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UAM Research – X4

Introduction to Community Based Rules (CBRs)

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Executive Summary

Recent advances in technology have enabled industry development of new and innovative vehicle types, offering lower operating costs and highly automated functionality that facilitates the introduction of new types of operations. These include low-altitude airspace operations with small Unmanned Aircraft Systems (UASs), short distance urban and intercity operations, and high-altitude Upper Class E operations. These and other new operations are expected to result in a much higher operational tempo than is currently experienced across the National Airspace System (NAS). The projected increase in operations, as well as the introduction of new aircraft form factors and supporting technologies—including increasing autonomy—will present challenges to the existing Air Traffic Management (ATM) system, which is currently unable to cost-effectively scale and deliver needed services.

In response to these challenges and opportunities, a highly automated, cooperative environment incorporating a federated network has been envisioned and described through multiple operational concepts, depicting the future operating environment as part of the NAS. Foundational to the success of this future operating environment is the establishment of common business rules and understandings across relevant stakeholders, referred to as Community Based Rules (CBRs).

Development, adoption, and implementation of CBRs will require collaboration across multiple stakeholders, including operators, support services (industry), and the Federal Aviation Administration (FAA), to identify and resolve a broad range of questions and challenges. Examples of these questions include "what rules are needed?", "how are they expressed?", and "how will they be managed?"

This document identifies and describes an initial set of questions and considerations to be examined as efforts begin to create the innovative, automated, cooperative operating environment of the future. The goal is to establish a common frame of reference to support discussions and decisions regarding the future implementation of CBRs as part of the NAS.

Version History

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1 Introduction

1.1 Purpose

This document provides an overview of the Community Based Rules (CBRs) construct, its history and objectives, and an initial set of questions and considerations to be examined for specific CBR elements. Its purpose is to support discussions and decisions regarding implementation of CBRs as part of a cooperative operating environment as part of the National Airspace System (NAS). The goal is to provide a common frame of reference for discussion, planning, and decision making through a shared understanding of potential challenges to be faced.

1.2 Background

Recent advances in technology have enabled industry development of new and innovative vehicle types targeting lower operating costs and highly automated operations; these vehicles facilitate the introduction of new types of operations. These include low-altitude airspace operations with small Unmanned Aircraft Systems (UASs) as well as urban and intercity operations for cargo and transport (UAM/AAM). These and other new operations are expected to result in a much higher operational tempo than is currently experienced across the NAS. The projected increase in operations, as well as the introduction of new aircraft form factors and supporting technologies—including increasing autonomy—will present challenges to the existing Air Traffic Management (ATM) system, which is unable to cost-effectively scale to meet the projected service needs. In response to these challenges and opportunities, Concepts of Operations (ConOps) have been developed for Urban Air Mobility (UAM) [1], UAS Traffic Management (UTM) [2], and Upper Class E Traffic Management (ETM) [3]. One common element of these concepts is the description of a highly automated, cooperative environment incorporating a federated network through which operators plan and manage their operations by sharing operational information with other operators to ensure a safe and efficient environment. Operations within this cooperative environment would have minimal or no interactions with existing Air Traffic Control (ATC) under nominal operations, as the cooperative operations are conducted within specific, defined volumes of airspace.

Foundational to the success of this federated, highly automated, cooperative environment is the establishment of common business rules across relevant stakeholders, referred to as CBRs. Development, adoption, and implementation of CBRs will require collaboration across multiple stakeholders—including operators, industry, and the Federal Aviation Administration (FAA) as the regulator—to identify and resolve a broad range of questions and challenges. Examples of these questions include “what rules are needed?”, “how are they expressed?”, and “how will they be managed?”

The FAA’s published UAM ConOps contains a notional architecture depicting areas expected to be developed and deployed by industry. Figure 1 depicts the UAM notional architecture. The expectation is CBRs will be created and implemented across the industry-developed federated network, making the CBRs actionable to support the operations. Interactions and relationships of industry-developed business rules to the FAA’s architecture/infrastructure and regulatory responsibilities will differ depending on the specific element or area addressed by the CBR.

