



April 14, 2023

National Telecommunications and Information Administration
1401 Constitution Avenue, NW
Washington, DC 20230
United States

RE: National Spectrum Strategy Request for Comment
Document ID NTIA-2023-003-000, Federal Registrar Number 1624,
FR Citation 88 FR 16244

To be uploaded: <https://www.ntia.doc.gov/federal-register-notice/2023/national-spectrum-strategy-request-comment>

Dear Sir or Madam:

In response to the NTIA, FR Citation 88 FR 16244, the Aspen Institute submits the following report:

Toward a National Spectrum Strategy: A Report of the Aspen Institute available as attached and online:

<https://www.aspeninstitute.org/publications/toward-a-national-spectrum-strategy/>

The report is the result of a May 2022 Aspen Institute convening that included NTIA Administrator Alan Davidson, FCC Chair Jessica Rosenworcel, and a range of senior government and private sector stakeholders. A full list of the participants appears in the Appendix, on page 52. The purpose of the meeting was twofold: first, to establish a common understanding of the relevant goals and principles of an all-of-government national spectrum strategy; and second, to produce a framework for a spectrum action plan indicating potential steps, key actors, and timeframe for implementation.

The NTIA document appropriately suggests that the national spectrum policy should rest on three pillars. The Aspen report provides specific information to support Pillar 1, the continued development of the spectrum pipeline; Pillar 2, planning; and Pillar 3, superior access and management through technical developments.

The Aspen Institute report stakes out ten key principles to inform spectrum policies, sets forth broad recommendations for U.S. spectrum policy for the years ahead, and details potential actions. It also catalogs a list of frequency bands that should be examined to assure that spectrum-dependent public and private enterprises are able to fulfill their missions, and not compromise the nation's defense.

2300 N Street, NW

Suite 700

Washington, DC 20037

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PH 202-736-5800

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www.aspeninstitute.org

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The report makes several observations and recommendations to elevate options for a national spectrum strategy. See, for example:

- Specific recommendations (pages 28-45)
- Bands for Consideration (page 50)

We join you in recognizing spectrum as a national public asset and foundational to meeting our national goals of security, economic growth, and international leadership in the information economy. I hope the enclosed report provides some concrete recommendations in support of your important work. Please contact me at vivian.schiller@aspeninstitute.org if I can be of assistance.

Sincerely,

A handwritten signature in black ink, appearing to read "V Schiller". The signature is fluid and cursive, with the first letter of each word being capitalized and larger than the others.

Vivian Schiller
Executive Director
Aspen Digital



TOWARD A
**NATIONAL
SPECTRUM
STRATEGY**

A Project of the Aspen Institute



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FOREWORD

Connecting us, protecting us, and enlightening us, wireless technologies are an integral part of our day-to-day lives and essential to our nation's economy. And that will be even more true in the decade ahead.

Underlying these technologies is an invisible world, yet one of great importance: all wireless devices require access to radio waves, otherwise known as the spectrum. As demand for the newest and greatest wireless services has accelerated, the spectrum environment has become increasingly contested and constrained. Meanwhile, policy disputes among a wide range of stakeholders — licensed incumbents, unlicensed upstarts, and government agencies — have become amplified as intensity of spectrum use has increased. Yet despite these competing demands, the United States does not have a holistic plan to accommodate the nation's future spectrum needs. As top policy makers have recognized, a National Spectrum Strategy to address these challenges is urgently needed.¹

On May 5–6, 2022, the Aspen Institute convened a roundtable on spectrum policy with government and private sector stakeholders whose input is vital to advancing progress. The purpose of the meeting was twofold: first, to establish a common understanding of the relevant goals and principles of an all-of-government national spectrum strategy; and second, to produce a framework for a spectrum action plan indicating potential steps, key actors, and timeframe for implementation.



**CONNECTING US,
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This report represents that collaboration. It begins with an overview of spectrum's role in the U.S. economy and society, including the vast opportunities for driving economic growth and social progress in the 21st century information economy.

Anticipating this future ecosystem, we turn to the changing economic and technological environment for spectrum, and the policy challenges that will need to be addressed as the environment evolves. With that foundation laid, the report reviews key principles that should inform spectrum policies. These principles include specific areas of focus across government and private sector entities that facilitate improved spectrum policy decision-making, such as access to needed resources, improved governance structure, and clarifying spectrum rights and responsibilities.

Finally, the report sets forth broad recommendations for U.S. spectrum policy for the years ahead, and potential actions to implement those recommendations.² The appendix contains a list of bands that should be examined in an effort to assure that spectrum-dependent public and private enterprises are able to fulfill their missions.

Vivian Schiller
Executive Director
Aspen Digital



INTRODUCTION

WHY SPECTRUM POLICY?

Spectrum policy has a significant impact on all Americans. The levers of spectrum policy can have enormous ripple effects, impacting everyday lives, driving economic growth, and furthering important government missions.



THE LEVERS OF SPECTRUM POLICY CAN HAVE ENORMOUS RIPPLE EFFECTS, IMPACTING EVERYDAY LIVES, DRIVING ECONOMIC GROWTH, AND FURTHERING IMPORTANT GOVERNMENT MISSIONS.

An Essential Resource at a Critical Juncture

Access to spectrum has been a primary driver of technological progress benefitting all Americans. Per capita, the average American is expected to use nearly 14 wirelessly connected devices and connections by 2023.³ These devices are served by an ever-growing number of networks using both licensed and unlicensed spectrum, including tens of millions of local area Wi-Fi hotspots and hundreds of thousands of wide area mobile cell sites.⁴ Yet these familiar wireless technologies are not the only users of wireless spectrum. As detailed below, access to radio spectrum has been a necessity for a broad array of vitally important products and services, and spectrum's foundational importance in the emerging interconnected global information economy

is rapidly multiplying. Already, spectrum underpins the Global Positioning System that lets us navigate anywhere on the planet, the instrumentation systems that help airplanes land safely without fail, the radars used in the daily weather forecast, the critical communications of our first responders, the satellite networks that connect the farthest reaches of the globe, and a multitude of systems our military uses to protect

America from foreign adversaries. Those indispensable services, however, are only a precursor of many more such use cases that we will soon regard as fundamental to a thriving economy and society. The challenge for spectrum policymakers is to ensure that these disparate uses can coexist even as the intensity of use grows year after year. If we want to meet that challenge, we must plan and act now.

Enabling Generational Change

Availability of spectrum, often accomplished through repurposing spectrum from prior uses, has enabled generational change in wireless networks. The original analog cellular networks launched in the 1980s in a single frequency band and supported only one use-case: voice. The first spectrum auctions in the 1990s enabled digital 2G networks and text messaging. With 3G came the mobile web. The repurposing of underutilized spectrum in the 2000s enabled 4G networks with true multi-megabit wireless broadband. The smartphone and a cornucopia of mobile apps followed soon afterward, driving more than 100x increase in consumer data usage from 2010 to 2020.⁵ And now we are well along the path to 5G, which promises to connect many more types of devices with 100x faster speeds and 5x lower latency compared to 4G.⁶ Cellular networks are beginning to compete with fixed networks in the broadband marketplace. The massive increase in spectrum available to the mobile industry from 1982 to 2022 has helped make these upgrades possible. A similar story of generational improvement can be told for many other spectrum dependent technologies, including unlicensed systems such as Wi-Fi, which from humble beginnings now delivers multi-gigabit data rates and carries approximately 70% of data used on consumer devices. Satellites, radars, and many other systems have evolved to utilize more spectrum in multiple frequency ranges, vastly increasing capability and performance.



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Economic Growth and Job Opportunities

Spectrum use has been, and will continue to be, a key driver of economic and job growth, creating new opportunities for enterprises and individuals. For instance, 4G was a huge boon to the U.S. economy and job market. The cellular industry contributed \$690.5 billion to the country's GDP in 2019 — a reflection of the impact of 4G and the nation's mobile wireless platform — including apps, devices, mobile advertising, and content.⁷ In fact, mobile wireless' share of the U.S. economy more than doubled during the 4G era, increasing from 1.3% in 2011 to 3.2% in 2019.⁸ 4G also had a profound impact on U.S. jobs. By 2019, 20.4 million jobs (or 1 in 6) depended in some way on the wireless industry, and the wireless industry added 16.7 million jobs from 2010–2020.⁹ In 2020, wireless providers invested \$30 billion in their networks.¹⁰ But continued investment in wireless networks — and the attendant economic stimulus and job growth — will be less effective if spectrum is misallocated. Unlicensed networks are deployed in a more diffuse fashion than cellular networks, but their economic impact is no less important. The economic value of Wi-Fi in the United States is predicted to increase from \$1 trillion in 2021 to \$1.6 trillion by 2025.¹¹ Wi-Fi also contributes significantly to job creation, generating approximately 542,000 U.S. jobs in 2021 alone, with annual U.S. job creation estimated to reach 720,000 by 2025.¹² And these numbers do not even include the many extensive downstream impacts of low-barrier-to-entry innovation, which enables smaller vendors and operators to introduce their own products and services, and creates a more competitive and vibrant supplier ecosystem.¹³ Further, advanced connectivity, which will rely heavily on spectrum, is essential for all manner of industries, including construction, energy production and distribution, metals and mining, travel, logistics, and, of course, information technology and electronics.¹⁴

Digital Equity and Inclusion

Spectrum is a key input in creating digital equity and inclusion, itself essential for enabling all Americans to fully participate in the economy and society.

