Concept of Operations

V2.0

Foundational Principles

Roles and Responsibilities

Scenarios and Operational Threads

Higher Airspace Traffic Management (HATM)

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Federal Aviation Administration

Higher Airspace Traffic Management

Concept of Operations

Version 2.0

Concurrence:

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1 Introduction

1.1 Increased Demand for Higher Airspace Operations

Higher airspace operations (HAO) refer to those that take place above the majority of today's general air passenger traffic, which is notionally above flight level 500. Operations have historically been limited at these altitudes due to the challenges conventional fixed wing aircraft face in reduced atmospheric density of the upper stratosphere and mesosphere. They have typically been conducted only by military aircraft or research aircraft on specific missions.

Recent advances in technologies, however, relating to power and propulsion, aircraft structures, flight automation, and aerodynamics have led to an increase in the number and types of aircraft that can operate in low atmospheric density airspace. New aircraft designed to operate at high altitudes, depicted in Figure 1, have proved to be attractive investments to commercial entities. Sophisticated unmanned free balloons, long endurance High Altitude Platform Stations (HAPS), remotely piloted aircraft systems, supersonic transport (SST) aircraft, and hypersonic aircraft comprise the fleet of future higher airspace operators. These aircraft will provide a range of services including telecommunications, scientific research, technology testing, environmental monitoring, disaster management, high speed passenger transport, and more. Demand for these types of services will likely continue to grow with the advent of new technologies and business markets.

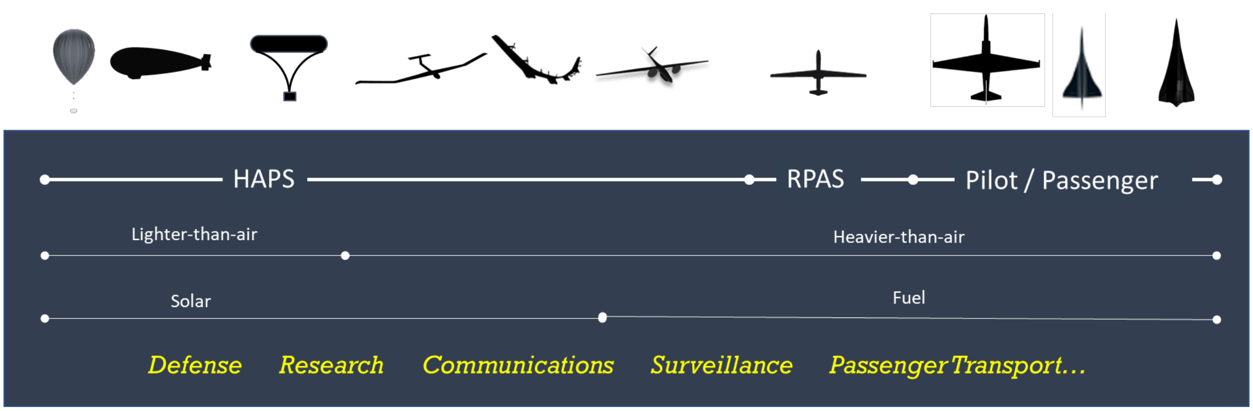

Figure 1. Higher airspace vehicles

1.2 Challenges with Higher Airspace Service Provisions

The increase in demand for HAO presents some challenges for the provision of airspace management services. First, aircraft that operate in higher airspace have vastly different performance characteristics and operational profiles than aircraft operating in the lower altitude strata, and many have high levels of automation. Second, existing supporting infrastructure for airspace management becomes more limited as altitude increases. Lastly, airspace regulations and air traffic services in higher airspace vary by country/State, yet HAO can and will span countries across the globe. Sections 1.2.1 through 1.2.3 describe these challenges in further detail.

1.2.1 Aircraft Characteristics, Performance, and Operational Profiles

Aircraft that plan to operate in higher airspace have a wide range of performance capabilities and diverse mission profiles. Heavier-than-air (HTA) aircraft can range from solar powered with maximum cruise speeds of under 100 knots to SSTs and hypersonics with speeds at the high end. Lighter-than-air (LTA) aircraft, such as unmanned free balloons, dynamically ascend and descend into suitable wind currents to control navigation, with potentially some "light" propulsion as an aid in performance of their mission. As a result, LTA aircraft may have probabilistic trajectories with widely varying standard deviations as one looks forward in the time. Beyond diversity of performance characteristics, the performance of a specific aircraft may also change over time, as a function of the battery state or other environmental parameters. For example, solar-powered HTA may climb during daylight hours and slowly glide downward at night to manage battery power. In the case of LTA's, vertical performance and achievable altitude range may depend on temperature.

The majority of aircraft operations today fly point-to-point, traveling on the shortest path to a destination in relatively straight lines, with durations on the order of hours. Existing traffic management systems are well suited to providing services for these types of operations. Flight paths in higher airspace, however, can be significantly more convoluted and beyond current ATM automation capabilities. They may be unintuitive and non-linear because some need to follow wind currents to get to their destination. Others will loiter in a pattern, moving very slowly and remaining nearly stationary for extended periods of time (days, months, even years), creating localized areas of dense operations. These 'persistent' operations are typically comprised of a fleet of aircraft, from one or more operators.

Upon reaching operational altitude, most HAPS fleets will operate with a high degree of automation. On-board and off-board software will dynamically manage and optimize the fleet, assigning missions or tasks, controlling navigation, and monitoring the health of each aircraft. This automation will shift human involvement towards the management and supervision of the controlling automated systems and not direct command and supervision of individual aircraft or groups of aircraft. As a result, traditional pilot roles may no longer be necessary and new roles will likely emerge, with teams responsible for configuring, maintaining, and overseeing the automation systems.

1.2.2 Airspace Management Support

1.2.2.1 Air Traffic Control Infrastructure

Air traffic control (ATC) infrastructure faces significant limitations in higher airspace. This includes reduced effectiveness of traditional terrestrial communications and radar systems, and increased uncertainty in altimeter reports. ATC communication today relies heavily on voice communications. In situations where direct communication ground to ground with the vehicle operator is not possible, radio relays via satellite links might be employed. Satellite communications can provide a reliable means for HAPS to maintain connectivity beyond line-of-sight. However, this can introduce significant latency for direct pilot and controller communication, coverage gaps, and signal interference from space weather, and can suffer from bandwidth limitations compared to direct ground links.

To expand on this, radar coverage in higher airspace is sparse as ground-based radar (primary and secondary) does not effectively cover these high altitudes. While Automatic Dependent Surveillance–Broadcast (ADS-B) may be usable at high altitudes, it is not widely deployed for persistent surveillance above FL500, and regulatory mandates do not extend there. When beyond radar coverage, if aircraft are equipped with ADS-B, surveillance is possible through a space-based ADS-B service, but otherwise ATC may need to rely on the less timely and precise voice position reports or ADS-C reports (if equipped).

In higher airspace, ATC knows an aircraft's vertical position primarily through barometric altitude. Barometric readings rely on standardized pressure settings which tend to have reduced accuracy in the higher altitude ranges that can lead to discrepancies between indicated and true altitude. To account for the increased altimetry error and associated safety concerns, ATC often has to apply greater vertical separation minima between aircraft. This results in less efficient use of airspace.

1.2.2.2 Air Traffic Management Tools

Even though higher airspace is generally less congested compared to lower altitudes, managing aircraft operations requires dedicated airspace planning and coordination, as the potential for conflicts remains. To maintain aircraft separation today, higher airspace operators have procedural agreements with nearby operators and Air Navigation Service Providers (ANSPs), coordinate with State aircraft operators, and often operate in segregated airspace. While this approach is sustainable in the short term given the current HAO traffic density, it is not scalable, and a managed deconfliction process is needed as more aircraft conduct HAO.

Today, air traffic procedures for these altitudes are highly specialized and often tailored to the specific needs of the aircraft and their missions. Air traffic services for flight planning and separation management are usually provided by specialized units within national or international air traffic control organizations. Air traffic personnel can establish altitude reservations (ALTRVs), where separation between different types of operations, usually military or special operations, is ensured through the deconfliction of volumes of airspace. Pilots flying in or near ALTRVs are required to maintain communication with ATC to ensure situational awareness and adherence to clearance instructions. ALTRVs can be inefficient though because they often block large volumes of airspace for extended periods, even if the space is not continuously used. This restricts other airspace users from operating in those areas, reducing overall airspace capacity and flexibility. Additionally, the fixed nature of these reservations can complicate dynamic air traffic management and limit opportunities for optimizing flight routes.

ATC may also delegate separation responsibility of State aircraft to the military when these aircraft are operating in higher airspace. This delegation occurs under the principle of Due Regard**,** where State aircraft are expected to ensure their own separation from other aircraft. This arrangement is often necessary during military operations, training exercises, or in situations where ATC resources are limited. The military assumes full responsibility for the safe navigation and separation of its aircraft (i.e., Military Authority Assumes Responsibility for Separation of Aircraft [MARSA]), ensuring that they avoid conflicts with other air traffic while operating independently of civil airspace procedures.

As density of operations increases in higher airspace, managing the operations will require more coordination between ATC, military authorities, and civilian/commercial operators. To handle new business cases, ATC will likely have to add larger buffers around aircraft to ensure separation, yet HAO business cases cannot operate with such large spacing. ATC tools and associated procedures will therefore need to evolve to support more flexible and efficient airspace management. In addition, allowing operators to contribute capabilities, such as onboard data processing and information sharing, will help create a more connected and transparent high altitude environment. This collaborative approach enables more efficient coordination and safer integration of diverse vehicles in higher airspace.

1.2.3 Global Nature of Operations

Higher airspace operations are inherently global in nature, as vehicles may traverse multiple sovereign airspaces, oceans, and even near-space environments during a single mission. While the International Civil Aviation Organization (ICAO) provides a standardized framework for airspace classification, individual countries may adapt these standards to fit their specific operational needs and geographical considerations. This leads to variations in rules governing operations across Flight Information Regions (FIRs) in the altitudes where HAO operations are conducted. Many HAO will occur over States where airspace is uncontrolled or even unclassified where ANSPs are not required or are unable to provide separation services.

Management of HAO on a global scale must account for these variations by establishing internationally harmonized frameworks for airspace access, traffic coordination, and regulatory oversight. Developing shared standards, data sharing protocols, and dynamic traffic management approaches will be key to enabling seamless and secure high-altitude transit worldwide.

1.3 Opportunities for Modernized Approaches to Higher Airspace Management

To address the challenges associated with future higher airspace demand, the FAA is exploring and maturing a concept called Higher Airspace Traffic Management (HATM)[1] that modernizes approaches and supporting capabilities for managing aircraft at high altitudes. HATM is a cooperative traffic management concept that provides a means for air traffic management (ATM) to manage the airspace more flexibly and efficiently through the authorized use of Cooperative Areas (CAs), on an as needed basis, within which operators take responsibility for the management of their operations, under the FAA's regulatory authority, while ATC maintains its traditional responsibilities outside these areas.

With HATM, higher airspace operators, and most notably those that loiter or operate persistently, often within fleets of aircraft, provide their own conflict management within CAs, as they are best suited to synchronize their operations with those of others. They share information with each other in a highly automated, information-rich environment that promotes shared situational awareness about each other's operational intent (OI), or an operator's intended/predicted position over a future time horizon, and status. They can use alternative, performance-based Communications, Navigation, and Surveillance (CNS) and conflict management capabilities that best suit their operations to manage traffic within CAs,

[1] Formerly called "Upper Class E Traffic Management (ETM)"

provided a standard CNS performance and FAA-approved operator-to-operator practices are employed. A digital information architecture provides seamless access to accurate and timely information across the federated network of stakeholders.

HATM is an airspace management option that does not require large investments. Services are tailored to the environment using new data-centric technologies that will link diverse entities, including operators, data and technology service providers, and automated systems. Airspace operations within CAs are able to be seamlessly integrated into the existing ATM system, with established rules, procedures, and standardized information exchange protocols to support interactions with ATM and other stakeholders as needed. Higher airspace operators execute missions and meet business objectives safely and efficiently within the CAs through continuous sharing of OI and cooperative deconfliction. ATM authorizes and has awareness of the operations but does not have to take on the computational and human workload associated with providing separation services.

2 HATM Operational Concept

2.1 Key Terms

- **HATM Operator, Cooperative Operator** - interchangeable terms
- **Cooperative Area** (CA)
- **Cooperative Operating Environment** (COE)
- **ATC Environment** (ATCE)
- **FAA Airspace Management Function**
- **Criteria-Based CA Authorization**
- **Case-Specific CA Authorization**
- **Airspace Eligible for Criteria-Based CA Authorization**
- **Airspace Requiring Case-Specific CA Authorization**
- **CA Registration and Information Services** (CARIS)
- **Cooperatively Managed Aircraft**
- **Air-Traffic Managed Aircraft**
- **Cooperative Deconfliction**
- **Conflict Identification**
- **Conflict Resolution**

2.2 Overview

HATM is an airspace management concept that supports the introduction and expansion of novel aircraft operations above where the majority of aircraft fly today. In the United States (US), this altitude is generally above FL500 and predominantly includes Class E airspace above FL600. HATM supports the co-existence of both traditional ATC-provided separation services and a cooperative traffic management approach where operators are responsible for the management, coordination, synchronization, and deconfliction of operations in FAA-authorized airspace, and under the FAA's regulatory authority.

HATM is particularly effective in addressing the diversity of aircraft performance and mission profiles, including most notably, persistent, or loitering operations, which are expected to increase in numbers in the future. With this approach, operators continuously share information with each other about their operations through a highly digitized, information-rich environment that promotes shared situational awareness about each other's operational intent and status. The functions necessary to cooperatively manage traffic can be directly performed by the operators with their own capabilities or they can outsource support to third party service suppliers.

Key components of HATM include 1) the establishment of dynamic airspace volumes that envelop cooperatively managed HAO and convey to others where such operations are occurring, 2) Cooperative Operating Practices (COPs) that dictate how operators will conduct their operations in concert with all stakeholders, 3) a digital information architecture and communication protocols that provide the backbone for sharing information across a federated network of stakeholders, and 4) data and technology providers that support HATM operators in meeting their obligations and conducting their operations safely and efficiently. Sections 2.3 through 2.8 further describe these key components.

