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Identifying Common Use Cases across Extensible Traffic Management (xTM) for Interactions with Air Traffic Controllers

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NASA's Extensible Traffic Management (xTM) builds on the foundation and the architecture of Unmanned Aircraft Systems (UAS) Traffic Management (UTM) concept and extends it broadly to other domains, such as Advanced / Urban Air Mobility (AAM/UAM) and Upper Class E Traffic Management (ETM). These xTM concepts assume the ability to fly in airspace that is authorized to operate solely under xTM services and mostly without any air traffic control (ATC) support. However, they also assume circumstances in which the xTM vehicles would need to operate in conventional ATC-managed airspace, both during nominal and off-nominal scenarios. Due to the vast differences in the xTM vehicle performances and missions, there is a concern that ATC may have difficulty in safely managing the xTM traffic and providing appropriate services to all vehicles, unless a consistent set of roles, procedures, and data exchange requirements are defined across the diverse set of xTM vehicle operations. In this paper, we describe a set of use cases that have been identified in UTM, AAM/UAM, and ETM operations that are related to ATC interactions, and we propose to categorize these use cases across xTM domains based on common trigger events. Organizing the use cases from the perspective of ATC roles per each trigger event is expected to provide the first step in discovering common procedures and data requirements across xTM domains that could help ease the controllers' cognitive task load and allow them to manage these interactions more safely.

I. Introduction

In recent years, there has been significant interest in development of new types of missions and vehicles that are seeking to use previously underutilized airspace by means of non-traditional methods. New missions such as drone delivery services, on-demand air taxi services, autonomous cargo freighters, commercial space launch, high-altitude

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balloons, high-altitude long-endurance vehicles, and supersonic aircraft, are predicted to substantially increase operations and be commonplace in the National Airspace System (NAS) [1].

The systems that serve these new vehicles and missions are collectively referred to as Extensible Traffic Management, or xTM. One of the key design thrusts of the xTM system is a new, highly automated information exchange infrastructure and a community-based, cooperative traffic management system, built upon third-party services that provide all basic functions, such as separation, flight intent, and schedule management [2]. The innovative approach employed in xTM framework has the potential to accelerate the growth of capabilities based on market forces and business incentives without relying or waiting on the FAA to implement these functionalities.

Unmanned Aircraft Systems (UAS) Traffic Management (UTM) for small drones was the first concept that pioneered and provided a template for the xTM framework [3]. UTM incorporates an industry-driven, federated system of services that rely heavily on highly automated information exchanges. Since then, several new xTM missions, using an architectural framework like UTM, have been proposed; air taxi operations in Advanced / Urban Air Mobility (AAM / UAM) using electric Vertical Takeoff and Landing (eVTOL) vehicles and High Altitude Long-Endurance (HALE) aircraft, balloons, and supersonic aircraft in Upper Class E (at or above 60,000 feet) Traffic Management (ETM) [4,5,6]. In this architecture, xTM operations are supported by federated service suppliers, developed mainly by industry partners, for coordination, monitoring, and execution of flight plans. In the UTM system, the coordination and data exchange between xTM and Air Traffic Services (ATS), which provides the data infrastructure for conventional air traffic in the National Airspace System (NAS), are handled through a gateway, called Flight Information Management System (FIMS), and other xTM systems are expected have similar gateway for information exchange between xTM and ATS. Fig. 1 shows the UTM architecture in detail.

