CSMAC
Unmanned Aircraft Spectrum
Subcommittee 4

April 8, 2021

Overview of Updates

- Iterated draft findings and conducted follow-on work
- Obtained feedback and input from full CSMAC
- Added interview highlights as an appendix of the report
- Updated and finalized report
  - Not too dissimilar to last presentation
  - UAS technical developments are evolving rapidly
  - Report is intended to give a generic snapshot of the current 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

Subcommittee Members

- 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
- NTIA Liaisons: Richard Orsulak, David Reed

Question:
Unmanned Aircraft Spectrum

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

Approach

Initiated a concurrent, two-tiered approach:

1. Identified options for spectrum access mechanisms for Unmanned Aircraft System (UAS)
   - ➢ Identified possible solutions that may meet some/all of UAS requirements
   - ➢ Evaluated in terms of advantages, disadvantages, and other observations
2. Examine current state of the UAS environment and the committees supporting it
   - ➢ Looked at the landscape of various organizations and their scope of activities pertaining to UAS spectrum
   - ➢ Conducted interviews with advisory boards and other organizations and experts to supplement this information

Approached this work to provide complementary, value-added contributions to ongoing activities in the UAS domain

Schedule

- Subcommittee kickoff: January 16, 2020
- Conduct interviews: February 2020 – September 2020
- Analyze information and develop a draft report: August 2020 – January 2021
- Iterate draft findings and conduct follow-on work: January 2021 – March 2021

- Typically met on a recurring two-week basis
- Held 30+ meetings via teleconference
- Provided updates at full CSMAC meetings (January, April, and July 2020; January and April 2021)
- Conducted outreach
  - FCC TAC
  - RTCA
  - 3GPP
  - FCC DAC
  - UAS ExCom
  - DoC Office of Space Commerce

CSMAC planned a staggered start this term in effort to help balance the workload across subcommittees

Background: The UAS Environment

- Dynamic state of development, innovation, and market evolution
- UAS applications are inherently complex due to the wide variety of types, sizes, scale, applications, altitudes, and safety-of-life and safety-of-flight requirements
- Regulatory structures are needed to support UAS growth and safe integration into the National Airspace System (NAS), which presents several policy and technical challenges
- Need suitable spectrum infrastructure, such as spectrum access mechanisms and necessary regulations, enabled by appropriate regulations for spectrum access
- 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

UAS SPECTRUM ACCESS MODELS

UAS Spectrum Access Models

- Third-party coordinator

- Terrestrial commercial wireless networks

- Commercial satellite communications (SATCOM) networks

- Unlicensed access

- Dynamic spectrum access

- Band partitioning

The order of the spectrum access mechanisms presented below conveys no meaning or preference by CSMAC

Third-Party Coordinator

- An aviation spectrum expert third-party coordinator acts on behalf of the 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 VHF 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** - Large UAS platforms required to fly at high altitudes and/or integrate with existing FAA-controlled airspace
- **Potential evolutions**
  - Automated system with pre-coordination of assignment criteria

Third-Party Coordinator

Advantages

- 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 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

- 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

Terrestrial Commercial Wireless Networks

- 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 single system
- **Technology options** - 4G/5G
- **Existing examples of Model** - Nationwide terrestrial carrier networks
- **Possible UAS Types** - Small UAS
- **Potential evolution**
  - Physical network modifications could be implemented to provide additional coverage for UAS at altitude, including future high altitude base stations
  - 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 (QoS) requirements

Terrestrial Commercial Wireless Networks

Advantages

- Nationwide terrestrial networks 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
- Lower cost of entry with mass market of devices

Disadvantages

- 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

Commercial SATCOM Networks

- 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 (GSO) and Non-Geostationary Orbit (NGSO) constellations ranging from L to Ka bands
- **Existing examples of model** - L-band services for Air Traffic Control, AMS(R)S and UAS C2, Ku/Ka SATCOM services for commercial aircraft passenger services
- **Possible UAS types** - Larger platforms flying at altitudes above the tree line in oceanic and remote areas, including within FAA-controlled airspace
- **Potential evolution**
  - Development of smaller antennas that could support small UAS

Commercial SATCOM Networks

Advantages

- 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

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

Unlicensed Access

- 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 ISM technologies
- **Existing examples of model** - UAS and model aircraft used for recreational use
- **Possible UAS types** - Small UAS flying locally, such as in low population density areas and for non-safety critical data
- **Possible evolution**
  - The policy/logic is controlled by a centralized database system to adjust system behaviors, performance, and enforcement measures as needed

Unlicensed Access

Advantages

- 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

- 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

Dynamic Spectrum Access

- Radios look for available spectrum; each airborne radio link independently decides on what secondary frequency to operate on, based on the detected local RF usage
- 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** - CBRS SAS, 5 GHz band Dynamic Frequency Selection
- **Possible UAS types** - Emergency operations, operations in undeveloped regions, and scenarios with more UAS than available channels
- **Possible evolutions**
  - 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

Dynamic Spectrum Access

Advantages

- Could be more efficient means of RF usage than other models that do not grant access is 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