2.3 Cooperative Operating Environment

HATM allows for the coexistence of air traffic-managed operations with cooperatively managed operations. It enables higher airspace users to choose the airspace management approach that best responds to their needs. Some airspace users will need the flexibility to cooperatively deconflict operations, leveraging automation and information-rich data exchanges. The deconfliction of HAPS, for example, may need to account for the unique characteristics of each pairwise encounter, including the state of each aircraft (e.g., state of battery charge), which impacts maneuverability. Large HAPS fleet operations providing connectivity services, for example, may require holistic optimization of the fleet to account for interdependencies between aircraft trajectories and states. Cooperative traffic management allows these operators to leverage their capabilities to manage the intricacies of their operations.

The HATM model is depicted in Figure 2. The figure shows the two distinct operating environments; the Cooperative Operating Environment (COE), where higher airspace operators cooperatively manage their operations and with one another, and the Air Traffic Control Environment (ATCE), where traditional air traffic services are provided.

- **Cooperative Operating Environment (COE)** – When operating in a COE, higher airspace operators are responsible for the coordination, execution, management of their operations, and deconfliction from other cooperatively managed aircraft inside designated Cooperative Areas (CAs), according to industry defined, FAA-approved COPs. It is expected that those who will predominantly operate in the COE will be HAPS, including balloons.

- **ATC Environment (ATCE) -** External to COEs is the *ATC Environment* (ATCE), where ATC is responsible for separating aircraft and traditional ATC services are provided. Examples of aircraft operating in the ATCE include piloted SSTs, high-performance business jets, and remotely piloted military aircraft operating with Instrument Flight Rule (IFR) services.

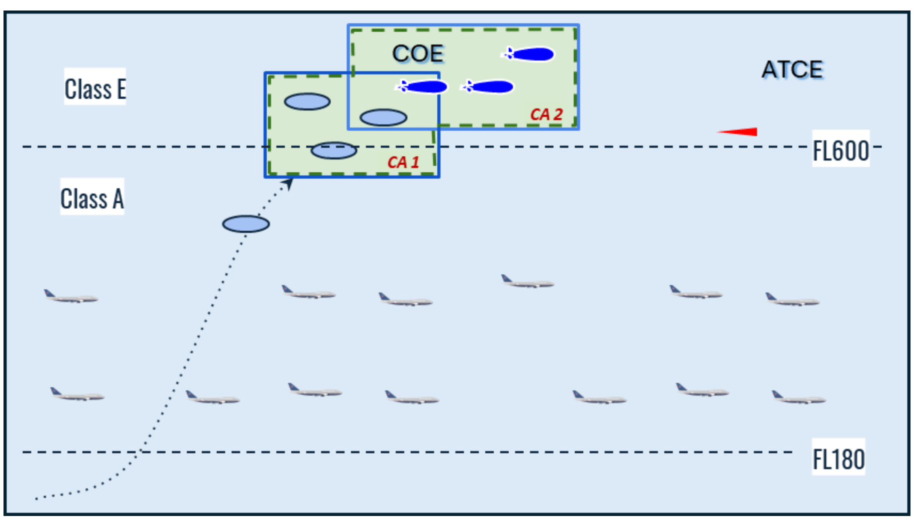

Figure 2. HATM airspace management model – Operational view

Higher airspace operators can decide which environment works best for them. There is no requirement for operators to participate in HATM. While the default is flying in the ATCE, on any given day, qualified operators may request to operate in a COE. They would base this on how adapted the environment is for the performance and specifics of their aircraft and mission.

At a high level, qualified COE operators are "digitally connected aircraft”. Because of this digitally connected aircraft network (similar to Internet-of-Things - IoT), there is no need for "traditional surveillance" infrastructure and [cryptographically] verified aircraft identity. The multiple position sources (and their accuracy estimates) get reported to the operator's systems via telemetry links. This enables worldwide position reporting without special built surveillance infrastructure. From there, the operator's systems cooperatively deconflict with other operators inside the COE via internet-based Application Programming Interfaces (APIs). The deconfliction is based on sharing 4D operational intent volumes and is not tactical separation based on position and a standard minimum separation distance.

The HATM operator can provide position information to ANSPs and State entities as needed via secured APIs. Inside the COE, however, this information would serve only for their situational awareness and/or national security purposes, since ATC/ATM separates aircraft from CAs, but HATM operators manage deconfliction of operations within the CAs.

2.4 Cooperative Operating Practices

At the core of HATM is the development of, and agreement to, a set of operator-defined, FAA-approved COPs, or governing principles, that describe how operators will conduct and manage their operations in concert with all stakeholders. COPs address all aspects of operations, including, but not limited to, the following:

- Flight/operation planning
- Information sharing with other operators and relevant stakeholders (including intents and performance capabilities)
- Intent sharing with stakeholders
- Conflict identification and resolution (including prioritization of operations)
- Procedures for required interactions with ATC
- Procedures for off-nominal and contingency operations
- Demand-capacity balancing
- Equity of airspace usage

The development of COPs is an ongoing activity as higher airspace industry stakeholders engage with each other and with FAA and the National Aeronautics and Space Administration (NASA) through regular working sessions, meetings, and other forums. COPs development is expected to continue evolving as experience from operations is gained; those that have been proposed to date are integrated throughout this document where applicable.

2.5 Cooperative Areas

CAs are 4D airspace volumes (i.e., a 3D space volume with start and end times) within which HATM operators safely manage their operations and are permitted to cooperatively deconflict with other operations. They are flexibly constructed on an operator needed basis in locations authorized by the FAA, and according to rules set by the FAA. The CAs do not change the underlying airspace class in which they are located. They allow operators to execute missions and meet business objectives safely and efficiently within them through COPs, and without reliance on air traffic separation services. Unlike Special Use Airspace (SUAs), Temporary Flight Restrictions (TFRs), or ALTRVs, CAs are not exclusive airspace reservations, nor are they airspace allocated/restricted to specific operators. The airspace within CAs is accessible to any airspace user that can operate according to the COPs.

Establishing a CA has advantages over an ALTRV when:

- Exclusive allocation of airspace to a group of aircraft is undesirable; the airspace must remain accessible to other potential HATM operators
- The nature of the mission cannot adequately be handled by an ALTRV (e.g., long duration)
- The growing uncertainty of flight paths far in the future would result in unacceptably large ALTRVs
- The need for flexibility cannot be effectively handled by an ALTRV (e.g., replanning while airborne, replanning with only a few hours' notice)
- The flight paths contain characteristics that cannot easily be handled with ALTRVs

CAs envelop the 4D OIs of the aircraft that operate inside. ATC does not need to track the intricate details of these OIs and operations while inside CAs. This reduces the load on ATC and the burden on ATM systems and external airspace users, who would otherwise need to stay updated on CA internal complexities to avoid conflicts. These complexities include:

- Intricate and/or frequently changing flight intents (e.g., probabilistic intent distributions, unconventional flight paths)
- Alternative performance-based CNS capabilities
- Atypical aircraft performance characteristics, including those that change over time

CAs are established and modified with sufficient notice to provide adequate visibility to ATC/ATM components and other airspace users so they can appropriately manage and plan operations outside of the CA. Additionally, CAs need to extend sufficiently far into the future to account for longer planning and deconfliction horizons certain airspace users require to adequately identify and resolve conflicts.

2.5.1 CA Creation, Modification, and Authorization

The FAA controls where CAs can and cannot be established and the mechanisms for granting their authorization. Two possible CA authorization paths are 1) a **criteria-based CA authorization** - where the

FAA offers a streamlined process for operators that meet certain criteria. The FAA would establish suitable criteria, for example, based on airspace usage/density, and manage maps and constraints that define where CAs can be authorized based on that criteria, and 2) a **case-specific CA authorization**, where CA requests not eligible for the criteria-based authorization would be subject to a case-specific review.

The FAA would digitally publish and update an airspace map that categorizes higher airspace, independent of airspace classification, into two categories (depicted in Figure 3):

- **Airspace eligible for criteria-based CA authorization**
- **Airspace requiring case-specific CA authorization**

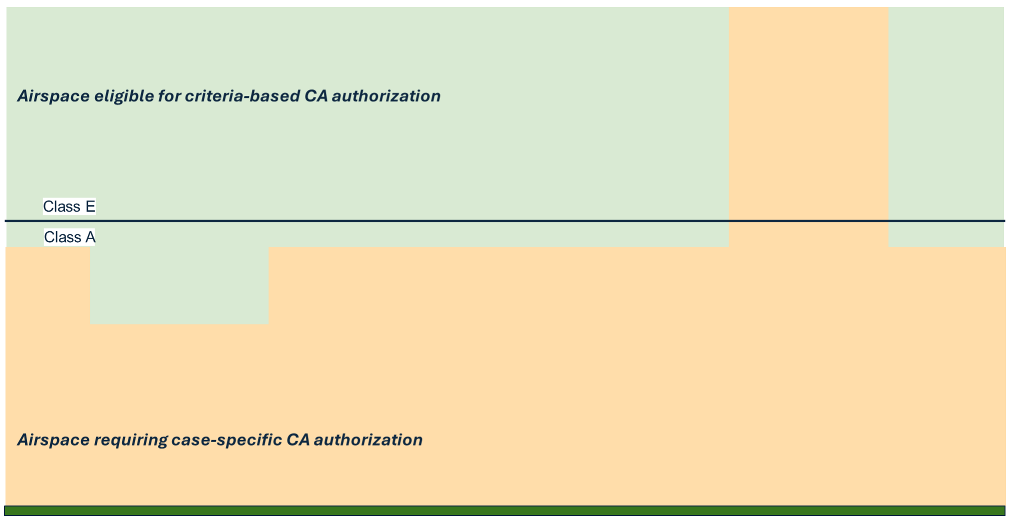

Figure 3. Airspace categorization for CA authorization

The map could contain multiple layers:

- A strategic layer that changes less frequently (e.g., monthly) based on, for example, analysis of historical airspace usage patterns and areas of acceptable air-ground risk, making criteria-based CA authorization possible in regions with statistically low ATC-managed traffic.
- A more tactical layer enabling the FAA airspace management function to tactically modify the strategic layer to allocate, or re-allocate, airspace for other operations (non-cooperatively managed). Tactical constraints include Special Activity Airspace, SUAs, Aircraft Hazard Areas, and Debris Response Areas.

While the FAA controls where CAs can and cannot be established, operators can request CAs anywhere in the airspace based on their operational needs. To request a new (or modified) CA(s), the HATM operator submits the dimensional properties of the CA(s) that are necessary for achieving their desired mission objectives. CAs contained entirely within airspace eligible for criteria-based authorization are granted authorization through a systematic process without requiring a case-specific FAA review. Conversely, CA requests that intersect with airspace requiring case-specific CA authorization undergo a case-specific review by the FAA to obtain CA authorization.

Table 1 summarizes the two CA authorization paths.

Table 1. CA Authorization Paths

Authorization Path 1	**Criteria-Based CA Authorization**	Authorization that is granted without the FAA needing to review the specific CA request, provided it meets criteria established and maintained by the FAA. Verification of compliance may be performed by authorized industry services.
	Airspace Eligible for Criteria-Based CA Authorization	Airspace where criteria-based authorization is possible.
Authorization Path 2	**Case-Specific CA Authorization**	Authorization that is granted directly by the FAA following a case-specific review. This path is required when an operation is not eligible for a criteria-based approach.
	Airspace Requiring Case-Specific CA Authorization	Airspace where an explicit FAA review and authorization is required.

Regardless of the CA authorization path, 1) the details of CAs are communicated by operators to the FAA, and 2) the FAA retains the ability to "reclaim airspace" inside CAs for other operations (non-cooperatively managed).

2.5.2 CA Registration and Information Dissemination

The responsibilities for registration, management, and dissemination of information about CAs are distributed between the FAA and the operator.

Operators will likely need to create new CAs during their operational planning process. CAs registered by other operators will rarely perfectly match the operational needs of the planning operator. Even when CAs are identical and fully overlap, a new CA will likely need to be registered to facilitate subsequent management and modification of CAs. The ability for an operator to join an existing CA may be limited to cases where an operator plans for a flight that will join their own airborne fleet (managed by that operator) for which the operator has already registered a CA.

Operators are required to make their CA information discoverable to other airspace users and to share information with airspace users who need to know. They must keep track of other CAs that overlap with their CAs. If a CA already exists and overlaps, it does not constitute a conflict and does not prevent a CA from being created that overlaps with the first one. However, when two operators have overlapping CAs, they need to exchange intents to identify potential conflicts and cooperatively resolve them as necessary.

Operators do not need to share intents with operators in CAs that do not overlap with theirs (e.g., Operator A with a fleet and CA over California does not need to exchange intents with Operator B with a fleet over Kansas).

It is important that an operator is able to cancel a CA that they no longer need, or modify a CA they previously registered, without impacting other cooperative operations, and without excessive coordination.

The following summarizes the responsibilities and steps associated with CA registration and information dissemination:

The FAA:

- ✓ Is the authority providing all CA authorizations
  - <u>Criteria-based CA authorizations</u>: Defines, maintains, and communicates the conditions for criteria-based CA authorizations (e.g., maps of eligible airspace)
  - <u>Case-specific CA authorizations</u>: Reviews CA requests that require case-specific reviews

The HATM operator:

- ✓ Creates a universally unique CA identifier
- ✓ Assesses if a CA meets all requirements for a criteria-based authorization and adjusts the request, if possible, to meet the criteria
  - If all requirements are met, registers the new CA and communicates the updated information to the FAA
  - If requirements are not met, submits a request to review a CA for authorization, considers FAA feedback and negotiates CA
- ✓ Disseminates information about an authorized CA
  - Informs FAA and other relevant stakeholders (e.g., users with overlapping CAs) about the CA creation
  - Makes the CA discoverable to other entities (FAA, other operators, etc.) who are searching for the existence of CAs in the region
  - Informs all relevant stakeholders about a CA that is no longer needed
  - Maintains knowledge about any overlapping CAs and informs the creating entity of an overlapping CA about the overlap
- ✓ Cooperatively deconflicts operations inside the CA and with any overlapping CAs

The following are operator responsibilities/functions associated specifically with CA registration and information sharing. Due to the digital sophistication required to perform them, these functions may be outsourced by the operator as externally provided services. These outsourced CA Registration and Information Services are referred to as 'CARIS.'