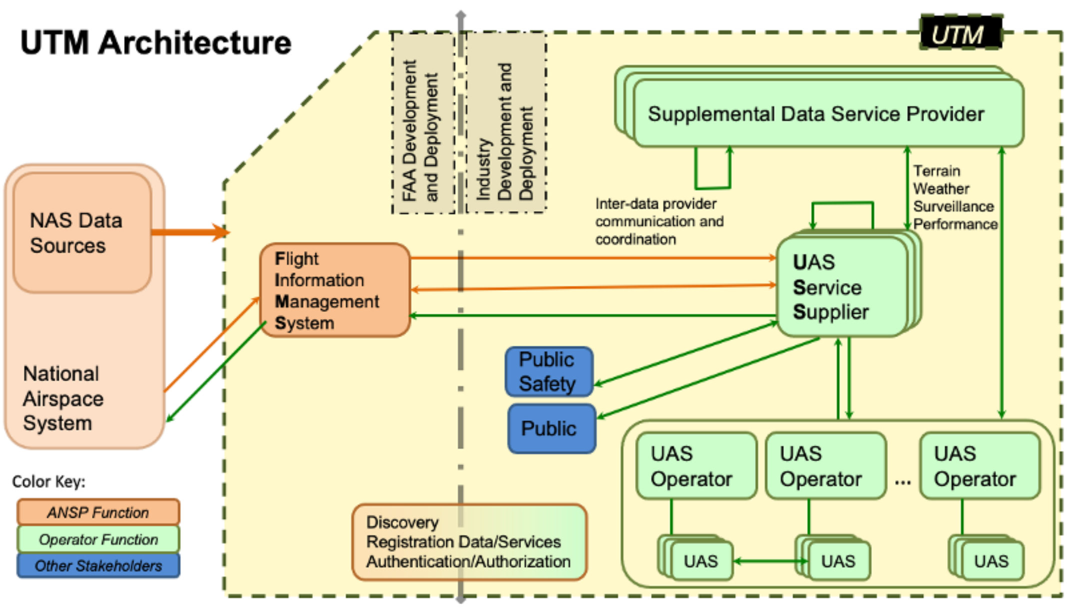

Figure 1. UTM Architecture

Other new missions, such as commercial space operations and large autonomous / remotely piloted cargo operations, have developed their concepts to operate within the existing conventional airspace infrastructure and procedures. Although they have not yet assumed the use of a xTM framework for their concept of operations, they may also utilize xTM framework or services in the future as the traffic density increases to a point that requires a different agenda which would rely less on ATC and ATS.

In the concept descriptions for UTM, AAM/UAM, and ETM, the initial implementations of the concepts assume that the new vehicles operate primarily in a separate, designated airspace, generally away from conventional air traffic and with minimal ATC support for separation or other services. However, xTM also assumes that xTM vehicles may need to co-exist with other aircraft in the NAS in certain scenarios, which requires sharing of integrated and interoperable digital information with ATS [2].

In situations where the xTM vehicles need to transition from xTM to conventional ATC operations, they are expected to fly under conventional air traffic rules or via waivers and rely on the controllers for help in maintaining separation and receiving clearances. Although understanding xTM-ATC interactions is critical for assessing the safety risk and the viability of the concept, these interactions are under-specified in the literature and research. To address this gap, NASA has initiated a new project called xTM-ATC Interactions to examine the issues.

II. xTM-ATC Interactions

In the FAA's vision for the future of aviation, xTM systems are part of a larger ATM system, that operate alongside conventional ATS [1]. In the early implementations of xTM operations, the vehicles are expected to operate in separate, designated airspace, mostly segregated by altitude. Initially, xTM operates in regions sparsely occupied by other traffic, but as the xTM traffic grows in the future, better integration of diverse xTM operations with conventional air traffic will be needed, as illustrated in Fig. 2.

