COMMERCE SPECTRUM MANAGEMENT ADVISORY COMMITTEE (CSMAC)

Report of Unmanned Aircraft Spectrum Subcommittee:

Carolyn Kahn, Co-Chair
Andrew Roy, Co-Chair
Audrey Allison
Donna Bethea-Murphy
Michael Calabrese
Tom Dombrowsky
Mark Gibson
Mark McHenry
Carl Povelites
Dennis Roberson
Mariam Sorond
Bryan Tramont
Richard Orsulak, NTIA Liaison
David Reed, NTIA Liaison

FINAL REPORT

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COMMERCE SPECTRUM MANAGEMENT ADVISORY COMMITTEE WORKING GROUP 4: UNMANNED AIRCRAFT SPECTRUM: FINAL REPORT

Date: April 2021

MANDATE

The National Telecommunications and Information Administration (NTIA) mandate to the Commerce Spectrum Management Advisory (CSMAC) Working Group 4 (WG 4) is as follows:

a. The FAA has the responsibility of ensuring the safe integrations of all classes of UAS into the national airspace, from small to large UAS. Spectrum to support command and control operations will be critical for these emerging industry applications, to include urban air mobility and transcontinental cargo delivery.
b. What are appropriate models for ensuring timely and secure access to frequencies necessary to support UAS command and control requirements? What governance characteristics are important? Are there liability issues to consider for this function? Is it a 3rd party frequency coordinator model?
c. What is the potential need to create an entity that supports and facilitates collaboration across the disparate federal advisory committees for UAS?
    i. Develop alternative mechanisms and governance structures for such an entity.

While the work of CSMAC has several commonalities with the current work on Section 374 of the FAA Reauthorization Act, comments to that separate proceeding are not included in the subcommittee's scope of work.

APPROACH OF THE SUBCOMMITTEE

To answer NTIA's questions, CSMAC initiated a concurrent, two-tiered approach. First, the subcommittee identified options for spectrum access mechanisms for Unmanned Aircraft System (UAS) and evaluated them in terms of advantages, disadvantages, and other observations. CSMAC approached this work to provide complementary, value-added contributions to ongoing activities in the UAS domain.

Second, the subcommittee examined the current state of the UAS environment and the committees supporting it. It looked at the landscape of various organizations and their scope of activities pertaining to UAS spectrum. The subcommittee then conducted interviews with advisory boards and other organizations and experts to supplement this information. The subcommittee's questionnaire and interview highlights are included in the appendix of this report.

CSMAC planned a staggered start this term in an effort to help balance the workload across subcommittees. The WG 4 subcommittee commenced work on January 16, 2020, and typically met on a recurring two-week basis. During this time, the subcommittee held over 30 meetings via teleconference. The sections below summarize the CSMAC WG 4 efforts and recommendations.

INTRODUCTION

THE UAS ENVIRONMENT

The UAS[1] environment in the United States is in a dynamic state of development and innovation, with the technology having evolved at a rapid pace over the past 10 years. While many may see unmanned aircraft (UA) used as toys or a hobby, the commercial sector's development has continued to mature and, combined with federal agency usage, is the main driver of UAS technology. However, regulatory structures are needed to support UAS growth and safe integration into the National Airspace System (NAS), and this presents several policy and technical challenges. While spectrum allocations have been made available at the international and domestic levels, and several technologies have been certified by the Federal Aviation Administration (FAA) for use by UAS applications, the development of the necessary service rules for the deployment of Control and Non-Payload Communications (CNPC)[2] links has not yet been formalized.

The advancement of the commercial UAS industry has been assisted by the FAA Modernization and Reform Act of 2012, which enabled the 14 Code of Federal Regulations (CFR) Part 107 rulemaking effort that is now the basis for professional UAS pilot certification and operating rules for platforms less than 55 pounds. This has helped to enable UAs to be deployed into numerous commercial industry sectors, including goods delivery, media, agriculture, surveying, public safety, infrastructure, and entertainment, to name a few. Package delivery has been one of the early successes for UAS, allowing urgent medical supplies to be delivered more easily during the ongoing COVID-19 pandemic.

These early applications are just the beginning of what the systems can achieve once they reach maturity and eventually operate nearly seamlessly with manned aviation in the same airspace with minimal restrictions. However, they can only reach this full capability with suitable spectrum infrastructure, such as spectrum access mechanisms and necessary regulations, enabled by appropriate regulations for spectrum access.

TYPES OF UAS REGULATIONS CURRENTLY IN EFFECT

Pilot certification and operation of small UAS for Commercial Use (CFR 14, Part 107) has been the major focus of commercial UAS development since its introduction in 2016. Part 107 defines small UAS as "an unmanned aircraft weighing less than 55 pounds on takeoff, including everything that is on board or otherwise attached to the aircraft." A large number of pilots have been certified for small UAS, restricted to Visual Line of Sight (VLOS).[3] However, the limits of Part 107 are well known and were never intended to foster full integration into the NAS; rather Part 107 is considered a crucial initial step to facilitate the deployment of small, unmanned aircraft at low altitude.[4] Full integration into the NAS requires a comprehensive regulatory regime that integrates UAS into current aircraft development and

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[1] UAS are known by many other names, including drones and Remotely Piloted Air Systems. This report uses the *UAS* terminology.

[2] A commonly used synonym for CNPC is Command and Control (C2). This report uses the *CNPC* terminology.

[3] 14 CFR 107.31 does restrict the operations of small UAS operating under Part 107 to within the pilot's visual line of sight. However, 14 CFR 107.33 allows visual observers to aid a remote pilot when the pilot's visual line of sight cannot be maintained. Importantly, 107.205 allows the FAA to waive 107.31 and 107.33 as well as seven other Part 107 operations rules. Such waivers can expand the types and applications of existing small UAS operations in the short term, but are not a long-term solution that can be scaled up to full operations at all times.

[4] https://www.faa.gov/news/press_releases/news_story.cfm?newsId=18295

certification to ensure that new UAS airframes are able to integrate safely across the NAS with both manned and unmanned platforms.

Many operators are now going beyond Part 107, pursuing certification options with FAA under CFR 14 Part 135 air carrier certification, allowing package delivery operations that can go beyond VLOS. Several companies have since been granted FAA certification for operation,[5] though this does not automatically clear the way for drone deliveries across the country. Airframes used for such deliveries are still required to receive an airworthiness certification, a flight operations certification, and a remote pilot certification, and to operate on location-specific waivers from FAA.

To fly UAS heavier than the regulated 55-pound limit in Part 107, at the time of this report, operators may apply for a determination from the Department of Transportation (DOT) under the Special Authority for Certain Unmanned Systems (49 U.S.C. §44807). Additionally, FAA has recently completed a rulemaking on Remote ID procedures and a public consultation on Section 374 of the FAA Reauthorization Act, addressing UAS CNPC links as well as Detect and Avoid and surveillance spectrum.

CNPC LINKS FOR UAS

With the ongoing development of regulatory frameworks for UAS CNPC, no one clear definition (or even name) has been agreed on by all relevant domestic and international bodies. However, they all follow broadly the same intent as summarized by RTCA[6] in its work developing standards for FAA certification:

> *Data and information sent to/from the Pilot Station and the UA for control of the UA and other safety-critical functions. It does not include any messages sent to achieve mission (payload) objectives.*[7]

The clarification of not including payload data is a key caveat for these links, as such data is not used for safety and may be significantly larger in size than the CNPC traffic. Dependent on the possible CNPC link, CNPC and payload communications may be separated by communications type, if not the software/security domain the communications links operate within. Only these communication types will be considered within this report.