Connectivity is no longer the luxury it once was: it is now a necessity. In an increasingly connected world, reliable and high-speed internet is needed to go to school, apply for a job, and access critically important public health information, among other functions. Spectrum policy is a powerful tool for bridging the digital divide and ensuring all Americans receive access to vital internet services. Due to recent advancements in wireless network performance, fixed wireless is increasingly competitive with traditional fixed broadband offerings. In remote areas, satellite broadband may be the best—or only—option for fixed

broadband access. Newer wireless solutions, including those using the Citizens Broadband Radio Service (CBRS), have proven to be an effective means of reaching underserved communities and providing some competition for broadband to the home. And some households are substituting mobile for fixed service altogether. Recent estimates indicate that at least 15% of American adults rely only on mobile broadband, without access to in-



ULTIMATELY, GLOBAL LEADERSHIP IN SPECTRUM POLICY ENABLES GREATER AMERICAN INFLUENCE IN SHAPING THE DIRECTION OF THE NETWORKS, DEVICES, AND APPLICATIONS THAT DEFINE OUR FUTURE.

policy is critical in three dimensions. First, policy can address critical supply chain issues by transforming the supply chain so the key components play to American strengths. Second, by building technologies and networks capable of generating the performance necessary to support next generation use cases and applications, the U.S. thereby creates the ecosystem for innovation to flourish. By leading in deployment and applications, the U.S. has the credibility and ability to shape how the technology is utilized to advance innovation, productivity, and investment to improve the lives of Americans and promote national interests. Third, global leadership will require that American manufacturing has every conceivable technological productivity edge to compete with lower labor costs overseas, an edge for which spectrum plays an essential role.

home fixed broadband.¹⁵ Achieving these benefits requires a significant and continuing supply of spectrum. But if spectrum use is concentrated or allocated in ways that limit its uses or the flexibility of providers, digital equity progress may be impeded.

Global Leadership

Ultimately, global leadership in spectrum policy enables greater American influence in shaping the direction of the networks, devices, and applications that define our future.

There are significant advantages to being a first mover with respect to generational iterations of wireless technology. By being first, a country can set the pace for innovation for wireless technologies, services, and applications for the ensuing generational cycle, which typically lasts about a decade. As America attempts to reinvigorate the importance of being “Made in America,” spectrum



SECTION I.
**THE ROLE OF
SPECTRUM IN A
CHANGING WORLD**

As wireless technology continues to evolve, it will play an even larger role in our society and fuel the next-generation capabilities that power the innovations of the future. For example, wireless smart city solutions can help reduce energy use and traffic congestion. Connected sensors can monitor the health and safety of critical infrastructure like buildings, roads, and bridges. Smart technologies will allow more accurate monitoring of the energy grid, improving management, reducing costs, and adding trillions in economic activity to the U.S. economy, including industrial applications like smart ports and factories. Next-generation radar systems will keep our airspace safe and protect us from foreign adversaries. Remote patient monitoring and remote treatments through connected healthcare devices can lead to better medical outcomes at lower cost. And wirelessly enabled Virtual Reality (VR) and Augmented Reality (AR) have the potential to transform educational opportunities. Space-based sensors will help us measure and respond to climate change. Radio telescopes will help us understand the most fundamental secrets of the universe. The examples are endless, but all demonstrate a core truth that warrants government attention and action: Spectrum is among the most valuable public assets for driving economic growth and social progress in the 21st century information economy.

We highlight here several areas in which availability of spectrum access will be crucial to America's prosperity going forward.

Powering Terrestrial Service Providers

Licensed spectrum underpins investment in and evolution of some of our nation's most important wireless infrastructure, including cellular and broadcast networks. Each of these technologies is undergoing generational change. As noted above, the transition to mobile 5G is now in full swing. 5G represents a significant opportunity to expand the wireless user experience with an unparalleled impact on day-to-day life and our society. Smart agriculture, improved and enhanced remote learning, smart



SPECTRUM IS AMONG THE MOST VALUABLE PUBLIC ASSETS FOR DRIVING ECONOMIC GROWTH AND SOCIAL PROGRESS IN THE 21ST CENTURY INFORMATION ECONOMY.

logistics/transportation, next-generation telehealth applications, smart manufacturing, smart grids and smart cities are just some of the proposed 5G use cases. Broadcasting is also transitioning from a single-purpose video delivery medium into a multicast data system with the rollout of ATSC 3.0. Wireless Internet Service Providers (WISPs) also rely on unlicensed and “lightly licensed” spectrum bands and technologies to provide service to rural and other hard-to-reach communities.

Unleashing Permissionless Innovation

Spectrum also represents a critical element of America’s “innovation infrastructure”. Technologies such as Wi-Fi and Bluetooth, installed on hundreds of millions of devices in the U.S., make use of the “permissionless innovation” enabled by unlicensed access. These systems are used in construction, manufacturing, and many other industries.¹⁶ Unmanned Aircraft Systems (aka drones) depend primarily on unlicensed spectrum both for command and control as well as for delivery of an information “payload” to end users. Wireless technology also promises to revolutionize transportation as we progress toward greater levels of vehicular intelligence and autonomy. Today’s vehicles already depend on an array of radar sensors for convenience and safety.¹⁷ New vehicle-to-everything (V2X) systems promise to facilitate higher levels of autonomy by allowing vehicles to communicate directly with roadside infrastructure (V2I) and with other nearby vehicles (V2V). This technology should make travel safer, while also reducing traffic, congestion, and pollution.

Launching the Space Economy

The space industry also depends upon access to spectrum. Wireless control systems are essential for rockets to reach space and for satellites to operate once deployed. Spectrum-intensive satellite communications links are now connecting people, ships, and airplanes across the globe, including in the most remote areas where few or no other communications infrastructure exists. Satellites are essential elements of weather tracking and forecasting systems and crucial to environmental monitoring and global asset tracking.¹⁸ They provide critical safety of life links for maritime, air, and even land transportation in remote areas, and for rapid emergency response such as wildfires and hurricanes when terrestrial links have been destroyed. And the radio transmitters operating in the Radionavigation Satellite Service such as the Global Positioning System

(GPS) and Galileo networks help us navigate anywhere on Earth, in addition to precision timing services that are vital for cellular network spectrum efficiency as well as wireline network management. Indeed, spectrum links are among humankind's most basic and indispensable tools for gaining the information we need to understand the Earth and, of course, the universe.¹⁹ In 2020, the overall global space economy generated revenue of \$371 billion, with the commercial satellite industry accounting for \$271 billion, or nearly 73 percent, of that total.²⁰ Additionally, GPS has become so pervasive, that some estimate it has contributed over \$1.4 trillion in U.S. economic benefits since its creation.²¹

Supporting Government Missions That Keep Us Safe and Secure

Spectrum is essential to an extraordinarily broad range of government missions that support the functions of a modern society. For example, the Department of Defense (“DoD”) is the largest user of spectrum, and the diversity and breadth of its spectrum use is unlike any other federal government or commercial user.²² DoD employs narrowband, wideband, broadband communications systems that are fixed, mobile, portable, satellite, vehicle, and ship-based. It uses satellites for imaging, navigation, positioning, weather forecasting, and earth observation. It fields radars of all types, different weapons systems like guided missiles, as well as systems to counter enemy attack. DoD also has air traffic control, flight systems, drones, and other uncrewed aircraft. It relies on spectrum for intelligence, surveillance, and reconnaissance applications, with individual branches of the military allotted significant ranges of frequency bands to enable various equipment and applications that support military operations. DoD is beginning to employ 5G technology in a “dual use” capacity in some of its missions.²³ All of these uses require extensive testing and training at domestic military bases and sites and at sea. A core principle of DoD training is to “train like you fight”, so while these systems may not be employed in combat in peacetime, the spectrum resources are used frequently both domestically and overseas.

But DoD is not alone within the government in its need for and use of spectrum. Virtually every endeavor by NASA now requires communications or data transfer via spectrum, including sending back amazing pictures of distant galaxies from the Webb telescope.²⁴ Additional uses include the Federal Aviation Administration's management of air traffic and the National Oceanic and Atmospheric Administration's gathering and dissemination of environmental information.²⁵ The National Science Foundation, meanwhile, utilizes spectrum to conduct research for radio astronomy and invests

in advanced wireless research supporting foundational research (National Center for Wireless Research), testing infrastructure (Platforms for Advanced Wireless Research and National Radio Dynamic Zones), coordination of R&D efforts among federal agencies, and education and workforce development efforts in spectrum.²⁶ Another set of government users include federal public safety agencies, such as the Federal Bureau of Investigations and Customs and Border Protection, who rely on radio communications every single day. At the state and local level, thousands of first responder agencies rely on wireless networks — including narrowband and broadband systems — to communicate and coordinate in times of crisis. Just as wireless innovation and technological advancements are changing commercial sector spectrum needs, they are also driving the federal government’s need for spectrum to provide mission-critical services.

Enabling Industry 4.0

Spectrum is a key ingredient for “Industry 4.0”, a term used to describe the “fourth industrial revolution” resulting from increasing interconnectivity and automation.²⁷ The Industrial Internet of Things (IIoT) and smart manufacturing technologies rely heavily on wirelessly connected sensors and actuators, bridging physical production and operations with large scale data collection, artificial intelligence (AI), and machine learning (ML) to enhance manufacturing and industrial processes. The estimated impact on global GDP of operational enhancements resulting from advanced connectivity in just 4 major industries (automotive and assembly, healthcare systems and services, aerospace and defense, and retail) is \$2 trillion.²⁸ These technologies also allow remote monitoring, maintenance, and “digital twinning” of key processes and assets. They can also pinpoint inefficiencies and problems sooner, saving time and money. Research indicates that predictive maintenance can drive a reduction of at least 50% in the costs associated with equipment operation, testing, and backups.²⁹ Moreover, many enterprises are in the process of deploying private cellular networks, often using shared CBRS spectrum, to enable high-reliability and secure wireless connectivity within warehouses, factories, ports, higher education campuses, and other similar “contained” facilities. This flexibility makes it possible to roll out mission-critical, wireless-enabled solutions such as connected robots, reconfigurable plant automation, and other demanding applications. All told, the potential of IIoT is enormous, with estimates indicating that the economic impact of such applications could reach \$1.2 to \$3.7 trillion by 2025.³⁰



SECTION II.
**OPPORTUNITIES,
CHALLENGES,
AND PRINCIPLES
FOR A NATIONAL
SPECTRUM STRATEGY**

The innovation seen across all industries has been driven in large part by the United States' legacy of policy successes in how the government manages spectrum. These include flexible use, spectrum auctions, unlicensed use of spectrum, and dynamic spectrum sharing policies.