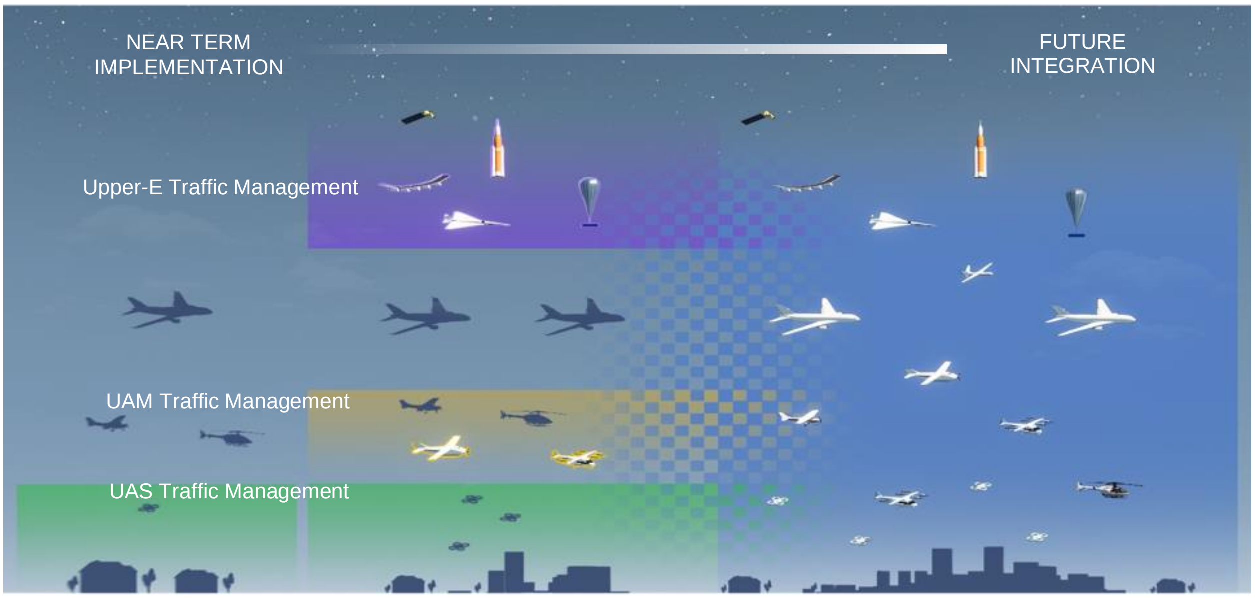

Figure 2. Integration of xTM within the conventional ATS environment

The different xTM operations have unique missions and flight profiles with divergent vehicle performances. Although xTM vehicles are expected to operate mainly within airspaces supported solely by xTM services, they will also encounter situations in which they must exit xTM operations and enter airspaces controlled by ATC, either as a part of a nominal operation or due to off-nominal / emergency situations. Upon xTM vehicle entry into ATC-controlled airspace, controllers will need to have adequate information about the xTM vehicles and be able to communicate with the pilot/remote pilot as needed. In the early stages of UTM, AAM/UAM, and ETM development (collectively referred to as xTM development in this paper), there has been a concern that xTM operations differ not only in their mission objectives and vehicle performances, but also in how they communicate their intent, location, other flight plan related information, and operational procedures. These differences may pose significant challenges to a controller when the xTM vehicles enter his/her airspace with different operating goals and practices, and the controller is expected to provide different types of services and maintain safety within his/her airspace.

Given these challenges, the xTM-ATC Interactions project aims to identify common xTM-ATC interaction procedures across the three xTM domains to examine if these common procedures can simplify ATC roles/responsibilities and data requirements across different xTM-ATC interactions under similar airspace and weather environments. As an initial step towards this goal, this paper describes an approach to collect and develop a set of use cases for UTM, AAM/UAM, and ETM operations that are related to ATC interactions, and categorize these use cases across xTM domains based on common trigger events. Organizing the use cases from the perspective of ATC roles per each trigger event is expected to provide the first step in discovering common procedures and data requirements across xTM domains.

Prior to describing the interaction use cases, the following sections describe some basic assumptions about xTM-ATC interactions that were found in the UTM, AAM/UAM, and ETM concept-of-operations and other related documents. Given that these concepts are not fully implemented in the current NAS operations, the basic assumptions identified in these documents provided an important basis for building the interaction use cases.

A. UTM-ATC Interactions

In the UTM concept, small Unmanned Aircraft Systems (sUAS) are expected to provide various services to people by delivering goods, surveying the fields, and providing other service-oriented tasks at or below 400 ft above ground level (AGL). Expected business cases for UTM include inspection, survey, monitoring, and package delivery. The predicted volume of sUAS in UTM is expected to increase significantly, to around 2–3 million by 2023 [3].

UTM vehicles are nominally expected to operate in a geofenced, segregated airspace, away from ATC control. A geofenced area could operate solely under UTM infrastructure and services and be kept separate from restricted areas and/or other non-UTM aircraft. UTM operational regions can be defined in permanent or temporary manner using the airspace authorization mechanisms [7]. Recently, the UAS Low Altitude Authorization and Notification Capability (LAANC) was introduced to provide access to ATC-controlled airspace. The access is provided through near real-time, automated processing of airspace authorizations, if it is below approved altitudes and facilitated by industry developed UTM service suppliers (USS). LAANC is now available at approximately 600 airports [3].

In the UTM concept, UTM vehicles are not expected to interact with ATC, unless they are non-compliant and fly into controlled airspace unplanned. If the UTM vehicle is out of conformance with its flight intent volume, the sUAS operator would be expected to notify the FAA with enough time for the controller to respond prior to the sUAS entering ATC-controlled airspace. In these scenarios, there is an expectation that USSs will exchange vehicle-relevant information with the ATS [7]. The exchanged information may include the flight identification, operational intent, contingency procedures, potential conflict information, NAS constraints, etc. [7]. When contingency and emergency plans are needed, associated procedures would need to be harmonized with ATS when UTM vehicles transit from UTM to ATC operations. Adequate tools and procedures will need to be developed to ensure the sharing of information, the interoperability of the UTM and ATS information systems, and to define roles, responsibilities in these interactions [7].

Once UTM vehicles enter ATC-controlled airspace, the remote pilot-in-command (RPIC) of the UTM vehicle would be required to follow the procedures and requirements, unless an exemption or alternate procedures have been established ahead of time. The assumption of RPIC and ATC interactions in ATC-controlled airspace applies generally to all other xTM vehicles under consideration as well.

