Development of a National Spectrum Strategy

Response to
National Telecommunications & Information Administration
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I. INTRODUCTION

Raytheon Technologies (NYSE: RTX) is pleased to present this response to the NTIA's initiative to create a National Spectrum Strategy. RTX is the world's largest aerospace and defense company. With a global team of 180,000+ employees—including over 58,000 engineers—we solve some of the world's biggest challenges by bringing together the brightest, most innovative minds across aviation, space, and defense. Our businesses include Collins Aerospace, Pratt & Whitney, Raytheon Intelligence & Space, and Raytheon Missiles & Defense.

Since our core products support critical Federal missions such as national defense, space exploration, and aeronautical safety, we urge the NTIA to recognize the importance of these missions in creating the Strategy. The Strategy should focus on sharing—not vacating—Federal spectrum to ensure that Federal missions can meet the growing challenges we face today, and the unknown challenges of tomorrow. It must also ensure that contractors such as RTX have fast and reliable access to spectrum to ensure that we can develop, test, and sustain the innovative products such as missile defense systems, space systems, and aviation products that support these critical Federal missions.

Over 66% of the world's airspace is managed by our systems.

Our space technologies support space exploration, weather observation, and global security.

Our naval systems defend the security of the U.S. and our allies all over the world.

We provide advanced radars, precision munitions, and navigation and landing systems to ensure air superiority.

From shoulder-fired weapons to ground-based air defense, our land systems deliver a decisive edge on the battlefield.

II. A HISTORY OF INNOVATION

RTX is a global leader in innovative technology. We hold over 60,000 patents and invest over $7.5B in company- and customer-funded research and development each year. Radiofrequency ("RF") systems are a core technology area, and RTX has been driving innovative solutions for a century:

1924  **Gaseous rectifier tube makes radio more affordable for all.**

1934  **First airborne radio on the Goodyear airship Enterprise.**

1942  **First seagoing microwave surface radar for U.S. Navy ships.**

1945  **Engineer Percy Spencer invents the microwave oven.**

1969  **Apollo 11 guidance computer, communications, and spacesuits.**

1977  **Our technology receives first GPS satellite signal.**

1991  **First missile intercept by Patriot in Operation Desert Storm.**

1992  **Launches first global aviation communications network.**

2022  **NASAMS defense systems with radar-guided missiles delivered to Ukraine. NASAMS also defends the airspace in Washington, D.C.**

III. HOW WE USE SPECTRUM

RTX develops commercial and government systems such as radars, satellites, communications systems, navigation systems, jammers, and missiles and other effectors. Our customers include various U.S. and foreign government agencies as well as commercial aviation customers around the world. We support DoD, FAA, NASA, DHS, USCG, NOAA, and several other Federal agencies.

We design, manufacture, test, and sustain RF products at vertically integrated facilities throughout the U.S.[1] We have invested billions of dollars in these facilities, which have specialized equipment and tooling, high-capacity power sources, and support tens of thousands of U.S. jobs. Our facilities also hold facility security clearances to enable us to perform classified work on behalf of our customers.

Our outdoor RF test ranges are a critical part of our facilities. We perform vigorous testing of our aerospace and defense products to ensure that they meet stringent military and safety-of-life standards. Our mission is to diagnose and resolve issues "at the factory" to ensure that our systems effectively perform their missions during operational use.

Immersive Design Center

Manufacturing Area

Outdoor Test Range

RTX's spectrum utilization occurs during the entire product lifecycle, which can extend several decades. We test modules and prototypes at our RF ranges early in the product development process, during the certification processes, and into the upgrade and sustainment phases of the lifecycle.

It can take over 10 years to develop and certify a new aircraft due to the strict testing and certification processes required by aviation regulators. Once certified, a commercial aircraft can be in service for 30 years or longer. While aircraft components such as avionics and sensors are upgraded over time, upgrades take several years to design, develop, test, certify and install on tens of thousands of commercial and business aircraft and associated service nodes.

Space systems can be in orbit for decades. The joint NASA/USGS Landsat program, which has acquired millions of images of the Earth, has been in operation since 1972. Landsat 5, which launched in 1984, set a Guinness World Record for the longest operating Earth observation satellite when it was finally decommissioned in 2013 after almost 29 years of service.

Defense systems have the longest lifecycle. Products may take up to 10 years from initial development to Stage 4 spectrum certification and may be in service for over 50 years.

[1] RTX also has several international facilities, but the focus of this response is on U.S. operations.

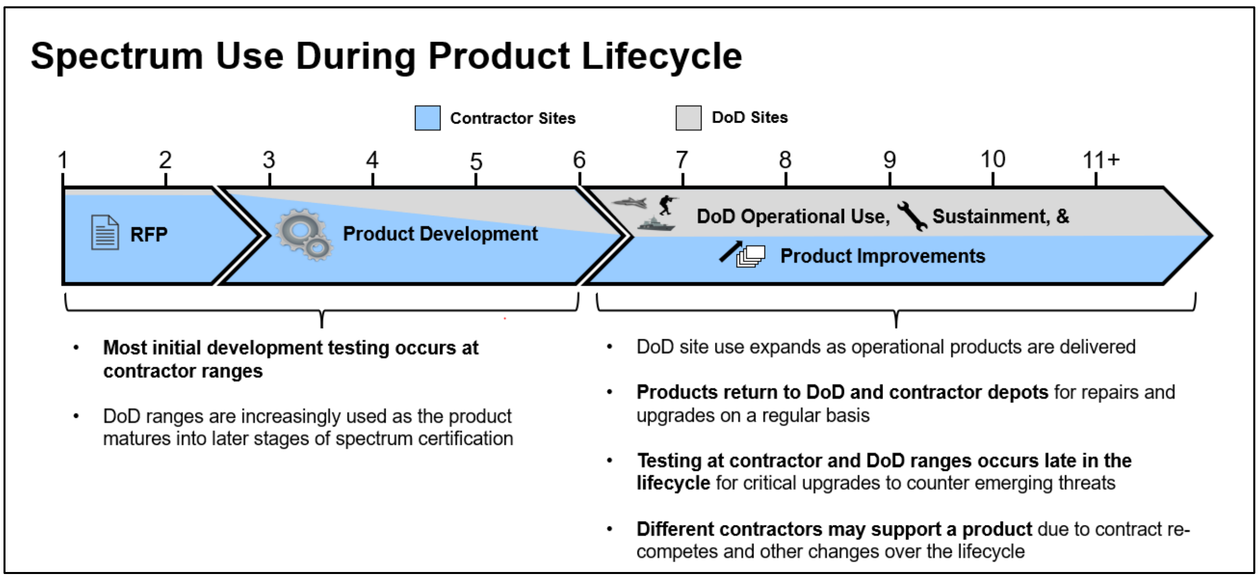
The Patriot air defense system was developed in the 1970s and is still widely deployed around the world. The Stinger shoulder-fired missile (put into service in the 1980s) and the HAWK air defense system (put into service in the 1950s) are currently being used in the war in Ukraine, despite newer systems being adopted by the DoD.

Patriot Air Defense System

Stinger Missile

HAWK Air Defense System

Below is an example of a typical DoD product lifecycle, which shows that **spectrum is used extensively at both DoD contractor sites during all phases of the lifecycle**:



It is critical to note that aerospace and defense products are specifically tailored to their allocated spectrum and mission, which dictates technical characteristics such as antenna size, power requirements, link budgets, gain, and path loss. Even minor changes to spectrum allocations can severely impact the operation of existing systems, triggering extensive retesting and certification processes. As such, the product lifecycle is a continuous process of design, development, testing, and sustainment over multiple decades.

RTX has a significant interest in the NTIA developing a national spectrum strategy that preserves its access to critical spectrum bands required to develop and sustain the aerospace and defense products that make our nation a global technology leader.

1. PILLAR #1: A SPECTRUM PIPELINE TO ENSURE U.S. LEADERSHIP IN SPECTRUM- BASED TECHNOLOGIES

<u>1.1 Question 1</u>

(a) What are projected future spectrum requirements of the services or missions of concern to you in the short (less than 3 years), medium (3–6 years) and long (7–10 years) term?

Short-Term

- Defense missions will require the same or greater amounts of spectrum to support requirements and initiatives such as:
    - The DoD's Joint All Domain Command and Control ("JADC2") vision for coherent "connected battlespace" across all forces that will utilize high speed, low latency, robust, and secure communications.

    - Greater use of spectrum for electromagnetic warfare to jam enemy communications and radar, distract enemy radars with decoys, and use high-power RF to disable or destroy enemy systems.

Dual Band Decoy

MALD Decoy

Next Generation Jammer

    - Growth in unmanned and autonomous systems requiring reliable, secure command and control to effectively operate over long distances.
    - Growth in intelligence, surveillance, and reconnaissance ("ISR") systems to gather information and intelligence, including the use of signals intelligence ("SIGINT") and electronic intelligence ("ELINT") technologies.
    - Growth of space-based systems for military and safety-of-life navigation, communications, and surveillance.

- **Wideband radars for (i) effective target discrimination against advanced threats such as hypersonic and ballistic missiles, (ii) resilience against enemy jammers, and (iii) interoperability in multi-unit operations.**

Hypersonic missiles can travel over 3,800 mph or Mach 5—five times the speed of sound—in lateral flight. At that speed it would take 10 minutes to travel from New York to Washington, D.C. Wideband radar spectrum helps to detect and track these high-speed threats.

Intercontinental ballistic missiles ("ICBMs") can travel over 15,000 mph in their midcourse phase. As ICBMs descend in their terminal phase, multiple warheads and decoys are released that travel at 2,000 mph. High-power, wideband radars are needed to counter this threat.