Implementation of CNPC is currently split into two main fields: systems specifically designed from the start as UAS, and existing systems/networks that can be adapted to certain UAS requirements. While new systems may sound like a better solution, existing systems may have established networks or technology that currently provides CNPC and therefore allows immediate access to UAS CNPC spectrum. This report considers all available options.

UAS CONSIDERATIONS FOR SPECTRUM

UAS (and indeed all aircraft) have many different operational and regulatory requirements that can often dictate different spectrum requirements for other industries. For example, many aviation applications are considered safety-of-life/safety-of-flight, requiring additional regulatory and certification requirements over other commercial traffic. Additionally, numerous other considerations for different Communication, Navigation, and Surveillance (CNS) functions need to be accounted for when considering spectrum access mechanisms for UAS:

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[5] https://www.faa.gov/uas/advanced_operations/package_delivery_drone/

[6] Known formerly as the Radio Technical Commission for Aeronautics

[7] See RTCA DO-377 - Minimum Aviation System Performance Standards for C2 Link Systems Supporting Operations of Unmanned Aircraft Systems in U.S. Airspace

- Aircraft can operate at all altitudes, and UAS can fly much closer to obstacles than traditionally larger, manned aircraft. This means long-range communications at altitude and also extremely low-level coverage are required.
- UAS mission types may range from automated activities confined to a small unrestricted area that can be under the supervision of a pilot within VLOS, up to long-range operation requiring direct control by a remote pilot in controlled airspace.
- UAS are inherently mobile and can operate with a wide range of different lateral and vertical flight profiles, up to and including the velocities of commercial aircraft (600 mph) or even beyond as new supersonic and sub-orbital vehicles are introduced.
- Fully automated operation for brief or longer periods may compensate for the loss of the CNPC link, through either loss of coverage or interference issues.
- Smaller UAS may not have the size, weight, and power to accommodate all necessary transceivers, and either limit mission types, or need to use other technologies that were not specifically designed for UAS operation but still meet the operational and regulatory requirements.
- Use in different airspace classes for different types of missions will prescribe certain CNS needs for each airframe, dictating possible spectrum requirements, link/network availability, and access models available to meet the required approvals for FAA certification.
- The UAS communications infrastructure may be controlled by single or multiple entities, which may or may not require a standardized communications system design.
- The number of anticipated UAS could exceed the capacity of systems designed for traffic from manned aviation, so alternative systems may need to scale for the large number of UAS anticipated (such as the recent FAA decision on Automatic Dependent Surveillance - Broadcast).
- Individual UAS may require spectrum access quickly (e.g., due to short-notice flights, changes to expected routes while in flight, or use of alternate airports).
- Maintaining Positioning, Navigation, and Timing (PNT) functions is critical for existing airspace users, and UAS will need such functions to an even greater extent, especially for autonomous flight.
- On a global basis, there are disparities in spectrum regulations that would need to be addressed and/or accommodated to facilitate the expected international UAS market.

At the time of this report, two aeronautical allocations are being analyzed by the Federal Communications Commission (FCC) for domestic UAS CNPC spectrum rules, 960-1164 and 5030-5091 MHz,[8] both of which have domestic and international Aeronautical Mobile (Route) Service (AM(R)S) allocations but lack the domestic service rules necessary to use them. Additionally, the FAA and aviation industry have been reluctant to approve CNPC links in the 960-1164 MHz band at this time until concerns about interference to incumbent navigation and surveillance systems have been resolved. However, the 5030-5091 MHz band has no significant restrictions foreseen and will be available for deployment on ground infrastructure once FCC service rules have been approved in coordination with the National Telecommunications and Information Administration (NTIA).

[8] The 5030-5091 MHz AM(R)S and AMS(R)S allocation is limited to internationally standardized aeronautical systems and could technically be used by any aeronautical system meeting such requirement (both manned and unmanned). However, work at ICAO and aviation authorities within the U.S. has focused on the band being dedicated for UAS links only.

FUTURE UAS DEVELOPMENT

The current and future types of UAS will vary widely both by physical size and by application. This will likely include the replacement of some manned aircraft types for commercial cargo (and even passenger traffic with suitable public acceptance), conforming with existing FAA regulations to ensure safe integration within the NAS. However, other applications that may not have been possible before, such as autonomous personal transport (e.g., Urban Air Mobility and Advanced Air Mobility[9]) and even sub-orbital space vehicles, are in development and expected to make significant headway in the near future. Each depends on the technology available, operational requirements, consumer demand, and suitable regulations.

The fast pace of development along with diversity of UAS applications has generated organic growth of the UAS development activities. Many groups and activities are working to advance UAS CNPC initiatives, including multiple government agencies and their federal advisory committees, as well as other committees. Technical innovation, standards development, performance requirements, investment, pilot programs, regulation and policy, and integration activities are needed to safely advance UAS technologies and markets.

[9] https://www.faa.gov/uas/advanced_operations/urban_air_mobility/

UAS SPECTRUM ACCESS MODELS

POTENTIAL SPECTRUM ACCESS MODELS

Based on information gathered and the subcommittee's own experiences, multiple spectrum access models have been identified and assessed as options for UAS CNPC links. These spectrum access mechanisms could apply to many bands, including some of them to the C-band AM(R)S and Aeronautical Mobile Satellite (Route) Service (AMS(R)S) allocation (5030-5091 MHz) that are the current focus of a petition for rulemaking at the FCC. UAS technical developments are evolving rapidly. This section is intended to give a generic snapshot of the models available at this time, with notes and suggestions for how the example technologies currently available for each model may be further refined, developed, and/or implemented for UAS operations.

Using a particular spectrum access mechanism for UAS in one band does not preclude using other models in other bands. The solution might vary depending on UAS certification and might require multiple, overlapping approaches. It should be noted that both licensed and unlicensed options may be possible for different types of UAS applications. Licensed spectrum access models may be required to ensure safety and regularity of flight (subject to FAA approval), while unlicensed spectrum access might be acceptable in other cases.

The order of the spectrum access mechanisms presented below conveys no meaning or preference by the group, and while the subcommittee does recognize that certain mechanisms are more suited to certain UAS types and operations, it does not preclude mechanisms from being used for other UAS types and operations not specifically commented on.

The models/mechanisms considered are:

- Third-party coordinator
- Terrestrial commercial wireless networks
- Commercial satellite communications (SATCOM) networks
- Unlicensed access
- Dynamic spectrum access
- Band partitioning

THIRD-PARTY COORDINATOR

Overview: An aviation spectrum expert third-party coordinator acts on behalf of FCC and NTIA to issue the necessary license authorization to transmit to UAS providers on a demand basis to terrestrial ground stations dedicated to UAS CNPC links. Each UAS would be assigned one or more frequencies (including alternate channels) along the planned route they intend to fly. The assignment process would use some combination of automation and/or human in the loop, similar to how current aviation air-to-ground systems are currently managed in the Very High Frequency band for Controller Pilot Datalink Communications (CPDLC). Both single and multiple third-party coordinators would be applicable for this model.

Technology options: Certified aviation UAS CNPC systems

Existing examples of model: Used to assign aviation frequencies for CPDLC and flight test functions; proposed frequency management organization discussed in RTCA DO-362.