B. AAM/UAM-ATC Interactions

The UAM concept envisions the use of eVTOL to enable practical, cost-effective air travel as an integral mode of transportation in metropolitan areas. AAM extends that vision to include air transportation beyond the metropolitan areas. Nominally, UAM vehicles are expected to operate inside specially designated airspace called “UAM Corridors” that can be operated solely with UAM infrastructure and services without ATC involvement [4]. Initially, the UAM Corridors connect two known vertiports or airports to support end-to-end UAM operations, but as UAM operations evolve, UAM Corridors may be segmented and connected to form more complex networks of available routing between vertiports. [4]. The traffic density is expected to be high, with hundreds of simultaneous operations in a single metroplex area. [5].

UAM vehicles may need to operate outside of UAM services and under ATC supervision, both in nominal and off-nominal scenarios. There are nominal situations in which UAM vehicles interact with ATC, such as when UAM landing site is collocated with an airport that support non-UAM aircraft, or when UAM vehicles file operation plans that transit through ATC-controlled airspace. Off-nominal situations include immediate landing at ATC-controlled airports, weather deviation that requires UAM vehicles to exit UAM Corridors into ATC supervision, and unplanned entry due to non-cooperative UAM vehicles experiencing lost link, vehicle malfunction, etc.

When UAM vehicles need to enter ATC-controlled airspace, they are expected fly under the same ATC rules as other aircraft and meet all requirements for operating in ATC-controlled airspace. Prior to the UAM vehicles exiting UAM Corridors into ATC-controlled airspace, the UAM RPIC or, if crewed, the pilot-in-command (PIC) is expected to turn on ADS-B Out and the transponder as a means of ATC identification and contact the controller. Prior to entry, flight intent and other relevant information about the UAM vehicle needs to be shared with ATS. If possible, the contingency plans should be developed and included as a part of the information exchange. Once contacted, the controller should determine the possible impact of the contingency plan and provide advisories and/or an ATC clearance to mitigate the risk to other aircraft.

C. ETM-ATC Interactions

Upper Class E Traffic Management (ETM) operates at or above flight level 60,000 ft (FL600), where there are very limited current ATC services. Operations include but are not limited to, commercial, state/government, and research entities operating both crewed and uncrewed vehicles. ETM environment consists of both cooperatively managed operations by ETM operators, as well as ATC-supported operations for certain vehicles that require additional provisions [6]. ETM-operated region is envisioned to have a diverse set of vehicles and missions, such as slow or fast HALE fixed-wing aircraft, high-altitude platforms like balloons and airships, as well as high-performance crewed/uncrewed supersonic/hypersonic aircraft.

In ETM operations, the vehicles are expected to share flight intent with ATC and other ETM operators prior to departure. They are also expected to operate in ATC-controlled airspace during the climb/descent phase of transitioning to/from Upper Class E airspace at or above FL600. When ETM vehicles need to transit through controlled airspace, they are likely to be isolated from other traffic using various types of special, designated areas, such as Special Use Airspace (SUA), restricted areas, Military Operation Areas (MOAs), alert areas, national security areas, or temporary flight restricted areas. Corridors or ‘sky lanes’ may also be considered, especially for supersonic/hypersonic vehicles within controlled airspace [6].

ETM vehicles are also expected to access a “flexible floor area” below FL600 [6]. Airspace between FL500 and FL600, which is technically ATC airspace but with very little conventional air traffic, provides an opportunity to allow ETM vehicles to fly in an area below FL600 using the ETM system, if they can provide intent and other vehicle related information to ATC for maintaining situational awareness of the operation.

Finally, ETM vehicles may encounter off-nominal or emergency scenarios, like UTM and UAM vehicles, that require unplanned descent into heavily congested ATC airspace. Due to vastly different vehicle characteristics between HALE fixed-wing, balloons, and supersonic aircraft, the off-nominal / emergency scenarios likely will require tailored procedures and solutions for each vehicle type.

In terms of information exchange between the FAA and ETM operators, the concept requires responsible parties to have access to all information necessary to maintain safe, equitable operations, like the information exchange requirements in UTM and AAM/UAM. ATS and ETM systems need to ensure data access and management in ways to satisfy the cooperative ETM operations and controllers’ needs when separating vehicles under their control.

III. Use Case Categorization of xTM-ATC Interactions across xTM Domains

To categorize the xTM-ATC interactions along common procedures across the xTM domains, the interaction use cases for the individual xTM domains were collected from various sources, such as concept documents, use case scenarios currently being developed at NASA and the FAA, and insights gained from interview sessions with xTM researchers at NASA.