POLICY SUCCESSSES IN MANAGING SPECTRUM

Flexible Use Policies

“Flexible use” typically refers to a set of reforms developed with the advent of cellular networks, in which the FCC refrains from specifying the nature of the technologies or services that may be provided through licensed spectrum. The policy has been augmented over time to include geographic definition of licenses (in place of more regulatorily intrusive site-based licensing) and secondary markets rules to enable an “aftermarket” in spectrum through license transfers or leases.

Spectrum Auctions

In the last quarter century, the U.S. pioneered a highly successful method of assigning spectrum licenses through auction. The FCC developed entirely new auction formats and then refined the formats to reallocate spectrum from existing users, such as in the broadcast incentive auction. More than \$230 billion has been realized from over 100 U.S. spectrum auctions, with approximately \$85 billion coming from two auctions launched in 2020 alone. As a measure of its success, the U.S. model has been imitated around the world — over 100 spectrum auctions are scheduled globally over the next few years in over 80 countries across many different spectrum bands.³¹

Unlicensed Use of Spectrum

As noted above, unlicensed access to spectrum allows permissionless innovation in wireless systems and services and is essential to innumerable devices used by consumers, businesses, and government. The rules that

permit unlicensed use of certain spectrum bands were also a U.S. policy innovation from decades ago that was not intensively commercialized until the 1990s. From these humble beginnings, unlicensed use has grown to encompass billions of devices and likely represents the single largest category of spectrum use around the globe.

Shared Spectrum

The U.S. has also pioneered the use of spectrum sharing policies to wring more utility from the airwaves.³² Sharing has allowed non-federal users to operate in bands previously dedicated to exclusive use by federal agencies, such as the AWS band and, more recently, the 3.45 GHz bands. The FCC, working with NTIA and DoD, has pioneered development of dynamic, multi-tiered sharing in the CBRS band, dynamically reconfiguring the permitted commercial operations by, for example, curbing power or switching to different channels to avoid causing harmful interference. Additionally, by allowing civil users to share federal spectrum, government users can enjoy the benefits of dramatic cost reductions for components that are made possible by the volume of civilian devices that the government could not manufacture for its own uses. Another, simpler, sharing approach called Automatic Frequency Coordination (AFC) is enabling unlicensed devices to share the 6 GHz band with point-to-point fixed microwave operations.

The FCC, NTIA, and other government agencies, as well as industry stakeholders, continue to seek and examine new ways to increase spectrum efficiency and enable more intensive use. Most recently, in the spring of 2022, the FCC issued a Notice of Inquiry examining the role of receiver performance in spectrum management responsibilities.³³ In doing so, the agency recognized that, as spectrum use becomes more intensive, its spectrum management policies “must consider potential efficiencies across all aspects of wireless systems, not just transmitters but receivers as well.”

But we cannot rest on our laurels or be satisfied with the policy successes experienced to this point. Indeed, the spectrum environment has become increasingly contested and constrained as a result of accelerating demand for the newest and greatest spectrum-dependent services, creating new challenges and opportunities.



IT IS IMPERATIVE THAT U.S. POLICYMAKERS EXAMINE THE NATION'S SPECTRUM POLICY AND DEVELOP A PATH FORWARD THAT ASSURES SUFFICIENT SPECTRUM FOR PUBLIC, PRIVATE, AND GOVERNMENT USE. NO SPECTRUM STAKEHOLDER CAN BE LEFT BEHIND.

It is imperative that U.S. policymakers examine the nation's spectrum policy and develop a path forward that assures sufficient spectrum for public, private, and government use. No spectrum stakeholder can be left behind.

By doing so, our leaders can ensure not only the success and sustainability of today's services and technologies that rely on spectrum resources, but also that the U.S. continues to play a leading role in innovating and developing the potential services of tomorrow.

A. ANTICIPATING THE FUTURE ECOSYSTEM

Today, spectrum use underpins many of the cutting-edge technologies and industries. This is a relatively recent phenomenon. In the 1990s individuals began to use mobile devices to transmit data, beginning with texts and emails. As network bandwidth increased, data use increased, leading to new applications that depend on spectrum.

This cycle of improvements in networks, data, and applications is increasingly important. The world has transitioned from an environment where the primary connected device was a phone to one where multiple devices, including watches and health monitors, depend on spectrum. We need to plan for a huge increase in machine-based wireless broadband communications over the next several years, as "smart" devices take advantage of the ubiquitous connectivity afforded by high-speed, low-latency, wireless packet data networks. While many of these devices are expected to consume relatively small amounts of bandwidth, others, such as wireless-enabled cameras, may make use of embedded video and other media that could substantially increase demand for wireless bandwidth.

We are undergoing a shift from one device per person to a world where "smart" connected devices greatly outnumber human beings. For example, one study estimated

that there will be 5.3 billion total Internet users, but 29.3 billion networked devices by 2023, with the majority of them powered by unlicensed spectrum.³⁴ Soon, we may also have wearable devices that connect us to augmented reality, virtual reality and extended reality, a term referring to all real-and-virtual combined environments and human-machine interactions generated by computer technology and wearables. Low-cost sensors and “sensor fusion” are enabling a revolution in artificial intelligence, computer vision, and machine learning.

Ultimately, the principal network technologies that underlie current and future developments are transforming. While ramping up the deployment of 5G, companies and policymakers are already in early discussions looking forward to the development of 6G, with hopes of deployment later this decade. In the same vein, unlicensed is moving to a new standard of Wi-Fi 6E and soon thereafter to Wi-Fi 7. Broadcasters are adopting ATSC 3.0, to enable them to offer new digital services.

Network architectures are also transitioning. Carriers are starting to deploy Open Radio Access Networks (ORAN) and Virtual Radio Access Networks (VRAN) in hopes of lowering costs and enabling faster innovations. Carriers are also changing the topologies (the way the constituent parts of the network are used), offering services over multiple bands. These new network designs include, in some cases, higher frequency bands that could not have been utilized using the technology of decades past. Private networks are rising in importance. And the satellite industry is moving toward constellations that include thousands of satellites circling the globe in Low Earth Orbit (LEO).



SPECTRUM IS A PUBLIC ASSET, AND WE MUST CONSIDER HOW IT CAN CONTRIBUTE TO NATIONAL GOALS.

A whole new generation of technologies is facilitating new and more innovative approaches to spectrum utilization. Artificial intelligence is enabling new forms of dynamic spectrum access through software-defined radios and antennas that can adapt to the spectrum environment. Some creative enterprises are even using blockchain technology to stimulate mesh network configurations. Additional spectrum, less encumbered by legacy approaches, may be helpful in fully realizing the potential of these and other new architectures.

At the same time, spectrum is a public asset, and we must consider how it can contribute to national goals.

Just as commercial spectrum use has evolved and expanded, so too has federal spectrum use. As noted above, a wide array of federal agencies and entities utilize spectrum—their current mission needs and uses cannot be expected to remain static and will also evolve and expand into the future. For example, DoD is a key stakeholder in federal spectrum management and has driven the development of many spectrum management technologies. It is particularly important that DoD stay at the cutting edge of spectrum knowledge and utilization. As a 2019 report from the Defense Innovation Board noted, “5G has the ability to enhance DoD decision-making and strategic capabilities from the enterprise network to the tactical edge of the battlefield. 5G will increase DoD’s ability to link multiple systems into a broader network while sharing information in real time, improving communication across services, geographies, and domains while developing a common picture of the battlefield to improve situational awareness.”³⁵

However, DoD is only one stakeholder across the landscape of federal interests. Fulfilling a variety of national missions over the long term depends on entities in the ecosystem regularly and consistently modernizing their use of technology to ensure that many systems can coexist. As new functionalities and use cases continue to be deployed, it is likely that spectrum use by federal and state entities will evolve and expand beyond its current uses. The better we identify — and estimate — the future spectrum needs of all entities in the ecosystem, the better we can ensure that both commercial and governmental wireless uses reach their full potential.



**AS WIRELESS USES
EVOLVE, SO MUST OUR
SPECTRUM POLICIES.**

B. UNDERSTANDING THE ROLE OF GOVERNMENT POLICY

As wireless uses evolve, so must our spectrum policies.

We must acknowledge that most of the desirable spectrum bands are already occupied. Determining whether and how to reallocate spectrum to meet future needs

and technologies is an age-old problem in spectrum management. But how to do so in a world of accelerating technological change presents new challenges. Key questions include but are not limited to:

- How should the government determine when and how to reallocate a spectrum band from existing uses to new uses?
- How should the government determine whether reallocation should be for licensed, unlicensed, shared or dedicated for passive services such as radio astronomy?
- How should the government measure spectrum utilization and when should those measurements trigger changes?
- Are there incentives the government can provide to existing spectrum users to cause them to voluntarily reduce their spectrum footprints? Are there similar incentives that can be provided to ensure efficient use of spectrum?
- Who in the government should have the final say about spectrum allocations and related questions, such as the required level of interference protection?
- How can the government ensure all stakeholders, particularly federal users, have a voice and are able to participate in the initial reallocation discussions?
- How can the United States influence international spectrum policymakers to adopt rules that do not constrain U.S. domestic spectrum policies and enable American companies to have a fair opportunity for global leadership?
- How can we reduce the need for government intervention when technology and uses change?

Market forces and mechanisms can help address the challenges that these questions probe. But market forces alone are not sufficient. Principled government policies inevitably play a leading role.