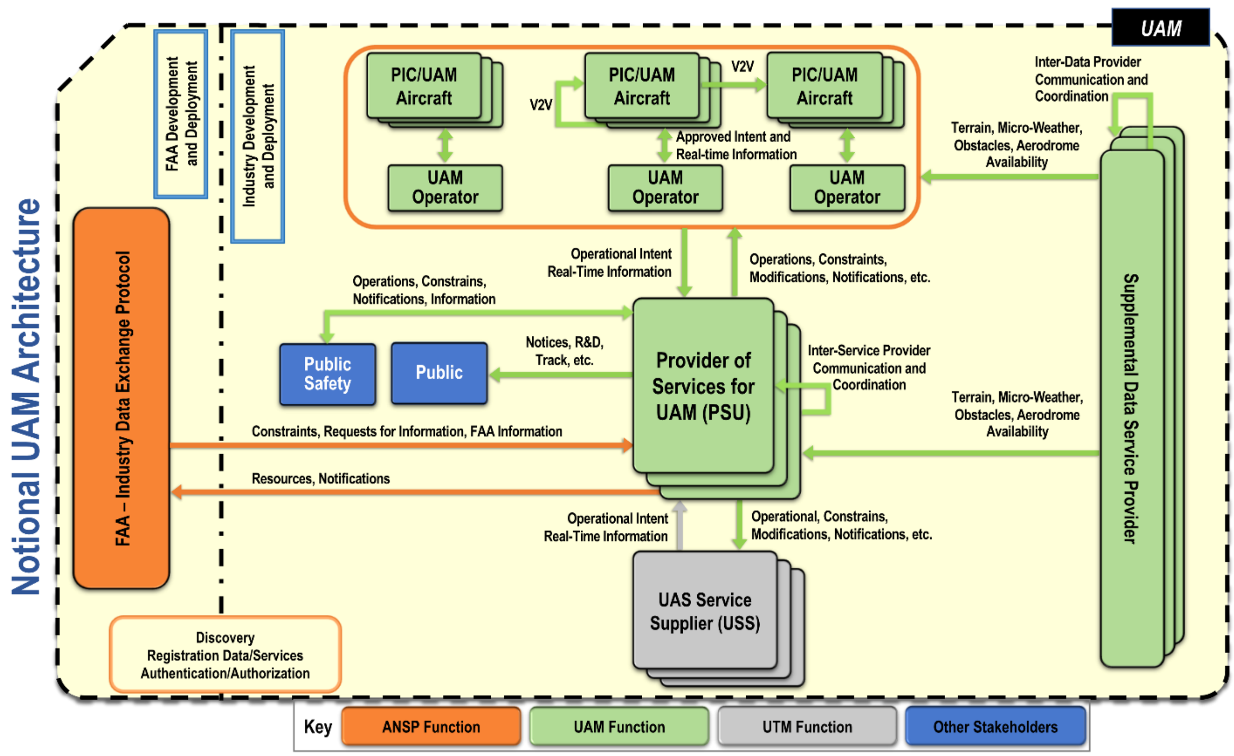

Figure 1: Notional UAM Architecture [1]

1.3 Scope

This document identifies and describes an initial set of questions and considerations to be examined as efforts continue to create the innovative, automated, cooperative operating environment of the future. The goal is to establish a common frame of reference to support discussions and decisions regarding the future implementation of CBRs as part of the NAS.

1.4 Assumptions

The following assumptions have been used to guide this consideration of CBRs.

- CBRs are foundational to the cooperative, highly automated, sharing environment described in the FAA's UAM ConOps [1] and executed in the National Aeronautics and Space Administration's (NASA's) Advanced Air Mobility (AAM) National Campaign (NC) X4 airspace simulation activity.
- CBRs reflect agreement across the airspace user (industry) community with regard to specific elements and interactions, including the manner in which they will be conducted and governed.
- CBRs will include a human readable version upon which the agreement is based, as well as a corresponding machine understandable (executable) version that delivers the agreed outcomes during operation of the automated environment.

- Based on the content/focus of the specific CBR, it may require coordination with the airspace regulator (i.e., the FAA). The level of coordination may differ based on the content of the specific CBR.
- The FAA retains regulatory and oversight authority for the NAS.

2 Community Based Rules (CBRs) Overview

CBRs are business rules agreed upon by relevant stakeholders and coordinated, qualified, and/or approved by regulatory authorities as appropriate. They are envisioned as part of the broad, updated framework governing and supporting NAS operations – specifically those conducted in the envisioned cooperative environments (UTM, UAM/AAM, ETM, XTM).

2.1 Purpose

The current NAS operating environment is predominantly centrally orchestrated and human centered. As a result, the framework—which includes broad guidelines, general priorities, and other elements—relies heavily on human judgement for execution. The future NAS framework, which includes the highly automated, federated, cooperative environment envisioned, specific, agreed-upon common rules will be needed for the disparate actors (and associated systems/automation) to undertake complementary actions/responses that ensure, at minimum, the target levels of safety, security, and efficiency are achieved. CBRs represent the instantiation of these agreements. They are foundational to the deployment and operation of a flexible, scalable environment necessary to meet the anticipated service demands.

2.2 Description and Classification

CBRs will be developed by industry and agreed upon by relevant stakeholders and will require differing levels of engagement with the FAA to effect coordination, acceptance, qualification, or similar action as appropriate based on the specific topic or area covered. As such, they serve as artifacts that reflect the agreement and intent of stakeholders (e.g., airspace users, third-party industry support vendors) with regulatory recognition as needed.

CBRs may be classified as being of two types, administrative and operational, described in Sections 4.1 and 4.2, respectively. Administrative CBRs address how CBRs are developed, managed, and changed, as well as the associated processes. Operational CBRs focus on areas/topics specific to (or required by) the operation itself. Operational CBRs are likely to include a human readable version upon which the cross-stakeholder agreement is based, as well as a corresponding machine understandable (executable) version to support the highly automated environment during operations.