Additional use cases were then developed when – for a given trigger event – use cases had been identified for one xTM operation, but not the others. In these situations, the existing use case was used as a template to replicate similar ones across the other xTM operations. These use cases were then grouped and categorized based on similar trigger events. The results of the use case identification and categorization resulted in the following broad categories:

- Planned entry and exit between xTM operated and ATC-controlled airspace (with and without intervention needed by the ATC)
- Planned airspace authorization for xTM operations for ATC-controlled airspace (and the release of the airspace authorization back to ATC operations)
- Unplanned entry into ATC-controlled airspace due to off-nominal events:
    - Equipment failure or degradation (e.g., sensor failure, low battery, etc.)
    - Unplanned xTM vehicle entry into ATC-controlled airspace due to environmental factors
    - Unplanned xTM vehicle entry due to C2 link loss (command and control)
- Unplanned entry of many xTM vehicles into ATC-controlled airspace due to weather or other environmental factors
- Non-xTM vehicle entry into xTM operational regions with limited ATC support

The detailed descriptions of the interaction use cases, categorized by the trigger events described above, are included in the Appendix. In the following sections, the trigger event categories are described further in detail.

A. Planned Entry and Exit between xTM Operated ATC-Controlled Airspace

While some xTM concepts assume that their vehicles fly mainly in xTM system from takeoff to landing [4], others assume that the vehicle will take off and land from ATC-controlled airspace before transitioning to xTM operations [6]. A good example of nominal planned transit through ATC-controlled airspace before entering xTM operations are the ascent / descent phases of ETM operations. For HALE fixed-wing aircraft in ETM operations, the ascent / descent of the aircraft takes many hours to reach FL600 / to land as it transits through the ATC-controlled airspace. ATC maintains separation by monitoring these aircraft and keeping other aircraft away from the HALE aircraft flight path.

For UAM operations, unlike ETM, the initial implementation of the concept assumes the authorization of UAM-operated region from takeoff to landing instead of transiting through ATC-controlled airspace. However, as the number of vertiports / airports increase with increase in UAM traffic, it may be infeasible to create end-to-end UAM Corridors without creating a complex network of UAM-operated region that cuts through ATC airspace in metroplex areas. Therefore, UAM operations may also need to consider transiting through ATC-controlled airspace during takeoff and landing before entering/exiting UAM Corridors. In such cases, UAM operations may need to implement similar procedures as the ones used by ETM operations during ascent and descent.

For UTM, the concept does not assume that sUAS transits through ATC-controlled airspace. They operate below 400 feet and in regions not generally occupied by crewed conventional aircraft, so their interaction with the ATC should be unlikely, except in unplanned, off-nominal events. These off-nominal events / scenarios will be captured in other categories in the following sections.

In general, if xTM vehicle needs to transit through ATC-controlled airspace before entering xTM-operated regions, or if it needs to exit xTM operations to enter ATC-controlled airspace, the concepts require that there is a RPIC for an uncrewed vehicle or a PIC for a crewed vehicle who can interact with the controllers. The RPIC/PIC or xTM vehicle operators would need to coordinate an operational flight / mission plan with xTM Service Suppliers to be approved to enter the xTM-operated regions at a specified time and location, but they would also need to file Instrument Flight Rule (IFR) flight plan in the ATS and be cleared to fly the IFR flight plan by a controller, like any other conventional aircraft. A possible exception may be balloons, which do not file IFR flight plans in today's operations.

In the early xTM implementations, xTM vehicles are expected to operate in sparsely populated airspace so that there is minimal need for the controller to intervene with the xTM vehicle or manage ATM traffic while it is transiting through the ATC-controlled airspace. Table 1 in the Appendix describes the climb phase of flight through ATC-controlled airspace with ATC supervision but with no active intervention needed. Table 2 describes a similar use case but with some traffic interactions between xTM and other vehicles such that controller issues clearances to either xTM or other vehicles to maintain safety.

Exit out of an xTM-operated region into ATC-controlled airspace is like the entry into xTM region, but before xTM vehicles can exit xTM and enter ATC operations, the controller would need to clear the vehicle to enter his/her airspace. Table 3 in the Appendix describes a descent phase of flight out of xTM and into ATC operations in a nominal case with no ATC intervention and Table 4 describes a similar use case with ATC intervention.

B. Planned Airspace Authorization for xTM Operations for ATC-Controlled Airspace

In situations in which xTM vehicles need to transit through an airspace that is under ATC control but is not occupied by other traffic, a preferred way of allowing the transit is to temporarily authorize the airspace to be operated by the xTM services and relieve the controller from his/her responsibility of the vehicle. For example, LAANC in UTM operations allow drone pilots to access controlled airspace below 400 ft near airports that are participating in LAANC. Although LAANC allows the drones to operate in this normally ATC-controlled airspace using UTM services and coordination mechanisms, the controller is given the ability to monitor where and when the drones are operating while in the controlled airspace.

A similar mechanism is likely to be used for ETM when the ETM vehicles need to access the “flexible floor” below FL600. In an airspace that is relatively free of conventional aircraft, such as between FL500 and FL600, ETM operations and services can be authorized to take over the airspace, while giving the controller the ability to monitor where and when the ETM vehicles are operating in this controlled airspace.