C. ARTICULATING PRINCIPLES FOR A FORWARD-LOOKING SPECTRUM STRATEGY

Any good strategy should have clear guiding principles that can inform concrete, actionable steps. The following principles synthesize some themes surfaced by the roundtable participants. As we demonstrate in Section III, these can form the basis of a National Spectrum Strategy.

Issue and Periodically Update a Long-Term Plan for Spectrum Abundance

Growth of the wireless economy will be hampered if the government fails to make spectrum available to enable network expansion and technology upgrades. If not addressed, a scarcity of spectrum could translate into higher prices, reduced performance, depressed demand, a national competitive disadvantage, and, ultimately, a drag on innovation. Policymakers must recognize that building spectrum-reliant systems at scale — whether they use licensed, unlicensed, or shared spectrum — can be expensive. To plan networks, raise capital, develop ecosystems, and deploy networks requires the government to provide private markets with predictability and reliability with respect to spectrum availability. Accordingly, spectrum policy must promote spectrum abundance and provide certainty about the rules and expectations associated with this spectrum. A strategic plan provides a good opportunity to present this roadmap to the public.

Assure a Balanced Portfolio of Spectrum for Different Use Cases, Business Models, and Government Missions

Although wireless broadband technology standards like 5G and Wi-Fi can support a broad range of use cases, it is important to recognize that the universe of spectrum-reliant systems is much broader than those most familiar to consumers. As explained above, spectrum civilian and government users need access to spectrum for many different purposes, including for sensors, position navigation and timing (PNT), radar, satellite, and passive scientific applications. Indeed, in some cases the combination of

multiple, different radio technologies can enable new capabilities where the sum is greater than the parts. For example, navigation apps typically use a GPS receiver, a cellular connection, and a Wi-Fi connection (to augment GPS triangulation). Newer sensor-dependent uses like autonomous vehicles and drones can be expected to use even more disparate spectrum-dependent technologies. Additionally, even where the use cases can be supported by a single technology, the way in which spectrum use is authorized can have a dramatic effect on business models and industry structure. For example, the multi-tiered CBRS licensing model is enabling a wide range of private networks serviced by a range of different providers. It is vital that spectrum policy keep these diverse interests in mind. The spectrum novelties of today may become the predominant network technologies of tomorrow. We need policy and regulatory processes that are agile, adaptable, and flexible, and that enable more agility, adaptability, and flexibility among users. A spectrum “monoculture” would be contrary to the national interest.



**THE SPECTRUM
NOVELTIES OF TODAY
MAY BECOME THE
PREDOMINANT NETWORK
TECHNOLOGIES OF
TOMORROW.**



**SPECTRUM POLICY
SHOULD CONTINUE
TO PUSH THE
BOUNDARIES OF
WHAT “FLEXIBLE
USE” TRULY MEANS.**

Facilitate More Productive, Flexible, and Innovative Use of Spectrum

Legacy “command and control” rules, high transaction costs, and highly specialized licensing regimes sometimes preserve outmoded band plans and prevent spectrum from being put into more valuable or modern license configurations. More flexible spectrum authorization ensures that spectrum moves to more productive uses through voluntary market mechanisms, allowing innovation and capital formation to occur with greater efficiency and without a frequent need for “rezoning” by the regulator. Flexibility can take many forms, including “flexible use” geographic area licenses, unlicensed access, licensed-by-rule authorization,

or hybrid schemes that provide a broad continuum of options depending on local needs. Still, spectrum “stovepipes” — typically defined by a static Table of Allocations — remain common. Can a single set of rights encompass terrestrial, airborne, and space uses of spectrum? Can it encompass active and passive uses? Spectrum policy should continue to push the boundaries of what “flexible use” truly means. And spectrum policy should also consider ways in which current rules, such as construction requirements or technology performance standards, may inadvertently impede flexibility of use.

Promote Digital Equity and Inclusion

Any analysis of spectrum policy should not simply assume an equitable distribution of benefits. Every significant federal action with respect to spectrum policy should consider how it may advance the goals of addressing economic inequality, e.g., through providing new benefits to marginalized communities on an expedited basis through deployment obligations, use of auction revenues, or other means. Numerous provisions of the Communications Act, including provisions that govern spectrum auction design, instruct the FCC to promote both access to spectrum licensees and to ensure the benefits of wireless policy flow to traditionally marginalized communities such as communities of color and businesses owned by women and people of color.³⁶ Despite these explicit statutory provisions, access to wireless services and the benefits of wireless communication remain disproportionately lower for communities of color and women-owned and non-white owned businesses. Native American communities remain among the least-served communities in the United States, even when accounting for income and geographic location.³⁷ As it implicates an essential and valuable national resource, spectrum policy provides an important means of addressing these longstanding inequities and the lack of opportunity these inequities perpetuate.³⁸



**AS IT IMPLICATES AN
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Promote U.S. Technology Leadership in the Global Marketplace

The U.S. should aspire to further advance many of the elements that exist in its spectrum ecosystem today. For example, the companies behind the two leading operating systems for mobile devices are both U.S.-based, as are the most important companies for mobile semiconductors. Several wireless technology standards have been developed and implemented by U.S. standards bodies. Additionally, wireless



POLICYMAKERS MUST ENSURE THAT ANY DECISIONS IMPACTING U.S. SPECTRUM POLICY MAINTAIN THE SUCCESS OF U.S. INDUSTRIES INTO THE NEXT DECADE AND BEYOND.

technology serves as a platform for innovative applications, with many of the world's most popular mobile applications developed and headquartered in the U.S. At the same time, the U.S. no longer domiciles any of the leading cellular network equipment makers. And only one of the top three makers of sensors for vehicular radars is headquartered in the U.S. Recent events around the globe have demonstrated the risks of ceding leadership to foreign countries, particularly adversarial ones, and the ways in which a robust U.S.-controlled supply chain is in our country's economic and security interest. As a key input into wireless innovation, spectrum

policy necessarily plays an important role in determining U.S. leadership across a wide array of technology-based markets. Policymakers must ensure that any decisions impacting U.S. spectrum policy maintain the success of U.S. industries into the next decade and beyond. The recent CHIPS Act signed into law by President Biden is an important first step, authorizing more than \$200 billion in federal funding to promote domestic semiconductor production, with \$1.5 billion specifically earmarked to further development of the ORAN ecosystem.³⁹ Another example of a spectrum related ecosystem is the satellite to terrestrial handset service, which has recently seen announcements by American mobile services, satellite, and device companies. Spectrum policies should further bolster these 'Made in America' efforts by taking into account how policies can facilitate domestic supply chains, emerging wireless ecosystems, and advanced manufacturing.

Improve Spectrum Governance at all Levels

U.S. spectrum policy and implementation happen in multiple fora, requiring intensive coordination across multiple agencies. Over the last several years, there has been bipartisan recognition that the system by which the federal government addresses spectrum issues has deteriorated. Unlike the system in other countries where governments have a single agency in charge of both commercial and government allocations, this responsibility is split between the FCC and the NTIA in the U.S., each with its own unique governance and oversight model. Representation at the International Telecommunications Union is led by the State Department, with support from the FCC and NTIA. And each of these agencies must deal with multiple — often conflicting — public and private sector constituencies. To improve spectrum governance, leaders at the highest level of government must articulate not only the needs and narrative of the moment, but long-term goals as well. Doing so will provide the FCC, NTIA, and other government agencies with clear targets to aim for as they develop spectrum policy in a collaborative fashion. The FCC and NTIA recently took a significant first step in this process by signing a new Memorandum of Understanding aimed at “revitalizing the spectrum coordination process.”⁴⁰ Implementation is also essential to policy success. Government agencies and committees must periodically revisit their own bureaucratic structures and processes for implementing and enforcing spectrum policy. Improved governance also means clarifying the interference rules and accelerating the resolution of the disputes, including what responsibilities users have to one another in adjacent bands. Disputes over interference standards continue to persist.⁴¹

Maintain a Competitive Wireless Marketplace

Spectrum policy can have an outsized effect on industry structure and conduct in markets for which spectrum is a key input. The nature and distribution of wireless licenses influences the competitive intensity of several industries, but especially the market for commercial mobile radio services (CMRS). In various proceedings, the FCC has adopted rules to ensure that spectrum holdings are not overly concentrated in the hands of any one company. At the same time, these proceedings typically balance the goal of vibrant competition with a desire to foster investment in networks and to “put spectrum to work”. The FCC’s current approach is a patchwork of band-specific rules and general guidelines developed at an earlier moment in the industry’s development. Keeping competition front and center is an essential part of spectrum policymaking. Competition

makes industry more efficient, productive, and innovative, while giving consumers access to a wide range of affordable services. Without adequate competition, policymakers must resort to regulation to achieve these benefits — which most stakeholders would agree is a second-best option. The FCC must consider competition policy from a broad perspective, as it does not occur in isolation from the other principles discussed here. For example, increasingly flexible spectrum rights may invite new competitors and forms of competition into the marketplace. Whatever the specific policy, it is important it be clearly articulated so that market participants can plan and invest accordingly.



COMPETITION MAKES INDUSTRY MORE EFFICIENT, PRODUCTIVE, AND INNOVATIVE, WHILE GIVING CONSUMERS ACCESS TO A WIDE RANGE OF AFFORDABLE SERVICES.

Augment the Policymaking Toolkit

Good policy requires a transparent, collaborative, and trust-based decision-making process based on science, engineering, economics, and grounded in the law. Data and expertise are the foundational elements of this equation. Questions such as who is using spectrum, what are they using it for, and how much spectrum are they using



ONGOING INSTITUTIONAL CAPACITY-BUILDING IS ESSENTIAL TO A WELL-FUNCTIONING SPECTRUM POLICY PROCESS.

may appear basic, but are not always easily addressed by policymakers with data at hand. Similarly, balancing perspectives of different stakeholders on highly technical matters requires significant staff expertise. Stakeholders may often bring more resources to the table than the FCC or NTIA can muster directly. The agencies must have the ability to ask hard questions, assess competing technical studies and

arguments, and determine what policy maximizes the public interest consistent with the Communications Act. Additionally, agencies' toolkits should facilitate informed, data-driven decision-making by external stakeholders. Ongoing institutional capacity-building is essential to a well-functioning spectrum policy process.