Possible UAS types for which current model examples are best optimized: Large UAS platforms required to fly at high altitudes and/or integrate with existing FAA-controlled airspace

Advantages of model:

- Proven model for current aeronautical air-to-ground communications that already have existing systems that have passed aviation certification/assurance for controlled airspace usage.
- Allows for a known and planned radio frequency (RF) environment.
- Allows for prioritization of public safety, high-value aircraft, etc.
- Assignments are based on worst case location and propagation model assumptions, providing slack in the system for unexpected events without requiring a potential chain reaction of modifications.

Disadvantages of model:

- Potentially long delay (hours to days) for coordination if using human-in-the-loop processing of assignments.
- Spectrum access inefficient as assignments are based on worst case location and propagation model assumptions, leaving part of the band potentially unused.
- Aviation certification requirements and creating new ground infrastructure may increase the cost of access.
- Requires more than one assignment for each UAS to allow for alternate or backup frequencies and some type of link reestablishment process/protocol in cases when the link is lost due to interference.

Potential evolutions:

- Automated system is envisaged to be website based for immediate access requirements, while long-term planning for permanent networks would require coordination with users.
- System would use pre-coordinated assignment criteria (co-site, propagation, etc.) to minimize processing overhead and maximize efficiency between users.
- The process would use a large number of automated machine-to-machine methods for frequency assignment management to reduce the time needed to approve requests, potential human errors, and costs.

TERRESTRIAL COMMERCIAL WIRELESS NETWORKS

Overview: Commercial licensed wireless network providers use existing cellular networks to provide individual UAS connectivity within most wideband channels. Mobile services spectrum is traditionally licensed exclusively in some bands and shared in others, using deployed network infrastructure. Use of existing access control structure accommodates the coordination of spectrum, with each base station dynamically assigning the available frequency bands and resource blocks while each network's time/frequency access is automatically controlled by a single system.

Technology options: 4G/5G networks

Existing examples of model: Nationwide terrestrial carrier networks

Possible UAS types for which current model examples are best optimized: Small UAS

Advantages of model:

- Mostly nationwide terrestrial networks are already established and in operation in some form in many countries.
- Use of global standards and existing roaming agreements means easier movement between regions/countries.
- Multi-band devices with the ability to roam to other established networks and commercial mobile bands outside of 5030-5091 MHz have inherent capacity and redundancy.
- Mass market technology across a wide user base lowers cost of entry and creates a significant focus for investment and development in quality and security.

Disadvantages of model:

- Operational range and altitude for existing networks are primarily designed for land-based users, not users at different altitudes or operating at significant speed.
- Limited to generic mobile technologies, which do not yet have UAS-specific protocol implementations.
- Need to identify how UAS traffic on shared commercial networks is protected and prioritized to the required aviation standards for certification, assurance, and security for flying in controlled airspace.
- Mass market technology across a wide user base creates a greater opportunity for possible security incidents.

Potential evolutions:

- Physical network modifications could be implemented to provide additional coverage for UAS at altitude.
- Development of specific UAS standards, protocols, and certification as part of the 3rd Generation Partnership Project (3GPP) open standards process for networks to meet FAA certification, security, and assurance requirements.
- Network slicing could provide end-to-end virtualization of the physical network and enable quality of service requirements.

COMMERCIAL SATCOM NETWORKS

Overview: One or more commercial SATCOM providers use current and future satellite commercial networks to provide UAS connectivity within either dedicated or shared wideband channels. Use of existing commercial SATCOM access control structure accommodates the coordination of spectrum use, with necessary traffic management in place. Services can provide overlapping coverage in large areas, including areas not possible with terrestrial services, such as remote or oceanic regions.

Technology options: Multiple nationwide and global coverage Geostationary Orbit and Non-Geostationary Orbit constellations ranging from L to Ka bands

Existing examples of model: L-band services for Air Traffic Control, Aeronautical Mobile Satellite (Route) Service (AMS(R)S) and UAS C2, Ku/Ka SATCOM for commercial aircraft passenger services

Possible UAS types for which current model examples are best optimized: Larger platforms flying at altitudes above the tree line in oceanic and remote areas, including within FAA-controlled airspace**Advantages of model**:

- Able to provide greater/more consistent coverage than terrestrial services.
- Signal coverage means easier movement between regions/countries.
- Time/frequency access automatically controlled by single system.
- Already has existing systems that have passed aviation certification and assurance for controlled airspace usage.
- Existing UAS systems are currently operating in AMS(R)S allocated spectrum.
- Provides a hybrid access mechanism in combination with other spectrum access models, for both extended coverage and contingency planning.

Disadvantages of model:

- Less robust coverage in urban canyons, etc.
- As with other access technologies, operation at frequency bands such as Ku/Ka SATCOM is susceptible to rain fade.

Potential evolutions:

- Development of smaller antennas that could support small UAS.

UNLICENSED ACCESS

Overview: All devices operate equally and are required to accept and mitigate interference on an equal basis, using a sensing capability that can help to overcome interference. Unlicensed rules can vary depending on band and purpose. Individual users need not be certified to operate in unlicensed spectrum.

Technology options: Wi-Fi, 5G NR-U, other Industrial, Scientific and Medical band technologies

Existing examples of model: UAS and model aircraft used for recreational use

Possible UAS types for which current model examples are best optimized: Small UAS flying locally, such as in low population density areas and for non-safety-critical data

Advantages of model:

- Low cost of access to radio equipment.
- Low technical barrier to entry.
- Spectrum efficient by making use of all available access possibilities.
- Highly robust, since by its very nature it can be designed to overcome assignment errors and interference.
- Does not require a central coordination facility to manage implementation, network planning calculations, and assignments.

Disadvantages of model:

- Interference protection must not rely on regulatory guarantees, but on the devices' own design and planning.
- RF environments of unlicensed bands are variable and cannot guarantee reliability or availability.
- Not appropriate for safety-critical data, and may have certification issues even for other uses, given hazards to objects on the ground.
- No control over devices once in the mass market if changes required.
- Limited range based on power and usage restrictions for unlicensed bands.

Possible evolution:

- The policy/logic is controlled by a centralized database system to adjust system behaviors, performance, and enforcement measures as needed.

DYNAMIC SPECTRUM ACCESS

Overview: Radios look for available spectrum; each airborne radio link independently decides what secondary frequency to operate on, based on the detected local RF usage. Dynamic spectrum access models can utilize licensed and/or unlicensed spectrum and dictate Primary and Secondary UAS spectrum users. Primary users are assigned a frequency by a Third-Party Coordinator or other method, while secondary use is on a non-interference basis to primary users.

Technology options: Acts as on overlay to existing communication technology.

Existing examples of model: Citizens Broadband Radio Service Spectrum Access System, 5 GHz band Dynamic Frequency Selection

Possible UAS types for which current model examples are best optimized: Emergency operations, operations in undeveloped regions, and scenarios with more UAS than available channels

Advantages of model:

- Could be more efficient means of RF usage than other models that do not grant access based on actual usage and propagation conditions.
- Does not require central coordination to mitigate network outages or unexpected operational changes.
- High robustness, can overcome assignment errors and interference.

Disadvantages of model:

- Increases UAS radio complexity to support necessary sensing.
- Need for technology updates to support detection of new signals as system develops.

Possible evolution:

- The core policy/logic is controlled by a centralized database system to adjust behaviors for sensing, cueing, and enforcement as needed.
- Coordination can be augmented through sensing, either terrestrial network and/or device-based sensing.