- ✓ Ingest FAA published information on the airspace eligibility/ineligibility for criteria-based CA authorization along with tactical CA constraints
- ✓ Receive CA requests from operators and assess whether they can be authorized using the criteria-based authorization path, or whether they need case-specific reviews and authorizations
- ✓ Assign universally unique identifiers for newly requested CAs (necessary for later modifications and identification of specific CAs)
- ✓ Automatically register CAs that meet FAA criteria for authorization (i.e., requests within airspace eligible for criteria-based CA authorization)
- ✓ Request review and authorization from the FAA airspace management function for CAs that do not meet the criteria for authorization. When the airspace has been delegated by the FAA to another entity (e.g., military SUA), the CA information service would seek authorization from the relevant airspace management authority
- ✓ Register authorized CAs/CA changes and disseminate the CA information to all other relevant services and stakeholders (push/pull mechanisms) including:
  - Other CARIS instances (in a federated network)
  - FAA automation services, and displays that require CA information (e.g., Traffic Flow Management System, ATC displays)
  - Airspace users of overlapping CAs (when CAs overlap)
  - Relevant authorized State entities
- ✓ Keep track of airspace changes and other CAs affecting the airspace within which the CA is created

CARIS may instantly register a CA that meets the conditions of the criteria-based CA authorization and inform the operator that the CA is authorized. As the airspace authority, the FAA sets the criteria for the criteria-based CA authorization. CARIS only verifies that the CA matches the authorization criteria provided by the FAA. Figure 4 shows a notional depiction of these interactions.

Figure 5 depicts the overall process and responsibilities associated with CA creation, modification, and authorization.

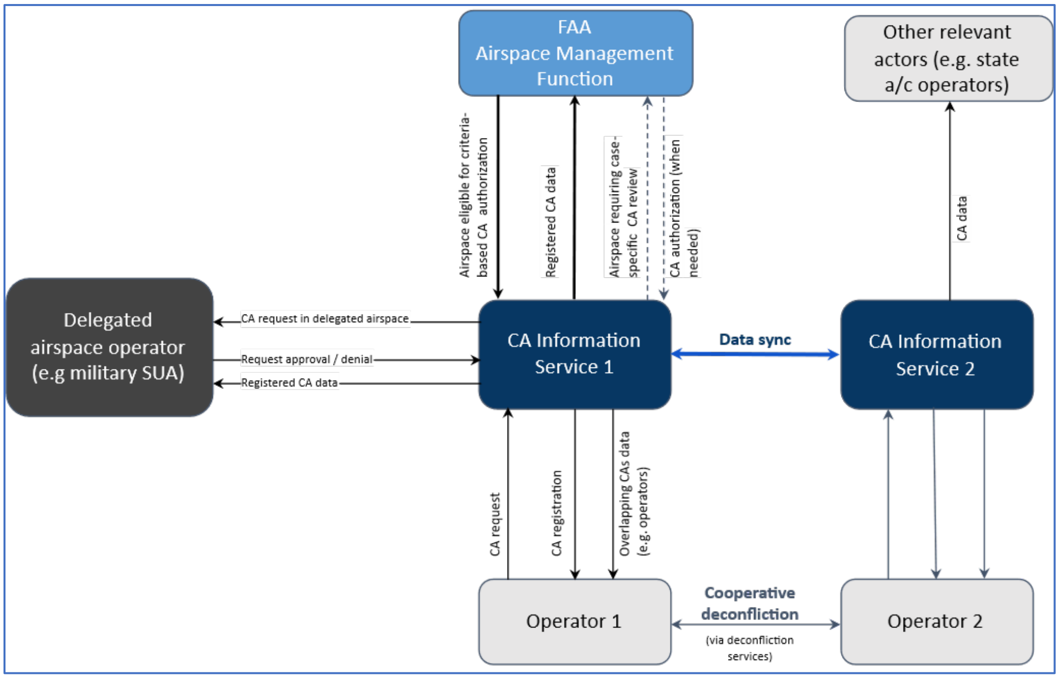

Figure 4. Notional information flow between CARISs, operators, and authorizing entities

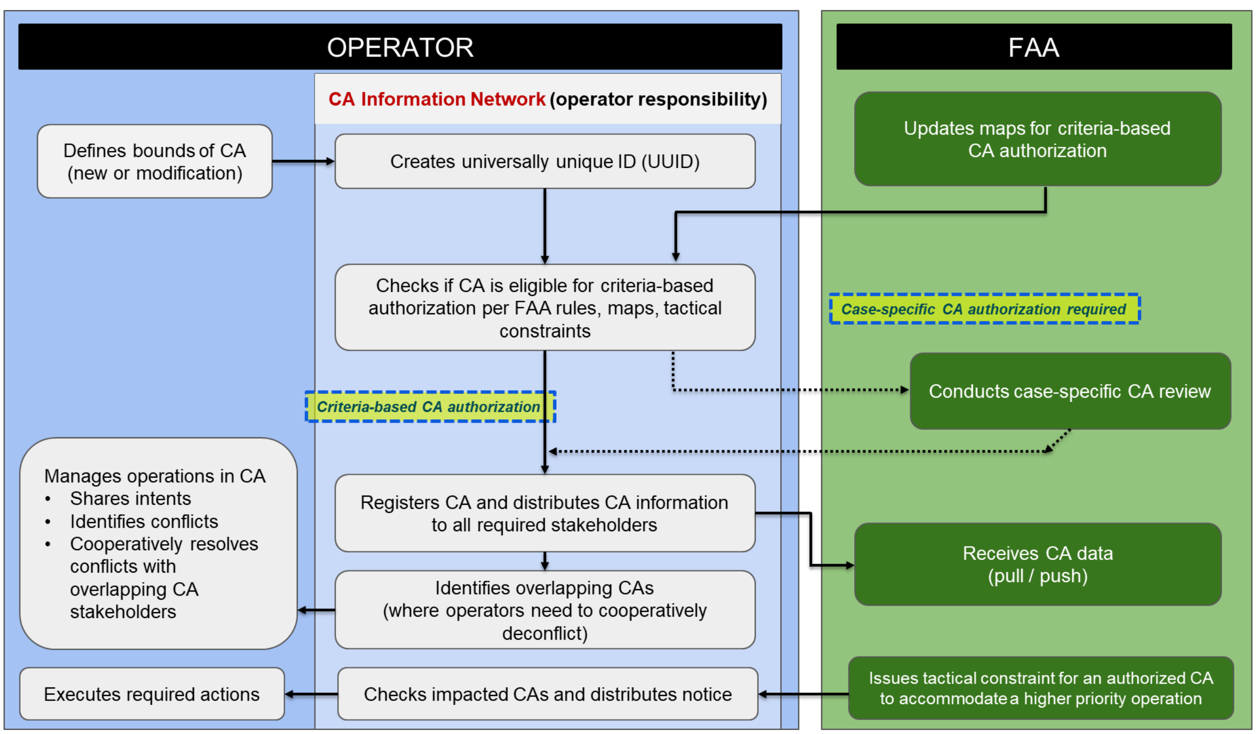

Figure 5. CA creation, modification, and authorization process and responsibilities

Note: Sections 2.5.3 and 2.5.4 contain material that is proposed by higher airspace industry stakeholders for FAA consideration.

2.5.3 CA Usages

CAs need to be flexible enough to address the needs of various operations including static operations, moving operations, intent uncertainty, and dynamically optimized/replanning operations. This section discusses how CAs can be designed to support the range of operations and presents example illustrations.

For the figures in this section, the key is as follows:

Grey CA no longer active (now > CA end-time)
Yellow CA not yet active (now < CA start-time)
Green Currently active CA (CA start-time < now < CA end-time)

2.5.3.1 Loitering Aircraft

A CA may be established to manage potential conflicts among multiple loitering aircraft, from one or multiple operators. This enables, for example, an operator to optimize the mission performance of a HAPS fleet acting as a connectivity network. It also enables multiple operators providing services in the same area to cooperatively deconflict their operations.

Figure 6 depicts how a single CA that is active for the necessary duration can be used to provide a cooperative operating environment for a fleet of loitering aircraft.

Figure 6. Static CA for fleet of loitering HAPS

2.5.3.2 Moving Aircraft Clusters

A CA may be established to facilitate cooperative deconfliction among a group (cluster) of aircraft moving across the National Airspace System (NAS). This approach supports effective cooperative deconfliction within the cluster without the need for exclusive airspace allocation. A series of successively active CAs can be used, with each CA being active for a limited time (shown in Figure 7). Each CA would encompass the flight intents of all the aircraft within the group during its active time segment. To minimize the spatial extent of a CA at any given moment, the number of CAs can be increased while reducing their individual active durations. In this illustrative example, each CA is active for 6 hours. A CA may be preferred to an ALTRV if reserving the airspace for the cluster is undesirable.

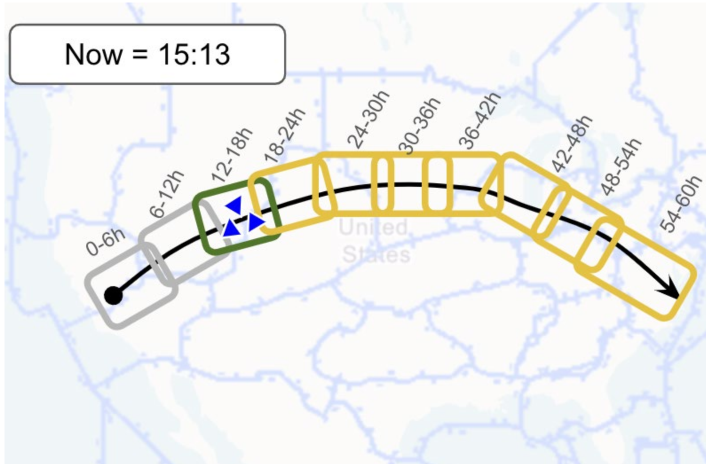

Figure 7. CAs for cluster of three HAPS moving west coast to east coast

To avoid unnecessary impact on the ATCE in cases where path uncertainty grows significantly in the distant future (e.g., due to wind or environment uncertainty), CAs are only established for the more certain near/mid-term future, with new CAs being established progressively along the way as uncertainty decreases. In this case, CAs may also be preferable to ALTRVs because they can be established and modified while airborne and do not restrict other cooperative entities from accessing the airspace.

In Figure 8, a cluster of HAPS is moving from the west coast to the east coast. Due to growing uncertainty, the CAs are only established for the next 15 hours (illustrational timeframe), with subsequent CAs being established at a later time, but with adequate notice to enable ATM and airspace users to plan effectively.

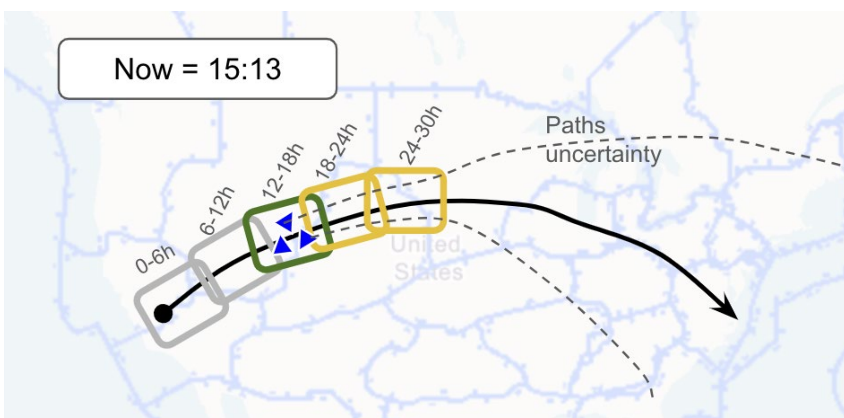

Figure 8. CA for HAPS cluster moving west to east with position uncertainty

2.5.3.3 Single Aircraft

CAs may be established around the intent of a single flight if its characteristics pose challenges for existing ATC/ATM tools, impose excessive workload on controllers, or the necessary separation would result in inefficient use of airspace. In such cases, cooperative deconfliction during potential encounters with cooperative flights can enhance airspace utilization and reduce excessive workload on controllers (e.g., deconfliction of two moving low-performance HAPS singletons).

Figure 9 depicts a single aircraft moving generally from west to east, with a highly intricate, dynamic, and convoluted flight path (intent shown in red). A CA is used to abstract the complexity and enable the aircraft to cooperatively deconflict with other cooperatively managed aircraft that may cross its path (see Section 2.5.4 - CA Properties). A CA may be preferred to an ALTRV to enable other cooperative operations to access the airspace.

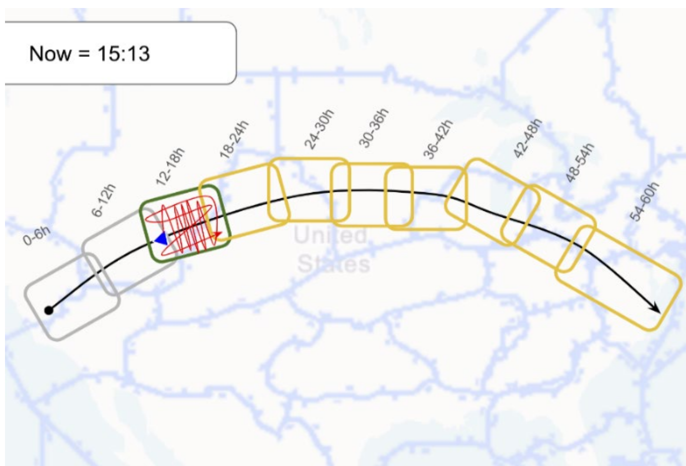

Figure 9. CA for single aircraft with intricate path, generally moving from west to east

2.5.4 CA Properties

2.5.4.1 CA Overlap

CA needs (e.g., size, location) of multiple HATM operators will rarely match perfectly. As a result, requests for overlapping CAs with different shapes and duration are expected to be the norm. Enabling CA overlap provides operators with different operational needs the ability to independently request and modify CAs to meet those needs, without impacting CAs established for other needs. As long as the COPs are identical, the overlapping CA requests do not constitute a conflict, and multiple overlapping CAs can be registered.

