to lessen the risk of their operations contributing to orbital debris, including their post-mission disposal plans for the satellite.[84] Since the existing rules were adopted in 2004, there have been significant developments, including an increase in the number of debris objects capable of producing catastrophic damage to functional spacecraft and plans for deployment of constellations with large numbers of satellites. In view of these developments,

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[80] 47 C.F.R. § 25.261.

[81] 47 C.F.R. § 25.164.

[82] 47 C.F.R. § 25.165.

[83] *Mitigation of Orbital Debris*, Second Report and Order, 19 FCC Rcd 11567 (2004).

[84] 47 C.F.R. § 25.114(d)(14). Such an orbital debris mitigation plan, must disclose: (i) the amount of debris released in a planned manner during normal operations, as well as the probability of the satellite becoming a source of debris by collisions with small debris; (ii) the probability of accidental explosions during and after completion of mission operations; (iii) the probability of the satellite becoming a source of debris by collisions with large debris or other operational satellites; and (iv) the post-mission disposal plans for the space station at end of life. *Id.*

the FCC is developing proposed changes to the orbital debris rules, designed to improve and clarify these rules based on recent experience gained in licensing large NGSO constellations and on improvements in mitigation guidelines and practices, as well as to address market developments.

III. Licensing Procedures for Earth Stations

All earth stations transmitting from U.S. territory must be licensed. No license is required, however, for receive-only earth stations operating with U.S. licensed satellites or foreign-licensed satellites that have been granted market access. An option to register receive-only earth stations is available in several frequency bands in order to ensure that the earth station is protected from transmitting terrestrial stations in the same band. A large number of technically-identical earth stations can be authorized under a single blanket-license.

Earth Stations in Motion (ESIMs), which comprise ESAAs (Earth Stations Aboard Aircraft), ESVs (Earths Stations on Vessels) and VMESs (Vehicle-Mounted Earth Stations), have been authorized as applications in the fixed-satellite service. The FCC has recently proposed to streamline existing rules and extend their applicability to other frequency bands.[85] Completion of these proposed changes is expected in the near future.

[85] *Amendment of Parts 2 and 25 of the Commission's Rules to Facilitate the Use of Earth Stations in Motion Communicating with Geostationary Orbit Space Stations in Frequency Bands Allocated to the Fixed Satellite Service*, Notice of Proposed Rulemaking, 32 FCC Rcd 4239 (2017).