2.3 Overarching Considerations

As described above, the topics addressed by CBRs range from those focused on the CBRs themselves to those supporting the operation. Development and implementation of an innovative cooperative environment supported by the novel CBR construct presents, a wide range of considerations, content questions, and process challenges. Identification, let alone resolution, will require significant effort over an extended period. To begin the shared conversations and interactions, a short list of considerations and questions is provided below.

- What are the initial set of CBRs (areas/topics) industry needs to address to ensure safe operations?
- What forum will be used to meet the needs of the broad stakeholder community as well as respond to the detailed technical elements?
  - Are certain topics handled in differing forums? By what mechanism is the selection made?
- CBRs will be developed collaboratively and include the range of information—at a level of granularity needed—to assure a clear, common understanding across all stakeholders.
- CBRs are transparent (i.e., public) to the extent possible, reflecting security and other relevant considerations.
  - Is there an agreement on whether the construct of the rules themselves (e.g., public, transparent) should be designed to be expressed in a digital format that is machine understandable (without losing context/intent)?
  - How is validation of the agreed rules' intent against that of the machine executable, digitally formatted rules "certified"?
- The management processes (e.g., creation, update, dispute resolution, validation, deprecation) are known and documented.
  - Does the dispute resolution process recognize and differentiate between objection to a rule being executed consistent with the human-agreed version's intent and objection to the agreement itself? If the rule in question has undertaken necessary coordination to gain regulatory consent, does disposition require regulatory participation?
- What content is standard (minimally required or expected) versus optional? For example:
  - What is the topic (e.g., noise requirements)?
  - Who is affected (e.g., which provider of services)?
  - Under what conditions does it apply (e.g., arrival/departure/enroute)?
  - When and for how long does it apply?
  - What is the level of precision and/or accuracy required?
  - Is the rule public or not?

2.4 Industry and Government Interaction

Relationships between industry and government (e.g., FAA, Department of Transportation [DOT]) differ based on the focus of the specific CBR. In some instances, the rules or topic area of an individual CBR will determine the level of engagement necessary with the regulatory authority. The level of engagement also has implications for the level of involvement that the authority will undertake as part of the applicable coordination for the specific CBR. The range of engagement by the regulator may span from minimal to high levels. At higher levels, significant documentation and testing, as well as formal acceptance, authorization, or qualification, may be necessary prior to operational use by Industry.

Another aspect of the relationship between government and industry before a specific CBR may be used operationally is “equity interest.” This refers to how closely the topic/area covered by the specific CBR is related to government responsibilities (i.e., mission) or policies. Some CBRs, for example, those focused on aviation safety, fall directly under the FAA’s regulatory mission. Other CBRs, such as avoiding unnecessary anti-competitive technical specifications for participation in the federated Provider of Services for UAM (PSU) (i.e., industry) network, may be subject to policies or mission responsibilities that fall under the purview of regulatory agencies beyond the FAA.

Figure 2 provides a notional depiction of examples across the range of anticipated government engagement and equity interest. The individual dots represent specific CBRs, while the boxes within which they reside reflect the expectation that multiple individual CBRs may address areas with similar equity and engagement profiles. Of particular significance, CBRs with high equity/engagement profiles may require significant government and/or industry resource commitments. The resource commitments would be driven, for example, by more extensive testing, validation, evaluation, and documentation compared to CBRs with minimal equity/engagement profiles. A specific example would be the level of resource commitment that can be anticipated to develop, test, and satisfy required coordination/approval/qualification requirements for CBRs focused on separation compared to those focused on the procedures and technical requirements for participation in the federated network.