Within a CA, or where CAs overlap, operators share intents and engage in cooperative conflict identification, and where necessary, conflict resolution. Operators of separate non-overlapping CAs do not need to share intents and cooperatively identify conflicts. When two CAs overlap (both geographically and in time), the operators of each overlapping CA need to be informed of the overlap and must engage in cooperative conflict management in the overlapping region. A CA may need to be modified if the conflict resolution results in an intent modification that extends beyond the initially defined CA.

CAs therefore play an important role in the determination of which operations must share intent information with one another (also known as the "discovery process"), avoiding the necessity for distant operations located in separate non-overlapping CAs to share intents. For example, Figure 10 shows a CA containing loitering operations (blue aircraft), active from 0h to 96h, which overlaps with a CA created for a transiting cooperative operation (red aircraft), expected to be active between times 12h to 18h.

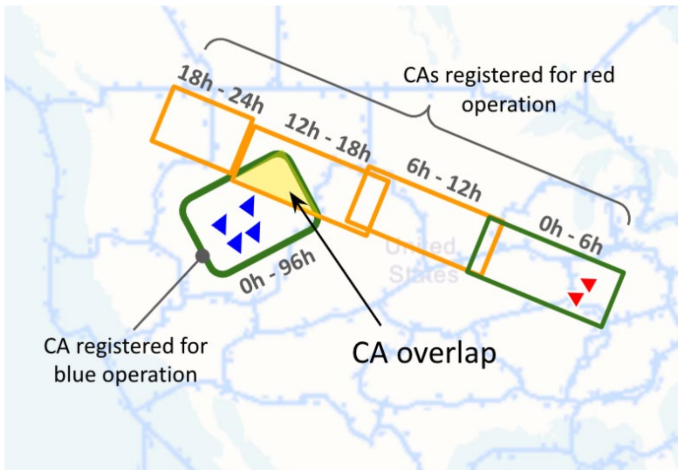

Figure 10. CA overlap

Both operators are informed of the overlapping CAs, enabling them to share intents inside the overlap and cooperatively deconflict as early as necessary for the aircraft involved. This approach also prevents operators from unnecessarily sharing intent details with other operators in regions where there is no conflict potential (i.e., blue operator does not need to know the OIs of the red operator outside of the CA requested by blue).

2.5.4.2 CA Size

CAs should not be unnecessarily large (both in geographic and time dimensions) such that they negatively impact the ATCE. In the absence of flight path or OI uncertainty, the geographical size of a CA is a function of how aircraft intents are grouped or clustered together. An arbitrary number of CAs can be used to cluster aircraft intents on the both the geographical and time dimensions. Figure 11 depicts a fleet of cooperatively managed aircraft loitering in a specific area.

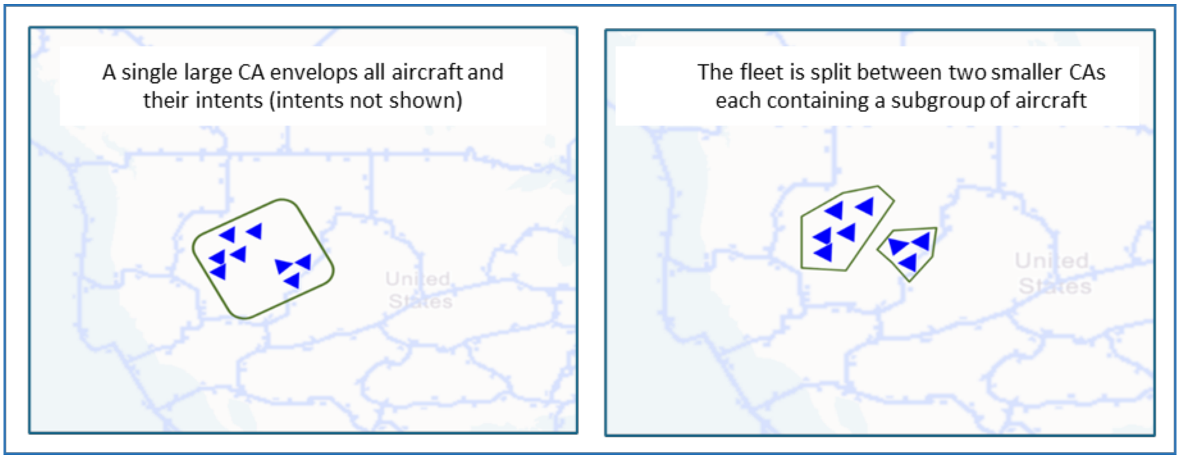

Figure 11. Two options to group a fleet of aircraft into CAs the geographical dimensions

Figure 12 depicts a group of cooperatively managed flights with intricate flight intents (individual flight intents not shown), gradually moving from west to east, with two approaches for clustering intents on the time dimension.

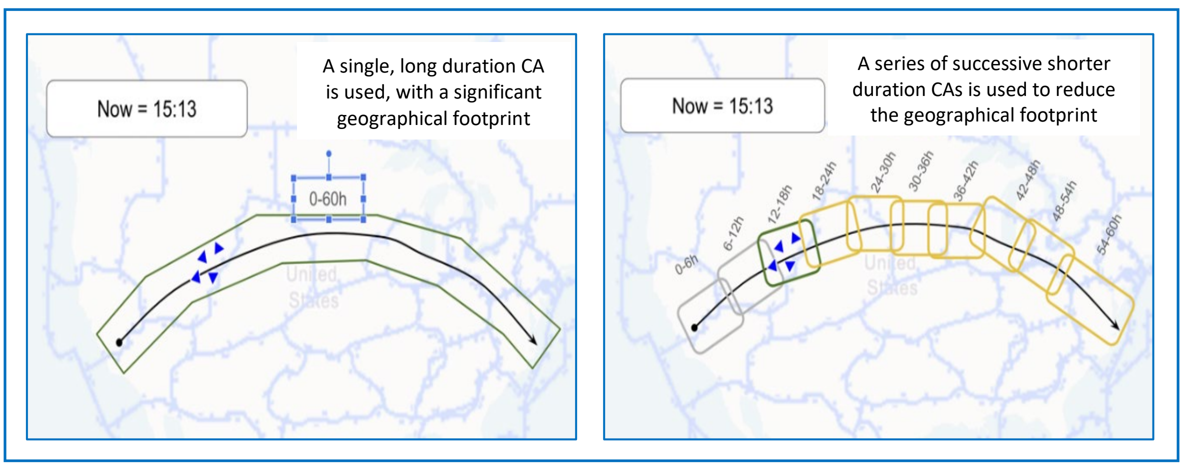

Figure 12. Two options to group a moving fleet of aircraft into CAs on the time dimensions

2.5.4.3 CA Flexibility

In the presence of intent uncertainty, an unavoidable tradeoff between CA size and CA modification flexibility must be considered. CA dimensions should strike a balance between efficient airspace use and providing adequate visibility and predictability for other airspace users to facilitate effective planning. If established CAs cannot be flexibly modified, operators may need to request larger CAs to hedge against possible uncertainty.

Figure 13 illustrates a group of cooperatively managed aircraft which collectively drifts from west to east, but with uncertainty in the drift path (multiple likely paths shown by dashed lines). Two approaches for establishing CAs are shown.

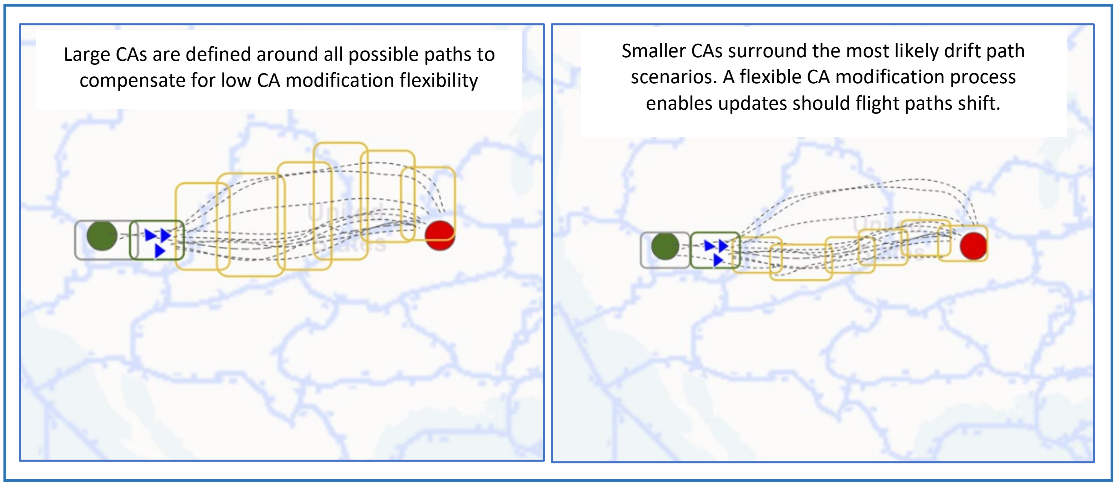

Figure 13. Size vs. modification flexibility tradeoff

The ability to modify previously established CAs will be required for operations to adjust to an inherently dynamic environment. Individual CA blocks may need to be modified during flight to accommodate, for example, changing mission objectives, fleet and flight path optimization, environmental and wind conditions, and delays. Examples are illustrated in Figure 14 (on-station adjustment) and Figure 15 (moving cluster path adjustment). The dashed CAs represent the initially established CAs, replaced or modified into the solid line CAs.

Figure 14. Individual CA update for on-station operation

Figure 15. CA update for accommodating the path change of a moving cluster of aircraft

Table 2 summarizes the key CA principles.

Table 2. Summary of CA Principles

CA Principles
✓ The requirements for establishing CAs will be dictated by FAA policy and COPs.
✓ CA design needs to strike a balance between flexibility and stability.
✓ CAs must be modifiable with enough flexibility to avoid the need for excessively large CAs to compensate for uncertainty.
✓ CA design should strategically cluster intents based on geography and time dimensions to minimize the 4D space occupied by them and reduce the impact on potential ATC-managed operations.
✓ A reasonably low fragmentation of COE with sufficiently simple shapes shall be maintained to be manageable for other airspace users and ATC/ATM.
✓ CAs should maintain a level of predictability, allowing other airspace users and ATC to plan their operations around (or through) them.

2.6 Operations

HATM operators plan their flights; they share flight plans with ATC/ATM and OI with cooperative operators, as required. They transit to and from higher airspace through the ATCE using air traffic services as they do today. Within the bounds of CAs, operators cooperatively deconflict and operate in accordance with COPs to separate from other aircraft in the COE. Interactions between HATM operators are highly automated with 4D intents shared digitally between fleet management systems. Enhancements to FAA automation systems may also support digital exchanges between the ATCE and COE.

HATM operators conduct their operations in compliance with the appropriate set of standards, rules, regulations, and/or special authorizations as specified by the FAA and/or COPs. These operating rules define specific requirements for information exchanges and communications. Sections 2.6.1 through 2.6.5 provide a high-level description of the phases of a generic operation (independent of aircraft type) and the roles various actors play in support of cooperatively managed operations.

2.6.1 Flight Planning

HATM operators perform the necessary flight planning and coordination prior to operating in both the ATCE (for transit to and from a CA) and the COE.

2.6.1.1 Flight Planning for ATCE

Operators file a flight plan or coordinate with ATC through other agreed upon means (e.g., as specified by Letter of Agreement [LOA]) to transit through the ATCE en route to airspace within a CA. If required, they receive authorization for the ATCE portion of flight. Operators need to communicate to ATC/ATM that they intend to operate in a CA for part of the flight.

CAs are treated as constraints in the flight management system, both pre-flight and after takeoff, to enable probing. They do not need to be persistently visible on ATC automation platforms (e.g., ERAM), or to controllers. All the deconfliction is done strategically between ATC-managed aircraft and a CA. A controller rerouting an aircraft would be aware of the CA via probing and a positive result would lead to the CA's visual display.

2.6.1.2 Flight Planning for COE

HATM operators conduct preflight planning activities for operating in a COE, including gathering information relevant to safe flight (e.g., airspace constraints), evaluating weather/atmospheric information, mapping out preferred flight paths, and registering one or more CAs. Through a discovery process, any CAs that overlap with newly registered CAs are identified. Operators with overlapping CAs are required to compare OIs for the portion that overlaps to identify conflicts between projected trajectories. If conflicts are identified, they engage in a conflict resolution process dictated by an agreed upon conflict management model. OI sharing and a conflict management process are discussed in detail in Section 2.6.3.

2.6.2 Ascent to a CA

The ascent profiles of high-altitude aircraft are dictated by their operating characteristics, including maneuverability, power, flight control, and structural limitations, as well as airspace efficiency considerations. See Figure 16 for a depiction of the various ascent profiles.

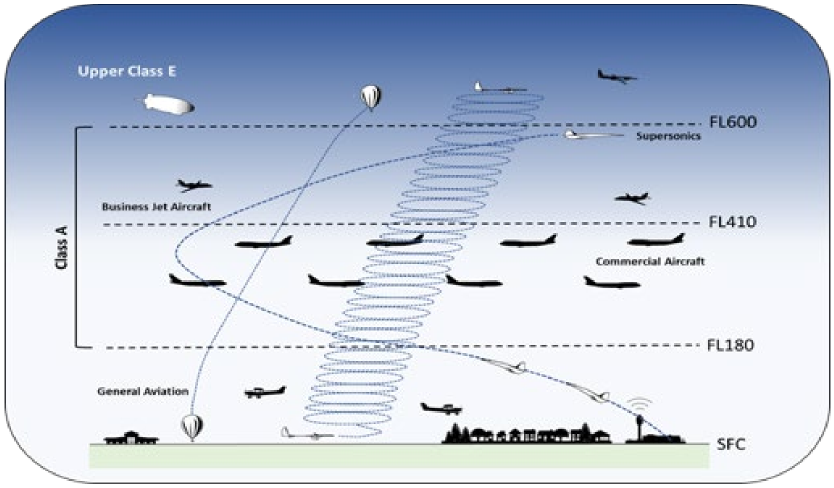

Figure 16. Launch and transit to higher airspace

On ascent to higher airspace, HATM operators comply with requirements for ATC communications and follow applicable procedures as prescribed by their operational rules or pre-established LOAs. They coordinate their flights with ATC facilities, provide ascent information, and update flight information at agreed upon intervals (e.g., ID, estimated date and time of ascent, launch location, duration of flight within ATCE, predicted flight path). ATC provides separation services in accordance with established policies and regulations using available surveillance information for the aircraft (e.g., radar, ADS-B) and using any additional information provided by the operator (e.g., projected trajectory). Due to the performance characteristics and vulnerabilities of the aircraft, some transiting flights receive special ATC handling on climb.