BAND PARTITIONING

Overview: Partition band between different models is dependent on operational requirements. Sharing can be achieved by either frequency/band partitioning (with potential guard bands) or geographic separation (with potential separation distances). This option continues to be explored.

Existing examples of model: European proposal for joint SATCOM/terrestrial UAS CNPC system in 5030-5091 MHz

Possible UAS types for which current model examples are best optimized: Multi-role mission UAS flying between vastly different airspace types.

Advantages of model:

- Partitioning of a band to accommodate different system requirements.
- Possibly dynamically uses most robust technology depending on the propagation and coverage.

Disadvantages of model:

- Would require additional filters, transceiver complexity, and/or a guard band between the different technologies, which in turn may reduce the peak frequency band capacity.
- Limited examples of UAS frequency band partition.
- Already predicted that existing spectrum capacity is not sufficient, let alone partitioning of the band, which may add further spectrum restrictions.

Possible evolution:

- Dynamic partitioning may change based on usage requirements for each service (e.g., urban vs. rural).
- Additional studies would be warranted.

FINDINGS ON SPECTRUM ACCESS MODELS

CNPC spectrum access and management is critical to enabling safe integration of UAS into the NAS. In reviewing the multiple categories of UAS and their mission types, it is clear to the subcommittee that no single spectrum access mechanism is a solution to all possible UAS types expected. Furthermore, spectrum access mechanisms could apply to many different bands and technologies, requiring multiple, overlapping approaches. Several existing examples of the listed access models are dependent on the use of aeronautical safety allocations for the safety and regularity of flight, and therefore new spectrum access models for certain UAS types may require aeronautical safety spectrum allocations dependent on regulatory mandates by FAA (e.g., spectrum requirements, airworthiness certification, CNS equipage, and NAS requirements).

The eventual decision on the most appropriate CNPC link(s) depends on a calculus involving numerous parameters as noted in the introduction of this report, with several crucial differences to existing manned aviation requirements, such as level of autonomation or even the expected scale of UAS in the NAS. Important governance characteristics include safety assurance, spectrum access prioritization, enforcement, coordination, planning to ensure link availability, continuity during handoffs, and contingency planning. There are different cost implications across the various models.

All spectrum access models considered in this report could have different potential liability issues, dictated by several factors including, but not limited to: the type of UAS utilizing the communications service, compliance with the relevant communications or other regulations under which the UAS is operating, and other relevant international, federal, or state laws impacting the operations of UAS. Compliance with FAA and FCC rules and regulations is likely to be a component of any liability issues for UAS operators, CNPC link service providers, and third-party coordinators of specific spectrum access models.

The most important governance characteristic issues differ across classes of UAS. Those most important to large UAS differ from those most important to small UAS. A third-party frequency coordinator model could be appropriate for large UAS because of the greater certainty it provides through enforcement and prioritization. However, terrestrial commercial wireless might be better suited for small UAS because of its lower cost of entry and established nationwide networks already in operation. Commercial SATCOM networks could be appropriate for larger UAS flying above the tree line, especially in oceanic or remote areas, but could evolve to support small UAS via development of smaller antennas/new broadband satellite constellations and combined as a hybrid model with terrestrial commercial licensed wireless to extend coverage and contingency planning. Unlicensed spectrum access has a low cost of access and low technical barrier to entry and does not require central coordination, and so may be optimal for small UAS flying locally, such as in low population density areas and for non-safety-critical data. Spectrum access requirements will evolve, and spectrum access models should be flexible to accommodate different needs of the emerging UAS market.

A third-party frequency coordinator may be feasible for most of the various spectrum access models and might be required to manage multiple spectrum access mechanisms. It could help in managing individual assignments and/or various networks to ensure safety in line with FAA requirements. It could also support more seamless operations across multiple spectrum access models and greater flexibility to adapt as the UAS environment changes through market evolution.

The parameters that FCC and NTIA will need to incorporate into possible service rules for UAS spectrum are extensive, with multiple concurrent options present for different UAS types and missions. This is combined with an urgent need for action given the rate of UAS development, which will not be able to operate to its full capability without the necessary regulatory framework to provide suitable spectrum infrastructure.

Therefore, in determining how such spectrum access models may (or may not) be implemented, NTIA and FCC need to be informed in a timely manner of UAS spectrum requirements, including those necessary to satisfy safety requirements per FAA and ensure coordination and integration across organizations and activities. Given the large number of executive branch and federal agencies that may have input to such a process, a leadership role is needed to provide the necessary direction and resources to pull the various information sources together and then manage the output.

FEDERAL ADVISORY AND OTHER COMMITTEES FOR UAS

This section highlights federal advisory[10] and other federal committees with ongoing and/or recent UAS activities: the FCC Technological Advisory Council (TAC), the FAA Drone Advisory Committee (DAC), UAS Executive Committee (ExCom), National Aeronautics and Space Administration (NASA) UAS Traffic Management (UTM) Pilot Program (UPP), and PNT Advisory Board. Based on inputs, the subcommittee has summarized their UAS activities below.

FCC TAC: FCC TAC provides technical advice to FCC to inform telecommunications policy. Its broad scope included a working group studying spectrum issues for UAS and identifying any areas that might require special attention or FCC spectrum management functions. Their activity was organized into three sub-working groups: commercial systems, technology analysis, and spectrum analysis. The TAC finished its UAS two-year effort for the FCC in 2018. More details are available at https://www.fcc.gov/general/technological-advisory-council. There is currently no ongoing work on drones within the TAC.

FAA DAC: As stipulated in the DAC charter, the objectives and scope for the DAC are to provide independent advice and recommendations to DOT and FAA and to respond to specific taskings received directly from FAA. The advice, recommendations, and taskings relate to improving the efficiency and safety of integrating UAS into the NAS. In response to FAA requests, the DAC may provide FAA and DOT with information that may be used for tactical and strategic planning purposes. Further information can be found at https://www.faa.gov/uas/programs_partnerships/drone_advisory_committee/.

UAS ExCom: The UAS ExCom includes senior executives from FAA, Department of Defense (DOD), Department of Homeland Security (DHS), Department of Commerce (DOC), Department of Energy (DOE), Department of the Interior (DOI), Department of Justice (DOJ), and NASA. It provides a dynamic forum for federal agencies to share information on UAS research and development as well as policy and procedures for safe integration of UAS into the national airspace. The UAS ExCom and its two subcommittees—the UAS Integration Senior Steering Group (SSG) and the UAS Security SSG—are supported by the UAS Science and Research Panel (SARP), a group of member agency research experts who collaborate on sound technical approaches and partnerships across member agencies and the broader academic and science community. The SARP provides briefs and updates to the ExCom and SSGs. CSMAC is not aware of any spectrum activities within UAS ExCom.

NASA UPP: A 2016 law directed FAA to establish the UPP in coordination with NASA. The goal of the UPP is to define an initial set of industry and FAA capabilities required to support UTM at flight levels below 400 feet. UPP transfers NASA research to FAA with the intent of developing and demonstrating enterprise services to support automated UTM operations using a cloud service infrastructure and cooperative, community-based traffic management under FAA guidelines. These include Remote Identification to enable safe, routine drone operations "by allowing the public, the FAA, law enforcement, and Federal security agencies to identify UAS flying in their jurisdiction."[11] Summaries and reports do not include discussion of spectrum bands. More information is available at https://www.faa.gov/uas/research_development/traffic_management/utm_pilot_program/.