U.S. and allied forces must overcome electromagnetic warfare such as jamming. Wideband radars are more resilient to jamming because they can switch to alternate frequencies when others are jammed.

Radar interoperability is critical because U.S. and allied forces operate with multiple units within close proximity such as a carrier strike group. Wideband radar allocations are required to ensure that each unit can operate with sufficient spectrum without interfering with friendly units.

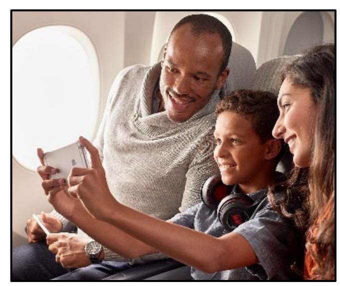
- Increases in augmented reality systems for training, remote support for system repairs, and battlefield utilization, will require high data rates.


- The deployment of new satellite systems, such as low Earth orbit ("LEO") constellations, may drive demand for additional spectrum in the Ka-band (26.5-40 GHz) and V-band (40-75 GHz).

- The growth of satellite communication and navigation systems is expected to drive demand for spectrum in the C-band (4-8 GHz), X-band (8-12 GHz), and Ku-band (12-18 GHz).

- Spectrum will remain critical for commercial and business aviation, especially as aviation systems become more intelligent and generate significantly more performance data that must be transmitted to ground, airborne, and space-based systems. Demand for satellite-based, high-speed in-cabin passenger services such as Wi-Fi connectivity and streaming entertainment is expected to increase.





Medium- and Long-Term

The Short-Term uses previously described will likewise continue into the medium- and long-term timeframes. In addition, RTX anticipates:

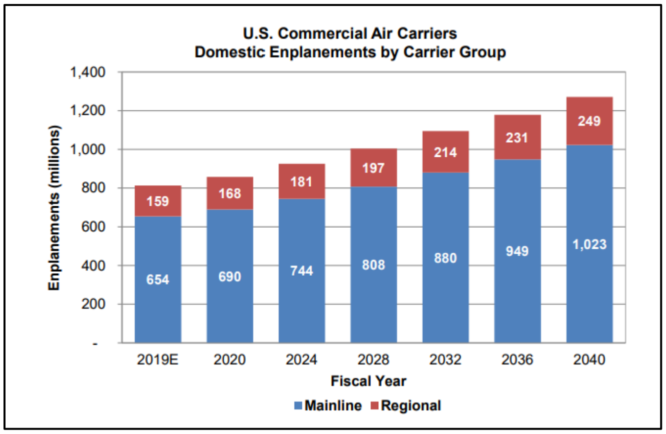
- U.S. systems must continually evolve to counter China's advances in aerospace and defense technology, including significant growth in naval power, advanced missile and stealth technology, and high altitude and space-based surveillance.

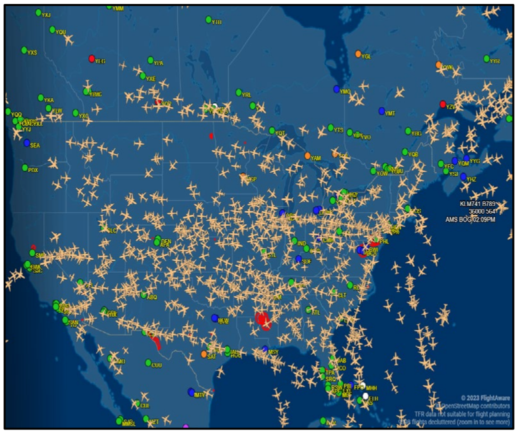
- There will likely be extensive growth in small satellites. Small satellite development, production, and deployment has seen significant cost reductions allowing constellations with thousands of satellites to be built, produced and launched with global coverage.

- The development of new space-based communication and networking systems, such as inter-satellite links and deep-space communication systems, may drive demand for additional spectrum in a range of frequency bands in support of both Federal and commercial space operations.

- The growth of space-based remote sensing, Earth observation, and weather forecasting systems is likely to drive demand for spectrum in a range of frequency bands, including the L-band, S-band, and C-band.

- Advanced commercial and business aviation systems, as well as ground-based radars and other safety-of-life systems, will require additional spectrum to ensure safe navigation in light of the continued growth of global air traffic. Currently, over 2.3 million passengers and 65,000 tons of cargo are transported daily in U.S. airspace, and these figures are projected to grow significantly.





- Higher volumes of both small unmanned aircraft systems ("sUAS") and larger systems such as electric vertical takeoff and landing vehicles ("eVTOL") will require spectrum for both in-flight operations as well as ground-based radar systems. An extensive nationwide network of smaller ground-based radars that can be mounted on communications towers and buildings may be required to support these low-altitude operations. X-band radars in the aeronautical radionavigation spectrum may be ideal for this mission given their compact size and high target resolution.

sUAS

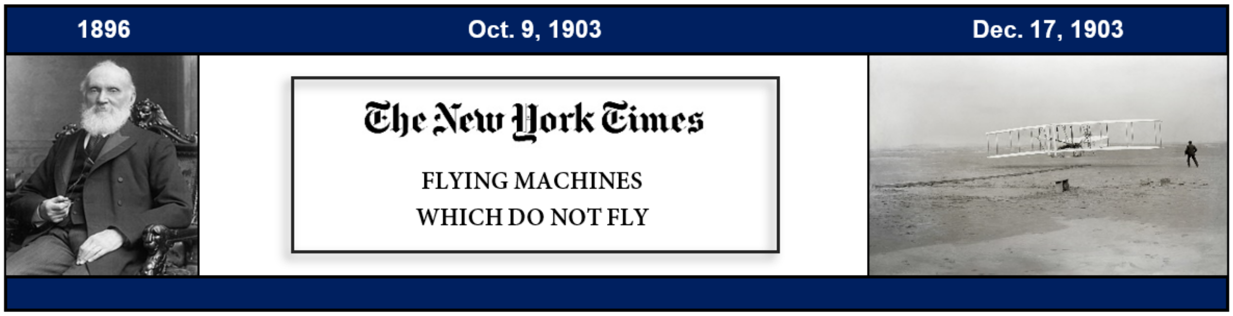
eVTOL

X-Band Radar

(b) What are the spectrum requirements for next-generation networks and emerging technologies and standards under development (e.g., 5G Advanced, 6G, Wi-Fi 8)?

N/A.

(c) Are there additional or different requirements you can identify as needed to support future government capabilities?



"*Heavier-than-air flying machines are impossible*."
-Lord Kelvin

"…the flying machine which will really fly might be evolved…[in] one million to ten million years…"

Wright Brothers
Kitty Hawk, NC

In addition to RTX's comments in Subsection (a), it is of critical importance that the NTIA's strategy be "futureproof" in light of critical and growing Federal aerospace and defense missions. **The government must be capable of meeting the challenges of today, the anticipated challenges of tomorrow, and even the unanticipated challenges of the future.** The government must be prepared to maintain the safety of our national airspace in 2023 and 2123; promote scientific advancement in remote sensing, astronomy, and space exploration; and counter whatever advanced threats our adversaries develop in the future. **The Strategy must assume that nothing is impossible when it comes to future challenges.**

To this end, it is inadvisable to base a Strategy—especially one that may result in the sharing or even vacating of Federal bands—only on what is known or anticipated today. **Vacating Federal bands is especially risky, as it assumes that the government will never need that spectrum in the future. Such an approach will jeopardize the government's capability to address future challenges, and will constrain the ability of the aerospace and defense industry to develop innovative solutions to meet those challenges.**

(d) What are the use cases and anticipated high-level technical specifications (e.g., power, target data rates) that drive these requirements?

RTX's comments in Subsection (a) described several potential use cases such as detection of advanced threats by wideband radars, new Federal and commercial space missions, and growing air traffic including sUAS and eVTOLs. RTX additionally states the following:

- *Defense and national security*: The use cases for defense and national security include communications, surveillance, reconnaissance, and intelligence gathering. The technical specifications that drive spectrum requirements may include high power levels, low latency, and high data rates for secure and resilient communication systems, as well as advanced technologies such as beamforming, encryption, and interference mitigation to protect against jamming and hacking. Applications such as low probability of intercept and detect require controlled power and larger bandwidth to spread and hop the signal from interception.

- *Space-based systems*: The use cases for space-based systems include Earth observation, remote sensing, and satellite communication. In addition, renewed interest in missions to the Moon and Mars will drive increased spectrum needs for faster communications links. The technical specifications that drive spectrum requirements may include high power levels, wide bandwidth, and high data rates for long-range and low-earth orbit communication systems, as well as coordination and interference avoidance with other space-based and ground-based systems.

- *Commercial aviation*: The use cases for commercial aviation include more sophisticated and connected avionics systems with extensive performance data; in-cabin passenger services such as Wi-Fi and streaming entertainment; and increases in global air traffic including sUAS and eVTOLs.

    - Commercial aviation's needs for spectrum are anticipated to expand to address the growing needs of UAS, Advanced Air Mobility ("AAM"), and other new technology. The needs spread across the facets of safety-of-life services to consumer content delivery on the airborne platforms.

    - Aviation typically uses safety spectrum for safety-of-life services but may investigate non-safety-of-life spectrum. Historically, the need to meet Required Communications Performance ("RCP"), Required Surveillance Performance ("RSP"), and Required Navigation Performance ("RNP") has driven safety-of-life services to use dedicated safety-of-life spectrum. The demands imposed by these safety critical services translate into a system that needs to demonstrate a very high level of availability, continuity, and integrity.