In addition to fulfilling requirements for the ATCE, HATM operators fulfill COPs requirements on ascent. If an operator is ascending to a CA that has no overlaps with other operators' CAs, then no further action is required. If, on the other hand, the operator's CA overlaps with another CA, they coordinate any changes to intent in affected areas of the overlapping CAs (e.g., due to unforeseen weather or flight adjustments made by ATC) with impacted HATM operators.

2.6.3 Operation within a CA

HATM operators comply with all FAA rules and COPs that guide the transition from receiving air traffic services to COE services. They stay within the bounds of their CA throughout the operation. They are responsible for deconflicting aircraft under their control and monitoring for notifications regarding any changes to their CA (e.g., ATM imposed modifications, airspace restrictions that impact CAs). Operators are also responsible for identifying operational conditions or flight hazards that may affect their operation. They monitor atmospheric conditions, the health of their aircraft (e.g., power levels, failures), and other factors that impact safe operations.

HATM operators may request/register CA modifications as necessary during the operation. Operators also monitor for CA overlap. In cases where CAs do overlap, operators share intents for overlapping portions of CAs and identify and resolve conflicts as they surface, leveraging information-rich protocols that handle atypical intents, and consider the wide-ranging (and possibly changing) aircraft performances, constraints, preferences, and business models in the conflict resolution.

Within the COE, deconfliction of operations is based on the time needed to safely resolve conflicts, which is largely determined by vehicle performance (deconfliction time, Command and Control (C2) link latency, and vehicle maneuvering capabilities). Risk-based performance criteria form the basis for deconfliction margins and factor in both risk to the aircraft and risk that the aircraft imposes on uninvolved parties (e.g., ground populations, aircraft in lower altitudes). Safe deconfliction is achieved through 1) identification of conflicts that need resolution, and 2) cooperative resolution of conflicts within an appropriate timeframe. Digitized information exchanges supporting cooperative deconfliction leverage standardized data formats and exchange protocols to ensure interoperability.

A conflict management model for cooperative traffic management developed by the Aerospace Industries Association (AIA) Higher Airspace Working Group - *Cooperative Operations in Higher Airspace: A Proposal* [2021] addresses the allocation of responsibilities, operator/system interactions, high-level information needs, and sharing of information. It describes an approach for operator sharing of intent, conflict identification, collaborative resolutions, and fallback resolutions. Sections 2.6.3.1 through 2.6.3.3 present an overview of this industry-proposed model.

2.6.3.1 Operational Intent Sharing

Operators inside the COE exchange OIs to cooperatively identify and resolve conflicts. Unless requested by the FAA, OIs do not need to be systematically shared with the FAA.

Within the COE, OIs are shared on a need-to-know basis. A discovery process enables higher airspace operators to identify other operators with whom they need to exchange information. Anytime CA overlap occurs it triggers the need for operators to share OI for the overlapping portion of the CAs.

Higher airspace vehicles can remain airborne for prolonged durations. As such, when sharing OIs with other COE operators, operators do not need to share intent for the entirety of the flight but do so on a “rolling-time-window”. To satisfy a rolling intent window, intent is provided for a certain number of hours into the future and is progressively extended to maintain a minimum intent horizon (defined by COPs). The intent should be provided with a sufficient forecast horizon such that all potential conflicts within the COE can be identified with sufficient anticipation.

High-altitude vehicle susceptibility to atmospheric conditions can result in less predictable flight paths further in the future. To address this, intent volumes for these operations could consist of a series of volumes representing position with a given confidence level, during a time segment. A notional illustration of this is provided in Figure 17.

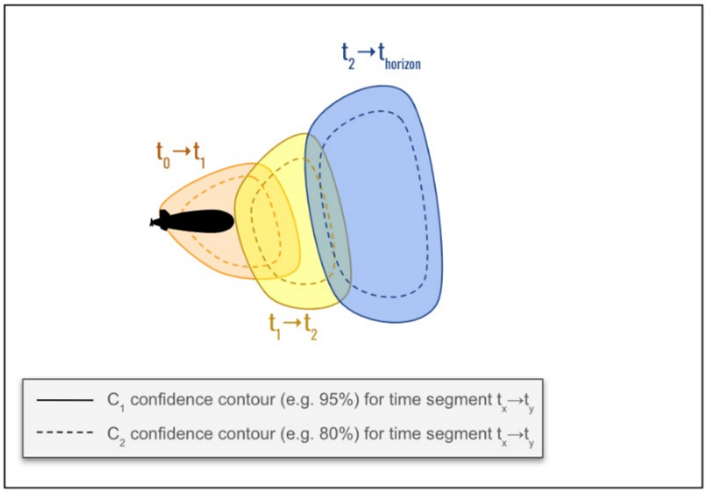

Figure 17. Notional intent volumes of low position determinism

To maintain the integrity of these probabilistic intent volumes and allow for convergence of position estimates, operators share and update their OI, both preflight and during flight, in accordance with rules and rates specified by the COPs. Intent update rates are predominantly influenced by proximity to the conflict, the granularity of intents, the rate at which uncertainty decreases with time, the operational stage of flight (e.g., preflight, ascent), and the frequency at which the intent needs to be extended further in the future. Operators must conform to their intents. They may change intents at any time but must first successfully complete the change process (and potential deconfliction that results) before acting on the change.

Probabilistic OI volumes are key to the conflict management process because they determine if, and when, a resolution between operators with overlapping intent volumes is required. Each intent update decreases the space occupied by the intent of a given confidence level over time (Figure 18). Intent volumes vary in size and shape, both depending on the aircraft and the mission.

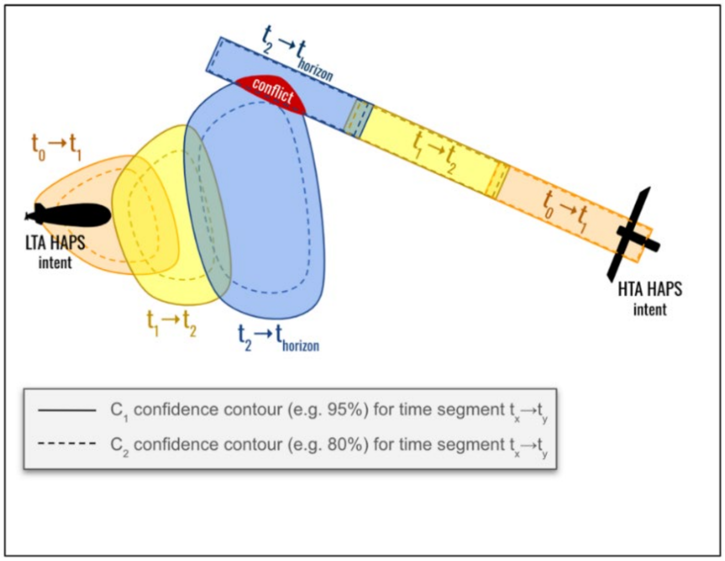

Figure 18. Examples of probabilistic intent volumes in identifying conflict

2.6.3.2 Conflict Identification

HATM operators identify conflicts that need to be resolved through shared intents. They follow well-defined protocols for information sharing that ensure potential conflicts are identified within a suitable timeframe, enabling safe and fair resolutions. During the conflict identification process, operators continuously monitor the evolution of the conflict likelihood and time horizon. This involves the continuous sharing and updating of 4D intents, along with evolving performance parameters and capabilities, to dynamically compute pairwise conflict detection lookahead times. Depending on the situation, aircraft performance, and risk, not all conflicts need to be immediately resolved. A wait-and-see approach can sometimes be adopted.

2.6.3.3 Conflict Resolution

HATM operators follow the rules that define how identified conflicts are managed and resolved to ensure both safety and fairness. They engage in a defined conflict resolution process within a specific amount of time to push the risk of an undesirable event to an acceptable threshold. The conflict resolution process is broken into two segments - Collaborative Resolution and Fallback/Emergency Rules. The first segment, Collaborative Resolution, is comprised of three stages: No Action (i.e., wait and see), Free Negotiation, and Standard Protocol. Figure 19 provides a depiction of the Conflict Resolution Process.

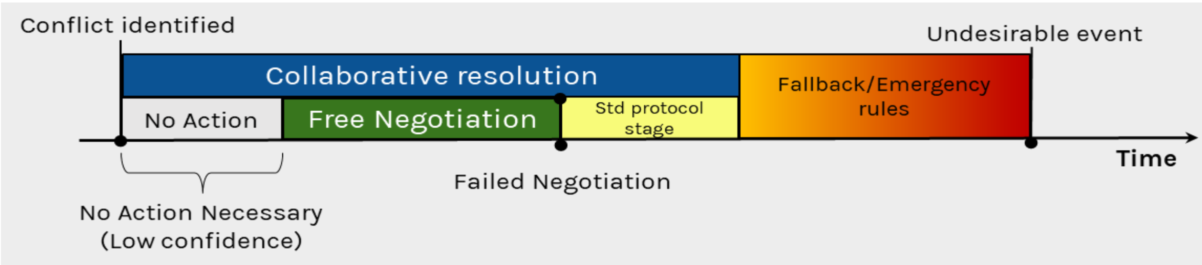

Figure 19. Conflict resolution process

No Action

When a conflict has a low probability of occurrence and plenty of time to safely resolve, it may require No Action. This situation may be due to the time horizon being far enough into the future that the confidence in exactly where the vehicle will be is low. An HATM operator may choose to make an early maneuver that causes little to no impact rather than take a 'wait and see' approach which could result in a more costly maneuver down the road.

Free Negotiation Stage

In the Free Negotiation stage, HATM operators are free to negotiate an equitable deconfliction plan with each other.

Standard Resolution Stage

If the Free Negotiation phase results in an unresolved conflict, HATM operators enter the Standard Resolution stage. Standard Resolution imposes pre-defined, industry agreed-upon conflict resolution protocols between the operators, which are designed to always yield to a solution in a set amount of time. The protocols must be used sufficiently early to account for the specific vehicle performance characteristics. They also prevent operators from purposely resorting to Fallback/Emergency Rules.

Fallback/Emergency Rules

The Standard Resolution stage is designed to prevent operators from resorting to the Fallback/Emergency Rules during nominal operations. Therefore, the stage in which Fallback/Emergency rules apply occurs only in the unlikely event Standard Resolution fails. At this stage, the ability to cooperatively separate is not possible and independent action is required by each operator. Operators must make the pre-defined fallback maneuver according to pre-defined, industry-agreed upon conflict resolution methods.

2.6.4 Interactions with Other Airspace Users

HATM operators will share the airspace with other aircraft, including those operating under IFR, State aircraft flying with due regard for civil operations, and space launch and reentry vehicles. The following sections address the interactions of these operations with CAs and cooperative operations.

2.6.4.1 ATC-Managed Aircraft

ATC-managed aircraft that plan to transit higher airspace may come into conflict with planned and/or active CAs. When the aircraft files its flight plan, the FAA's flight planning system compares the flight plan against known constraints, including any CAs scheduled to be active along the aircraft's route. If there is a conflict, several approaches can be considered to deconflict the operations. The chosen method can depend on, for example, the type and performance of the aircraft in conflict, the associated risk to operations (e.g., passenger carrying aircraft), and the lead time to conflict. The following describe some approaches that may be considered.

<u>Approach 1</u> - ATC-managed aircraft avoids the COE (goes around)

CAs are known to ATM. As such, an ATC-managed aircraft can be routed around the CA in the same way aircraft are separated from incompatible airspace today (e.g., Military Operating Area [MOA]).

<u>Approach 2</u> - ATC/ATM modifies the CA to allow aircraft to continue on flight plan

ATM can coordinate the resizing and/or reshaping of a CA through issuance of a tactical constraint (e.g., make lateral/horizontal adjustments to the borders of the CA) to enable an ATC-managed aircraft to transit per its planned trajectory. The CA modification accounts for separation requirements between aircraft operating within the COE and the aircraft transiting in the ATCE. Use of this approach is limited by lead time, that is, the time it would take for traffic in the COE to move away from the ATC-managed aircraft's path and adjust to the new borders of the CA.

<u>Approach 3</u> - ATC/ATM creates a CA for the aircraft to transit through the COE

ATM can strategically deconflict the 4D trajectory of the transiting ATC-managed aircraft through the process of cooperative deconfliction. To do this, they can register a CA that accounts for the aircraft's separation needs, exchange OIs with the operator(s) in the overlapping CAs, and coordinate deconfliction of aircraft where intent overlaps using the same process as cooperative operators. The use of this approach is limited by lead time—namely, the time it would take for cooperative aircraft in conflict to safely remove themselves from overlapping air traffic-registered CA.

Figure 20 depicts the three approaches for resolving conflicts between ATC-managed aircraft and CAs.

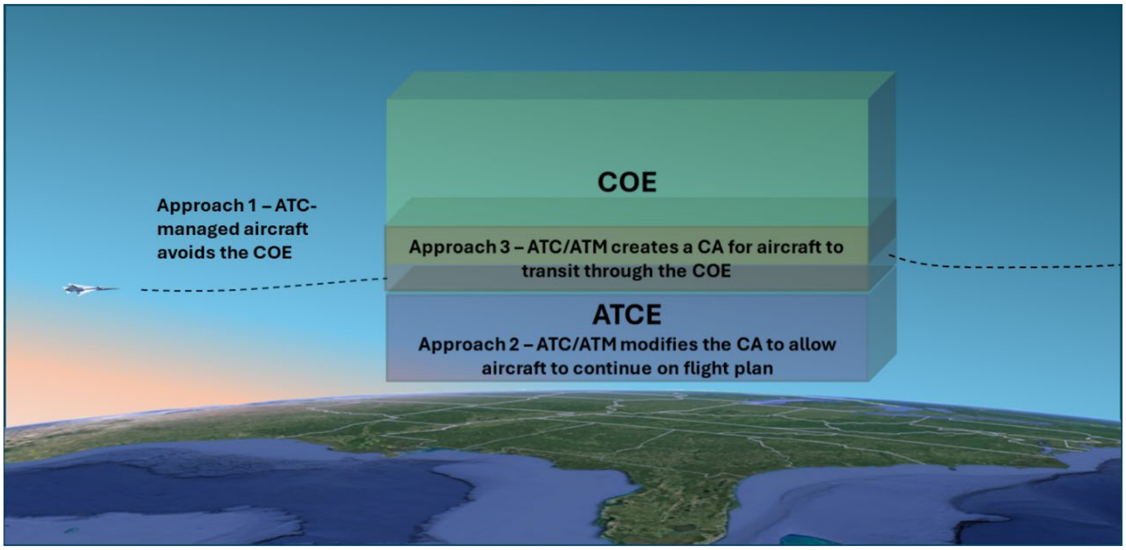

Figure 20. Approaches for resolving conflicts between ATC-managed aircraft and the COE

2.6.4.2 State Aircraft

State aircraft are those operated by the Government for sovereign, noncommercial purposes, such as military, customs, and police services. They operate in higher airspace and will interact with civil HAO, particularly as they increase in number. Interactions with State aircraft will occur, creating the need to consider how these operations can effectively interact given the sensitive nature of many State aircraft operations.