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[10] The Federal Advisory Committee Act (FACA) governs the operation of federal advisory committees.
[11] "UTM Pilot Program Background," FAA and NASA (2019), available at https://www.faa.gov/uas/research_development/traffic_management/utm_pilot_program/media/UPP2_Industry_Workshop_Handout.pdf

PNT Advisory Board: The National Space-Based PNT Advisory Board advises on Global Positioning System-related policy, planning, program management, and funding profiles relating to the current state of national and international satellite navigation services. Additional information on the PNT Federal Advisory Committee Act (FACA) is available at https://www.gps.gov/governance/advisory/.

FINDINGS ON FEDERAL ADVISORY AND OTHER COMMITTEES FOR UAS

While there are disparate federal advisory and other committees with ongoing UAS activities, no committee is assuming leadership, specifically as a national focal point and centralizing function, on UAS spectrum. Instead of making spectrum decisions in isolation, NTIA and FCC need to be informed of UAS spectrum requirements and coordinate federal, nonfederal, and shared spectrum use. U.S. leadership is needed to provide direction, coordination, and integration for UAS spectrum activities across organizations, and to advance the way ahead. Therefore, the subcommittee concluded that there is a need to create an entity that supports and facilitates spectrum-related collaboration across the disparate federal advisory and other committees for UAS. CSMAC developed alternative mechanisms and governance structures for such an entity, summarized below.

ALTERNATIVE MECHANISMS AND GOVERNANCE STRUCTURES

The subcommittee identified alternative mechanisms and governance structures to fill gaps identified and support and facilitate greater collaboration across federal advisory committees and their respective government agencies.

CSMAC determined that numerous organizations are working on UAS-related topics, but the work would be more efficient, effective, and impactful if more closely focused and aligned. A higher level of coordination on UAS issues and specifically spectrum usage is needed. Establishing a "north star," via a mandate or other mechanism, would help diverse stakeholders pursue a common, overarching, and purposeful direction in the national interest.

Further, it is difficult to identify appropriate points of contact (POCs) given the multiple and varied operational and technical aspects of UAS. This observation was reinforced during our subcommittee work as we developed a landscape of various organizations and their scope of activities pertaining to UAS spectrum. A central POC who tracks and coordinates UAS activities and can provide "signposts" to the right POCs would be very useful. Therefore, there is a need to create an entity that supports and facilitates collaboration across the disparate federal advisory committees, and their respective agencies, for UAS.

CSMAC developed alternative mechanisms and governance structures for such an entity. These options are described below; the order presented conveys no meaning or preference by the group.

DESIGNATE A CENTRAL POC

In this option, a central POC would be designated to coordinate information sharing and collaboration across federal agencies, industry, and academia and other non-profit organizations. This option includes the possibility of starting small and maturing over time into an office within a federal agency (see below).

ESTABLISH AN OFFICE WITHIN A FEDERAL AGENCY

An office within a federal agency would help align, coordinate, and synchronize government, industry, and academic and other non-profit activities. It would convene stakeholders to bring together multiple perspectives and serve as an industry advocate within the executive branch in support of a whole-of-nation approach. While remaining light-touch and permissive, it would work toward effectively achieving goals rationalized in advance. This governance structure is analogous to that of the DOC's Office of Space Commerce.

CREATE A NEW EXECUTIVE STEERING COMMITTEE

A new Executive Steering Committee would be created and charged with the responsibility of helping to reform how the various FACA groups might work in a more collaborative manner. This is a time-honored approach to providing a higher level of coordination across federal agencies. A federal government Executive Steering Committee on UAS could be established that includes representation from all relevant stakeholders (e.g., NTIA, FCC, NASA, FAA, DOD, DOC, DHS, DOJ, and DOI). This new Executive Steering Committee should be made aware of the activities of the various FACA groups working on UAS-related issues. If this Executive Steering Committee believes there is a need for a new organization beyond itself to coordinate the work, then it should charter this new entity. NTIA could serve as the initiator and call the first meeting for this new Executive Steering Committee.

EXPAND THE CHARTER OF AN EXISTING FEDERAL ADVISORY COMMITTEE

The scope of an existing federal advisory committee could be expanded to include supporting and facilitating collaboration across the disparate federal advisory committees for UAS. Federal advisory committees are chartered by various government organizations, and the mission and questions for each FACA group are provided by their parent organizations. Given this, although there are overlapping assignments for the groups, the groups themselves have very limited authority to identify or pursue efforts independent of directions provided by the organizations they support. Therefore, having an entity that provides, or even supports, collaboration across the FACA groups makes limited sense absent coordination at the level of the sponsoring government entities.

EXPAND UAS EXCOM

UAS ExCom could be expanded so that its scope of responsibilities includes coordination across the different federal advisory and other committees for UAS.

ESTABLISH A NEW FEDERAL ADVISORY COMMITTEE

A new federal advisory committee could be established to include coordination across all the existing federal advisory committees for UAS. However, this adds yet another FACA group.

CSMAC RECOMMENDATIONS

CSMAC's recommendations to NTIA are as follows:

1. CSMAC recommends that NTIA play a leadership role in coordinating across federal government and providing direction and resources to facilitate UAS spectrum access. Given the pertinence of UAS spectrum across various executive branch agencies, NTIA should convene a group of federal stakeholders to gain consensus on spectrum requirements and to ensure that multiple spectrum access models and multiple bands can be leveraged to meet those needs. UAS spectrum access is a complex and essential issue, requiring significant spectrum expertise and prioritization across multiple aspects of technical, regulatory and operational issues. NTIA must coordinate federal agency uses of spectrum for UAS, inform the FCC of federal agency UAS spectrum requirements in a timely manner, and work with the FCC and FAA to ensure that the spectrum access models maximize industry's ability to offer terrestrial and satellite-based UAS solutions that are consistent with FAA safety requirements and FCC and NTIA regulatory requirements.

2. CSMAC recommends that NTIA initiate and champion designation of a central POC within the executive branch for UAS coordination—including spectrum—to facilitate information sharing and collaboration across federal agencies, industry, and academia and other non-profit organizations. One year after the establishment of this central POC, CSMAC recommends that NTIA assess if this option should be matured over time into an office within a federal agency. This office would convene stakeholders to bring together multiple perspectives and serve as an industry advocate within the executive branch in support of a whole-of-nation approach for UAS. While remaining light-touch and permissive, it would work toward effectively achieving U.S. goals rationalized in advance. It would serve as a standing coordinating committee to advance UAS.

APPENDIX A: INTERVIEW QUESTIONNAIRE

CSMAC Subcommittee 4: Unmanned Aircraft Spectrum

Interview Questions

Background – CSMAC's Question from NTIA:

a. *The FAA has the responsibility of ensuring the safe integrations of all classes of UAS into the national airspace, from small to large UAS. Spectrum to support command and control operations will be critical for these emerging industry applications, to include urban air mobility and transcontinental cargo delivery.*

a. *What are appropriate models for ensuring timely and secure access to frequencies necessary to support UAS command and control requirements? What governance characteristics are important? Are there liability issues to consider for this function? Is it a 3rd party frequency coordinator model?*

b. *What is the potential need to create an entity that supports and facilitates collaboration across the disparate federal advisory committees for UAS?*

    i. *Develop alternative mechanisms and governance structures for such an entity*

Advisory Board Functions (with respect to spectrum for UAS)

1. Please can you describe your current advisory board, including its functions, objectives and members?
    a. What is your advisory board's objectives/responsibility pertaining to UAS?
    b. What drone categories are within the scope of the work you are doing?
    c. Please briefly describe your membership, and how it is structured.
    d. What plans and timelines do you have in place to meet any key UAS objectives? What further timelines are needed?
    e. What recommendations has your committee provided up to this point?
2. Can you describe what and how your committee has worked with other federal and non-federal entities?
    a. What other organizations/agencies do you rely on to provide input or follow?
    b. What other federal and non-federal groups are working on similar activities that you are aware of?
3. Would a new an entity that supports and facilitates collaboration across the disparate federal advisory committees for UAS be useful/supported?
    a. What functions should and should not be collaborated on?

   b. Do you consider that achieving your objectives would be enhanced by greater cross-collaboration? How? Are there any restrictions that would prohibit greater cross-collaboration by your advisory committee with others?