A general method for authorizing airspace for xTM operations requires an initial assessment that xTM vehicles need to access ATC-controlled airspace and identify the airspace that is needed. This function is expected to be done by one of the xTM Service Suppliers and coordinated with ATS that handles the data exchange with the conventional air traffic system. Unless there exists a pre-coordinated procedures for automatically approving the airspace authorization with the impacted ATC facilities, ATS would need to coordinate with the impacted ATC facilities to get approvals for the release of the airspace control. Once approved, ATS can notify the xTM services that the airspace is authorized to operate under xTM control. During the xTM operations, the controller monitors the xTM traffic and ensures that they maintain safe distance from surrounding non-xTM traffic in his/her airspace. Table 5 in the Appendix describes the process more in detail for UTM, UAM, and ETM.

Once the xTM vehicles complete the transit through the temporarily authorized airspace or situations arise in which the ATC needs to take control of the airspace, the airspace authorization is terminated and control is released back to the controller. In these situations, ATS would send a termination notification to the xTM services, which is then received by the xTM vehicle operators. xTM services and operators would coordinate together to leave the airspace by the termination time so that there will be no xTM vehicles in the airspace when the control is given back to the controller. Table 6 in the Appendix describes the process more in detail.

C. Unplanned Entry into ATC-Controlled Airspace due to Off-nominal Events

In each of the UTM, UAM, and ETM operations, there could exist situations in which the xTM vehicle cannot continue to operate within the xTM-operated region / system and needs to transition into controlled airspace and ask for ATC support for separation and services. In UTM, it could be due to a loss of communication and/or command and control (C2) link that results in UTM vehicle flying into ATC-controlled airspace.

In UAM, severe wind could prevent UAM vehicles from remaining in UAM Corridors, causing them to deviate into ATC-controlled airspace. controllers would then keep them separated from other vehicles and direct them to re-enter the UAM Corridor when the condition inside the UAM Corridor is more favorable. Similarly, the wind and weather conditions could force ETM vehicles into ATC-controlled airspace where other conventional aircraft are present. In such situations, ATC will need to keep ETM vehicles and other aircraft separated from each other, and when able direct the ETM vehicles back into the ETM operated region.

There are a spectrum of off-nominal and emergency scenarios which presents ATC with different challenges. Following are three main categories of unplanned events:

- Equipment failure or degradation (e.g., sensor failure, low battery, etc.)
- Unplanned xTM vehicle entry into ATC-controlled airspace due to environmental factors

- Unplanned xTM vehicle entry due to C2 link loss (command and control)

Equipment failure / degradation represents a variety of emergency situations in which the vehicle has partial loss of control or other functionalities that result in unplanned intrusion into ATC-controlled airspace or being required to perform an emergency landing. An assumption is made that RPIC can still maneuver the vehicle effectively in these scenarios. Table 7 in the Appendix provides more detailed procedures for the UAM and ETM vehicles. For UTM, unplanned intrusion of UTM vehicles into ATC-controlled airspace, in which the RPIC can maintain control of the vehicle, was not considered. UTM vehicles generally operate at an altitude below where conventional aircraft operate, so actions related to equipment failures, such as an emergency landing, are expected to occur within UTM-operated regions and not require interaction with ATC.

The second category of unplanned events assume that xTM vehicles intrude into ATC-controlled airspace because of various environmental factors, such as severe wind, unexpected airspace closure, etc. In these scenarios, the RPIC is expected to have full control of the xTM vehicle, but impromptu coordination is needed to smoothly transition the xTM vehicle into and out of ATC-controlled airspace. If an xTM vehicle needs to enter ATC-controlled airspace, xTM Service Suppliers are expected to notify ATS and the RPIC/PIC of the xTM vehicle's deviation. ATS will need to identify which ATC-controlled airspace the vehicle will enter and notify the impacted ATC facility. As the vehicle enters the airspace, the RPIC/PIC turns on the vehicle's transponder, tunes into ATC sector frequency, and contacts ATC. ATC maintains safety for the vehicle once it is under his/her control until it can return to the xTM-operated region. Table 8 in the Appendix provides further details.

Another category of unplanned events occurs when RPIC loses command and control of the vehicle due to a link loss. With no ability to control the vehicle, ATC must rely on pre-defined contingency plan or other established procedures if no such plan exists. When link loss occurs, the RPIC loses command and control of the vehicle. If no contingency plan exists, the vehicle is expected to fly away on its current heading. If there is a pre-defined contingency plan, the plan information is exchanged between xTM Service Suppliers and ATS. If the vehicle's flight path leads to ATC-controlled airspace, xTM Service Suppliers are expected to notify ATS about the unplanned vehicle entry, which in turn can notify the impacted ATC entity. The RPIC should also contact the appropriate ATC facility to provide all relevant vehicle status information. ATC notifies all aircraft in the vicinity of the xTM vehicle's anticipated location and keeps aircraft under ATC control away. The detailed procedures for specific contingency situations are described in Table 9 of the Appendix.