SECTION III.
**MOVING FORWARD:
RECOMMENDATIONS
FOR ACTION**

Any spectrum strategy should focus on the success of wireless technologies in the short-term, and maintain flexibility for technological advances in the future. It is important to set ambitious but achievable goals that are rooted in sound interagency processes and, to the extent possible, anchored in specific spectrum bands. These goals also must be actionable in the sense that initial steps can be taken in the short term (within 2–3 years), even if the process ultimately takes longer to complete. With that in mind, below we summarize a series of high-level recommendations tied to each of the strategic principles above along with actionable ideas generated by the roundtable participants.



ANY SPECTRUM STRATEGY SHOULD FOCUS ON THE SUCCESS OF WIRELESS TECHNOLOGIES IN THE SHORT-TERM, AND MAINTAIN FLEXIBILITY FOR TECHNOLOGICAL ADVANCES IN THE FUTURE.



STRATEGIC PRINCIPLE	RECOMMENDATION
National Plan for Spectrum Abundance	As part of its National Spectrum Strategy, the U.S. government should issue a 10-year plan with clear national goals to release more spectrum into the commercial marketplace.
Balanced National Spectrum Portfolio	In making new spectrum available for commercial use, Congress, the FCC, and the Administration should ensure a balance of licensed, unlicensed, and shared authorization models as appropriate for the bands under consideration.
More Productive, Flexible, and Innovative Use of Spectrum	The FCC and NTIA should enhance and expand policies that enable market- and technology-driven determination and evolution of spectrum uses.
Digital Equity and Inclusion	A National Spectrum Strategy should provide assurance that all Americans have access to all generally-used wireless services, regardless of geography, income level, race, sexual orientation, or education.
Global Technology Leadership	The FCC and NTIA should ensure that the National Spectrum Strategy and associated plans are conducive to U.S. leadership in strategic, spectrum-dependent platform technologies.
Spectrum Governance	The FCC and NTIA should modernize the core institutions and processes of spectrum governance to ensure that the U.S. continues to lead the world in developing and implementing spectrum policy.
Competitive Wireless Marketplace	The FCC, in coordination with DoJ/FTC, should undertake a comprehensive review of wireless competition policy.
Policymaking Toolkit	Congress, the FCC, and NTIA should implement multiple reforms to build capacity for ongoing improvement in spectrum policymaking and management.

Table 1. "Principles and Recommendations for a National Spectrum Strategy," *Toward A National Spectrum Strategy*, The Aspen Institute, 2022.



A. NATIONAL PLAN FOR SPECTRUM ABUNDANCE

Recommendation: As part of its National Spectrum Strategy, the U.S. government should issue a 10-year plan with clear national goals to release more spectrum into the commercial marketplace.

The National Spectrum Strategy should make a clear statement of national spectrum goals — agreed to by the FCC and the Administration — that sets a roadmap for rulemaking and administrative actions over the next decade. Clear, quantifiable goals provide a lodestar for whole-of-government action. They also help various stakeholders plan for the future and can influence technology development and resource allocation by private actors. Of course, the plan will need to be updated over time to account for new information. Therefore, this plan should not be viewed as a “once and done” activity but rather an instance of a process that should repeat at regular intervals.

HEADLINE IDEAS

Plan for 3–4 Bands Below 15 Ghz, Each with Approximately 400 Megahertz Bandwidth

Realizing this goal would enable multiple network operators to use 400 MHz channels in lower, better propagating bands as a foundation for multi-gigabit 6G (or advanced 5G) service in the U.S. (Capacity and speed would be further augmented in densely populated areas by thousands of megahertz already licensed in the Upper Microwave Flexible Use service.) The Spectrum Strategy could further identify a spectrum pipeline for potential repurposing, including assessment of incumbent uses in identified bands, next steps for bringing the band forward for new uses, and possibly a process for rationalizing holdings among mobile operators to maximize channel contiguity.

Make the “Spectrum Horizon” Bands Unlicensed by Default

Although the FCC recently authorized use of bands above 95 GHz, technology is still in early stages and the band is only sparsely used. Given the inherent limited and highly directional signal propagation at these frequencies along with the super abundance of bandwidth, any concerns raised regarding interference in these bands should take

a back seat to maximizing spectrum access and innovation. Just as the liberalization of the Part 15 rules in the 1980s later led to amazing technologies such as Wi-Fi and Bluetooth, so too could unleashing these vast, undeveloped spectrum bands produce future innovations that change our daily lives. Of course, any such authorization should come with appropriate protections for incumbent scientific uses of the band.

OTHER IDEAS FOR CONSIDERATION

Executive Order

The White House, in consultation with NTIA, the FCC, and other federal entities, could set out the country's overall spectrum goals through an Executive Order (EO). The EO might include several of the most important goals and action items contained in the first National Spectrum Strategy.

National Spectrum Inventory and Balance Sheet

This might include: (a) an accounting of the current uses of spectrum; (b) an estimation of the intensity of the current and planned use of the spectrum bands; and (c) an estimate of the "holding value" (i.e., the opportunity cost) of the spectrum based on principled economic analysis.

Report on Future Federal Spectrum Needs

NTIA could produce a periodic report projecting the spectrum needs of federal departments and agencies for the decade ahead along with supporting assumptions.

B. BALANCED NATIONAL SPECTRUM PORTFOLIO

Recommendation: In making new spectrum available for commercial use, Congress, the FCC, and the Administration should ensure a balance of licensed, unlicensed, and shared authorization models as appropriate for the bands under consideration.

Future spectrum policy should not favor one successful authorization approach over another. A balanced portfolio is needed to facilitate an expansive ecosystem of technologies and market participants. Flexible licensed and unlicensed spectrum

allocations have been mainstays of spectrum policy for years — and that trend should continue. However, the National Spectrum Strategy should also prioritize opportunities for less conventional models, especially including shared spectrum and hybrid licensing schemes that are ushering in new wireless industries.

HEADLINE IDEAS

Revise Congressional Budgeting to be “Spectrum Policy Neutral”

The Congressional Budget and Impoundment Control Act of 1974 established the Congressional Budget Office (CBO) and tasked it with estimating the “the costs of bills and resolutions approved by Congressional committees other than the House and Senate Appropriations Committees,”⁴² a process usually referred to as “scoring”. Current budget scoring rules consider inflows of auction revenues but do not account for economic benefits of other spectrum authorization approaches. As a result, spectrum auction directives are often legislated as a “pay for” to offset some Congressional spending priority. Congress should consider revising the rules to level the legislative playing field for other ways of making spectrum available into the commercial market, such as unlicensed or shared uses.

Make Shared or Locally-Licensed Spectrum Available for Industry 4.0

Although 5G is usually understood as a technology to be deployed by the national network operators, the technology may also be deployed in private networks to support advanced industrial technologies such as automated manufacturing or logistics, typically referred to as Industry 4.0. CBRS has provided a launchpad for private networks in the U.S. However, just as the nationwide operators will require more spectrum to upgrade their 5G networks, so too should we expect that private network users will also need more spectrum. Fortunately, the inherently localized (and often indoor) operation of these private networks means that they can typically share spectrum with other uses. Indeed, many countries in Europe are allocating locally licensed spectrum in shared bands specifically to facilitate private/industrial networks. The U.S. should ensure that its balanced portfolio includes spectrum for private networks that could prove essential to American industrial competitiveness in years ahead.

OTHER IDEAS FOR CONSIDERATION

Congressional Budgeting, Continued

Congress could further enable a more flexible approach to authorizing spectrum to different uses by any or all of these means:

- ▶ Amending the Commercial Spectrum Enhancement Act (CSEA), to allow for cost reimbursements from sources other than auction revenues, and to facilitate band sharing authorized on an unlicensed or licensed-by-rule basis.
- ▶ Amending or reducing the CSEA requirement that the total cash proceeds from an auction equal at least 110% of the estimated relocation or sharing costs provided to the FCC by NTIA.
- ▶ Not tying licensed auction revenues to specific “pay-fors” to fund other programs unrelated to the FCC’s statutory responsibilities or general Treasury funds, as this creates a bias in favor of exclusive, licensed spectrum auctions.
- ▶ Changing the scoring process to account for the substantial economic value of both shared and unlicensed spectrum.

Spectrum Efficient Mission Platforms

The Administration should consider concepts by which spectrum proceeds can be used to modernize and transition legacy federal uses to state-of-the art platforms that can support multiple enduring missions in a shared domain (e.g., airborne, radar, etc.). The Administration should leverage Spectrum Relocation Fund (SRF) funds to develop high-level Concepts of Operations (ConOps) for “multi-purpose” wireless platforms that could provide equal or greater mission capability with a smaller spectrum footprint than legacy single-use technologies. These ConOps need not be fully fleshed out plans. Rather, they should be brief concept papers intended to produce hypotheses worthy of further study by affected agencies. Examples:

- ▶ Consolidate military L- and S-band test and training missions into a unified, high-bandwidth, IP-based Joint Aeronautical Network (JANet), possibly in a higher frequency band.
- ▶ Consolidate multiple radar systems on shared platforms, similar to the

Spectrum Efficient National Surveillance Radar (SENSR) initiative, but for additional radar types and bands.

- Consolidate non-federal 6 GHz and federal 7 GHz fixed microwave operations through sharing/frequency coordination.
- Migrate siloed government communications channels (e.g., microwave links) to secure modern commercial platforms (e.g., fiber optics, 5G, satellite).