CNPC Link

4. What are the biggest challenges or impediments to UAS CNPC link implementation?

   a. What gaps exist that are not being addressed by other organizations to support spectrum for UAS CNPC links?

   b. What redundancies and/or overlapping responsibilities exist in multiple organizations addressing spectrum for UAS CNPC links?

5. What initiatives do you have that address use of different radio link technologies, such as a terrestrial-based cellular, SATCOM, etc.?

   a. What has already been considered/speculated for possible regulatory service rules in the CNPC link implementation, and how might these rules be established?

Spectrum Considerations

6. Does you committee intend to address spectrum requirements and associated regulatory structures for CNPC spectrum access? For example, licensed dedicated aeronautical spectrum, 5G, unlicensed, proprietary systems, etc.

   a. What systems and/or frequencies have been considered or discussed for UAS CNPC links?

   b. What systems and/or frequencies have been discounted for UAS CNPC links, and why?

7. What work have you done or considered on how would the frequencies used for UAS CNPC links be managed or coordinated? If no formal thoughts from the advisory board, do you have any considerations of your own?

   a. What standards and certifications should be required for UAS systems to access spectrum?

   b. What solutions, procedures or policies could be implemented in UAS design or implementation to improve spectrum efficiency?

APPENDIX B: INTERVIEWS CONDUCTED

This appendix lists the interviews conducted by CSMAC.

Interview	Date	Name
3GPP	October 14, 2020	Francesca Stockton Melissa Tye Bri O’Neill
DOC Office of Space Commerce	September 9, 2020	Diane Howard
FAA DAC	August 27, 2020	Gary Kolb
FCC TAC	April 29, 2020	John Chapin Joe Cramer Stephen Hayes Dennis Roberson
RTCA SC-228	July 28, 2020	Jim Williams Steve Van Trees Al Secen

APPENDIX C: SUMMARY OF INTERVIEW RESPONSES

3GPP

- UAS CNPC links could use spectrum allocated for commercial mobile radio services (i.e., cellular). This leverages existing infrastructure globally and has an ecosystem that includes low cost and efficient solutions for the market.
- Several industry studies (e.g., Ericsson, Qualcomm, Nokia) show that terrestrial cellular networks can serve UAS in low-altitude airspace quite well today.
- Standards bodies, such as 3GPP, are consistently evolving the technology to achieve performance and security requirements at a reasonable cost.
- There are recommended enhancements to more efficiently serve UAS. Because the current network is tuned to terrestrial, more resources are required to serve airborne users (different RF environment). The economics scale to the market, and it is important to keep cost down by optimizing the network to maintain the economics and deliver efficient services.
- 3GPP's Release 15 includes aerial enhancement features. For UAS specifically, it can be applied to operations in low-altitude airspace. Specific work in 3GPP includes building features to support specific applications in UAS. They are looking at application support, supplementary data support, service profiling, minimum performance requirements, hardware and system guidelines, interoperability, and roaming.
- Mobile network operators can build solutions with any feature standardized in 3GPP, whether or not it was designed/implemented specifically for airborne use. Currently, all devices are in same spectrum and network area. They are not differentiating the network between terrestrial and UAS use. Today we have commercial service to access the wireless network for airborne use. It is geared toward use of UAS and offered on spectrum used for Internet of Things services today. Special requirements and policy implementations are included on the network and developer side.
- An aerial User Network Interface profile is key to enable roaming. Roaming does not exist today for these services/features. Minimum requirements are not established yet. GSMA is developing roaming guidelines for UAS. There is not a guarantee that there will be service all of the time in all locations. But the aircraft are built in way to maintain safety. Some systems can operate completely on cellular today (e.g., operate in an area with full cellular service or in area that can tolerate intermittent interruptions). In general, there is good coverage and service availability today.
- To standardize system requirements, need to take 3GPP key performance indicators (KPIs) and translate into KPIs that represent the aviation industry.
- Minimum performance requirements are needed for the system to specify what is expected of the cellular link and service within those coverage areas. One system might have high requirements, whereas another system might have low requirements. 5G requirements might be greater. There is a resource trade-off. Different reliability is needed for different services. There are design techniques that can enable high reliability. It is an iterative process, and timing is key in terms of

when requirements need to be put in place. For small UAS, cellular is already built or being built into their systems. They are working on the design challenge of how best to implement their security and network path.

- The business case is very strong. There is a parallel to the automotive industry. To scale more complex operations, remote ID, a solution for high-density operations (e.g., package delivery in cities), and detect-and-avoid features are needed.

<u>DOC Office of Space Commerce</u>

Introduction:

- The CSMAC UAS Subcommittee interviewed the DOC Office of Space Commerce (OSC) to gather, based on its expertise and experiences, best practices and lessons learned on how best to coordinate and collaborate in a rapidly emerging new domain area of high national importance with multiple stakeholders.

Background:

- The DOC OSC was formed in 1988 by Department Organizational Order (DOO). In 1996, it moved from the Office of the Secretary of Commerce to the DOC's Technology Administration and was codified in law in 1998 as the Office of Air & Space Commercialization and subsequently its name changed to the Office of Space Commercialization. In 2005, the office moved to the National Oceanic and Atmospheric Administration (NOAA). In 2015, its name was changed back to the Office of Space Commerce and its policy goals as articulated in successive DOOs were codified. Kevin O'Connell serves as its Director.

- Space Policy Directive-2, Streamlining Regulations on Commercial Use of Space, directed the reorganization of the DOC and consolidation of its responsibilities with respect to regulation of commercial space flight activities. This was more robust recognition of the OSC, which previously had less visibility and limited resources.

- The role of the OSC is to serve as an industry advocate within the executive branch. This includes helping industry and helping align, coordinate, and synthesize private sector and government equities. FCC is included in many of its discussions.

Collaboration:

- The OSC collaborates with other federal and non-federal entities. Everyone is working together. Previously, there were a lot of stovepipes. Now there is much more communication. Action officers are really trying to negotiate language. OSC works with DOE, NASA, DOD, FAA, State, FCC, across other bureaus within DOC, and with non-federal groups. Non-federal groups include non-governmental organizations and industry organizations. It is not a static list.

- It works to be light-touch and permissive, but also effective and works to achieve goals rationalized in advance before policies are made.

- Much of its focus is on information sharing and coordinating (versus top-down directing).