    - This also necessitates performing detailed systems compatibility assessments early on in system planning to ensure spectrum compatibility with other aviation systems, as well as non-aviation systems.

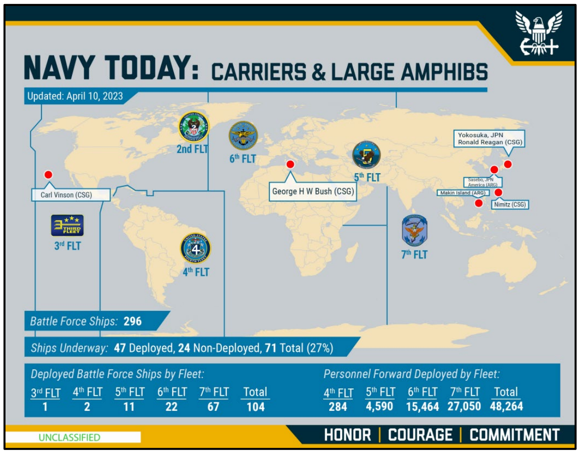
(e) How much, if at all, should our strategy by informed by work being performed within recognized standards-setting bodies (e.g., 3GPP, IEEE), international agencies (e.g., ITU), and non-U.S. regulators or policymakers (e.g., the European Union)?

While the U.S. should consider the work of international agencies and non-U.S. regulators or policymakers, **it should not be a *deciding* factor in U.S. spectrum strategy**.

There are several advantages to having internationally-harmonized frequency bands, as seen in civil aviation, maritime, space, and commercial wireless uses. However, the method of achieving harmonization—especially in critical Federal spectrum bands—is not a simple cut-and-paste exercise based on what other nations have done. **The U.S. is distinguished from other nations by the dominance of our aerospace and defense systems that are used around the world**.

With respect to defense, the extensive role the U.S. military plays in global security distinguishes Federal spectrum requirements from those of other nations. The U.S. has the most powerful military in the world with advanced technology that not only keeps our homeland safe, but also supports the defense of our foreign allies.

Our forward-deployed assets such as Navy carrier strike groups and long-range radars provide for the common defense of the U.S. and our allies, even allies that do not have such systems—or spectrum availability—within their borders.[2]



Likewise, U.S. land-based systems deployed in one nation may provide security for an entire region. For example, the Terminal High Altitude Area Defense system ("THAAD"), which uses RTX's AN/TPY-2 radar, is deployed globally and can detect and intercept ballistic missiles that may threaten several neighboring allied nations.

U.S. defense contractors also play a critical role in global security by developing, testing, and sustaining the products that ensure U.S. and allied military dominance. Contractors require access to DoD spectrum to test products that are used by both the U.S. military and allied militaries via foreign military sales ("FMS"). **While a U.S. Navy or allied navy radar may be operated on a vessel far away from the U.S., the system must still be tested at land-based contractor sites in the U.S.** Other nations do not have a defense industrial base comparable with U.S., which is evidenced by the fact that **the DoD manages over $50B in FMS exports each year**.

The same distinguishing factors apply to the commercial aerospace sector. **New aircraft and components play a major role to the U.S. economy, producing the highest trade balance of all manufacturing sectors with a recent positive balance of over $50B and pre-COVID balances above $80B**. Aircraft likewise contribute to the global economy by facilitating the international trade of goods and services, as well as the ability of millions of people to travel safely and affordably. As with defense products, commercial aerospace products are

[2] In terms of sheer numbers, the U.S. far exceeds our allies in several areas. The U.S. operates 11 of the 17 NATO aircraft carriers and 13,000 of the 20,000 NATO aircraft. The U.S. also operates over 750 military bases in 80 countries around the world.

developed, manufactured, and tested in the U.S., and spectrum plays a critical role in this process.

Other nations may be able to share government spectrum for commercial use within their borders, but these nations do not have militaries that match the scale of the U.S., nor do they have comparable aerospace and defense industries. Yet, these same nations benefit from products built and tested in the U.S., and U.S. defensive systems just outside their borders. In light of these distinguishing factors, the U.S. must chart its own course.

(f) What relationship (if any) should our strategy have to the work of these entities?

The U.S. should maintain awareness of the work of these entities and participate in working groups. However, the U.S. must ensure that its Strategy and positions reflect the needs of <u>all</u> U.S. spectrum users, including government, the aerospace and defense industry, and a wide variety of other industries.

(g) Are there spectrum bands supporting legacy technology (e.g., 3G, GSM, CDMA, etc.) that can be repurposed to support newer technologies for Federal or non-Federal use?

The NTIA should recommend further studies in this area to validate whether the commercial wireless industry is efficiently using its exclusive licensed spectrum. Since 5G and NextG systems can operate in any frequency, legacy bands could certainly be utilized to provide such services. Furthermore, the NTIA should consider bi-directional sharing whereby the commercial wireless industry shares its spectrum with the Federal government. A true sharing regime should work both ways.

<u>1.2 Question 2</u>

Describe why the amount of spectrum now available will be insufficient to deliver current or future services or capabilities of concern to stakeholders. We are particularly interested in any information on the utilization of existing spectrum resources (including in historically underserved or disconnected communities such as rural areas and Tribal lands) or technical specifications for minimum bandwidths for future services or capabilities. As discussed in greater detail in Pillar #3, are there options available for increasing spectrum access in addition to or instead of repurposing spectrum (i.e., improving the technological capabilities of deployed systems, increasing or improving infrastructure build outs)?

N/A.

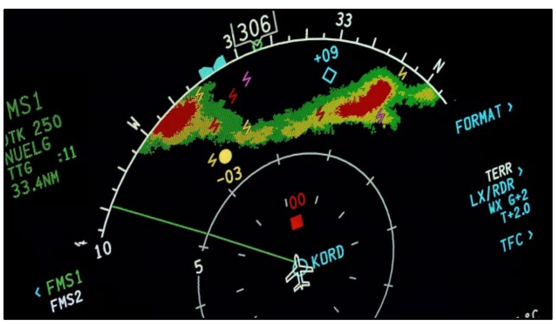
1.3 Question 3

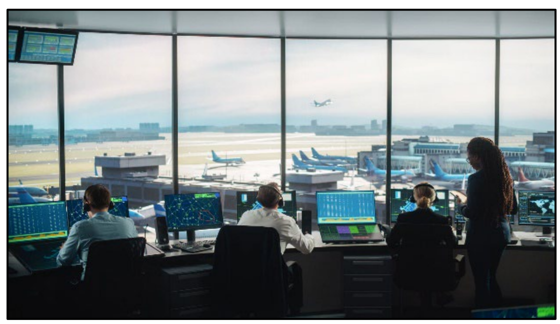
What spectrum bands should be studied for potential repurposing for the services or missions of interest or concern to you over the short, medium, and long term? Why should opening or expanding access to those bands be a national priority. For each band identified, what are some anticipated concerns? Are there spectrum access models (e.g., low-power unlicensed, dynamic sharing) that would either expedite the timeline or streamline the process for repurposing the band?

Bands supporting critical Federal government missions such national defense and aviation safety are poor candidates for "full power" sharing with the commercial wireless industry. The deployment of nationwide 5G networks where subscribers expect full coverage on a 24/7/365 basis is often incompatible with the needs of incumbent Federal missions within these bands or adjacent to them.

For example, the DoD—and its contractors—require access to full radiolocation bands for radar development, testing, training, operation, and sustainment activities. Operational DoD use may require spectrum access on a 24/7/365 basis in some areas, and contractor developmental testing may be ongoing 24/7 for several months at a time.

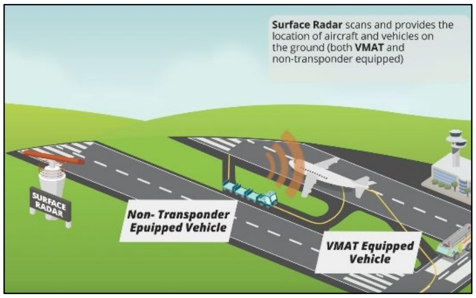
Likewise, aviation safety-of-life systems such as radar altimeters, traffic collision avoidance systems, and surveillance radars have zero tolerance for interference. Pilots and controllers sometimes have seconds to make life-or-death decisions and depend on equipment to function flawlessly.





In contrast to "full power" 5G systems, low power and/or unlicensed systems may be suitable secondary uses for sharing of *some* Federal bands. For example, low-power tank fluid level radars used by the petroleum and chemical industries operate in the 8.5 – 10 GHz band using downward-facing antennas under the "RS" Part 90 secondary radiolocation service. These radars cross the 9.0 – 9.2 GHz band, which is allocated for aeronautical radionavigation safety-of-life for ASDE-X surface radars and DoD precision approach radars. These fluid level radars can utilize this spectrum without any adverse impact to aeronautical and military systems. There may be several new and innovative low power or unlicensed use cases to explore similar to this example.

Tank Sensor



ASDE-X

DoD Radar

With respect to accommodating "full power" 5G services, there will continue to be an inherent conflict between Federal missions and the commercial wireless industry as long as the focus is on vacating Federal bands and reallocating spectrum to the wireless industry on an exclusive basis. Vacating Federal spectrum bands is not viable when national security or aviation safety is at stake.

A superior model would be to identify spectrum bands to be shared with the commercial wireless industry on a secondary basis. Federal incumbents would still have access to spectrum when and where it is needed, including potential future use cases and locations. Non-Federal users could access the spectrum when it is not used for Federal missions. This concept is similar to the incumbent access model of the Citizens Broadband Radio Service ("CBRS") where Federal users always have access when needed, but lower tier users can use spectrum when it is available.