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

Band Partitioning

- 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)
- **Existing examples of model** - European proposal for joint SATCOM/terrestrial UAS CNPC system in 5030-5091 MHz
- **Possible UAS types** - Multi-role mission UAS flying between vastly different airspace types
- **Possible evolution**
  - Dynamic partitioning may change based on usage requirements for each service (e.g., urban vs. rural)
  - Additional studies would be warranted

Band Partitioning

Advantages

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

Disadvantages

- 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 not sufficient, let alone partitioning of the band, which may add further spectrum restrictions

Findings: Spectrum Access Models

- Multiple UAS spectrum access models are appropriate
  - Multiple overlapping approaches expected for a mature UAS ecosystem
  - Safety spectrum a consideration dependent on the regulatory mandates by the FAA
- Important governance characteristics of UAS spectrum access models
  - Safety assurance, spectrum access prioritization, enforcement, coordination, planning to ensure link availability, continuity during handoffs, and contingency planning
  - Third-party coordinator could be a broader, less specific role across other access models
- All models have potential liability issues
  - Compliance with FAA/FCC regulations a large component
  - Applicable to UAS operators, CNPC link service providers, and third-party coordinators
- Necessary parameters that FCC and NTIA will need to incorporate into possible service rules for UAS spectrum is potentially extensive
  - Combined with an urgent need for action given the rate of UAS development

FEDERAL ADVISORY AND OTHER COMMITTEES FOR UAS

Federal Advisory and Other Federal Committees for UAS

- FCC TAC
- FAA DAC
- UAS ExCom
- NASA UPP
- PNT Advisory Board

Findings: Federal Advisory and Other Federal Committees for UAS

- There are disparate federal advisory and other committees with ongoing UAS activities
- No national committee is assuming leadership, specifically as a national focal point and centralizing function, on UAS spectrum
- Instead of making spectrum decisions in isolation, the 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
- 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

Alternative Mechanisms and Governance Structures

- Designate a central POC
- Establish an office within a federal agency
- Create a new executive steering committee
- Expand the charter of an existing federal advisory committee
- Expand UAS ExCom
- Establish a new federal advisory committee

Recommendations

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.

BACK-UP

Definitions: UAS CNPC and C2

Control and Non-Payload Communications (CNPC)

- ITU-R: The radio links, used to exchange information between the UA and UACS, that ensure safe, reliable, and effective UA flight operation[1]
  - Includes telecommand messages, non-payload telemetry data, support for navigation aids, air traffic control voice relay, air traffic services data relay, target track data, airborne weather radar downlink data, non-payload video downlink data
- FCC TAC: Includes C2, detect and avoid, air traffic management, etc.[2]
- RTCA: 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[3]

Command and Control (C2)

- ICAO: The data link between the remotely piloted aircraft and the remote pilot station for the purposes of managing the flight[4]

- FAA: The link between the ground control station and the small unmanned aircraft[5]

UAS Activities

	FCC Technological Advisory Council (TAC)	FAA Reauthorization Bill, Section 374	FAA Drone Advisory Committee (DAC)	International Civil Aviation Organization (ICAO)	NASA UAS Traffic Mgt (UTM) Pilot Program (UPP)	RTCA	3GPP
Purpose	Provides technical advice to the FCC, under FACA	Responds to Congress under Section 374 of FAA Reauthorization Act of 2018 (Public Law 115-254)	Provides FAA with advice on key UAS integration issues by helping to identify challenges and prioritize improvements	Builds consensus on international civil aviation standards and recommended practices and policies, under the UN	Develops, demonstrates, and provides enterprise services to support implementation of initial UTM operations	A standards development organization, including SC-228 which develops minimum operational performance standards (MOPS) for UAS	A standards organization which develops protocols for mobile telecommunications, including UAS 5G connectivity
Scope	Study the spectrum issues for UAS and identify spectrum useful for UAS C2	FAA, NTIA, and FCC to submit a report to Congress on use of 960-1164 MHz (L-band) and 5030-5091 MHz (C-band) for UAS operations	Create broad support for an overall UAS integration strategy and vision	Addressing spectrum planning for 5 GHz band, including UAS in 5030-5091 MHz; coordinating with ICAO RPAS Panel	Define initial set of industry and FAA capabilities to support UAS traffic mgt (UTM) at flight levels below 400 feet; transfers NASA research to FAA to support automated UTM operations	Development of aviation standards and supporting guidance material for FAA certified C2 links to be used by UAS operating in non-segregated, controlled airspace	3GPP TR 36.777 in Release 15 provides the results of a study on potential LTE enhancements for UAS; 3GPP RAN provided technical specs for LTE support of UAS
Spectrum	Aviation and non-aviation bands (incl. terrestrial mobile and unlicensed)	960-1164 MHz (L-band) and 5030-5091 MHz (C-band); other spectrum might be acceptable depending on safety case		Focus on licensed spectrum for operation	No discussion of spectrum bands in summaries or reports	960-1164 MHz (L-band), 5030-5091 MHz (C-band) and commercial SATCOM links	Commercial cellular bands
Access Models	Consider extension of Service Area Boundaries metric to higher altitudes	White space approach for L-band; need to identify access mechanism for C-band		Dedicated aviation spectrum for terrestrial links or detailed aviation performance models defined for commercial SATCOM links			