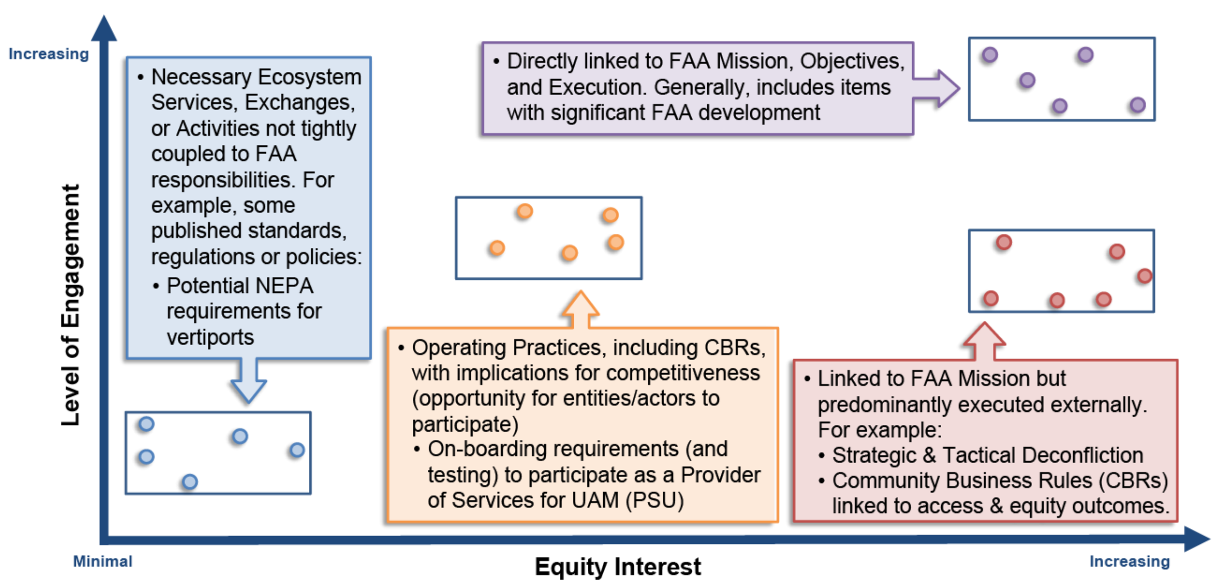

Figure 2: Notional Depiction of FAA Equity Interest and Engagement

2.5 Governance of CBRs

Included in the consideration examples above (Section 2.3), identification and agreement on a forum to facilitate and bring to closure discussions on the CBRs will be crucial to success. Historically, the creation and maintenance of standards used across industry participants has been handled through industry-led working forums and established standards bodies. Application and use of such forums or governing bodies to address CBRs will present novel challenges—especially following implementation when the need for quick response to unforeseen circumstances may arise. To support and respond quickly and effectively to the dynamic environment envisioned for UAS operations, CBR management and update processes present different challenges from historical standards development and management practices. The tight coupling of systems, data exchanges, etc. necessary for complementary actions across many entities to meet the safety, security, and other service demands will necessitate agreement at very detailed levels of interaction with associated time sensitive considerations among the federated, industry network and participants depicted in Figure 1.

2.5.1 Governing Body

The identification of a governing body for development and management of CBRs brings questions related to participation, decision-making, and appeals while maintaining agility. In addition to the traditional administrative artifacts created (e.g., documents, manuals), operational CBRs will require a "live" or executable version accessible to relevant stakeholders for use across the federated network during operations. This results in questions around the possible use of multiple governing bodies to maintain all or some of these executable versions (e.g., multiple governing bodies based on the CBR topic) or another construct to ensure the integrity of executables. For CBRs (including the executable versions) that require significant testing, validation, and coordination with regulatory authorities to gain necessary permission(s) for use, is the selected governing body expected to undertake these efforts on behalf of the relevant stakeholders?

3 Operational Categories

Included in discussions of CBRs has been connection to the category or state of the operation at that point in time. This refers to references or links made between what CBRs are needed or how they should be construed if the operation is described as nominal, off-nominal, emergency (or exigent), or a contingency event. To aid in creating a common framework for future discussions, this section provides general descriptions or characteristics of the differing categories as a starting point for discussions. The descriptions provided are not intended to be the definitive or exclusive framing. Recognizing the breadth of NAS operations, the many individual airspace uses, flight conditions, and events that occur, there are no clear, bright lines separating specific events into one category as opposed to another. As an example, an aircraft may experience a loss of communication and not be in distress, while another is (the latter constituting an emergency, while the former may or may not depending on the specific circumstances). The same is anticipated to be true for UAS operations. A UAS experiencing lost link with a defined, detailed procedure known to relevant stakeholders and systems may or may not constitute an emergency depending on the circumstances—or some may describe it as an emergency, but not of the same criticality as an emergency in which the flight integrity of the vehicle is in jeopardy.

3.1 Nominal Operations

Nominal operations refer to operations that are unimpacted, to any significant degree, by unplanned events (e.g., changes in flight conditions).

3.2 Off-Nominal Operations

Off-nominal operations refer, generally, to planned operations that are impacted to a significant level. There may be associated (i.e., second order) safety implications, however, the responses to address the conditions are intended to mitigate them. The conditions by themselves do not result in declaration of an emergency or the operational prioritization of an individual aircraft's operation over that of another in response[1]. Examples of off-nominal operations include:

- Weather
    - The predominant cause of off-nominal operations is weather. Impacts may be large-scale in nature, such as extended lines of convective storms, or highly localized, such as unusual winds resulting in infrequently used vertiport/airport configurations with significant throughput impacts.
    - In the case of UAS operations, winds greater than those forecast or anticipated that preclude flight to destination would also fall into this category.
- Equipment or services
    - Off-nominal operations may result from impact to an individual aircraft's equipage status. An example is an outage that does not permit the aircraft to attain the usual cruise altitude or speed, but the vehicle is able to safely continue flight to its destination.

3.3 Contingency Operations/Events

Generally, a contingent event results in impact to airspace services or capacity caused by unforeseen incidents. Contingent events include large-scale system, equipment, or service outages (e.g., radar, navigation, communication, PSU network). Additional examples that result in contingency actions may involve pop-up airspace restrictions (e.g., Temporary Flight Restrictions [TFRs], hazards) or unplanned aerodrome closures. At a high level, the unplanned nature of the incident or event and reactive nature of the response characterizes it as a contingency event.