State aircraft have their own set of rules for operating and they do so with due regard (taking proper care and concern) for civil aircraft operations. They can, however, be aided in this responsibility through the one-way sharing of information by cooperative operators on CA and cooperative aircraft locations. This capability provides visibility of cooperative operations to State aircraft operators via the federated network of service providers. Equipped with this information, State operators can assess the best way to execute their missions. They can avoid a CA altogether or, they may elect to enter CAs without sharing intent and tactically separate from cooperative operations by either accessing intent information of proximate operations and/or avoiding conflicts with cooperative aircraft using their equipage (e.g., radar identification).

An authorization and authentication management framework could be used for information sharing by allowing State aircraft operators to prove legitimate access to the cooperative data, without requiring them to share their own position or intents, or without revealing their identity. Additionally, these frameworks could allow State actors to securely share intents with a limited number of other trusted entities if they wish to do so.

2.6.4.3 Space Vehicles

Temporary hazard areas are created for space launch and reentry operations in the NAS that stretch into the upper atmosphere to protect for high-speed vehicles, potential debris, and off-nominal trajectory deviations. To ensure safety, HATM operators must be aware of these areas and stay out of any restricted airspace associated with these space operations. Airspace closures and restrictions will be communicated to HAO through Notices to Airmen (NOTAMs).

2.6.5 Descent from a CA

A descent from a CA follows a similar set of actions as the ascent phase. A flight plan or other means of notifying ATC of the intent to descend is required based on the applicable operational rules (e.g., 14 Code of Federal Regulations (CFR) part 91 IFR/VFR operations, 14 CFR part 101.37) and/or agreements (e.g., LOA stipulations). COPs and applicable FAA rules and regulations facilitate the transition to ATC services. The operator coordinates with ATC to obtain clearance to enter Class A airspace (if exiting from Class E) and follow ATC instructions to descend. Aircraft descent profiles will be dictated by airspace efficiency considerations and their operating characteristics, including maneuverability, available power, and structural limitations (refer to Figure 21). HATM operators notify ATC of landing as required.

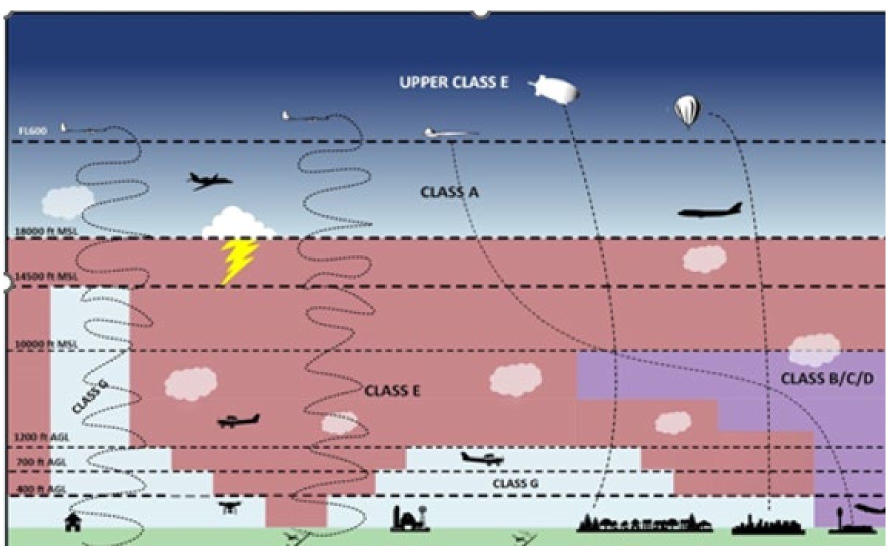

Figure 21. Operating altitude to landing

2.6.6 Contingency Management

Contingency responses vary based on the event, aircraft capabilities and performance characteristics, phase of flight (e.g., takeoff, transit, operating altitude), location (e.g., over populated areas versus over the ocean), aircraft occupancy (e.g., unmanned or pilot onboard, no passengers or passengers onboard) service environments (e.g., COE or ATCE) among other factors. In any case, HATM contingency procedures should be known and predictable to support the operator and ATC management of situations that have the potential to cause injury to people on the ground and in the air, and/or damage to property. HATM operators must be capable of identifying off-nominal situations (e.g., loss of C2 link, uncontrolled descent) in a timely manner so they can enact contingency procedures and protocols to correct or mitigate them. Where possible, operators utilize existing equipment/mechanisms to coordinate and mitigate issues (e.g., use squawk codes to signal issues to ATC). Common, standardized terminology and procedures support situations where ATCE/COE coordination is needed. If the situation cannot be corrected or presents a hazard to others, operators must notify potentially impacted entities as soon as possible and provide operational information sufficient for them to act.

When an off-nominal situation occurs in a CA, the operator notifies other impacted operators according to prescribed COPs, providing the information needed to manage the situation and facilitate deconfliction of affected flights. Depending on the situation, the operator may:

- Calculate and communicate new intent information for the operation, accounting for additional positional uncertainty due to limited control
- Send advisories and updates regarding the event to proximate cooperative operations
- Use projected intent to identify cooperative operations in conflict with the operation's projected trajectory to deconflict the operation
- Determine whether there will be an impact on the ATCE and, if so, notify ATC of the situation, providing all known, relevant information for them to respond to the event.

In the case where an off-nominal event in the ATCE may impact operations in the CA, ATC identifies and alerts affected HATM operators, via CARISs or other means.

2.7 Equity of Airspace Usage

All airspace is a usable resource (Global Air Traffic Management Operational Concept [GATMOC], 2005). Incorporating dynamic and flexible airspace management techniques and establishing agreed upon principles and practices among stakeholders will promote equitable use of airspace for all users. This is particularly important given the diversity of performance, operating characteristics, and mission objectives of higher airspace operations.

If an HATM operator chooses to operate cooperatively, they agree to participate in the negotiation process for airspace usage. It is expected that HATM operators will not request more airspace than they require when such airspace is in high demand. Since aircraft performance is a primary contributor to the amount of airspace required to support an operation, the HATM community may consider minimum performance requirements for operating in certain regions, if the density of operations and/or competition for airspace increases to levels that require them.

HATM operators limit the impacts of their operations on others and reduce airspace used to the degree possible by optimizing aircraft performance and remaining flexible during periods of high demand. They do not optimize their own operations at the expense of sub-optimizing the environment as a whole.

HATM operators transiting to and from operating altitude (through controlled and/or uncontrolled airspace) shall consider their impacts to other airspace operations, particularly due to their performance limitations on climb or descent. For example, operators can, to the extent possible, launch and land in areas with sparser traffic, or invest in capabilities that decrease the required separation between aircraft to the greatest extent possible.

2.8 Security

Security is a priority of HATM and is paramount to safety. Security refers to the protection against threats that stem from intentional acts (e.g., terrorism) or unintentional acts (e.g., human error), affecting people and property in the air and on the ground. Security risk management goals include balancing the needs of the members of the HATM community who require access to the airspace with the need to protect other stakeholder's interests and assets, including the FAA, public entities, other airspace users, and the general public.

To meet security objectives for the NAS, HATM must include 1) the ability to identify and verify the identity of who is aloft and under what authority, 2) a trusted digital information sharing environment used for exchanging verifiable and non-repudiable information between authenticated stakeholders, with FAA archival and cyber security requirements and 3) a resilient system capable of continued operations during failures or other disruptions (which are further discussed in Sections 2.8.1 through 2.8.3).

2.8.1 Identification and Authentication of Flights and Digitally Communicating Entities

Every high-altitude operation, including those within the COE, has a globally unique flight ID, persistent throughout the entire duration of the flight, and unique through time. The flight ID is associated with a digital flight object, which includes the associated aircraft and operator details. Every operator, service provider, or entity which exchanges information on the network has a globally unique and verifiable digital identity. This identity is used to authenticate all messages sent on the network.

The identity and authentication mechanisms provide means to address security threats and protect the public from security vulnerabilities by enabling accountability and traceability of all operations, and the integrity and non-reputability of all transactions. It enables the FAA and other designated public officials to access information associated with any operation through both FAA systems and those of HATM network.

2.8.2 Information Access and Management

All operators must satisfy FAA-stipulated data sharing and archiving requirements to support safety and security regardless of service provision method (cooperative or ATC-provisioned). In the event of threats to aircraft or threats using aircraft, HATM operators provide relevant information and assistance to responsible authorities. Operators may use third party entities to fulfill their obligations for data sharing and archiving.

The FAA has access to this historical data as needed for FAA analytics, regulatory, and operator accountability purposes. Other authorized entities (e.g., DoD, public safety officials) may also require information on active or historical HATM operations for the purposes of aircraft separation (e.g., due regard) or for public safety/security reasons (e.g., malicious activity). This information could include, but is not limited to, operation intent, 4D position tracks, and off-nominal event records (e.g., safety violations).

2.8.3 Network Security and Resiliency

Digitization and automation in HATM introduce new security challenges. C2 system architectures, which vary by manufacturer, could be manipulated in ways that impact the safety and security of people on the ground and in the air. In absence of adequate authentication, identities of entities on the digital network and position reports could be misrepresented or spoofed to disrupt operations. Improperly secured C2 link infrastructure, security of information systems, surveillance infrastructure and global positioning system signal vulnerabilities are example threat surfaces capable of being exploited for misuse (intentional and unintentional).

To protect for these system vulnerabilities, cybersecurity architectures (e.g., zero-trust) are developed and implemented to mitigate the potential for malicious activities and prevent unauthorized access to third party and FAA systems. The FAA considers security risks proposed for an operation and evaluates the adequacy of proposed solutions in relation to applicable requirements (e.g., digitally signed or encrypted links). Given the high dependence on interconnectivity and information services supporting HATM, it will be necessary for operators to avoid single point failures that could disable the availability of their services across large portions of the airspace. Communication systems do fail, and the outages can impact large geographical areas. Due consideration should be given to the implementation and use of multi-region services. Instantiations of services interconnected across national boundaries can provide high levels of service availability and resilience.

3 HATM Operational Scenarios

The scenarios presented in this section focus on different aspects of HATM operations. They are *examples* of how procedures, technologies, and techniques can be used to support cooperative traffic management and HAO goals. The scenarios cover a range of operational situations occurring prior to flight, in the ATCE, in the COE, and interactions occurring between the ATCE and COE. Table 3 presents a high-level summary of each scenario.

Table 3. HATM Operational Scenario Overview

Section	Title	Summary
3.1	Establishment of a CA	Explores how a CA request could be processed, evaluated, and granted for a: • CA that meets the conditions set by the FAA for criteria-based authorization • CA that must be reviewed and authorized
3.2	Conflict Management within the COE	Explores potential avenues for operation intent sharing, cooperative deconfliction functions, and conflict management model processes.
3.3	Interactions with Transiting ATC-Managed Aircraft	Examines several different approaches for managing conflicts between an IFR aircraft and CAs.
3.4	Off-Nominal Event Contained in the COE - *Aircraft in Distress Meets Criteria for Fallback/Emergency Rules*	A cooperative operator experiences a power issue that requires an immediate change to their intent. A conflict with an aircraft in an overlapping CA triggers Fallback/Emergency rules.
3.5	Off-Nominal Event Impacts ATCE – *Emergency Descent of an Unmanned Balloon*	A balloon in a CA experiences a failure that requires termination of flight. An emergency descent is coordinated through the COE and ATCE.

3.1 Establishment of a CA

A higher airspace operator providing commercial crop monitoring services intends to launch a fleet of four fixed-wing HAPS aircraft to loiter on station over an area over western Kansas for the crop growing season - 01 May through 31 August. The operator starts the planning process by registering the initial CA for the operation. They use an authorized CARIS to meet their responsibilities for registering the CA.

Step 1: CA Verification – The operator inputs the 4D volume and submits the request for the CA into the CARIS. The CARIS creates a universally unique ID for the CA. The CARIS checks the 4D volume against the FAA-published map to 1) identify any airspace restrictions or constraints – none are found; 2) ensure it meets all applicable FAA rules for authorization; and 3) determine the type of authorization for which the operation is eligible (two cases are explored below).

Case A: CA is eligible for criteria-based authorization

The CARIS determines that operator's proposed CA is eligible for criteria-based authorization by the FAA airspace management function and is therefore instantly authorized.

Case B: CA requires review and authorization

The CARIS determines that the operator's proposed CA requires a case-specific review and authorization by the FAA. This is due to routine IFR operations and occasional military operations that are performed in the region of the planned CA. The CARIS electronically submits the request to the FAA airspace management function for review. The airspace management function evaluates the details of the operation (e.g., geographic location, aircraft type) and analyzes the impacts of airspace usage for the requested date/times. No known traffic, military or civilian, is scheduled to occur during the planned operation. Authorization is granted.

Step 2: CA Registration - The CARIS, using the universally unique ID for the CA, communicates the full CA details to the FAA and to cooperative operators with overlapping CAs. It makes the newly registered CA information discoverable. The CARIS then confirms to operator that the CA has been created. It provides the CA ID and the list of all operators with overlapping CAs with whom they must share intents and cooperatively deconflict. The CARIS continues to monitor for any future CA that overlaps with the newly created CA and informs the operator accordingly.