Portfolio Forecasting

Using the metrics in the NSI noted above, and as part of the periodic NSS noted above, NTIA and the FCC could identify spectrum bands that could be appropriate for different use cases and business models. Further, they could make initial recommendations regarding authorizations for licensed, unlicensed, and shared spectrum as appropriate for the bands under consideration.

Passive Bands

Protect key scientific/passive bands by establishing meaningful and appropriate ex-ante interference protections without totally forbidding any use of those bands or any other bands in the vicinity.

Next-Generation Transportation Infrastructure

Promote spectrum availability and utilization for next-generation vehicles, including unmanned vehicles.

- Release long-identified spectrum to promote the use of UAS.
- Revise/update government V2X strategy to reflect current generation spectrum availability and wireless standards.
- Review existing regulations that might otherwise impede licensed or unlicensed networks from helping to fulfill these objectives.

C. MORE PRODUCTIVE, FLEXIBLE, AND INNOVATIVE USE OF SPECTRUM

Recommendation: The FCC and NTIA should enhance and expand policies that enable market- and technology-driven determination and evolution of spectrum uses.

The U.S. government should consider expanding flexible policies, including flexible-use licenses, unlicensed access, and advanced spectrum sharing, across multiple bands so that technology advances and market transitions can happen without government intervention. Such a policy should include clearly defined interference protection criteria to prevent (or enable negotiated solutions to mitigate) harmful interference. Over time, the policy would likely result in fewer (but more general purpose) radio service allocations in place of the high degree of fragmentation that characterizes the spectrum chart today. The FCC and NTIA could prototype various “ultra-flexibility” concepts to understand the art of the possible before proceeding with larger-scale policy changes.

HEADLINE IDEAS

Develop a Spectrum Currency

NTIA and OMB should develop a spectrum token, currency, or shadow-pricing system so that government spectrum allocation decisions take into account opportunity costs of current government uses of spectrum to the broader economy.⁴³

Implement Advanced Sharing

NTIA and the FCC should partner to advance the state of the art in sharing between federal and non-federal users. Two concepts in need of urgent development and implementation are: (a) an Incumbent Informing Capability (IIC),⁴⁴ which could potentially be deployed as in one or more identified bands (e.g., Lower 3 GHz), and (b) systematic bidirectional sharing between federal and non-federal users in a specified band (e.g., Lower 37 GHz). NTIA should leverage R&D funding from the Spectrum Relocation Fund⁴⁵ to develop the IIC, which could greatly increase opportunities for non-federal access to federal bands in the future. These initiatives should be pursued using lean/fast/iterative software development principles, leveraging digital fellows and other similar talent pools, with advice from a multi-stakeholder group of expert technologists.

OTHER IDEAS FOR CONSIDERATION

Overlay Licensing

The FCC could start a proceeding to consider whether overlay licenses could be auctioned in legacy command-and-control bands, where appropriate, to encourage band transitions.

Secondary Markets

The FCC should consider ways to supercharge secondary markets in spectrum licenses.

- ▶ **Light touch review.** Consider whether to employ the CBRS “light touch” secondary market process and use-it-or-share-it opportunistic approach in other spectrum bands.
- ▶ **New technologies.** Consider whether private sector use of new technologies such as Blockchain can facilitate/enable more dynamic secondary markets by lowering regulatory and transaction friction.
- ▶ **Enhanced incentives.** Consider the “depreciating license” concept proposed by several leading economists (including a Nobel Prize winner who co-invented the modern spectrum auction), in which incumbents have strong, ongoing economic incentives to make unused spectrum available to others for sale or lease.⁴⁶

Dynamic Spectrum Sharing

The FCC should consider ways to assess and improve the state of the art of spectrum sharing.

- ▶ **New opportunities.** Consider opportunities to use dynamic spectrum sharing to expand access to existing command-and-control bands.
- ▶ **Ongoing assessment.** Periodically assess the state of sharing regimes, including a detailed analysis of usage in the CBRS band to identify opportunities to improve the approach.

“Super Flexible Use” Policy

The FCC could explore evolving the “flexible use” rules to encourage market-oriented

spectrum evolution without regulatory intervention, even where different radio services and allocation types may be implicated in the transition. Concepts worthy of exposition and prototype implementation include:

- **License to receive.** In at least one new band, prototype a “license to receive”, specifying reception (not just transmission) rights, which would entitle the licensee to receive with a degree of “quietude” for its own receivers. Others could use the band on a secondary basis in places/times where no receivers are active and hence harmful interference with the primary licensee cannot occur.
- **Z-axis uses.** The FCC should launch a proceeding exploring the extent of terrestrial rights to support airborne or space uses (and, potentially, vice versa), blurring the lines between these traditionally siloed allocations and enabling greater spectrum sharing and network convergence between terrestrial and non-terrestrial networks (NTN).
- **General purpose satellite license.** The FCC should consider a “general purpose” satellite band that encompasses traditional silos (GSO, NGSO, MSS). In this band, auctions could be used as a method for the initial assignment of licenses (as distinct from orbital slots, which is currently prohibited by the ORBIT Act).

Receiver Performance

The FCC recently launched a Notice of Inquiry about receiver performance. The FCC should move expeditiously to adopt policies and/or propose rules that clarify rights and obligations around receivers. The Commission might consider implementing a “default policy or rule” that would phase in slowly (e.g., 5 years) that would be applied in the absence of band-specific interference rules.

Interference Policy Statement

Concurrent with this rulemaking, the FCC and NTIA could issue a policy statement articulating core foundations of policy regarding the evaluation of interference claims. Such a policy statement might, for example, state:

- **Harmful interference is not zero interference.** “No harmful interference” is the appropriate standard and it is based on actual impact on a service based on operating assumed for reliable service. It is not the same as “zero interference” or protection of service at the extreme fringe of performance.

- **Probabilistic analysis.** Radio systems need to operate with a probabilistic expectation of some, non-harmful interference, and that receivers must be designed to minimize reception of signals outside the band in which their associated transmitters operate.
- **Reasonable flexibility.** Assessment of necessary interference protection should be informed by the performance of most receivers, not the small fraction of receivers that due to poor design extend far outside the allocated spectrum. Reasonable flexibility in receiver design should be the norm.
- **Disclosure.** Any private party requesting receiver protection must have previously disclosed their receiver characteristics in a publicly accessible FCC database.

Refactoring of Existing Bands

Beginning with the 3 GHz Band, the FCC and NTIA should examine ways to “refactor” existing band plans to reduce incompatible band adjacencies, thereby improving access to spectrum by ensuring more compatible neighboring uses.⁴⁷

Performance requirements

The government could modernize performance requirements (i.e., buildout rules) to avoid wasteful “license saver” builds while encouraging productive use of spectrum for which no network has been deployed. One way to accomplish this would be to implement “use or share” policies in place of conventional buildout requirements for new bands. As an alternative, the FCC could consider an “incentive lease” policy for undeployed spectrum, based on the Milgrom, Weyl, and Zhang proposal, noted above.

D. DIGITAL EQUITY AND INCLUSION

Recommendation: A National Spectrum Strategy should provide assurance that all Americans have access to all generally-used wireless services, regardless of geography, income level, race, sexual orientation, or education.

The shift of more and more aspects of daily life from offline to online services has had a profound impact on and compounded inequities for historically marginalized groups.

Policymakers must continue to focus on how the tools of the information economy, including spectrum policy, be employed to create a more equitable and inclusive society.

HEADLINE IDEAS

Apply an Equity Lens to Spectrum Policymaking

As spectrum is all-pervasive in modern life, it also requires an equity lens in policymaking. To assure this, the FCC and NTIA should consider digital equity and inclusion initiatives. Equitable impacts can manifest in unexpected ways, including on groups that have suffered from historical digital discrimination.⁴⁸ Policymakers should therefore take care to understand and analyze these impacts before making final decisions.

Use Auction Proceeds to Advance Digital Equity

Currently, auction proceeds by default go to the general Treasury. In some cases, Congress has authorized auction funds to pay for specific projects, such as a national public safety broadband network. The National Spectrum Strategy could recommend that Congress authorize the FCC to direct a portion of auction proceeds to provide long-term funding of digital equity initiatives, such as the Affordable Connectivity Program, which helps ensure that households can afford the broadband they need for work, school, healthcare, and more.⁴⁹

OTHER IDEAS FOR CONSIDERATION

HBCU Talent

Bolster Radiofrequency (RF) engineering in universities, with a particular focus on HBCUs, tribal and HSIs or overhauling the spectrum management career field and associated training to ensure more diversity by recruiting staff, especially engineers, from HBCUs.

Preferences for Underserved Communities

Where communities meet some threshold for long-term underserved status, such as on tribal lands, consider spectrum preferences as a way to accelerate and intensify deployment.

E. GLOBAL TECHNOLOGY LEADERSHIP

Recommendation: The FCC and NTIA should ensure that the National Spectrum Strategy and associated plans are conducive to U.S. leadership in strategic, spectrum-dependent platform technologies.

The FCC and NTIA, in concert with other federal agencies (e.g., NIST, DoD), and with leadership from the OSTP, should determine which wireless technologies are strategically important to U.S. national interests and evaluate whether its future spectrum portfolio will enable the United States to lead the world in these technologies. Examples for consideration might include next-generation wireless standards (e.g., 6G, Wi-Fi 7), architectures (e.g., ORAN), sensor and scientific applications (e.g., RADAR), and space platforms (e.g., LEO satellite constellations).

HEADLINE IDEAS

Draw a Technology Roadmap

The National Spectrum Strategy should set out a roadmap for necessary spectrum allocations and other policies for deploying 6G, ORAN, and other strategic wireless technologies.