This additional secondary spectrum could supplement the exclusive spectrum bands already used by the commercial wireless industry in its existing networks. Since these networks already have low-band spectrum to provide a "coverage" layer and higher bands to provide "capacity," the secondary bands would be a "speed boost" to data rates when they are available. The unavailability of this spectrum would not result in a "dropped call" or disruption of a video, although the user may have to watch a video in 720p instead of 4K resolution.

If multiple bands are identified for this type of secondary access, several "channels" can be created to increase the availability of spectrum. Commercial users could employ dynamic spectrum sharing techniques similar to Wi-Fi that allow their networks to "hop" onto available channels and likewise vacate channels when used for Federal missions. The graphic below shows several channels allocated for shared use, with blue shading for channels used by Federal incumbents and green shading for available channels for commercial use. Availability changes over time depending on incumbent use.

In this way, Federal users—including contractors—do not suffer a permanent loss of access to critical spectrum bands while non-Federal users enjoy enhanced data rates during Federal downtimes. It could be a win-win for all.

1.4 Question 4

(a) What factors should be considered in identifying spectrum for the pipeline?

- *Federal Agency Planning:* Each Federal agency should maintain a long-term spectrum plan that identifies its projected future needs as well as any bands that may be appropriate for sharing. These agencies have the expertise to determine which spectrum is critical to their missions what the impacts of sharing may be.

- *Critical Mission*: Does the spectrum—including adjacent bands—support a critical mission such as national defense of aviation safety? The more critical the mission, the less appropriate the band may be for sharing.

- *Adjacent Band Compatibility*: The proposed use of the targeted spectrum should be compatible with the "neighborhood" of users in adjacent bands, and not be the equivalent of a skyscraper next to a house. The *Ligado* issue is an example of potentially incompatible neighbors where there would be a full-power terrestrial wireless network in close proximity to highly-sensitive, low-power GPS operations.

- *Stakeholder Input*: **Aerospace and defense manufacturers are key stakeholders in initiatives to share Federal spectrum**, as Federal systems are designed, manufactured, tested, and sustained at contractor facilities. Contractor test facilities were not taken into account during the AMBIT proceeding in 3.45 – 3.55 GHz, and as a result, many facilities now lack reliable access to the Federal radiolocation band for product testing.

- *Full Product Lifecycle*: **Spectrum utilization must be considered for all aspects of the lengthy product lifecycle, including the extensive amount of RF testing that occurs at contractor test ranges during product development, manufacturing, and sustainment**. Merely counting how many operational NTIA frequency assignments have been issued at government-owned facilities runs the risk of missing early developmental testing that occurs at contractor facilities under FCC experimental licenses before Stage 2 certification, as well as the long-term sustainment activities after Stage 4 certification.

- *Foreign Military Sales*: DoD FMS must be taken into account, as these systems are built and tested in the U.S. by aerospace and defense contractors. Even if the DoD no longer utilizes a legacy FMS system, foreign allies often rely on this technology and it must still be tested in the U.S. at contractor facilities.

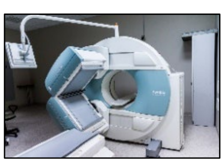
- *Diversity of Future Users*: The NTIA should consider a diversity of potential future users when identifying spectrum beyond the commercial wireless industry. There are multiple other commercial, educational, and scientific users of spectrum that could drive innovations to increase U.S. competitiveness.

- *Scientific Method*: The feasibility of spectrum sharing must be based on unbiased, neutral scientific analyses, including extensive field studies to determine compatibility between incumbent and new uses.

(b) Should the Strategy promote diverse spectrum access opportunities including widespread, intensive, and low-cost access to spectrum-based services for consumers?

The Strategy should consider opportunities for a wide variety of users to maximize opportunities for innovation for all parties, including small businesses and nascent industries that may not have funding to outbid other parties at spectrum auctions.

For example, the industrial, scientific, and medical bands, which were first established in 1947, have provided tremendous benefits to consumers in the form of Wi-Fi, microwave ovens, Bluetooth, baby monitors, garage door openers, contactless payment systems, MRI machines, and RF manufacturing devices. Consumers benefit greatly from the unlicensed spectrum utilized by these devices. Likewise, low-power uses such as the tank level monitor described in the response to Question 3 can be compatible with higher-power Federal missions.



There are also benefits of allocating spectrum for special uses that also drive innovation. For example, various bands managed by the Aerospace & Flight Test Radio Coordinating Council ("AFTRCC") are reserved for flight testing. These frequencies include HF/VHF channels for flight test communications as well as various bands for aeronautical mobile telemetry. Flight testing is critical for the development and certification of aerospace products, as it identifies issues that may impact aircraft performance or flight safety. During flight testing, pilots perform aggressive maneuvers that push aircraft to their limits while ground-based engineers analyze telemetry data such as stresses on wings and control surfaces, engine temperatures, and fluid pressures.


In contrast to 5G bands where wireless carriers have paid significant sums for spectrum for exclusive 24/7 use, flight test licensees use spectrum on a non-exclusive, as-needed basis in coordination with others. Flight test licensees do not need to win spectrum at auction nor pay a recurring monthly fee to use it.

However, flight test spectrum has become exceedingly crowded as data volumes increase and telemetry bands are repurposed for other uses. In light of the benefits of reserving spectrum for special uses such as flight testing, the NTIA should consider this use as well other potential innovative uses that could benefit from a similar approach.

(c) Should the Strategy promote next-generation products and services in historically underserved or disconnected communities such as rural areas and Tribal lands?

New spectrum is not necessarily needed to serve these communities, especially mid- and high-band spectrum with limited propagation range. Existing low-band spectrum in 600, 700 and 800 MHz that is already exclusively allocated for commercial wireless use is most appropriate to provide economical coverage of large geographic areas.

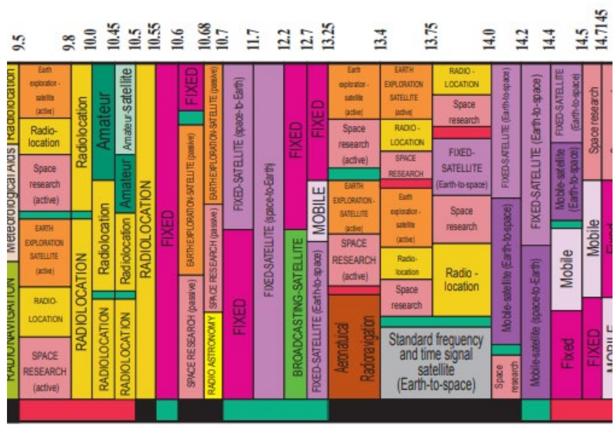
(d) Should the Strategy prioritize for repurposing spectrum bands that are internationally harmonized and that can lead to economies of scale in network equipment and devices?

As previously discussed in Question 1 regarding the influence of international standards, the U.S. should be cognizant of international harmonization but should chart its own course based on the specific needs of incumbent users and the feasibility of sharing. Likewise, the term "repurpose" should not be part of the Strategy, as this word implies that existing incumbent users will vacate the band to make room for new user. The term "share" is more appropriate.

(e) How should the Strategy balance these goals with factors such as potential transition costs for a given band or the availability of alternative spectrum resources for incumbent users?

This question presumes that spectrum "sharing" means the permanent vacation or compression of Federal bands to make room for commercial wireless services. **However, this concept of sharing is not sustainable because at some point—which we may have already reached—the Federal government will have no more spectrum to cede or relocate to.**

Spectrum allocations are already exceedingly cramped, with some bands having multiple co-primary users and secondary users competing for the same spectrum. Passive services such as radio astronomy are increasingly threatened by intensified uses in adjacent bands, as is the experimental radio service that is critical to new product development.



Federal missions also have evolving requirements that demand more spectrum, and Federal missions must also be prepared to address future challenges. "Transitioning" out of a band is gambling that the Federal government will never need that spectrum again, as it is financially and logistically unfeasible to "reclaim" spectrum from the wireless industry. National emergency powers to temporarily utilize non-Federal spectrum are hardly sufficient to support a national defense mission that operates 24/7/365.[3]

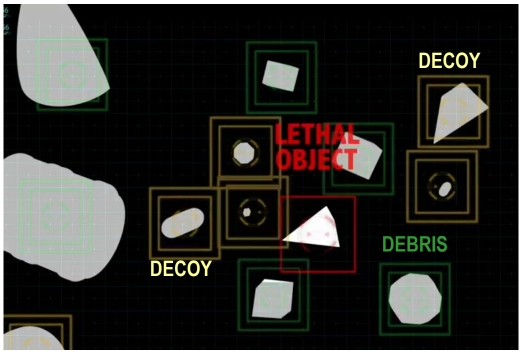
NTIA strategy should be focused on retaining Federal spectrum but providing non-Federal secondary access, as well as promoting intelligent spectrum sharing techniques to allow co-existence of Federal and non-Federal users.

(f) How should the Strategy balance these goals against critical government missions?

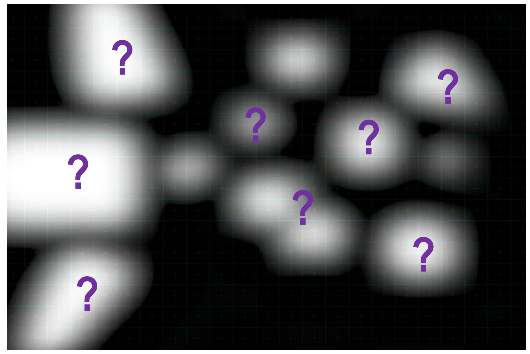
Critical government missions such as national defense and aviation safety cannot be compromised to provide additional spectrum to the commercial wireless industry. Federal government missions such as ballistic missile defense, naval and air superiority, and air traffic control have zero margin for error, and every second counts.