- The space environment is changing dramatically and dynamically. In most areas of the space domain, it is premature to direct too much. OSC is gathering a lot of information and taking the opportunity to engage in discussion.
- However, DOC has regulatory authority. Space Policy Directive-3 directs the establishment of an open architecture data repository, which moves more toward regulating. DOC believes that the best regulations will be those we know will be effective, such as those grounded in physics and operational realities.
- OSC was placed under NOAA because they are both doing space work. The legislative directive names OSC as the principal unit coordinating all space policy within DOC; some are NOAA issues. OSC has a great relationship with NOAA. NOAA is rich with resources.

Best Practices and Lessons Learned:

- Follow domestic diplomacy. Learn to listen. What you hear is not always what was intended by the person speaking. No knee-jerk reactions. If you do not have outcomes you seek right away, keep at it; things evolve and change over time. Many of us in the stakeholder community are here for the same reason. We want to thrive, love the space domain, and have aspirational connections. When things get tough, remind ourselves that most of us are doing this for the same reason. Common starting points help in forming future positions and directions.
- OSC interacts through industry, not through an advisory committee. OSC hosts industry days and convenes summits and workshops. The door is always open. Serious issues are prioritized.
- For international issues, OSC works with the Department of State. It collaborates to finalize cooperation agreements with other international space organizations and continues to work with them, including in training exercises and Sprint Advanced Concept Trainings.
- Rather than a one-stop shop, OSC works more like a whole-of-government approach. It coordinates activities. A recent National Academy of Public Administration study on space traffic management (STM) analyzed different players in the federal government and reaffirmed that OSC is the civil agency best suited to perform STM tasks.
- OSC is a convener and collaborator, and it leverages good infrastructure support from DOC. OSC is nimble and responsive to the changing environment. It functions to provide some direction and feedback, and it convenes stakeholders. Flexibility is required to encourage innovations. Sometimes stakeholders do not know that someone is already overseeing a particular function.
- Develop a list of stakeholders. The list will change. Be as inclusive as possible. Try to avoid decisions made in isolation. Learn what each stakeholder perceives as their equities, concerns, and expertise. If all of the stakeholders are subject to the decision-making process, we want them to be a part of it. Work together to achieve improvement and a more robust solution. Do not need to reinvent the wheel. Be creative and collaborative. What you end up with is different than what any one entity would have developed.
- OSC appreciates that CSMAC is asking questions beyond the immediate confines of the problem set.

FAA DAC

Background:

- The DAC charter specifies the objectives and scope for the DAC, providing independent advice and recommendations to DOT and FAA and responding to specific taskings received directly from FAA. The advice, recommendations, and taskings relate to improving the efficiency and safety of integrating UAS into the NAS. In response to FAA requests, the DAC may provide FAA and DOT with information that may be used for tactical and strategic planning purposes.
- The members of the DAC are currently divided among 11 stakeholder groups that represent all aspects of the drone community—manufacturers, operators, software applications, and hardware components, as well as government entities and trade organizations. The DAC members have interests at all levels of drone categories from small Part 107 operators to large corporate fleets.
- In the past year, the DAC has provided recommendations on Facility Maps, Remote ID, Beyond Visual Line of Sight, UAS Security, Unmanned Traffic Management, and Part 107 waivers.

Working Methods:

- The task groups have the ability and freedom to reach out to any federal or non-federal entity they feel is necessary to develop their recommendations. Many of the members of the DAC have ongoing relationships through other programs and initiatives, and they can use this expertise to provide FAA with the latest industry trends and information.
- FAA relies very heavily on several organizations and agencies that deal with UAS issues. Virtually all the industry trade organizations, both manned and unmanned, provide input to DAC recommendations. All federal agencies dealing with UAS issues also can provide information and feedback, especially those of FAA federal security partners.

Collaboration Options:

- It might be a little early to say for sure about the usefulness of proposals for a new an entity that supports and facilitates collaboration across the disparate federal advisory committees for UAS, but it certainly would be supported at this time.
- As the new entity evolved, it would be important to ensure there is no duplication of effort or that any decisions were not being made in a vacuum without full agreement of all the affected agencies. It would also need to address possible restrictions or limitations for time/resources.

CNPC Links:

- There have been several working groups that focus on these areas, and there are entire divisions within FAA that continuously look at navigation and spectrum issues.

Spectrum Considerations:

- Spectrum requirements and associated regulatory structures for CNPC spectrum access have been mentioned in relation to some of the recommendations provided from the DAC. While no specific discussion or development of these has occurred yet, they will almost certainly be addressed in the future.

FCC TAC

Advisory Board Functions:

- The FCC TAC was responsible for informing telecommunications policy. Its broad scope included studying spectrum issues for UAS and identifying any areas that might require special attention or FCC spectrum management functions. The TAC reviewed existing aviation spectrum and how existing systems could make use of systems with spectrum already allocated.
- The TAC was tasked across all aspects of UAS, though it did not specifically examine oceanic or beyond line of sight (BLOS). It focused on cellular terrestrial and unlicensed in the U.S. More than one airspace usage is also possible. The TAC scanned frequency bands designated for aviation use from 100 MHz to 5 GHz.
- The TAC's activity was organized into three working groups: commercial systems, technology analysis, and spectrum analysis.
- The TAC obtained input from other organizations, including the FAA (UAS office), RTCA Special Committee (SC)-228, NASA UTM, MITRE, 3GPP, CTIA, and private industry (e.g., Qualcomm, Lockheed, Amazon Prime Air). It indirectly received federal agency viewpoints via private sector member perspectives.
- Other groups working on UAS spectrum topics include CSMAC, 3GPP, the American National Standards Institute, NASA UTM, the UAS Integration Pilot Program, the National Science Foundation, ATIS, and the European Commission.
- The TAC found it difficult to identify who they should be talking to. However, a central POC who tracks, coordinates UAS activities, and can provide the right POCs would have been very useful to the FCC TAC's work. Any coordination should focus on information sharing, not directing focus of attention or an outcome; coordinating work across diverse stakeholders might be too overreaching.
- The TAC accomplished its goals for the FCC. There is no ongoing work on drones within the TAC.
- The TAC did not examine whether or not additional spectrum is needed for UAS. CSMAC could examine that issue.
- The TAC took a technology-agnostic view and assumed multiple technologies rather than convergence on a specific technology (even for C2C). Development of standards is needed to support the regulatory requirements. Regulatory requirements need to be developed, and the technology must meet the reliability, safety, and performance needs to be allowed to provide the service.

CNPC Link:

- UAS CNPC links could include licensed dedicated aeronautical spectrum, 5G, unlicensed, proprietary systems, etc.

- Gaps that are not being addressed by other organizations to support spectrum for UAS CNPC links include:
  - Standardized communications functionality.
  - Specification of the performance requirements by the relevant regulator.
  - Systematic regulatory effort to review aeronautical restrictions. Identify what restrictions could be relaxed to support more spectrum availability for UAS.
- No significant redundancies identified across organizations addressing spectrum for UAS CNPC links.
- Regulatory options: Wi-Fi and cellular (non-aviation spectrum) and aviation spectrum bands. Could those bands be utilized for UAS C2? Didn't get beyond that from regulatory view. There are aeronautical restrictions on terrestrial bands. Didn't look at if some of those restrictions still made sense.
- In some cases, a system could use the same link for CNPC and payload communications. It might have the same physical link (same link and receiver), but applications would be separated. There could be a cost savings due to integration.