OTHER IDEAS FOR CONSIDERATION

ORAN Investment

The CHIPS Act appropriates \$1.5 billion through NTIA, in coordination with NIST and other agencies, to spur innovation in ORAN and other “leap ahead” wireless broadband technologies.⁵⁰ NTIA should promptly develop a plan to disburse this funding in a strategic manner (as opposed to uncoordinated, incremental grants) to provide the biggest and quickest boost to ORAN and catalyze third-party investment in the sector. This plan might include leveraging multilateral associations (such as the Quadrilateral Security Dialogue, G7, etc.) to develop principles that will promote a global marketplace in which manufacturers compete to develop and sell ORAN components and software and promoting testbeds to prove out ORAN capabilities.

WRC Coordination Process

Inefficient national spectrum governance and a lack of clarity regarding coordination processes have undermined the U.S. government's efforts in international spectrum coordination proceedings. To address these deficiencies and strengthen U.S. efforts in the international realm, the government should consider the following steps:

- **One government voice.** The White House should ensure that the State Department plays a lead role in coordinating U.S. efforts.
- **Clarity of process.** The Department of State, backed by the White House, should establish firm deadlines for formalizing positions and initiate a multi-stakeholder process to resolve disputes as they arise to mitigate the possibility of protracted disagreements. Earlier outreach to stakeholders and earlier support from the White House can lead to better informed and earlier resolution of difficult issues. Department of State coordination should include:
 - Establishing agreed-upon procedures to help guide U.S. efforts to design technical studies and consider tradeoffs between what is desirable versus practical.
 - Reviewing documentation guiding U.S. preparation for WRCs to coordinate efforts for international processes.
 - Developing a means to continually monitor and update this preparation document.
 - Establishing procedures to help guide the design of spectrum-sharing and potential-interference studies intended as U.S. contributions to WRC technical meetings.
- **Ratification.** Congress should ensure that it ratifies the treaty after the conclusion of the WRC to signal that the outcomes have been accepted by all stakeholders.

F. SPECTRUM GOVERNANCE

Recommendation: The FCC and NTIA should modernize the core institutions and processes of spectrum governance to ensure that the U.S. continues to lead the world in developing and implementing spectrum policy.

As noted above, the U.S. has long led the world in devising and implementing a wide range of new spectrum policies. Over time, all institutions need to reflect on their basic structure and processes and make adjustments that reflect evolving mission, work practices, technologies, etc. Only Congress can change the basic two-agency spectrum management structure unique to the United States. But within this framework, there is much room for modernization and institutional reform, in ways big and small. The National Spectrum Strategy can recommend a process for identifying potential changes and eventually implementing them.

HEADLINE IDEAS

Elevate NTIA Leadership

Congress should promote the rank of the NTIA Administrator to Under Secretary within the Department of Commerce to reinforce NTIA's role as the steward of the federal spectrum.

Create the Spectrum Bureau at the FCC

The FCC Bureau structure reflects a “siloed” view of wireless industry structure and has not been revised in many years. The FCC should adopt a more modern, “converged” approach to spectrum management, consolidating many spectrum-related functions into a single Spectrum Bureau. This reform could be part of a broader plan to reorganize the FCC Bureaus (e.g., the creation of a Data and Analysis Bureau, described below).

OTHER IDEAS FOR CONSIDERATION

Data and Analysis Bureau

Create a Data and Analysis Bureau at the FCC whose remit would include quantification of use of different bands, including a periodic “spectrum census.”

Spectrum Policy Team

Reconvene, through a White House action, a “Spectrum Policy Team” of senior agency officials, with support from an Executive Office of the President (EOP) staffer who is focused on spectrum issues.

Enhanced PPSG

Broaden the role of the interagency Policy and Plans Steering Group (PPSG) to broadly support the nation’s spectrum goals beyond accommodating and protecting federal services. Upgrade Inter-department Radio Advisory Committee (IRAC) participation to ensure the impacts of changes in the spectrum environment are understood by all stakeholders.

Agency Collocation and Collaboration

Enhance collaboration between the FCC, NTIA and other spectrum agencies by collocating offices in the same facility and creation of cross-agency detail programs.

Enforcement

Enforcement is where the “rubber meets the road” for spectrum regulation and should be an intentional focus of policy going forward. Among the ways the FCC should consider doing so are the following:

- Enhancing field enforcement capability, including potentially deputizing third parties, similar to the equipment certification process.
- Exploring the use of software tools that would assist in identifying any violations of rules or regulations.
- Periodically reviewing regulations to spot and remove unenforceable provisions.
- Streamlining the process for issuing fines to parties for minor rule violations. Because the current process is extremely tedious, resource-intensive, and slow, parties risk violating the rules because the chances they will get caught are slim.

G. COMPETITIVE WIRELESS MARKETPLACE

Recommendation: The FCC, in coordination with DoJ/FTC, should undertake a comprehensive review of wireless competition policy.

The wireless industry is undergoing structural and technological change. At the same time, agencies are also adjusting their approach to competition policy. The FCC has not issued a comprehensive statement of its standards of competitive review, as they relate to spectrum holdings, in several years. It is time to reexamine these policies to make sure they are up to date with modern developments. A consistent and predictable framework would help stakeholders to make appropriate capital allocation plans for deploying and operating networks.

HEADLINE IDEAS

Update the Mobile Spectrum Holdings Policy

The FCC should replace the current, outdated ad hoc policy with a comprehensive, long-run mobile spectrum holdings policy that reflects modern network design, wireless industry market structure, and modern antitrust policy. Any new policy framework should provide appropriate safe harbors and/or bright line limits for spectrum holdings to ensure consistent treatment across similar bands.

OTHER IDEAS FOR CONSIDERATION

Competitive Equipment Market

Consider promoting ORAN ecosystem development to provide a greater range of U.S.-based sources in the input market for wireless network equipment.

Permitting

Permitting of wireless sites is a barrier to entry; improving the permit process could facilitate competitive entry. The federal government could assist state and local governments by collaborating with stakeholders to develop software that would expedite permit processes required for the deployment of wireless networks.

Resiliency

To ensure the resiliency of wireless networks, the federal government could conduct further research and consider new standards to assist stakeholders in developing networks that can withstand more problematic weather conditions, including those due to climate change.

H. POLICYMAKING TOOLKIT

Recommendation: Congress, the FCC, and NTIA should implement multiple reforms to build capacity for ongoing improvement in spectrum policymaking and management.

The “toolkit” describes a grab bag of authorities, capabilities, and processes that have developed over many years to solve various problems related to spectrum management. Incremental additions and changes to these authorities can have an outsized impact. Congress, the FCC, and NTIA should consider implementing as many toolkit upgrades as possible to facilitate ongoing, incremental improvement in spectrum policymaking and management.

HEADLINE IDEAS

Update the Commercial Spectrum Enhancement Act

Congress should update the Commercial Spectrum Enhancement Act and Spectrum Relocation Fund to provide for more flexibility in disbursements, including for up-front planning, experimentation, and transition approaches. Several specific ideas are called out below.

OTHER IDEAS FOR CONSIDERATION

Talent Pipeline

The FCC and NTIA should consider implementing opportunities and the capabilities to increase spectrum engineering talent, including:

- ▶ Compensating spectrum engineers competitively and consistently with market conditions.

- Reinstating the engineer training program at the FCC.
- Establishing an engineering honors program at the FCC and NTIA.
- Partnering with universities to develop programs that offer training in engineering skills to support analysis of spectrum issues, including a work-study program that could result in employment.
- Supporting engineer participation in technical organizations and conferences such as those sponsored by the IEEE.
- Establishing educational programs and opportunities where staff (including non-engineers) can learn about and understand the latest technical developments outside the context of any particular FCC proceeding.

NTIA/ITS Technical Capacity

Improve NTIA's technical capacity and laboratory resources so it can more effectively engage with both the FCC and other federal spectrum users on technical issues. Fully fund the Institute for Telecommunication Sciences (ITS), an integral arm of NTIA's spectrum management efforts, which provides valuable research and analysis to inform NTIA's Office of Spectrum Management as it works to identify additional spectrum efficiencies and potential opportunities to increase spectrum access. The ITS can be viewed as a trusted technical expert that can help resolve disputes.

Research

Improved research initiatives would enhance the nation's ability to promote continued U.S. leadership in spectrum-intensive research and development. Among the initiatives the federal government agencies (such as the FCC, NSF and NTIA) could consider are the following:

- Establishing a sustainable plan for an open, multilocation, interdisciplinary research center modeled on the Engineering Research Centers, focused on spectrum and wireless technologies.
- Funding both a wireless testbed, such as that run by ITS on behalf of DoD, for promoting the science underlying spectrum policymaking and a testbed for evaluating the network security needed to provide a secure broadband infrastructure.

- Initiating a rulemaking to establish faster and more flexible experimental licensing rules for spectrum, including identifying and eliminating barriers to experimental licensing that require coordination.
- Facilitating the use of the spectrum by researchers and encouraging more academic research and writings on spectrum sharing policy, including identifying the conditions under which sharing is feasible and what tools best enable sharing.
- Encouraging the FCC and NTIA to explore other technologies that may have a positive impact for use of the spectrum such as machine learning, artificial intelligence, mitigation techniques, optical communications, and any others they may deem appropriate.

Experimental Licensing

Allowing research organizations such as universities greater flexibility to temporarily utilize fallow spectrum by:

- Evaluating whether regulatory restrictions should be relaxed to permit research organizations to conduct broader market studies.
- Identifying underutilized spectrum that may be suitable for conducting research activities and conducting workshops to advance research activities involving spectrum use.

Statutory/Process Reforms

Congress could authorize a variety of spectrum process reforms to help facilitate evolution of spectrum bands to more flexible, modern uses, including:

- Creating an unlicensed clearing/repacking fund to facilitate relocation of legacy incumbents, akin to the UTAM authority used in the Unlicensed PCS band.
- Extending FCC auction authority, with a sufficient but limited window for a Congressional veto.
- Amending the pay-go rules on spectrum scoring to reflect actual cash collections.