[3] While the President can authorize the utilization of non-Federal spectrum in a national emergency, this authority is for true emergency situations where there is imminent danger. It is insufficient for the day-to-day usage of spectrum for Federal missions such as monitoring U.S. airspace for threats.

For example, compressing a wideband radar allocation may cause the system to fail its mission. Insufficient bandwidth may prevent a radar from identifying critical threats that exist today such as a hypersonic missile that is traveling over 1 mile per second or an ICBM traveling over 4 miles per second. Tomorrow's hypersonics may travel even faster. Below is an example of how a wideband radar uses spectrum to distinguish between warheads and decoys released from an ICBM vs. a radar with insufficient spectrum to "discriminate" these objects. Being able to distinguish between a warhead and a decoy is essential for our defensive systems to intercept such a dangerous threat.

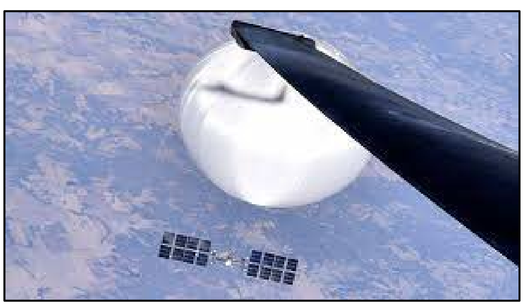


Wide Radar Band
Target Identified



Compressed Radar Band
Target Missed

Defense systems must also be able to detect and counter new threats such as the Chinese surveillance balloon that traversed the U.S. in early 2023. **While much attention is placed on the threat of China in the "Race to 5G," China's aggressive military and intelligence activities pose an ominous and very real threat to U.S. national security.** To counter these threats, the U.S. must maintain a technological edge over our adversaries, as aptly stated in the DoD's *2022 National Defense Strategy*.[4] Defense spectrum superiority is a critical component of that strategy.



Surveillance Balloon

DF-17 Missile w/DF-ZF Hypersonic Vehicle

[4] The *2022 National Defense Strategy of The United States of America* states: "The United States' technological edge has long been a foundation of our military advantage."

The benefits of having a technological edge over our adversaries has been clearly demonstrated in the war of Ukraine against Russian armor. Russia employs "reactive armor" developed during the Soviet era that was intended to reduce damage from horizontally-fired enemy tank rounds. However, the Javelin anti-tank weapon—produced by a joint venture between RTX and Lockheed Martin—can defeat tanks with reactive armor by attacking them from the top. Javelins have destroyed countless Russian tanks in Ukraine, providing a numerically inferior force with a superior technological advantage.



Just as military systems support critical missions, safety-of-life aviation systems such as radar altimeters, ADS-B transponders, and traffic collision avoidance systems cannot fail due to RF interference. These systems are particularly important as global air traffic steadily returns to pre-COVID levels of 4.7 billion passengers per year, and pilots must contend with sUAS and eVTOLs in the national airspace.

A balanced approach would be to share—not vacate—Federal spectrum bands, provided that critical government missions are not compromised. NTIA strategy should promote new or upgraded Federal systems capable of co-existing with non-Federal systems using advanced spectrum sharing techniques. More resilient and dynamic Federal systems would permit incumbent operations to continue while creating opportunities for non-Federal users to dynamically utilize a shared band over larger geographic areas, at increased power levels, and with minimal disruption to their operations.

(g) How should the Strategy assess efficient spectrum use and the potential for sharing?

The Strategy should identify older Federal systems that could be upgraded or replaced with newer systems more capable of coexisting in a shared environment, but with the primary understanding that Federal bands will not be vacated. Older systems may be more susceptible to interference, requiring potential non-Federal users in a shared band to reduce power levels and setback distances from Federal systems, or power down entirely. Newer systems could permit Federal and non-Federal users to share spectrum without compromising important government missions. Likewise, non-Federal systems should employ similar technologies to facilitate a true sharing environment.

The Strategy must be cautious not to focus solely on allocated Federal bandwidth and how many frequency assignments are in the Government Master File, as this view of "efficiency" does not account for wideband requirements and the need for a diversity of bands to accomplish different missions.

Federal radiolocation bands, for example, are frequent targets for spectrum compression due to their wide allocations and the mistaken assumption that such allocations "inefficient." However, wideband allocations are required for radars to operate effectively for target discrimination, jamming resiliency, and unit interoperability. Compressing bands substantially increases the risk that our systems will fail their critical missions.

Another important factor to consider, especially for radars, is that multiple frequency bands are used across the spectrum due to vastly different missions of the radars and the physical propagation characteristics of their spectrum. The government cannot vacate a critical band and move elsewhere.

Over-the-horizon radars (“OTHR”), which operate in the HF band using less than 30 MHz of bandwidth, can detect objects over 1,000 miles away. These systems may be perceived as being extremely efficient, but in reality, their accuracy is limited and they must be supplemented by radars in other bands. L-band radars such as FAA air route surveillance radars have much less range than an OTHR and require more spectrum, but can detect and track targets with superior accuracy. L-band systems are likewise very large and not suitable for mobile platforms such as aircraft and ships. S- and C-band systems are a “sweet spot” of range, accuracy, and portability, but require wideband allocations to effectively perform their missions. X-band radars provide excellent target and weather resolution and can be portable enough to fit in the nose cone of aircraft. Ku-band systems are compact and ideal for detecting small targets such as drones, rockets, and mortars.

OTHR (HF Band)

ARSR (L Band)

SPY-6 (S Band)

LTAMDS (C Band)

APG-79 (X Band)

KuRFS (Ku Band)

The various characteristics of systems like radars operating in various bands must be considered in any feasibility analysis. **The Federal government cannot merely vacate S- or C-band because there are other radiolocation bands available, as doing so would result in the loss of the critical and unique capabilities served by systems in those bands.**

(h) What is an ideal timeline framework suitable for identifying and repurposing spectrum in order to be responsive to rapid changes in technology, from introduction of a pipeline to actual deployment of systems?

The ideal timeline for spectrum *sharing* should depend on the impacted Federal incumbent user, the feasibility of sharing, and the timetable to develop upgrades or replacements to current systems. **The needs of the commercial wireless industry should not be the sole factor in determining which Federal bands should be shared and the timeline for doing so. Such a methodology is inherently reactive and can result in poor outcomes for Federal users, including aerospace and defense contractors.**

Federal systems—especially DoD systems—are more complex than commercial systems employed by wireless carriers and broadcasters. One does not simply “repack” a wideband radar allocation in the same way broadcast television spectrum is “repacked.” The radar depends on wideband waveforms to effectively track an ICMB traveling at 15,000 mph while overcoming enemy jamming. Even minor system modifications within the allocated spectrum band such as software upgrades require extensive testing to ensure that the radar’s mission is not compromised. These changes are not as simple, for example, as converting from analog to digital television technology that can operate with less spectrum.

Furthermore, Federal acquisition and certification timelines take significantly longer than commercial systems due to various reasons including the handling of export-controlled and classified information, **rigorous field testing (which can be significantly delayed if contractors lack sufficient access to a band**), supplier constraints, production capacity, and compliance with complicated acquisition regulations.

Instead of a reactive approach, the Strategy should promote a *proactive* approach whereby Federal users continually identify legacy systems that could be upgraded or replaced with systems with greater spectrum sharing capabilities. Expanded use of the Other Transaction consortium model could promote prototypes of new Federal systems with enhanced spectrum sharing capabilities. Federal users could *initiate* spectrum sharing endeavors based on the capabilities of more evolved prototypes.

1.5 Question 5

Spectrum access underpins cutting- edge technology that serves important national purposes and government missions. Are there changes the government should make to its current spectrum management processes to better promote important national goals in the short, medium, and long term without jeopardizing current government missions?

The following changes are recommended to improve current government spectrum management processes:

- *RFAs for Contractor Testing.* **Federal contractors must have rapid access to NTIA radio frequency authorizations ("RFAs") when performing RF testing at their facilities in support of Federal contracts.** While many Federal agencies such as the DoD obtain RFAs at contractor facilities, the practice is not consistently followed and can take up to 18 months. RFAs at contractor facilities are critical to ensuring that the NTIA and Federal users have the "full picture" of spectrum utilization for Federal systems during the product lifecycle, including early product development and long-term sustainment. RFAs are likewise needed to ensure that contractor sites enjoy incumbent protections in spectrum sharing schemes such as CBRS.

- *"Stage 2(a)" Spectrum Certification.* One of the major obstacles in securing RFAs at contractor facilities is the requirement that systems have Stage 2 spectrum certification. Stage 2 certification requires an extensive amount of technical data (much of which is not needed for early experimentation) and can take 6-18 months to obtain. In contrast, FCC experimental licenses are issued in a matter of weeks for uncertified systems with a limited amount of technical data. **The NTIA should work with Federal agencies to either (i) modify the Stage 2 requirement for an RFA or (ii) create a fast-track "Stage 2(a)" certification that can be issued with the same amount of data submitted for an FCC experimental license.** A more detailed Stage 2(b) certification can follow. The combination of a fast-track Stage 2(a) certification and faster access to RFAs would create a system similar to the FCC experimental licensing process and accelerate contractor testing.