In contrast, off-nominal operations described above tend to impact multiple operations with broad, coordinated (i.e., planned, proactive) responses, such as Traffic Management Initiatives (TMIs) or published constraints. While there are in many instances precoordinated contingency plans, contingency actions are reactive to the incident after it occurs, while plans in response to off-nominal operations can generally be described as anticipatory.

[1] Traffic Management Initiatives (TMIs) result in the prioritization of flows or operations for traffic synchronization purposes but are distinct from the prioritization described for emergency operations.

3.4 Emergency/Exigent Operations

In the case of emergency operations, the entity providing separation services predominantly uses information about the causal factor to arrange additional services (e.g., fire rescue, Search and Rescue [SAR]). Use of the term in this context focuses predominantly on a single aircraft event. Priority is provided to the distressed aircraft experiencing the issue and other traffic/operations are managed in response the needs of the emergency flight. For this reason, significant focus is on the actions or movement of the aircraft in difficulty, rather than the cause of the condition, unless it is relevant to the support services needed (e.g., medical personnel on arrival).

While there are broadscale emergency conditions and hazards (e.g., fires, emergency responses to hurricane/flooding), the flights responding to them receive priority based on established protocols and actions, such as TFRs. Other restrictions would potentially result in off-nominal operations depending on the scope of the restriction's impact.

4 Types of CBRs

As introduced in Section 2.2, CBRs may be classified as being of two types: administrative and operational. Administrative CBRs address how CBRs are developed, managed, and changed, as well as the associated processes. Operational CBRs focus on areas/topics specific to (or required by) the operation itself.

4.1 Administrative CBRs

Administrative CBRs refer to the agreements across relevant stakeholders regarding how CBRs themselves are managed. They serve as reference artifacts of agreed-upon processes for creating, changing, and amending CBRs. There is a significant amount of effort required to define and settle administrative CBRs before operational CBRs can be finalized. In other words, the rules for creating and modifying an operational CBR should be in place first.

4.1.1 Management

CBRs are envisioned to be created, updated, and managed by industry, with regulatory interaction as applicable for the specific topic. Administrative CBRs provide the organizational structure and associated reference artifacts reflecting the community's agreements around what processes are needed and how they function. Recognizing the innovative nature of CBRs, a variety of questions around basic efforts for community interaction and agreement present themselves. Building on the short list of overarching considerations provided in Section 2.3, additional questions focused on the governance and management of CBRs include the following.

- What processes are required to begin creating CBRs?
- What forum should be used to identify and prioritize the CBRs needed?
    - If a single forum/governing body is not used for all CBRs (or even the administrative CBRs), how is the allocation of topics effected?
- What are the criteria for participation in the governing body?

    - Is participation linked to financial contribution to offset the costs of the forum?
    - How are disagreements over the processes adjudicated?
- Will the same governing body be used for administrative and (all) operational CBRs?
- Presumably, the governing body selected has established processes for most basic needs, but are those processes extensible to operational CBRs as envisioned?

4.2 Operational CBRs

Operational CBRs are those that reflect agreements on the direct conduct of operations, rather than focusing on the management of the CBRs themselves. At their heart, they concentrate on actions, exchanges, and rules to ensure overall service expectations[2] and needs are met. As a foundation for any of the services/functions envisioned in the UAM ecosystem, a minimum of information will be needed. For example, CBRs would establish requirements for PSUs, sharing intent, updates, precision, accuracy, etc. under a range of conditions (e.g., potentially shorter update cycle and greater accuracy for arrival/departure than while operating in an enroute phase of flight).

4.2.1 Components of Operational CBRs

As noted earlier, another difference between operational and administrative CBRs is those which are operational include an "executable" component. This results in the operational CBR being comprised of, at minimum, two components:

1. An artifact or document that contains the assumptions, objectives, performance requirements, services, technical details, etc., reflecting a common understanding and agreement across the relevant stakeholders. This "specification" is sufficiently detailed, so individual system development efforts result in complementary actions within the federated network.
2. A machine-understandable (executable) version of the above artifact(s) that is used during daily operation as the operational instantiation of the agreement(s) to support the highly automated environment envisioned.

In some cases, CBRs may be constructed such that they are embedded or are precursors to others. For example, to reconcile demand/capacity imbalances or resolve conflicts, the CBR(s) governing how operations are prioritized may be needed.

Operational CBRs include the business rules covering all operating categories (e.g., nominal, off-nominal, etc.) described in Section 3.

4.2.2 Validation

In light of the components of operational CBRs and planned operational (i.e., automated) nature, the importance of validation cannot be overstated. The purpose of validation is to confirm to the relevant stakeholders (i.e., those party to the agreement or covered by it) that the executable version

[2] A listing and description of service expectations from ICAO's *Global Air Traffic Management Operational Concept* [4] is provided in Appendix A.

not only performs predictably, but also meets the intent articulated in the agreement. Additionally, validation for CBRs focused on areas/topics with regulatory engagement and equity interests will need to provide required documentation to gain acceptance, authorization, approval, or qualification, as applicable, from the regulator.