3.2 Conflict Management in the COE

An LTA HAPS is providing internet services after a storm that caused large-scale damage to a region over Florida. An HTA HAPS is operating in a CA over the Gulf of Mexico fulfilling a surveillance contract. Each CA has some area of overlap indicating that the operators of both CAs need to share intents to identify and resolve potential conflicts. Both operators are monitoring OI information for conflicts. Based on the intents, it is possible that a conflict between the LTA and HTA aircraft could occur in three hours (see Figure 22). The risk of the conflict is low. According to the conflict management model, no action has to be taken by either operator at this point (see Figure 27). Both operators choose to simply monitor the situation.

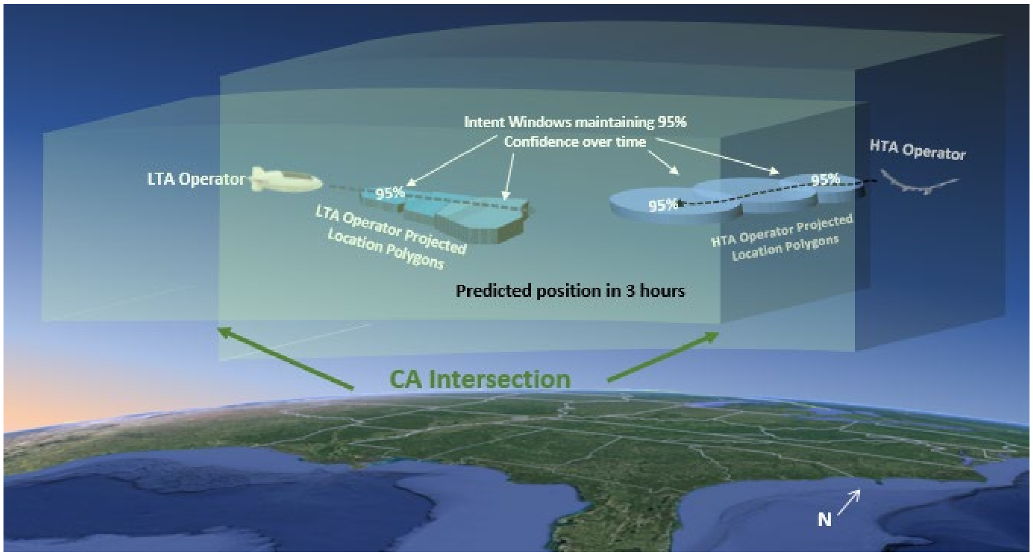

Figure 22. Notional conflict resolution model calculations between HTA HAPS and LTA HAPS

The operators continue updating their intent according to established rules and specified update rates as dictated by the COPs. Each update decreases OI uncertainty for both aircraft. The LTA is traveling at a slower rate than originally modeled due to wind speed differentials from the initial forecast. An hour later (two hours prior to the predicted conflict), with the LTA moving more slowly than planned and the HTA operation considerably further west than predicted, the two aircraft are no longer calculated to be in conflict (see Figure 23). No action is necessary.

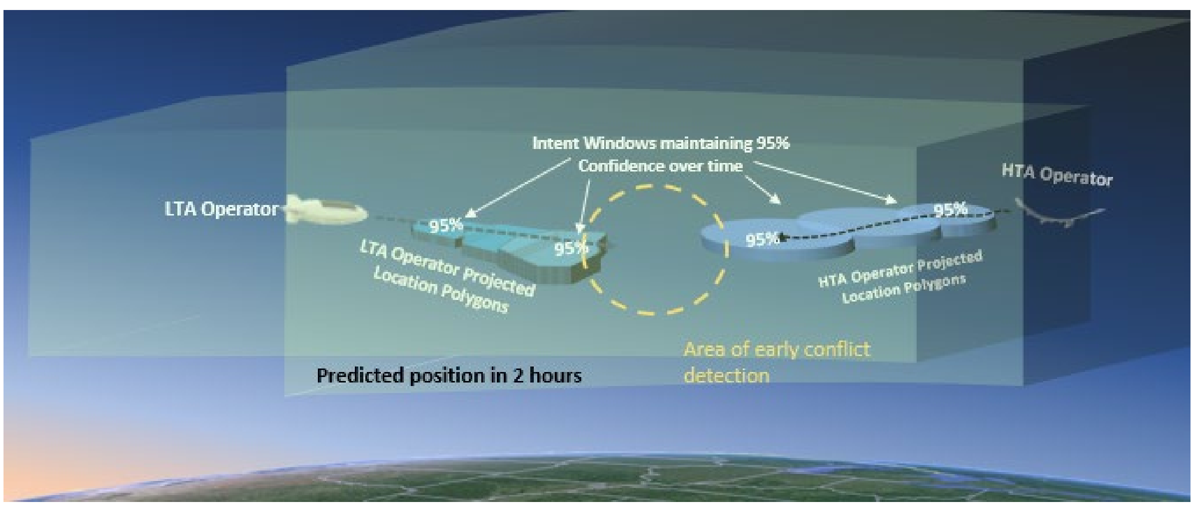

Figure 23. Notional recalculation to eliminate probability of conflict

At the same time, the LTA operator determines they need to adjust location to achieve mission needs and submits updated intent. Once submitted, intent polygons again overlap with the HTA operation, restoring the predicted conflict in one hour. Figure 24 depicts notional conflict resolution model calculations between the two aircraft. With a relatively short time horizon and high confidence of overlap, the operators enter the Free Negotiation Phase of conflict management to deconflict their operations (see Figure 25).

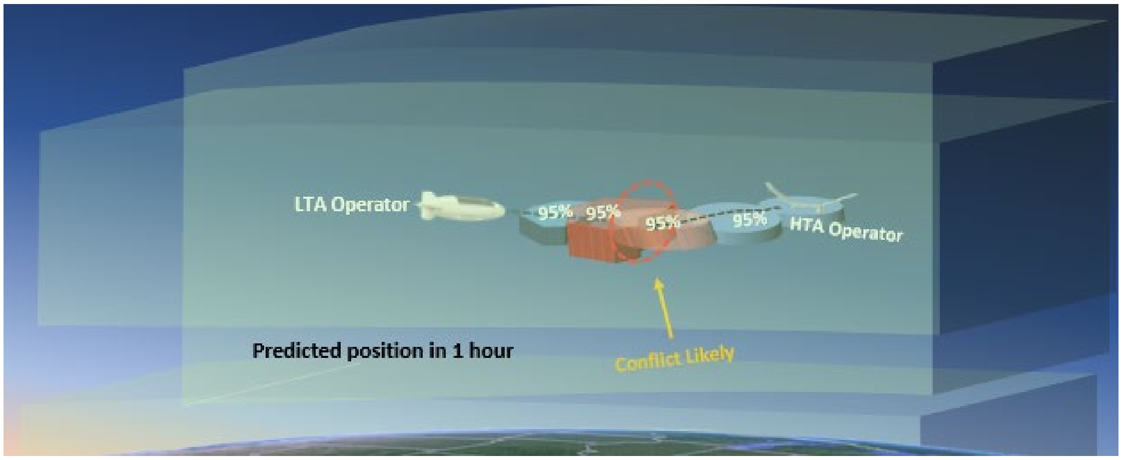

Figure 24. Notional conflict resolution

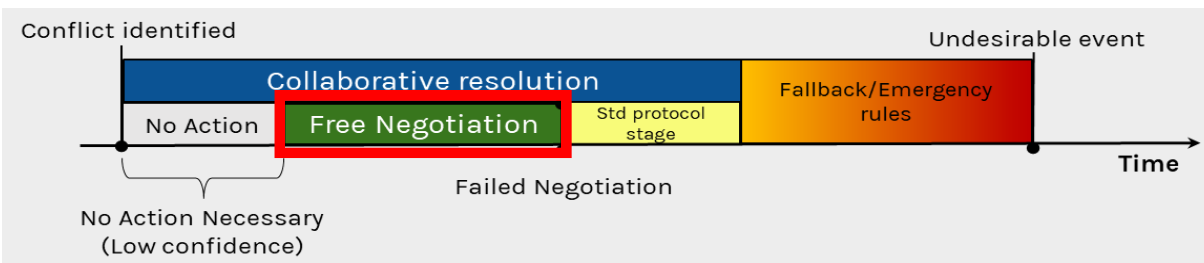

Figure 25. Conflict management model – Free negotiation

The HATM operators enter negotiations. They agree to share the burden of maneuvering. The LTA operator is unable to adjust altitude and limited power levels restrict the aircraft's ability to hold position with current winds. The HTA operator has greater maneuverability both vertically and laterally due to greater propulsion capabilities. With enough stored power, the HTA operator agrees to increase altitude while maintaining course. The LTA agrees to reduce forward thrust to slow its cruise as the HTA ascends. The operators update and mutually exchange their intent to reflect their planned actions. Both operators recalculate conflicts and determine that the new intents are conflict-free.

3.3 Interactions with Transiting ATC-Managed Aircraft

3.3.1 Regularly Scheduled Supersonic Flight

An SST company operates routine supersonic transcontinental operations between high traffic US city pairs. One of their SST aircraft flies from California to New York on a weekly basis. The flight departs each Tuesday from LAX at 1500Z and lands at JFK at 1800Z.

The company's operations center files an IFR flight plan for the flight two days prior to its scheduled departure. Upon submission, the flight planning system compares the flight plan against known constraints to include identifying any planned or active CAs in conflict with the submitted route.

Because this is a regularly flown route, the FAA airspace management function determines that any requests for CAs that intersect the route on Tuesdays between 1500Z and 1800Z require FAA review and case-specific authorization.

3.3.2 Chartered Supersonic Flight (Not Regularly Scheduled)

An SST company operates an on-demand charter service, scheduling flights based on customer request. As a result, flights are not operated on a predictable schedule. On a Friday morning, the SST company gets a request to fly from Teterboro, New Jersey to Van Nuys, California.

The company's operations center files an IFR flight plan for a non-routine charter flight from Van Nuys, California to Teterboro, New Jersey at FL600. Upon submission, the flight planning system compares the flight plan against known constraints to include identifying any planned or active CAs in conflict with the submitted route.

The system identifies a CA being in direct conflict with the SST's route (see Figure 26). As a result, the flight plan is routed to the FAA to resolve the conflict. Three options for managing this conflict are explored in the following sections.

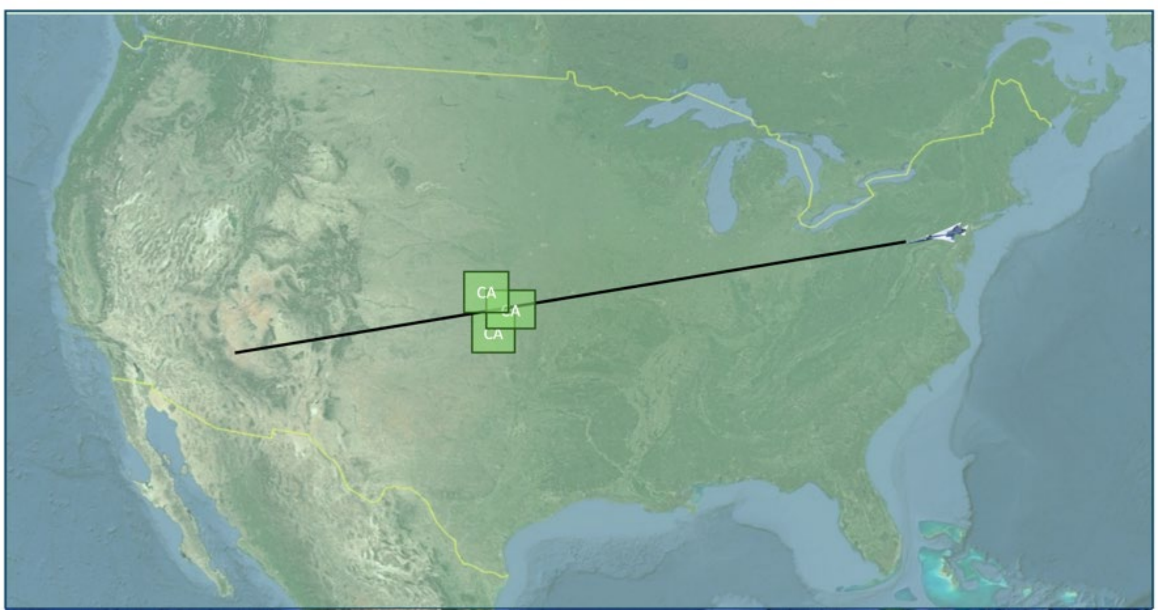

Figure 26. ATC-managed SST flight with CA transit

<u>Approach 1</u>: Route the SST around the CA

The SST's flight plan could be modified to vector the aircraft around the CA to the north, minimizing the length of the deviation (shown in Figure 27).

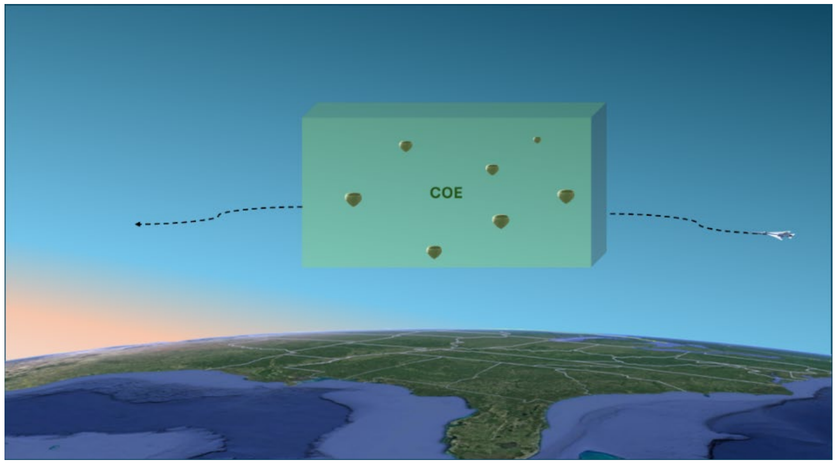

Figure 27. SST routes around the CA

<u>Approach 2</u>: Modify the CA to allow the SST to continue on its planned trajectory

The configuration of the CA could be modified using a tactical constraint to enable the aircraft to traverse the airspace without having to amend its filed route. The FAA airspace management function would assess reconfiguration alternatives, coordinate with CA users as needed, and select the option that is least impactful to cooperative and ATC-managed operations. The FAA would then issue a tactical constraint, and impacted operators would acknowledge their ability to comply. In this example, the tactical constraint limits the floor of their CA (see Figure 28).