- *FMS Utilization*. The NTIA should develop a method to track spectrum utilization of FMS systems. FMS systems must be accounted for in spectrum sharing analyses, as these systems are built, tested, and often serviced in the U.S. at contractor facilities.

- *FAA as Mandatory Stakeholder of all Aviation Bands*. The FAA should be consulted in any spectrum sharing initiative that could impact aviation bands, regardless of whether the FAA itself operates systems in that band. The FAA has a dual role as both a Federal spectrum user—such as operating air route surveillance radars—and also as the primary regulator of aviation safety. The FAA may not have RFAs for systems in 4.2 – 4.4 GHz, which is extensively used by commercial aircraft and is licensed by rule, but it has a critical safety interest in potential impacts to radar altimeters.

1.6 Question 6

(a) For purposes of the Strategy, we propose to define ''spectrum sharing'' as optimized utilization of a band of spectrum by two or more users that includes shared use in frequency, time, and/or location domains, which can be static or dynamic. To implement the most effective sharing arrangement, in some situations incumbent users may need to vacate, compress or repack some portion of their systems or current use to enable optimum utilization while ensuring no harmful interference is caused among the spectrum users. Is this how spectrum sharing would be defined? If not, please provide a definition or principles that define spectrum sharing.

> RTX proposes a definition of spectrum sharing as:
>
> "[O]ptimized utilization of a band of spectrum by two or more users that includes shared use in frequency, time, and/or location domains, which can be static or dynamic. *Sharing of Federal spectrum shall be (1) without degradation to the Federal mission; (2) in a manner that provides current and future Federal users with sufficient regulatory protection; and (3) with minimal risk that such sharing will not result in a loss of access to the spectrum necessary to perform the Federal mission."*

This definition clarifies that "sharing" is true to the meaning of the word of two parties using the same resource, and likewise incorporates a "do no harm" principle to Federal missions. "Sharing" does not mean surrendering spectrum for another party's exclusive use, although the term is often used in this manner. Furthermore, the mention of the terms "vacate, compress, or repack" with respect to Federal spectrum implies that non-Federal users would never share spectrum bi-directionally with Federal users. The same principles of "sharing" should apply to all parties.

(b) What technologies, innovations or processes are currently available to facilitate spectrum sharing as it should be defined? What additional research and development may be required to advance potential new spectrum sharing models or regimes, who should conduct such research and development, and how should it be funded?

N/A

1.7 Question 7

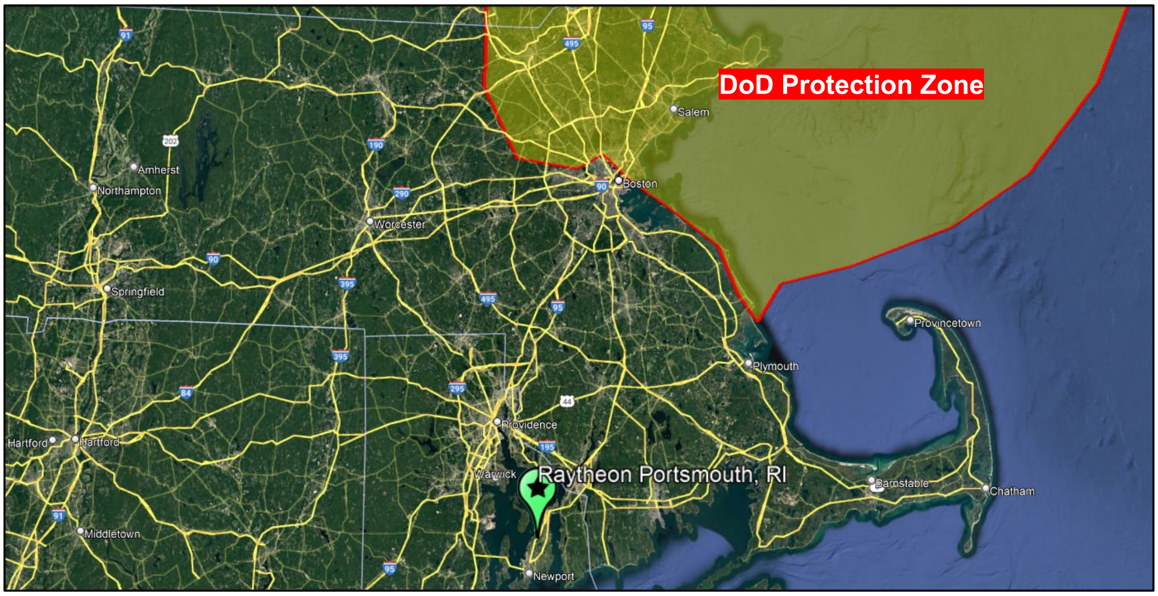
What are the use cases, benefits, and hinderances of each of the following spectrum access approaches: exclusive-use licensing; predefined sharing (static or predefined sharing of locations, frequency, time); and dynamic sharing (real-time or near real- time access, often with secondary use rights)? Are these approaches mutually exclusive (i.e., under what circumstances could a non-Federal, exclusive-use licensee in a band share with government users, from a non- Federal user point of view)? Have previous efforts to facilitate sharing, whether statically or dynamically, proven successful in promoting more intensive spectrum use while protecting incumbents? Please provide ideas or techniques for how to identify the potential for and protect against interference that incumbents in adjacent bands may experience when repurposing spectrum.

The three spectrum access approaches listed in the question have their own use cases, benefits, and hinderances.

- Exclusive-use licensing is the traditional method of spectrum access, where a licensee has the exclusive right to use a particular frequency band. The benefits of this approach are the ability to operate in a band without the need to coordinate with others and significantly less concerns of interference. However, exclusive-use licensing can result in the concentration of spectrum in a small number of companies with sufficient capital to win spectrum at auction, which could stifle new market entrants. Likewise, exclusive-use licensing may permanently prevent other parties from ever using the spectrum, as commercial wireless networks represent billions in sunk costs (as well as long-term leases that cannot be terminated) that would need to be reimbursed if such spectrum were ever repurposed. The most appropriate use of exclusive-use licensing is for "mission critical" uses such as safety-of-life aeronautical services, public safety, low-band commercial wireless frequencies that provide a "coverage" layer for emergency calls, low-power space transmissions (especially deep space), passive services such as radio astronomy, and various military systems.

- Static sharing involves pre-defined sharing of locations, frequency, or time. This approach can be challenging because it requires incumbent users to "snap a chalk line" as to its current spectrum utilization without regard to future use. This was the case of the AMBIT proceeding in 3.45 – 3.55 GHz where the DoD vacated radiolocation spectrum in all locations except pre-defined protection zones called CPAs and PUAs. The DoD has lost access to this spectrum and cannot regain it, even if a new threat such as a Chinese spy balloon drives a need for a wideband S-band radar sited outside of these areas.

Static protection zones also present a major challenge to aerospace and defense contractors who must test in full Federal bands per contract requirements, but whose facilities may fall outside of protection zones, as with AMBIT as shown below. Without access to the full band, contractors cannot meet Federal contract requirements.



RTX Portsmouth, RI Naval Test Site (outside of AMBIT protection zone)

Static protection zones also create an unfair playing field in the Federal acquisition process. Contractors that are coincidentally within a static protection zone have an unfair advantage over contractors outside of one.

- Dynamic sharing provides real-time or near real-time access, often with secondary use rights. This approach can enable more efficient spectrum use and increase opportunities for innovation and new entrants, while also providing some degree of certainty for incumbent users. However, it can also be more complex to manage and may require greater technical capabilities. While a perfect dynamic sharing system does not yet exist, dynamic approaches such as CBRS are a possible solution for Federal and non-Federal sharing. **CBRS preserves Federal incumbency and allows Federal use to be expanded as the need arises upon the issuance of an RFA. This model is "future proof" because no spectrum is surrendered and it is always available when needed.** CBRS also supports the Federal product lifecycle because RFAs can be issued for contractor sites supporting product development and sustainment, which ensures that RF testing requirements in contracts can be met. Furthermore, since RFAs can be issued (or revoked) at any location at any time, no contractor has a permanent advantage due to its facility being coincidentally located within a Federal static protection area.

NTIA strategy should focus on dynamic sharing models like CBRS. While the technical aspects of CBRS could be improved, the incumbency/RFA concept is the ideal method to support critical Federal missions while allowing secondary commercial use of the band when it is not needed. The availability of multiple shared bands, as outlined in our response to Question 3, would provide the flexibility to hop to available channels when others are used by Federal incumbents. Advancements in both Federal and non-Federal systems would be needed for a more effective sharing regime. These may include advanced interference detection and mitigation techniques, the use of interference protection criteria and standards, and the development of shared protocols and rules for spectrum access.

1.8 Question 8

What incentives or policies may encourage or facilitate the pursuit of more robust Federal and non-Federal spectrum sharing arrangements, including in mid-band and other high priority/demand spectrum? For example, does the current process for reimbursement of relocation or sharing costs adequately incentivize the study or analysis of spectrum frequencies for potential repurposing? Are there market-based, system-performance based or other approaches that would make it easier for Federal agencies to share or make spectrum available while maintaining Federal missions? At the same time, what mechanisms should be considered to meet some of the current and future Federal mission requirements by enabling new spectrum access opportunities in non-Federal bands, including on an ''as needed'' or opportunistic basis?

There are several incentives and policies that may encourage or facilitate more robust Federal and non-Federal spectrum sharing arrangements, including:

- *Dynamic Federal Systems*: Federal contracts for new systems could require contractors to design systems with dynamic sharing capabilities. Prototypes developed through OT consortia awards could result in follow-on contracts for full production models. Contractors would be incentivized to expend research and development funds and to pursue OT opportunities for systems with dynamic capabilities.