Entities responsible for validation of the CBRs, as well as the regulatory body, may vary depending on the specific topic and level of engagement and equity interest, as discussed in Section 2.4.

4.2.3 Considerations

Building on the overarching considerations provided in Section 2.3, additional questions focused on operational CBRs include the following.

- What specific entity is responsible for performing validation?
  - For CBRs requiring extended coordination with regulatory authorities, is the same entity responsible for that engagement as well?
- How is the context/intent of the agreed rule (human readable format) validated in the digital expression/execution so that the agreed rule is implemented correctly in the digital format?
- How is consistent incorporation/execution across the federated industry network validated and assured?
- If an off-nominal event requires the UAM vehicle to leave the cooperative environment and enter controlled airspace, the FAA/ATC would require notification. How are CBRs with direct implications for ATC operations developed? Who (i.e., what entities) participate and in what forum? Is it possible that local or regional operating practices and requirements necessitate incorporation into Facility or Area Letters of Agreement?
  - How would locally specific needs be addressed in CBRs? Would agreements with the regulator be necessary to move forward? If so, would these be more administrative than operational in nature?
  - At what level of perturbation or circumstance will cooperative operations be expected (permitted?) to impact the ATC control environment? What are the rules, lead times, and data exchanges required/expected to ensure the safety and integrity of the NAS as a whole? For example, unless CBRs are designed such that virtually all off-nominal situations envisioned which impact operations in cooperative volumes will be resolved within the volume, impact and implications for ATC services will need to be taken into consideration (and agreed with FAA/ATC) when developing CBRs for off-nominal events.
- What conditions constitute declaration of emergency status (i.e., safe conduct of the flight is in sufficient jeopardy to warrant priority handling)? Do UAS operators use a common framework to avoid emergency prioritization being afforded or sought differently?
  - When an emergency is declared, what information at a minimum is expected to be exchanged? Examples of information may include remaining flight time available, aircraft identification and type, nature of the emergency, Remote Pilot in Command

(RPIC) desires, and if the vehicle can remain within the cooperative volume or requires entry into the ATC control environment.

5 CBR Examples

Operational CBRs include the business rules that reflect agreements on the direct conduct of operations. This includes conflict identification and resolution, managing demand/capacity imbalances, and performance requirements, among others. Examples of operational CBRs with descriptions, including several being developed to support X4 [5], are provided in the following subsections.

5.1 Onboarding Requirements

Entities providing services to support UAM operators in meeting operational requirements will be subject to meeting specific requirements prior to becoming qualified to provide services that support safe and efficient operations in UAM. With UAM operations envisioned to be highly automated and information-centric, service providers such as PSUs will be required to meet onboarding requirements that include areas such as data exchange, performance, as well as security and data protection. Onboarding requirements may vary based on the services being provided, however, it is expected that PSUs will be held to a certain standard for meeting specific requirements for supporting UAM operations. Onboarding requirements for X4 are briefly mentioned, with no actual requirements listed, as stated in the X4 CBR Catalog [5] Identification (ID) CBR-GEN-1:

- The PSU should meet onboarding requirements to participate in the PSU network.

The rationale for this CBR is that security and authentication are required for the PSU network due to the safety-critical nature of the operational plan and the system's connectivity to FAA systems (which will include its own onboarding process).

5.2 Strategic Conflict Management

Strategic conflict management considerations include pre-departure flight planning with time and volume over a specified point. Within the necessary agreements would be common definitions/calculations of what constitutes a confliction, along with the rules for deconfliction. Note that as with today's operation, strategic operations and deconfliction refer to a phase and is not exclusively pre-departure. As vehicle capabilities increase to support extended flight times, circumstances may evolve in which the considerations defining strategic and tactical deconfliction are met while the vehicle is in flight. Strategic conflict management is addressed in the X4 CBR Catalog [5] ID CBR-OP-2 as follows:

- Strategic operational intent should be shared with all participants in the PSU network.

The rationale for this CBR is that in order to execute strategic conflict management cooperatively, strategic operational intent needs to be made available to all participants in the PSU network.

5.3 Tactical Conflict Management

While not presently a part of the X4 simulation, tactical conflict management refers to CBRs defining resolutions, tactics, or methodologies unavailable in the strategic phase. Examples include the following.

- Time-based measures or direction may be issued to flights by the separation service of the federated network.
- Under defined circumstances with supporting performance requirements, separation responsibility may be delegated from the federated separation service to specific vehicle(s) to execute complementary Vehicle-to-Vehicle (V2V) maneuvers. (This can be viewed as analogous to visual separation or in-trail procedures today.) Upon completion of the maneuver and at a defined point, the delegation would end.
    - *Note:* Collision avoidance capabilities such as the Traffic Collision Avoidance System (TCAS) and Airborne Collision Avoidance System (ACAS) are distinct from the V2V maneuvers as part of the separation service described above.