ANNEX C

International Space Communications Background

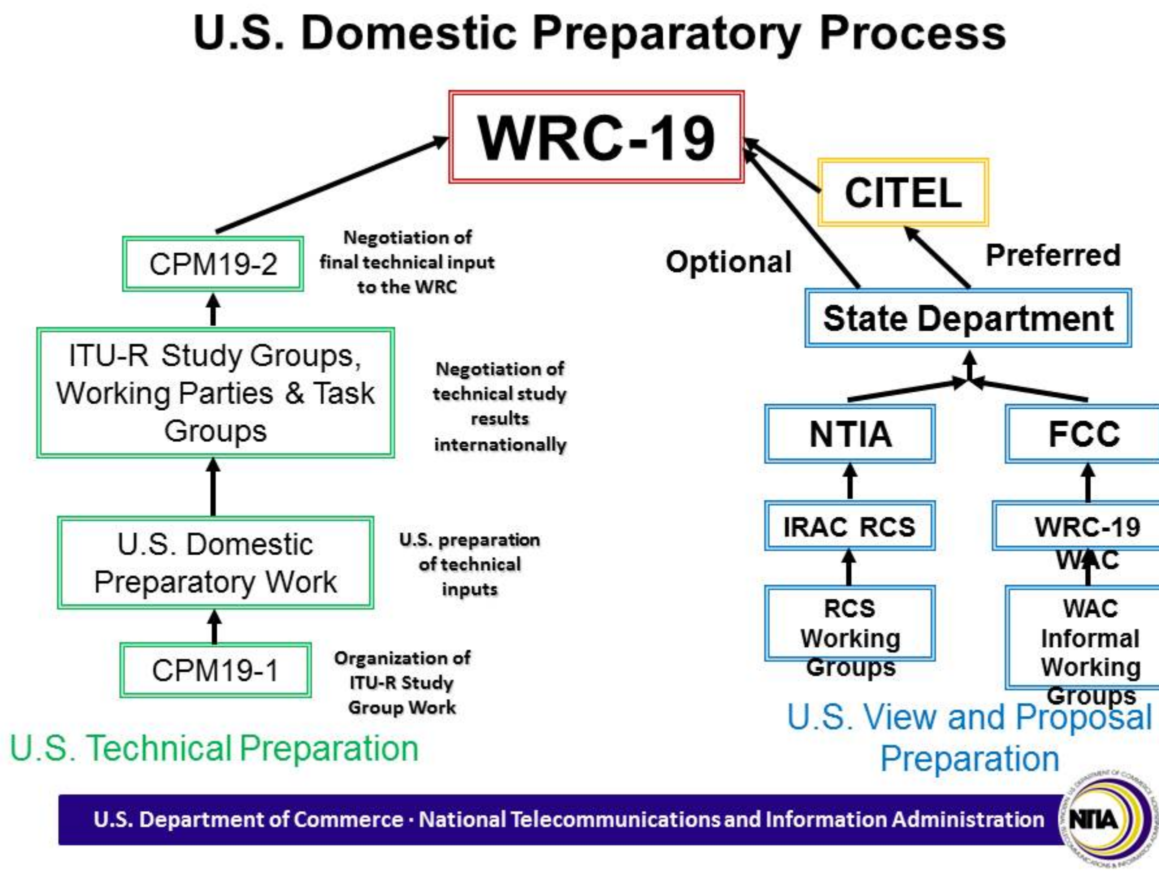
The U.S. Department of State (State) is ultimately responsible for development of the United States' positions at the International Telecommunication Union (ITU). State has developed a robust process by which interested parties (State, NTIA, the FCC, federal agencies and the private sector) address international spectrum issues. The ITU maintains treaty text. This treaty text contains the international table of allocations and international procedures for registration and coordination of satellite systems. Approximately every four years the ITU Radiocommunication Sector (ITU-R) holds a World Radiocommunication Conference (WRC) to revise the international treaty text.

The United States develops policy positions for issues on the agenda of each WRC, addressing a wide variety of technical and operational affecting the radio frequency spectrum operations of space systems. There are satellite-related agenda items at each WRC, including items addressing spectrum sharing between new entrants and existing systems. NTIA and FCC work through established processes shown in the figure below, and based on that advice and administration priorities, reconcile the government and private industry proposed positions into U.S. positions.

As part of its preparations for the WRC, the FCC establishes a Federal Advisory Committee focused on the international frequency spectrum issues identified on the WRC agenda. The WRC Advisory Committee (or WAC), provides to the FCC advice, technical support, and recommended proposals for WRCs. The WRC-19 WAC, composed of entities from both the public and private sectors, is charged with gathering data and information necessary to formulate meaningful recommendations for WRC-19 agenda items with the goal of identifying the private sector/public priorities and objectives.

As part of the federal preparations, NTIA utilizes the Interdepartment Radio Advisory Committee (IRAC), to provide advice of the federal agencies developed through its sub-committee, the Radio Conference Sub-committee (RCS) on WRC agenda items. The RCS is dedicated to development of federal positions and proposals for WRCs.

To the extent possible, the U.S. utilizes the Americas regional group, the Inter-American Telecommunication Commission (CITEL), to develop regional proposals to each WRC. CITEL support maximizes the U.S. chance of success at each WRC.


U.S. Domestic Preparatory Process
WRC-19
CITEL
Optional
Preferred
State Department
NTIA
FCC
IRAC RCS
WRC-19 WAC
RCS Working Groups
WAC Informal Working Groups
U.S. View and Proposal Preparation
CPM19-2
Negotiation of final technical input to the WRC
ITU-R Study Groups, Working Parties & Task Groups
Negotiation of technical study results internationally
U.S. Domestic Preparatory Work
U.S. preparation of technical inputs
CPM19-1
Organization of ITU-R Study Group Work
U.S. Technical Preparation
U.S. Department of Commerce · National Telecommunications and Information Administration
NTIA