- *Non-Federal Dynamic Systems*: Non-Federal systems intended to operate in shared bands should be required to incorporate dynamic sharing technology. Current networks are deployed with the expectation of exclusive, full-power use. However, such an approach is not viable when dealing with a limited resource in extremely high demand. New non-Federal systems must have the agility to operate in a shared environment. Techniques such as spectrum sensing, geo-location databases, and dynamic spectrum access can be used to identify and protect against interference. Licenses should only be awarded to users that can demonstrate that their systems can meet these performance requirements.

1.9 Question 9

How do allocations and varying spectrum access and governance models in the U.S. compare with actions in other nations, especially those vying to lead in terrestrial and space-based communications and technologies? How should the U.S. think about international harmonization and allocation disparities in developing the National Spectrum Strategy?

As explained in Question 1(e), the U.S. should consider the actions of other nations, but must chart its own course.

2. PILLAR #2: LONG-TERM SPECTRUM PLANNING

2.1 Question 1

Who are the groups or categories of affected stakeholders with interests in the development of the National Spectrum Strategy and participating in a long-term spectrum-planning process? How do we best ensure that all stakeholders can participate in a long-term spectrum planning process in order to facilitate transparency to the greatest extent possible, ensure efficient and effective use of the nation's spectrum resources?

The groups or categories of affected stakeholders with interests in the development of the Strategy and participating in a long-term spectrum-planning process may include, but are not limited to:

- Federal agencies, including those responsible for national defense, public safety, space, cybersecurity, transportation, and other critical infrastructure sectors that rely on spectrum for their operations;
- Federal contractors;
- Commercial device manufacturers;
- Commercial spectrum users, including commercial wireless providers, broadcasters, cable providers, satellite operators, and other private sector entities that rely on spectrum for their businesses;
- Academic and research institutions, who may have a stake in ensuring access to spectrum for scientific and educational purposes;
- Industry associations;
- Coordinating bodies such as AFTRCC; and
- Standards development organizations, who may be involved in developing technical standards for spectrum use and sharing.

To ensure that all stakeholders can participate in a long-term spectrum planning process, it may be necessary to employ a variety of methods, such as:

- Providing ample time for parties to respond to requests for information and comments;
- Providing multiple channels for input, such as public comment periods, stakeholder meetings, and online forums, as opposed to in-person meetings in Washington, D.C.;
- Ensuring that the process is transparent and accessible to all interested parties;
- Providing clear and understandable information about the process, including the goals, ground rules, and timelines;

- Leveraging technology and data to facilitate collaboration and decision-making, such as through the use of modeling and simulation tools to assess spectrum sharing scenarios; and

- National level conferences to bring all the identified stakeholders that can be designated with ITAR/US citizen sections, and possibly classified sections.

2.2 Question 2

What type of timeline would be defined as a ''long-term'' process? What are key factors to consider and what are the key inputs to a long-term planning process? What data are required for planning purposes? Do we need data on spectrum utilization by incumbent users, including adjacent band users, and, if so, how should we collect such data and what metrics should we use in assessing utilization? Do we need information from standards-setting bodies and, if so, what information would be helpful and how should we obtain such information? What is the appropriate time horizon for long-term spectrum planning and how often should we revisit or reassess our prior findings and determinations? How do we balance periodic review and reassessment of our spectrum priorities with providing regulatory certainty to protect investment-backed expectations of existing spectrum users? How can Federal and non-Federal stakeholders best work together?

A "long-term" process in spectrum planning can be defined in different ways depending on the specific needs and goals of the stakeholders involved. Some key factors to consider in a long-term planning process may include:

- Current and future spectrum requirements and demands, including those of both incumbent Federal users and potential non-Federal users;

- The full product lifecycle of Federal systems (including FAA regulated non-Federal systems) including early research and development, prototype testing, operational use, and long-term sustainment at both Federally-owned facilities and Federal contractor facilities; and

- The full product lifecycle of DoD FMS products, which are designed, manufactured, tested, and sustained in the U.S.

Key inputs to the process may include:

- The current and future missions of Federal systems, and an acknowledgement that Federal systems must adapt to all future challenges, even those believed to be impossible today;

- Research and development efforts related to *potential* new Federal systems, including efforts by Federally Funded Research & Development Centers ("FFRDC"), contractors through independent research and development ("IRAD"), and universities;

- Current and anticipated Federal acquisitions, which captures systems that will be built, but do not yet have spectrum certifications and RFAs, and are unlikely on the "radar" when assessing Federal spectrum interests;

- Challenges in updating or replacing legacy Federal systems with newer systems, including research and development timelines, regulatory certification timelines (including any modification of internationally-recognized standards and specifications), manufacturing timelines, and system deployment/installation timelines; and

- Current standardization obligations under international treaties such as the North Atlantic Treaty Organization Standardization Agreements ("STANAGs") to ensure allied force compatibility.

The NTIA should collect data regarding spectrum utilization by incumbent users—including Federal contractors—as well as adjacent band users. However, this is not a simple quantitative assessment that counts the number of RFAs and FCC licenses. A counting exercise misses a number of critical issues:

- All testing that is performed in anechoic chambers;

- Systems that are licensed by rule;

- Systems that are not yet built (and therefore do not yet have RFAs), but are being considered through research and development as well as current and planned Federal acquisitions;

- FMS utilization; and

- The qualitative aspects of the critical mission served by the system.

Instead, data collection should focus on metrics such as:

- Bandwidth utilization including wideband waveforms;

- Power levels and propagation distances;

- Receiver resiliency (recognizing that older systems may be more susceptible to out-of-band emissions);

- The number of current and projected systems, including those in IRAD and early contract phases;

- Geographic locations of current and projected systems, including all sites supporting the product lifecycle including contractor sites, government sites, and mobile areas for platforms such as aircraft, vessels, and ground vehicles; and

- Typical spectrum utilization periods (24/7, once per month, etc.), but acknowledging that infrequent system use is not a marker of inefficiency for critical missions (for example, ground-based interceptors may only be used in the event of an incoming ballistic missile attack on the U.S., which will hopefully never happen, but spectrum must be readily available in case it does).

Information from standards-setting bodies can also be helpful in the planning process, as it can provide insights into future spectrum requirements and technology trends. This information can be obtained through participation in standards bodies and through regular engagement and collaboration with industry stakeholders. Standards-setting bodies would not only include those supporting 3GPP, but also bodies in the civil aviation industry, space, and emerging industries such as autonomous vehicles.

Federal and non-Federal stakeholders can best work together by establishing clear communication channels, fostering collaboration and trust, and developing shared goals and objectives. Regular stakeholder engagement and participation can also help ensure that all voices are heard and considered in the planning process.

2.3 Question 3

How can Federal and non-Federal stakeholders best engage in productive and ongoing dialogue regarding spectrum allocation and authorization, repurposing, sharing, and coordination? Learning from prior experiences, what can be done to improve Federal/non- Federal spectrum coordination, compatibility, and interference protection assessments to avoid unnecessary delays resulting from non- consensus?

N/A.

2.4 Question 4

What technical and policy-focused activities can the U.S. Government implement that will foster trust among spectrum stakeholders and help drive consensus among all parties regarding spectrum allocation decisions?

N/A

2.5 Question 5

Are additional spectrum-focused engagements beyond those already established today (e.g., FCC's Technical Advisory Committee (TAC), NTIA's Commerce Spectrum Management Advisory Committee (CSMAC), and NTIA's annual Spectrum Policy Symposium) needed to improve trust, transparency, and communication among the Federal government, industry, and other stakeholders (including Tribal Nations) and why? What would be the scope of such engagements, how would they be structured, and why would establishing new engagements be preferable to expanding the use of existing models? If existing models are sufficient, how (if needed) should FCC and NTIA maximize their usefulness or leverage their contributions to enhance and improve coordination?

N/A

2.6 Question 6

In considering spectrum authorization broadly (i.e., to include both licensed and unlicensed models as well as Federal frequency assignments), what approaches (e.g., rationalization of spectrum bands or so-called ‘‘neighborhoods’’) may optimize the effectiveness of U.S. spectrum allocations? Are there any specific spectrum bands or ranges to be looked at that have high potential for expanding and optimizing access? Which, if any, of these spectrum bands or ranges should be prioritized for study and potential repurposing? Conversely, are there any bands or ranges that would not be appropriate for access expansion? What, if any, metrics are ideal for measuring the intensity of spectrum utilization by incumbents in candidate bands?

In general, the more critical the Federal mission—especially national defense and aviation safety—the greater the "standard of care" must be in analyzing the feasibility of *sharing* spectrum. Systems performing functions such as ballistic missile defense and air traffic control, for example, have zero tolerance for failure due to band compression or interference. Wideband radiolocation bands are particularly poor candidates for sharing due to high power levels and long-distance propagation, as well as the critical need to use wideband waveforms for effectiveness against advanced threats. Any bands supporting—or in proximity to—aeronautical safety-of-life services are also poor candidates.

In addition, extensive scrutiny must be given to any initiative to vacate or compress Federal bands, which could have catastrophic consequences for current and future missions. In contrast, initiatives that would preserve Federal incumbency while allowing shared secondary access for non-Federal use would preserve the government's ability to use the full band both now and in the future.

Our response to Question 2 identifies some of the metrics to be considered. As previously stated, Federal systems are significantly more complicated than non-Federal systems such as broadcasting and personal wireless services, so utilization analyses are more complicated than those performed in studies such as broadcast repacking.