D. Unplanned Entry of Many xTM Vehicles into ATC-Controlled Airspace

In situations where there is a high traffic flow of xTM vehicles along a traffic corridor, problems can arise if the path is blocked, forcing many xTM vehicles to exit xTM-operated regions and enter ATC-controlled airspace simultaneously. A simpler version of the two possible scenarios involves route deviation in response to Temporary Flight Restriction (TFR) or activation of Special Use Airspace (SUA). In response to these types of events, temporary authorization of airspace can be issued to let xTM operations take control of a piece of ATC-controlled airspace to reroute xTM traffic flow. Table 10 in the Appendix describes the procedures.

A more complex scenario involves reroute of xTM traffic flow in response to severe wind or convective weather. The procedures to handle this case is like the one involving TFR/SUA. However, determining the location of the airspace that would be needed for xTM traffic reroute and identifying potential dynamic changes in the airspace needed as the weather changes provide additional challenges to the problem. Table 11 in the Appendix describes the procedures.

E. Non-xTM Vehicle Entry into xTM Operational Regions with Limited ATC Support

Finally, xTM concepts include situations in which non-xTM vehicles enter regions operated by xTM services and require ATC support in these regions. In some cases, the non-xTM vehicle is a conventional aircraft that is not fully equipped to interact with xTM services and therefore need help from controllers, in conjunction with xTM services, to provide it with course, altitude, and time constraints to navigate through the xTM region. In other cases, xTM vehicles may lose the link to xTM services and therefore need to operate like a non-xTM vehicle. Finally, supersonics in the ETM operations have vastly different characteristics than other ETM vehicles, which could potentially lead to requiring a special transit corridor within ETM-operated region. In this case, controllers would not provide separation services but may need to provide other support. The details of these various use cases are described in Table 12 of the Appendix.

IV. Insights from Interaction Use Case Categorization

The prior section summarized the categorization results of xTM operations by trigger events. Prior to this organization, the use cases were examined using different categorization features, such as organizing by phase of flight, airspace class, weather conditions, etc., but organization by trigger event seems to have the best promise of identifying common procedures for different xTM operations. Whether this organization can fulfill that promise is to be determined over the course of the research.

During the identification and development of the interaction use cases, several insights were gained on the xTM concepts, existing use cases, potential operational issues related to the interactions, discrepancies in the operational assumptions across xTM operations, and gaps in the concepts, procedures, and research for the interactions. Following are some of the insights from the activity.

First, there exists active research and development of new use cases in ETM, AAM/UAM, and UTM operations at NASA, the FAA, and other organizations. However, not all xTM concepts had well-developed use cases for the different trigger events, so new procedures were developed for some xTM operations by using previously developed use cases from another xTM operations with similar trigger events.

Second, although use cases in different xTM operations could be similar enough to benefit from “standardizing” the procedural steps, there were still significant differences in vehicle characteristics, operational airspace, missions, etc. that could limit the ability to find common procedures. In general, greater potential for common procedures seems to exist between ETM and AAM/UAM operations than with UTM. Within UTM, sUAS drone operations differ significantly in size, available sensors / equipment onboard, operational airspace, etc., as compared to conventional aircraft and other airborne vehicles. As a result, ATC’s roles in the interactions may need to be tailored separately for UTM, even when the trigger events are similar.

On a related note, unlike UTM and AAM/UAM vehicles that have homogenous characteristics (e.g., eVTOLs), ETM vehicles, such as balloons, slow HALE fixed-wings, and supersonics, have vastly different vehicle characteristics from each other and thus, differences in the procedures may exist between them for similar trigger events. Finding common procedures across different ETM vehicles may pose as much challenges as finding common procedures between the xTM operations.

Third, examination of use cases generally divides into planned, nominal trigger events where xTM vehicles transition between xTM and ATC operations and unplanned, off-nominal trigger events that occur when xTM vehicles enter ATC-controlled airspace to handle emergency, equipment failure, etc. In general, there seems to be a better potential for finding a common set of procedures for the planned, nominal events than the unplanned, off-nominal events. For the off-nominal events, the variety of situations may differ enough between xTM operations such that, although there are common high-level similarities in the procedures, each event may require specific responses tailored to individual events. As the xTM-ATC interaction research progresses, the potential for finding common procedures for off-nominal events will be better understood.