The operator continues executing their operations within the modified CA without violating the constraint. After the established period, the CA reverts to its original configuration.

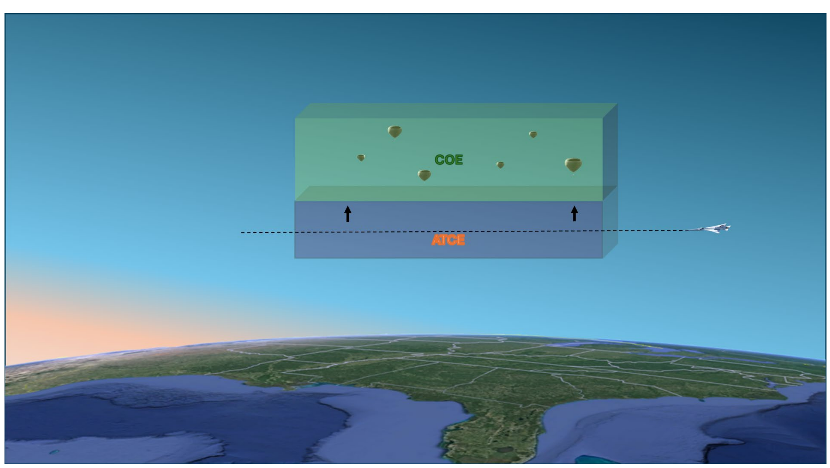

Figure 28. CA is modified to enable SST to transit

Approach 3: Deconflict the SST from cooperative traffic within the CA

The FAA can use automation to deconflict the SST's 4D trajectory from cooperative operations in the CA in the same manner a HATM operator might. FAA ATM can calculate a 4D trajectory for the portion of the flight that overlaps the CA and register a corresponding CA. Once the overlap with the CA is identified, cooperative operators and FAA systems exchange OIs and identify conflicts (overlapping OIs). In this case (as depicted in Figure 29), the HTA HAPS operator's OI indicates that the operation will be positioned well above the transiting SST's planned altitude for the intended time of transit with adequate pairwise spacing - no conflicts are detected.

Leading up to and during flight, OIs are refreshed and updated as needed. FAA automation and cooperative operators continue to monitor for conflicts. No conflicts are detected.

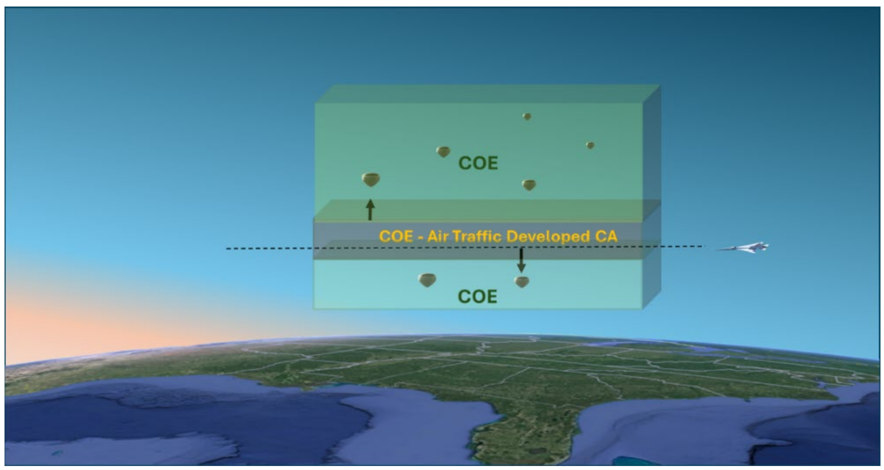

Figure 29. SST transits COE in ATM-created CA

3.4 Off-Nominal Event Contained in the COE: Aircraft in Distress Meets Criteria for Fallback/Emergency Rules

An HTA HAPS operator is performing a 3-month telecommunications operation in a CA. The operator has implemented all HATM functions for which it is responsible in its fleet management automation software and does not rely on a third party.

Sixty-five days into the operation, the operator determines they cannot conform to their submitted OI due to less than anticipated power levels. The operator has limited control of the aircraft. The operator expects to recover from the power issue without impact to the ATCE, but they need to quickly revise the aircraft's OI to account for the descent to a lower altitude.

The HTA's operator immediately updates their OI. An LTA balloon operator, operating in an overlapping portion of the CA (also relying on self-provisioned HATM functions) receives the 4D intent update. They process the new 4D intent information provided by the HTA HAPS operator to identify any conflicts. A conflict is detected. (See Figure 30).

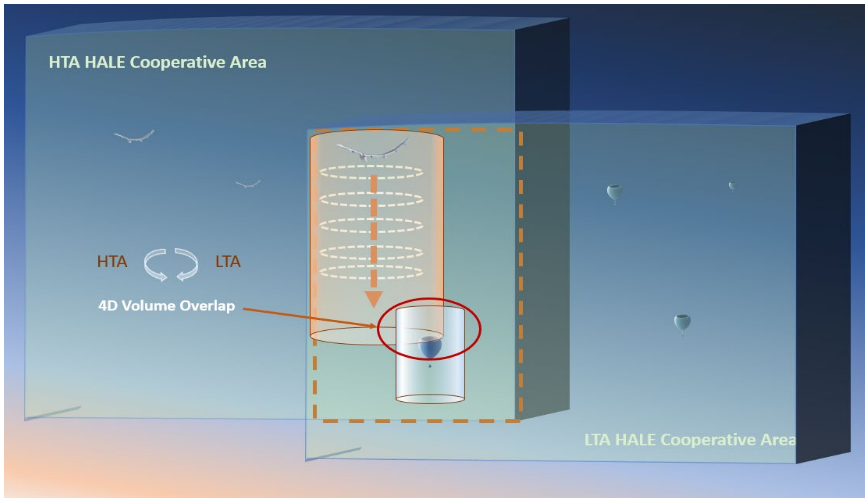

Figure 30. Overview of impending conflict

Upon looking at the conflict timeline, it is determined that:

- The LTA balloon has the performance to avoid the HTA HAPS
- The HTA HAPS does NOT have the performance to avoid the LTA balloon

Because one of the aircraft is not able to avoid the other, cooperative resolution is not possible. This places the conflict in the "Fallback/Emergency Rules" (see Figure 31).

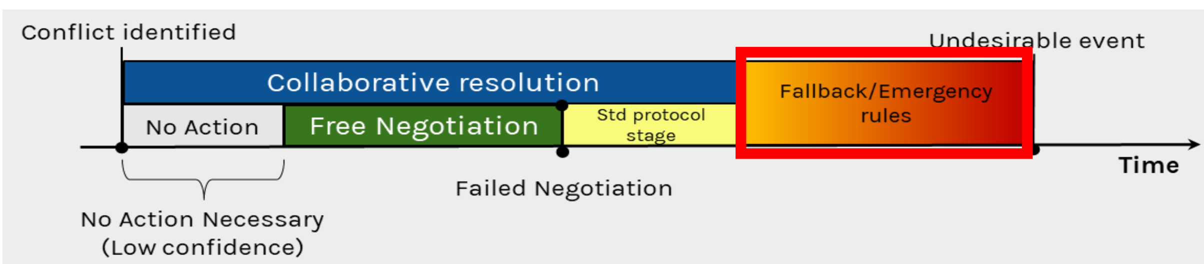

Figure 31. Conflict management model – Fallback/emergency rules

Since the HTA HAPS operator has limited ability to maneuver, the responsibility for spacing falls on the LTA balloon operator. The simplest and most effective maneuver the balloon can make to avoid the HTA is to descend as quickly as possible.

The operator plans the descent, updates their intent, and safely moves away from the HTA's projected path (see Figure 32). The HTA operator safely descends the aircraft and operations resume as normal.

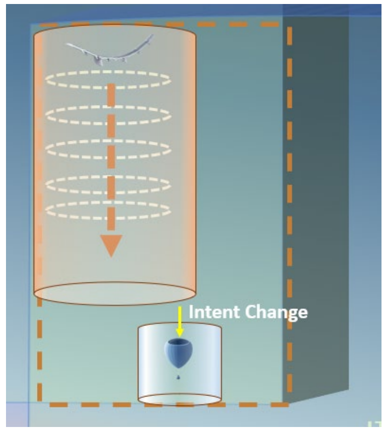

Figure 32. LTA balloon maneuvers to avoid HTA HAPS

3.5 Off-Nominal Event Impacting the ATCE: Emergency Descent of an Unmanned Balloon

A balloon is operating in its CA at FL650 providing internet and telecommunications services to a remote area. At 3:00 a.m., monitoring equipment alerts the operator that the balloon has experienced a failure, making continued operation hazardous. The operator investigates the situation, confirms the failure, and determines they should immediately initiate the process to terminate the flight (see Figure 33). The termination process starts with coordination with other entities, including other cooperative operators and ATC.

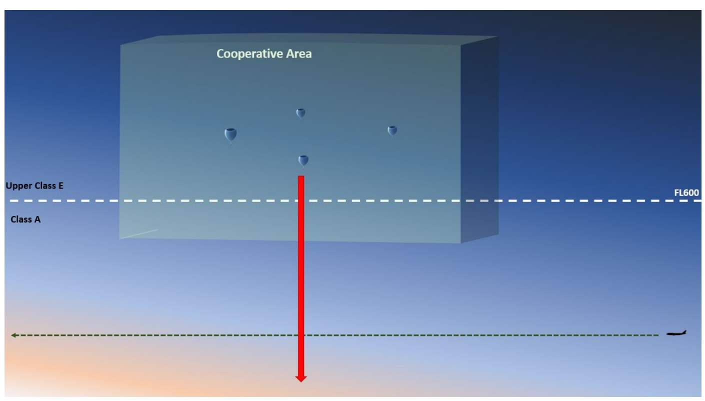

Figure 33. Balloon experiencing failure plans descent

The balloon operator outsources its cooperative deconfliction responsibilities to an authorized service supplier, which performs the cooperative management functions on the operator's behalf. The operator immediately notifies the service supplier to declare an emergency, providing all information needed to deconflict the terminating balloon from other vehicles (e.g., projected trajectory). The service supplier acknowledges the balloon's 'Emergency Status,' processes new intent information (accounting for any uncertainty), and uses it to identify operations in conflict with the balloon's new projected trajectory. No operations within the CA are in conflict with the emergency operation.

The projected trajectory indicates that the balloon will exit the floor of the CA at FL590 and enter Class A airspace in three minutes from the time termination commences. As the operator coordinates COE emergency procedures, they notify ATC of the emergency along with the need to initiate a descent, providing information in a standardized format (e.g., call sign, aircraft type/equipage, location, actual track, projected trajectory, and nature of emergency, point of entry into ATCE).

ATC acknowledges the emergency and the intended descent flight path, including entry point and time into the ATCE. They start clearing impacted traffic under their control and coordinate with the balloon operator on when to initiate termination. When termination is initiated, they monitor the position of the distressed balloon as it descends into the ATCE.

The balloon is equipped with a transponder, but it was not active during the operation. The operator activates it, squawks the appropriate emergency code, and initiates the flight termination process (release of the lifting gas and deployment of the recovery chutes). (Note – in this case, a transponder code specific to ‘unoccupied’ aircraft emergencies is used to differentiate it from emergencies where aircraft are transporting people.)

As the balloon transitions into the ATCE, ATC vectors aircraft under its control to maintain separation based on the balloon’s current and projected position. After the balloon exits the CA, the service supplier informs other CA users that the emergency no longer poses a threat to COE operations and nominal operations can resume.

4 Moving towards HATM Operationalization

As the higher airspace environment transitions from low density operations to an operationally diverse, technologically sophisticated environment, with increased tempo, new solutions for managing the airspace are prudent. Cooperative traffic management allows operators to derive solutions that meet their business needs while maintaining a safe operating environment. This will necessitate the formulation of rules for fair sharing of airspace; an architecture and information sharing protocols to ensure common language and foster situation awareness; harmonized procedural and operational protocols that account for the needs of all participants; and adoption of operational systems/technologies/capabilities that are compatible where necessary (e.g., aircraft to aircraft component interoperability).

The FAA, NASA, and Industry will continue to work together to conceptualize, develop, and demonstrate elements of HATM operations, addressing characteristics unique to the airspace and operations - long duration, multinational flights, wide range of aircraft speeds and performance characteristics - and high-altitude safety risk considerations, among others. Industry involvement will ensure operational needs are accounted for in the development process and will help validate proposed solutions and development of performance standards through research (e.g., modeling/simulations) and operational testing.

Higher airspace operations are global in nature. Vehicles capable of long duration operations open new possibilities for uses that can span multiple countries, making a global, harmonized concept important. The FAA will mature and refine the HATM concept domestically and begin to socialize it more broadly with the international community through the appropriate forums.

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List of Acronyms

Acronym	Definition
4D	Four Dimensional
ADS-B	Automatic Dependent Surveillance – Broadcast
AIA	Aerospace Industries Association
ALTRV	Altitude Reservation
ANSP	Air Navigation Service Provider
ATC	Air Traffic Control
ATCE	Air Traffic Control Environment
ATM	Air Traffic Management
CARIS	Cooperative Area Registration and Information Service
CA	Cooperative Area
CFR	Code of Federal Regulations
CNS	Communication, Navigation, and Surveillance
COE	Cooperative Operating Environment
COPs	Cooperative Operating Practices
DoD	Department of Defense
FAA	Federal Aviation Administration
FIR	Flight Information Region
GATMOC	Global Air Traffic Management Operational Concept
HAO	Higher Airspace Operations/Higher Airspace Operator
HA	Higher Airspace
HAPS	High Altitude Platform Station

HATM	Higher Airspace Traffic Management
HTA	Heavier-than-Air
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
KTS	Knots
LOA	Letter of Agreement
LTA	Lighter-than-air
MARSA	Military Authority Assumes Responsibility for Separation of Aircraft
MOA	Military Operating Area
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
OI	Operational (Operation) Intent
RPAS	Remotely Piloted Aircraft System
SST	Supersonic Transport
SUA	Special Use Airspace
TFR	Temporary Flight Restriction
US	United States