2.7 Question 7

What is needed to develop, strengthen, and diversify the spectrum workforce to ensure an enduring, capable and inclusive workforce to carry out the long-term plans (including specifically in rural and Tribal communities)?

N/A.

3. PILLAR #3: UNPRECEDENTED SPECTRUM ACCESS AND MANAGEMENT THROUGH TECHNOLOGY DEVELOPMENT

We seek input on what categories of new or emerging technologies could best help to ensure the U.S. continues to innovate and maintain its global leadership in spectrum-based services.

3.1 Question 1

What innovations and next- generation capabilities for spectrum management models (including both licensed and unlicensed) are being explored today and are expected in the future to expand and improve spectrum access (and what are the anticipated timelines for delivery)?

The following spectrum management models and associated technological capabilities should be considered:

- *Dynamic Spectrum Sharing (DSS):* DSS enables the sharing of spectrum between multiple users in real-time without interfering with each other. This technology can be applied to both licensed and unlicensed bands and has the potential to significantly increase spectrum access and efficiency;

- *Spectrum Access Systems (SAS)*: SAS is a cloud-based system that dynamically assigns available spectrum to users in the CBRS band. SAS allows for the efficient and flexible use of spectrum, enabling new services and applications;

- *Artificial Intelligence (AI) and Machine Learning (ML)*: AI and ML can be used to optimize spectrum use by predicting usage patterns, identifying interference sources, and managing spectrum allocation in real-time. This technology has the potential to significantly increase spectrum efficiency and reduce the risk of interference;

- *Software-Defined Radios (SDR)*: SDRs are radios that use software to define their functions, making them highly adaptable to different frequency bands and modulation schemes. SDRs can be reprogrammed remotely, allowing for efficient and flexible spectrum use;

- *Advanced Antennas*: Antenna technology plays a crucial role in increasing the efficiency and capacity of wireless networks. Advanced antenna technologies such as MIMO (Multiple Input Multiple Output), massive MIMO, and beamforming can increase spectral efficiency and expand the usable capacity of spectrum;

- *Multi-Band Antenna*: The technology is progressing where antennas that can support multiple bands are increasing, leading towards the ideal software defined radio;

- *Forward Error Correction*: Algorithms and techniques are improving so that holistic bit errors can be improved with algorithms that can inject redundant bits and recover errors on the receiver side;

- *Data Modulation*: Modulation techniques have been improving that can increase data spectral efficiencies and mitigate potential interference and multipath; and

- *Cognitive Radios*: Cognitive radio technology allows devices to dynamically sense and adapt to their environment, enabling them to use spectrum opportunistically and efficiently. Cognitive radios can help to address spectrum scarcity and increase overall spectrum utilization.

3.2 Question 2

What policies should the National Spectrum Strategy identify to enable development of new and innovative uses of spectrum?

N/A

3.3 Question 3

What role, if any, should the government play in promoting research into, investment in, and development of technological advancements in spectrum management, spectrum-dependent technologies, and infrastructure? What role, if any, should the government play in participating in standards development, supporting the use of network architectures, and promoting tools such as artificial intelligence and machine learning for spectrum coordination or interference protections? What technologies are available to ensure appropriate interference protection for incumbents in adjacent bands? What spectrum management capabilities/tools would enable advanced modeling and more robust and quicker implementation of spectrum sharing that satisfies the needs of non-Federal interests while maintaining the spectrum access necessary to satisfy current and future mission requirements and operations of Federal entities? How can data- collection capabilities or other resources, such as testbeds, be leveraged (including those on Tribal lands and with Tribal governments)?

The government already plays a vital role in promoting research and development of technological advancements in spectrum management, spectrum-dependent technologies, and infrastructure. The government can facilitate and support research initiatives in collaboration with academia, industry, and non-profit organizations. The government can also invest in the development of advanced tools, such as artificial intelligence and machine learning, to enable more efficient and effective spectrum coordination and interference protection. The use of FFRDCs, allowability of IRAD efforts in government contracts, use of OT consortia for innovative prototypes, and standard Federal contracts support the advancement of new spectrum-dependent technologies.

The Small Business Innovation Research (“SBIR”) and Small Business Technology Transfer (“STTR”) programs are ideal to encourage domestic small businesses to engage in Federal Research/Research and Development with the potential for commercialization. These vehicles can be used to motivate a larger group for new ideas.

The government should participate in or monitor standards development and support the use of network architectures that are conducive to spectrum sharing. By doing so, the government can promote interoperability and ensure that spectrum-dependent technologies work seamlessly across different networks and systems, identify gaps and if necessary, provide competitive funding vehicles.

There are several technologies available to ensure appropriate interference protection for incumbents in adjacent bands. These technologies include dynamic spectrum access, cognitive radios, and spectrum sensing. These technologies can enable real-time spectrum sharing while minimizing the risk of harmful interference.

Advanced modeling capabilities and more robust spectrum sharing tools can enable quicker implementation of spectrum sharing that satisfies the needs of non-Federal interests while maintaining spectrum access necessary for current and future mission requirements and operations of Federal entities. These capabilities can include the use of advanced simulation tools and data analytics to evaluate different spectrum sharing scenarios and identify the most efficient and effective approach.

Data collection capabilities and resources such as testbeds can be leveraged to support spectrum management and sharing. Tribal lands and governments can play a vital role in this effort by providing access to spectrum resources and participating in research and development initiatives. The government can work with Tribal governments to ensure that their unique perspectives and needs are considered in the development of spectrum management policies and strategies.

3.4 Question 4

NTIA is pursuing a time-based spectrum sharing solution called the incumbent informing capability (IIC) to support spectrum sharing between Federal and non-Federal users. What are some recommendations for developing an enduring, scalable mechanism for managing shared spectrum access using the IIC or other similar mechanism, with the goal of increasing the efficiency of spectrum use? What challenges do non- Federal users foresee with potentially having limited access to classified or other sensitive data on Federal spectrum uses and operations as part of the IIC or similar capabilities, and what recommendations do users have for ways to mitigate these challenges? What are the costs and complexities associated with automating information on spectrum use?

The IIC could effectively enable *some* incumbent operations—including those at Federal contractor sites—to submit information, reliably and securely, about when and where they would be employing certain frequencies. The following are some general ways in which an approach like IIC could potentially be improved:

- Limit to uses that are reasonably capable of scheduling such as testing and training;

- Avoid operational uses where spectrum access requirements are constant and/or may be unpredictable and immediate (such as ballistic missile interceptors);

- Increase the accuracy and granularity of the information submitted. The information submitted by Federal users needs to be accurate and granular enough to allow the SCS to make informed decisions. This would achieve more precise location and frequency data by developing more sophisticated modeling and prediction tools;

- Add some mechanism to understand and manage adversarial interference, which could involve working with DoD to understand adversarial monitoring or jamming;

- Ensure that the process is streamlined, since an overly-complex and time-consuming process may discourage Federal users from using the IIC approach; and

- Develop more robust security measures to prevent unauthorized access or tampering.

Non-Federal users may have concerns about limited access to classified or other sensitive data on Federal spectrum uses and operations as part of the IIC or similar capabilities. To mitigate these challenges, NTIA should work with Federal agencies to ensure that non-Federal users have access to as much information as possible without compromising security or classified information. As an added security measure, Federal agencies should sponsor non-Federal employees for security clearances to facilitate more secure communications.

3.5 Question 5

What other technologies and methodologies are currently being, or should be, researched and pursued that innovate in real-time dynamic spectrum sharing, particularly technologies that may not rely on databases?

There are several technologies and methodologies being researched and pursued that innovate in real-time dynamic spectrum sharing, including:

- *Cognitive radio*: This technology enables devices to sense their environment and dynamically adjust their frequency, power, and modulation parameters to avoid interference and optimize spectrum use;

- *Spectrum sensing*: This technology involves using sensors to detect the presence or absence of signals in a particular frequency band, which can then be used to dynamically allocate spectrum to non-Federal users;

- *Geolocation*: This technology involves using the location of the device to determine which frequencies are available for use, allowing for dynamic allocation of spectrum in real-time;

- *Artificial intelligence and machine learning*: These technologies can be used to develop more sophisticated algorithms for dynamic spectrum sharing, enabling real-time decision-making based on changing network conditions and user demand;

- *Cooperative communication*: This technology allows devices to communicate with each other and share spectrum resources, enabling more efficient spectrum use and reducing interference;

- *Multi-band antennas*. Technology development is needed to create wide antenna arrays that can be truly used for software defined and cognitive radios; and

- *RF System on a chip*. Technologies and in semiconductor to enable wide spectrum components are needed to evolve spectrum sharing.

Research and development efforts in these areas could lead to new and innovative approaches to dynamic spectrum sharing that do not rely on databases, providing greater flexibility and efficiency in spectrum allocation.

CONCLUSION

RTX appreciates the NTIA's efforts to develop a National Spectrum Strategy. A proactive, strategic approach to spectrum sharing is superior to rushed, ad hoc efforts that may result in permanent degradations to Federal capabilities. A Strategy focused on true sharing of spectrum—rather than vacating Federal bands for permanent, exclusive non-Federal use—could make more spectrum available without compromising important Federal missions. This Strategy must consider the full picture of Federal spectrum use, including early-stage research and development at FFRDCs and contractor facilities all the way through sustainment at both government and contractor facilities. Consideration must be given to future Federal missions, both anticipated and unanticipated.

A thoughtful Strategy can be a win-win for all stakeholders. Non-Federal users can have greater access to Federal bands, government users can continue to fulfill their critical missions, and Federal contractors can continue to develop innovative solutions to our nation's greatest challenges.