5.4 Service Prioritization

Service prioritization has traditionally been described as "first come, first served." Will this "base" prioritization schema extend to cooperative operations? Priority may vary for various stages of operations, such as routes, changes in flight plans, and departures/arrivals at vertiports. Service priority could begin with route planning, mutually agreed upon by stakeholders, and extended by a predetermined number of operations on a route or at the vertiport at a certain time. Arrival and departure priority could be determined in advance or within a specified window that the operation must begin. Individual operator priorities could change as circumstances change. From a system perspective this would encourage relevant data sharing to support reallocation/availability of newly available slots/routes – which also require CBRs for execution during operations (in real time).

For example, an operator is going to miss their departure window, would other UAM operators be able to make use of the now available slot – and if multiple operators can (and desire) to adjust their operations to take advantage it, how are their requests prioritized?

5.5 Demand Capacity Balancing (DCB)

Recognizing the capacity is neither finite nor static, there are times when service demands will exceed available capacity. As conditions change, capacity may be adversely impacted by elements such as weather. In order to balance (manage) demand when it exceeds – or is projected to exceed – capacity, a variety of information is necessary. These include projections of capacity available and the planned demand. For effective use of the resources sharing of information by operators is necessary and agreement on how available capacity is determined are prerequisites to automated DCB capabilities envisioned and described for the cooperative environment. Examples of CBRs related to DCB and included as part of X4 include capacity information and imbalance resolution.

5.5.1 Capacity Information

As stated in the X4 CBR Catalog [5] ID CBR-DCB-1:

- Capacity information about shared resources should be discoverable by PSUs.

The rationale for this is that the resource owner would be responsible for defining the capacity information and making it available to PSU; as there could be different resource owners for different resources, there needs to be a way for PSU to discover how the information can be obtained.

5.5.2 Imbalance Resolution

As stated in the X4 CBR Catalog [5] ID CBR-DCB-8:

- PSUs' submitted operational plans should adhere to nominal scheduling rules when a predicted demand/capacity imbalance exists on a shared resource.

The rationale for this is, to promote efficiency and fairness, PSUs should have a common method of identifying which operation(s) would be modified when there is a predicted demand/capacity imbalance.

6 Next Steps

Building on this document's initial description of CBRs, potential classification methodology, example subject areas/topics, and other considerations, significant effort remains to expand and finalize these and other elements. CBRs are foundational to realizing the flexible, scalable, automated, cooperative operational environment described in the ConOps. Delays in developing and maturing the CBRs are likely to adversely impact the ability to initiate Beyond Visual Line of Sight (BVLOS) UAS operations if not available when the regulatory framework is updated. To avoid these delays, the following activities and efforts are recommended going forward:

- Identification and agreement on the forum for industry to begin the needed, structured collaboration
- Identification and prioritization of the CBRs needed for initial operations
- Agreement on the format and content for both administrative and operational (including human readable as well as executed) CBRs

7 Conclusion

As the NAS becomes more complex and incorporates cooperative UAS operational environments (i.e., UTM, UAM, AAM, ETM, Extensible Traffic Management [XTM]), establishing CBRs is a necessary, foundational element for safe and efficient integration into the overall ATM system. While the FAA retains regulatory and oversight authorities, the responsibility for initiation, development, management, and validation of CBRs relies heavily on industry stakeholders to move the processes forward to make cooperative operations a reality. As an additional consideration, overarching rules and practices reflected in CBRs are expected to be used in the multiple cooperative domains. While each environment with its differing form factors (aircraft types), range of vehicle operating envelopes present, and types of operations, are expected to require CBRs addressing environment specific issues, care should be taken to avoid unnecessary CBR specificity. To the extent practicable, use of common CBRs addressing similar topics or areas which present themselves across the cooperative environments should increase cost-effectiveness, reduce validation requirements and coordination timelines needed prior to operational use/implementation.

The UAS environment will continue to mature, becoming significantly more automated in the years to come. Establishing CBRs will provide foundational practices that are scalable and flexible to meet the future demands of this dynamic environment while ensuring target service expectations (see Appendix A) are met.

Appendix A ATM Service Expectations

The following list of service expectations and descriptions is excerpted from Appendix D of the ICAO Document 9854, Global ATM Operational Concept [4].

Key to the operational concept is a clear statement of the expectations of the ATM community. The expectations for the global ATM system have been discussed among members of the ATM community in general terms for many years. These expectations stem from efforts to document ATM "user requirements". The expectations hereafter are interrelated and cannot be considered in isolation. Furthermore, while safety is the highest priority, the expectations are shown in alphabetical order as they would appear in English.

Access and Equity

A global ATM system should provide an operating environment that ensures that all airspace users have right of access to the ATM resources needed to meet their specific operational requirements and that the shared use of airspace by different users can be achieved safely. The global ATM system should ensure equity for all users that have access to a given airspace or service. Generally, the first aircraft ready to use the ATM resources will receive priority, except where significant overall safety or system operational efficiency would accrue, or national defense considerations or interests dictate that priority be determined on a different basis.