Spectrum Considerations:

- From a spectrum perspective, much of the rulemaking did not consider high-density use of transmitters at altitude. Previous out-of-band emissions considered ground-to-ground transmission. If put in the air, might change signals received by receivers. For example, FirstNet and non-FirstNet users had not been assessed. Need to quantitatively figure out interactions between UASs and other services in the same or adjacent band.
- There is a great deal of interest in commercial cellular. Primarily looking at commercial users with heavily automated drones using directives and internal guidance mechanisms to reduce load on the network. It appeared that cellular systems have this capability, but need to prove this capability everywhere at altitude. Also, downlinks are not addressed by existing cellular technology (area of coverage across multiple cells). Unlicensed cannot be used in urban areas because interference would be too high to rely on for critical systems. Unlicensed might be usable in rural areas or in industrial settings where interference can be controlled.
- Operational requirements to consider include location of ground stations (e.g., on existing airports, new locations, mobile, etc.) and communications paths (A-G, other drones, mesh networks, etc.). Control station does not mean it is a ground station.

RTCA SC-228

Background:

- RTCA's SC-228 WGs are charged to develop standards for UAS Detect And Avoid (systems (focus of WG-1) and for communication link systems between the UA and a control station (focus of WG-2). Initial Minimum Operational Performance Standards (MOPS) for both systems have been published and implemented by the FAA's Technical Standard Orders. Many of the questions posed by CSMAC have been considered and the resulting views expressed in these two standards.

- In March 2019, RTCA published Minimum Aviation System Performance Standards (MASPS) for C2 Link Systems operating through basic terrestrial and/or SATCOM systems. The scope of this MASPS was for lower altitude missions using smaller UAs.
- In 2019, efforts began to develop revisions to the MASPS (DO-377A) and MOPS (DO-362); these revisions address an expanded number of CONOPS including higher altitude and longer-range scenarios using larger UAS and will eventually address all categories of UAS except the small sUAS flown within VLOS.
- As with all RTCA committees, membership is open to all relevant industries and government organizations. Current WG-2 members reflect all UAS stakeholders; it is co-chaired by one from industry and one from the government. All reports are reviewed by WG members and open for the general public to offer comments.

Working Methods:

- RTCA SC-228 works closely with FAA, DOD, NASA, and DOC and then with individual industries and their organizations, to include the Aerospace Industries Association and Air Line Pilots Association.

Collaboration Options:

- RTCA SC-228's efforts have identified the need for two new federal or federal-supported organizations that would help facilitate expanded UAS operations in the U.S. airspace:
    - Frequency Management Organization (FMO): As with any scarce, valuable, public resource and because of its safety-critical nature, the frequency assignment scheme must be well defined and controlled. Therefore, the assignment scheme, which would be approved by FAA and/or FCC, must be dynamic in both time and spectral occupancy. It must only assign a channel to any particular UA for the minimum amount of time so that other UA can use the same RF spectrum as soon as it is no longer needed.
    - Competent Authority: This organizations will help ensure that the C2 Link System Communications Service Providers (C2CSP) satisfactorily provide their portions of the C2 Link System (e.g., a C Band CNPC link or a satellite based C2 Link) for the operation of a UAS. Since it is very important to ensure that the Quality of Service Delivered (QoSD) of the C2 Link System always meets the Quality of Service Required, such quality needs to be stated within any Service Level Agreement between the C2CSP and the UAS operator. Additionally, monitoring of the QoSD during the UAS's operation to proactively address any deficiencies in the QoSD, particular if they are caused by harmful interference, is included in the responsibility of the UAS operator.
    - RTCA SC-228 sees the FMO being part of the FAA, and it defines the ground rules, but with a Competent Authority where one of its subordinate organizations would prepare the detailed frequency channel assignments for each UA during it flight. Such assignments would be for both industry and federal agency UA.

C Band CNPC Link:

- No organization exists that would dynamically assign the C-band (5030 to 5091 MHz) frequency/channels to be used by UA CNPC links. This is especially important for UAs that fly over extended distances requiring multiple ground stations. (See reference to the FMO)
- Generic performance requirements exist for different radio link technologies dealing with terrestrial- and SATCOM-based C2 links in the DO-377A MASPS, which is planned to address cellular systems within the Phase 3 efforts (DO-377B). DO-362A has established equipment performance standards that can be used in conjunction with DO-377A to help establish service rules for C Band CNPC links. FCC action is required to change the service rules to allow use of equipment built to the standards.

Spectrum Considerations:

- There is a need for a FMO to improve spectrum efficiency; see the suggested frequency assignments concepts in Appendices I and J of DO-377.
- DO-377 and the drafts of DO-377A addresses performance requirements for all C2 link types (except small UAS). The specific requirements for the C-Band support establish channelization and use rules for the 5030-5091 MHz band. The committee's Phase 3 efforts include the development of a MOPS to support the use of Mobile Network Operators (MNOs) for C2 links. Possible other standards may be developed within the SC-228 Phase 3 work program if other licensed spectrum is found that can meet the safety standards established in the DO-377A MOPS.
- Bands appropriately allocated by the International Telecommunication Union, and MNO frequencies not prohibited from airborne use have been considered or discussed for UAS C2 links.
- The 960-1164MHz AM(R)S allocated L-Band was rejected due to interference concerns with deployed systems. FAA is researching the possibility of limited use of the L-Band if technical solutions can be found to mitigate the risk of interference with existing deployed equipment.
- The frequency assignment proposals within RTCA standards are on the basis of coordinated spectrum sharing and non-licensing. This means that a frequency assignment is available only for a particular UAS flight operation based on filed flight plan. The FMO will use radio installation and terrain information to maximize frequency re-use in a given region. The FMO vision is near-real-time frequency assignment on a per-flight basis.

APPENDIX D: ACRONYMS

AM(R)S – Aeronautical Mobile (Route) Service

AMS(R)S – Aeronautical Mobile Satellite (Route) Service

BLOS – Beyond Line of Sight

C2 – Command and Control

C2CSP – C2 Link System Communications Service Providers

CDPLC – Controller Pilot Datalink Communications

CFR – Code of Federal Regulations

CNPC – Control and Non-Payload Communications

CNS – Communication, Navigation and Surveillance

CPDLC – Controller Pilot Datalink Communications

CSMAC – Commerce Spectrum Management Advisory

DAC – Drone Advisory Committee

DHS – Department of Homeland Security

DOC – Department of Commerce

DOD– Department of Defense

DOE – Department of Energy

DOI – Department of the Interior

DOJ – Department of Justice

DOO – Department Organizational Order

DOT – Department of Transportation

ExCom – Executive Committee

FAA – Federal Aviation Administration

FACA – Federal Advisory Committee Act

FCC – Federal Communications Commission

FMO – Frequency Management Organization

KPI – Key Performance Indicator

MASPS – Minimum Aviation System Performance Standards

MNO – Mobile Network Operator

MOPS – Minimum Operational Performance Standards

NAS – National Airspace System

NASA – National Aeronautics and Space Administration

NOAA – National Oceanic and Atmospheric Administration

NTIA – National Telecommunications and Information Administration

OSC – Office of Space Commerce

POC – Point of Contact

QoSD – Quality of Service Delivered

PNT – Positioning, Navigation, and Timing

RF – Radio Frequency

SARP – Science and Research Panel

SATCOM – Satellite Communications

SC – Special Committee

SSG – Senior Steering Group

STM – Space Traffic Management

3GPP – 3rd Generation Partnership Project

TAC – Technical Advisory Council

UA – Unmanned Aircraft

UAS – Unmanned Aircraft System

UPP – UTM Pilot Program

UTM – UAS Traffic Management

VLOS – Visual Line of Sight

WG – Working Group