- Amending the Anti-Deficiency Act to allow private entities to reimburse government agencies for radio upgrades/fixes up to a certain amount.
- Amending the Commercial Spectrum Enhancement Act (CSEA) to provide that the SRF covers the full range of costs, including up-front planning, technology development, and staffing to support any relocation effort.
- Amending the CSEA by removing or relaxing the “comparable capability” requirement, so that federal spectrum users will gain the ability to modernize their outdated equipment as part of the spectrum reallocation process, generating greater incentives to relinquish underutilized spectrum bands.
- Amending the CSEA to expand SRF eligibility to encompass unlicensed or other non-auctioned access to Federal spectrum.
- Amending the CSEA to allow earlier and more liberal draws from SRF for agency analyses/studies and to advance relocation and sharing.
- Directing 1% of auction proceeds into an evergreen SRF-like fund administered by the FCC to facilitate unanticipated post-auction “band cleanup” needs (e.g., to fund altimeter filter upgrades in the C-Band).

Data Collection

The FCC should review its data collections to identify “blind spots” that inhibit informed policymaking. Two examples where increased data collection could help:

- **Unlicensed devices.** Conducting an annual data collection on unlicensed device shipments and estimated installed bases in the U.S. by band would help inform allocations of bands for unlicensed use.
- **Receiver characteristics.** As noted above, a database of receiver characteristics (perhaps as an augmentation to OET’s equipment authorization database) would facilitate analysis and policymaking around changes to the interference environment.

CONCLUSION

Developing a coordinated, national approach to spectrum use is imperative to ensuring continued American technological leadership around the world.

Previous technological advancements have demonstrated that smart, flexible government policies with concrete goals can have an enormous impact on the economy and spur American innovation and leadership. The time has come for policymakers to carefully craft a comprehensive spectrum strategy that appropriately considers the interests of the full range of stakeholders.

With 5G deployment well underway and 6G on the horizon, with myriad unlicensed uses of spectrum now commonplace, with new national imperatives like Industry 4.0, reinvigorating "Made in America" and the space economy, and with expanding and evolving government missions, spectrum resources must be able to meet these current and future demands. Policies must be modernized to ensure optimal use of spectrum.

This document strives to provide a roadmap for policymakers and stakeholders to inform the development of a strong, bold, and forward-looking National Spectrum Strategy. We define the path ahead by articulating current and future trends, outlining principles for action, and offering a catalog of actionable policies. Though we recognize the ambitious nature of some of the policy proposals we set forth and understand that adopting them may be a never-ending task, our hope is that even if not fully implemented, these proposals will drive serious and fruitful discussions among policymakers and stakeholders. Only by broad collaboration and engagement can we ensure continued American technological leadership and the best possible outcome for all Americans.



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APPENDIX

BANDS FOR CONSIDERATION

Spectrum policy changes have historically been implemented through band-specific proceedings. In order to effectuate the overall goals, NTIA and the FCC, in consultation with other federal entities, should explore identifying specific bands that are appropriate for the policies recommended above. Below we provide an illustrative list of bands for consideration in the spectrum “pipeline”. Different bands may be more appropriate for different policies (e.g., exclusive vs. shared use). This list is by no means exhaustive and is not intended to contain bands that are currently the subject of active proceedings.

Expand Terrestrial Use

The following bands were identified for potentially increased flexibility of terrestrial (and in one case, airborne) use.

BAND	CURRENT USE(S)	HYPOTHESIS
UHF TV Band	Broadcasting, Unlicensed	Increased liberalization/flexibility for incumbents; potential voluntary channel reconfiguration; consider potential for overlay licenses coupled with incumbent flexibility
900 MHz	Narrowband licenses, Unlicensed	Band reconfiguration
1300-1350 MHz	FAA Radar	Restart the SENSAR process
1920-1930 MHz	Unlicensed PCS	Modernize the rules
3000-3450 GHz	DoD Radars	Currently under study, likely a shared band
3 GHz (Overall)	DoD, Flexible Use, CBRS	Rationalize band by consolidating “like” next to “like”
4.4-4.9 GHz	U.S. Government	Shared use

BAND	CURRENT USE(S)	HYPOTHESIS
5030-5091 MHz	Allocated for UAV	Move to authorization / assignment for UAV
7125-8500 MHz	Federal (Fixed Service, Satellite, Space Research)	Pool federal and non-federal (6 GHz) fixed uses in the same band or offload to other facilities to reduce fixed microwave allocation overall
10.0-10.5 GHz	Federal Radar, Amateur	Shared use
12.75-13.25 GHz	Cable Television Relay Service, Broadcast Auxiliary Service, Fixed Satellite Service	Migrate to alternate facilities, liberalize including for possible 6G use
14.5-15.35 GHz	Federal Fixed, Mobile, Space Research	Shared use
25.75-27.5 GHz	Federal (SRS, EESS)	Sharing, align with European Band
37-37.6 GHz	UMFUS (shared band)	Two-way licensed sharing
40-42 GHz	FSS	Shared use
50.4-52.6 GHz	FSS	Shared use
70/80/90 GHz	Shared Band	Upgrade/modernize rules to expand automated access
95 GHz - 3 THz	Vacant, Unlicensed, Passive, Experimental	Expand Unlicensed (or GAA) throughout band

Table 2. "Identified Bands for Potentially Increased Flexibility of Use," *Toward A National Spectrum Strategy*, The Aspen Institute, 2022.

Expand Satellite Use

The following bands were identified for potentially increased/expanded satellite use:

- 17.3–17.7 GHz
- 18.6–18.8 GHz
- 20.2–21.1 GHz
- 30–31 GHz
- 40–50 GHz
- 71–76 GHz
- 81–86 GHz



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Alan Davidson

Assistant Secretary of Commerce
for Communications and Information
National Telecommunications and
Information Administration (NTIA)

Amit Mital

Special Assistant to the President,
and Senior Director
National Security Council
The White House

Jessica Rosenworcel

Chairwoman
Federal Communications
Commission (FCC)

Tim Wu

Special Assistant to the President
for Technology & Competition Policy
National Economic Council
The White House

Participants

Elizabeth Andrion

Senior Vice President of
Regulatory Affairs
Charter Communications

Barbara Baffer

Vice President
Government and Industry Relations
Ericsson

Jeff Blum

Executive Vice President
External and Legislative Affairs
DISH

Paula Boyd

Senior Director
Microsoft Corporation

Michael Calabrese

Director of Wireless Future
Open Technology Institute

Charles Cooper

Associate Administrator
Office of Spectrum Management
National Telecommunications and
Information Administration

Scott Deutchman

Senior Policy Advisor
Google

David Don

Senior Vice President of Public Policy
Comcast Corporation

Harold Feld

Senior Vice President
Public Knowledge

David Goldman

Senior Director of Satellite Policy
SpaceX

Anna Gomez

Partner
Wiley Rein

John Hane

Chief Executive Officer
BitPath

Hank Hultquist

Vice President - Federal Regulatory
AT&T

Umair Javed

Chief Counsel
Office of the Chairwoman
Federal Communications Commission

Will Johnson

Senior Vice President
Federal Regulatory and Legal Affairs
Verizon

Colleen King

Vice President of Regulatory Affairs
Charter Communications

Maria Kirby

Vice President of
Government Relations
The Walt Disney Company

Julius Knapp

Former Chief, Office of
Engineering & Technology
Federal Communications Commission

Grace Koh

Vice President of Legislative Affairs
Nokia

Monish Kundra

Partner
Columbia Capital

John Kuzin

Vice President, Spectrum Policy
and Regulatory Counsel
Qualcomm Incorporated

John Leibovitz

Principal
Jupiter LLC

Blair Levin

Non-Resident Fellow
Brookings Institute

Nathaniel Livesey

Principal Scientist
NASA Jet Propulsion Laboratory
California Institute of Technology

Terry McVenes

President and Chief Executive Officer
Radio Technical Commission for
Aeronautics

Milo Medin

Distinguished Engineering Fellow
Schmidt Futures

Ruth Milkman

Partner
Quadra Partners

Craig Moffett

Senior Managing Director
MoffettNathanson Research

Brian Regan

Executive Vice President of Strategy,
and Chief of Staff
Starry, Inc.

Greg Rosston

Senior Fellow
Stanford University

Vivian Schiller

Executive Director
Aspen Digital
The Aspen Institute

Steve Sharkey

Vice President
Government Affairs, Technology
and Engineering Policy
T-Mobile

Mariam Sorond

Chief Technology Officer of
Service Provider and Edge BU
VMWare

Jayne Stancavage

Global Executive Director of Product
and Digital Infrastructure Policy
Intel Corporation

Alisa Valentin

Senior Director of Telecommunications
and Technology Policy
National Urban League

Dave Wright

President
OnGo Alliance

Julie Zoller

Head of Global Regulatory Affairs
Project Kuiper
Amazon

Observers**Ian Forbes**

Rapporteur

Derek Khlopin

Deputy Associate Administrator
for Spectrum Planning and Policy
NTIA

Kyle McEneaney

Director
Schmidt Futures

Phil Murphy

Senior Advisory
Office of the Assistant Secretary
NTIA

Matthew Pearl

Assistant Bureau Chief
Federal Communications Commission

Jess Quinley

Legal and Policy Advisor
Wireless Telecommunications Bureau
Federal Communications Commission

Peter Shroyer

Rapporteur

Staff**Tricia Kelly**

Senior Director, Operations
Aspen Digital

Tasha Overpeck

Events Manager
Aspen Digital

**Titles and affiliations as of May 2022*

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For additional information please contact:

Vivian Schiller
Executive Director
Aspen Digital
The Aspen Institute
2300 N Street, NW
Suite 700
Washington, DC 20037

www.aspeninstitute.org/aspendigital