Capacity

The global ATM system should exploit the inherent capacity to meet airspace user demands at peak times and locations while minimizing restrictions on traffic flow. To respond to future growth, capacity must increase, along with corresponding increases in efficiency, flexibility, and predictability, while ensuring that there are no adverse impacts on safety and giving due consideration to the environment. The ATM system must be resilient to service disruption and the resulting temporary loss of capacity.

Cost-Effectiveness

The ATM system should be cost-effective, while balancing the varied interests of the ATM community. The cost of service to airspace users should always be considered when evaluating any proposal to improve ATM service quality or performance. ICAO policies and principles regarding user charges should be followed.

Efficiency

Efficiency addresses the operational and economic cost-effectiveness of gate-to-gate flight operations from a single-flight perspective. In all phases of flight, airspace users want to depart and arrive at the times they select and fly the trajectory they determine to be optimum.

Environment

The ATM system should contribute to the protection of the environment by considering noise, gaseous emissions and other environmental issues in the implementation and operation of the global ATM system.

Flexibility

Flexibility addresses the ability of all airspace users to modify flight trajectories dynamically and adjust departure and arrival times, thereby permitting them to exploit operational opportunities as they occur.

Global Interoperability

The ATM system should be based on global standards and uniform principles to ensure the technical and operational interoperability of ATM systems and facilitate homogeneous and non-discriminatory global and regional traffic flows.

Participation by the ATM Community

The ATM community should have a continuous involvement in the planning, implementation, and operation of the system to ensure that the evolution of the global ATM system meets the expectations of the community.

Predictability

Predictability refers to the ability of airspace users and ATM service providers to provide consistent and dependable levels of performance. Predictability is essential to airspace users as they develop and operate their schedules.

Safety

Safety is the highest priority in aviation, and ATM plays an important part in ensuring overall aviation safety. Uniform safety standards and risk and safety management practices should be applied systematically to the ATM system. In implementing elements of the global aviation system, safety needs to be assessed against appropriate criteria and in accordance with appropriate and globally standardized safety management processes and practices.

Security

Security refers to the protection against threats that stem from intentional acts (e.g. terrorism) or unintentional acts (e.g. human error, natural disaster) affecting aircraft, people, or installations on the ground. Adequate security is a major expectation of the ATM community and of citizens. The ATM system should therefore contribute to security, and the ATM system, as well as ATM-related information, should be protected against security threats. Security risk management should balance the needs of the members of the ATM community that require access to the system, with the need to protect the ATM system. In the event of threats to aircraft or threats using aircraft, ATM shall provide the authorities responsible with appropriate assistance and information.

Appendix B References

[1] FAA, UAM Concept of Operations, Version 1.0, June 2020. Available: https://nari.arc.nasa.gov/sites/default/files/attachments/UAM_ConOps_v1.0.pdf (accessed December 22, 2021).

[2] FAA, UTM Concept of Operations, Version 2.0, March 2020. Available: https://www.faa.gov/uas/research_development/traffic_management/media/UTM_ConOps_v2.pdf (accessed December 22, 2021).

[3] FAA, ETM Concept of Operations, Version 1.0, May 2020. Available: https://nari.arc.nasa.gov/sites/default/files/attachments/ETM_ConOps_V1.0.pdf (accessed December 22, 2021).

[4] ICAO, Document 9854, *Global Air Traffic Management Operational Concept*, First Ed., 2005.

[5] NASA X4, CBR Catalog 012722, January 27, 2022.

Appendix C Acronyms

A list of acronyms used throughout the document is provided in Table 1.

Table 1: Acronyms

Acronym	Definition
AAM	Advanced Air Mobility
ACAS	Airborne Collision Avoidance System
AI	Artificial Intelligence
ANSP	Air Navigation Service Provider
ARC	Ames Research Center
ATC	Air Traffic Control
ATM	Air Traffic Management
CBR	Community Based Rule
CCE	Corridor Control Environment
ConOps	Concept of Operations
DAA	Detect and Avoid
DCB	Demand Capacity Balancing
DOT	Department of Transportation
ETM	Upper Class E Traffic Management
FAA	Federal Aviation Administration
FOC	Flight Operations Center
GATMOC	Global Air Traffic Management Operational Concept
LOA	Letter of Agreement
NASA	National Aeronautics and Space Administration
PIC	Pilot in Command
PSU	Provider of Services for UAM
ROW	Right of Way
RPIC	Remote Pilot in Command
SAR	Search and Rescue
TCAS	Traffic Collision Avoidance System
TFR	Temporary Flight Restriction
TMI	Traffic Management Initiative
UAM	Urban Air Mobility
UAS	Unmanned Aircraft System

Acronym	Definition
UTM	UAS Traffic Management
UVR	UAS Volume Reservation
V2V	Vehicle-to-Vehicle
VIP	Very Important Person
XTM	Extensible Traffic Management