The categorization of these use cases was done for this paper as a precursor activity to finding common procedures across xTM operations. Whether well-defined, common procedures could be found is to be determined over the course of the xTM-ATC interactions research but examining the use cases and the associated procedures across the xTM operations is an important research effort. Already in the early stages of xTM concept development, each xTM operation seems to be making different assumptions about xTM-ATC interactions. For example, the UAM concept assumes that the climb and descent phases of flights will be handled mostly using UAM Corridors, without ATC involvement, but in the ETM concept, climb and descent phases assume transiting through ATC-controlled airspace. Because ATC is required to handle the vehicles based on different sets of rules and assumptions, different procedures will arise if UAM and ETM vehicles co-exist in the same airspace, likely complicating operations. The advantages of having these different operational assumptions should be weighed against the advantages of "standardizing" the operations by either changing climb and descent operations in ETM to operate like a UAM Corridor, or to handle UAM climb and descent like ETM operations. On a related note, currently there are very few research efforts to examine the use cases across xTM operations and therefore, the concept developers may not be fully aware of the different implementation assumptions made in each xTM concept and whether those assumptions may result in incompatible procedures and data exchange requirements when future operations are expected to overlap significantly. Identifying common features and touch points between xTM operations early in the research and development process can facilitate future implementations that could lead to easier integration of operations.

V. Summary and Next Steps

When xTM vehicles operate in conventional airspace, they need to be managed safely by controllers despite vast differences in the xTM vehicle performances and missions. To identify these xTM-ATC interaction conditions, a set of use cases has been identified in this paper for potential interactions between ATC and UTM, AAM/UAM, and ETM operations. The interactions have been categorized by similar trigger events / scenarios across different xTM operations that could potentially lead to the identification of similar procedures, operational rules, and roles / responsibilities. The overall goal is to see if such assessment and organization of use cases across the different xTM domains could help to identify ways to keep ATC responsibilities as consistent and as manageable as possible, especially in situations where different xTM systems may interact with ATC in the same airspace.

Given the use cases identified and categorized in this paper, the next steps are to develop step-by-step event sequences and associated roles and procedures for each trigger event. Given similarities between the event sequences across xTM operations for similar trigger events, an effort will be made to develop a common set of procedures across xTM operations for each trigger event that, may differ in some of the details, but have a common structure. We hope that such effort would lead to the development of common procedures and data exchange requirements for xTM-ATC interactions despite a large and diverse set of xTM vehicles and missions.

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Appendix: Use Case Descriptions by Trigger Event Categories

A. Acronyms

UTM		AAM/UAM		ETM	
Acronym	**Definition**	**Acronym**	**Definition**	**Acronym**	**Definition**
101e	Part 101 Subpart E	4DT	Four-Dimensional Trajectory	4D T	Four-Dimensional Trajectory
4D	Four Dimensional	AAM	Advanced Air Mobility	4G	Fourth Generation
AAO	Authorized Area of Operation	ADS-B	Automatic Dependent Surveillance - Broadcast	ADS-B	Automatic Dependent Surveillance – Broadcast
ADS-B	Automatic Dependent Surveillance - Broadcast	AGL	Above Ground Level	ANSP	Air Navigation Service Provider
AGL	Above Ground Level	ANG	FAA Organization – NextGen Program Office	AOA	At or Above
ANSI	American National Standards Institute	ANSP	Air Navigation Service Provider	AOB	At or Below
AOL	Airspace Operations Laboratory	AOB	At or Below	AOL	Airspace Operations Laboratory
API	Application Program Interface	AOL	Airspace Operations Laboratory	ARTCC	Air Route Traffic Control Center
ARC	Aviation Rulemaking Committee	ATC	Air Traffic Control	ATC	Air Traffic Control
ATC	Air Traffic Control	ATIS	Automatic Terminal Information Service	ATM	Air Traffic Management
ATS	Air Traffic Services	ATM	Air Traffic Management	ATS	Air Traffic Services
ATM	Air Traffic Management	ATS	Air Traffic Services	C2	Command and Control
BVLOS	Beyond Visual Line of Sight	BVLOS	Beyond Visual Line of Sight	CFR	Code of Federal Regulations
CFR	Code of Federal Regulations	CBR	Community Business Rule	CNS	Communication, Navigation, and Surveillance
CNS	Communications, Navigation, and Surveillance	CCP	Corridor Control Point	COA	Certificate of Authorization
ConOps	Concept of Operations	ConOps	Concept of Operations	ConOps	Concept of Operations
DAA	Detect and Avoid	DAA	Detect and Avoid	DoD	Department of Defense
DFR	Digital Flight Rules	DCB	Demand Capacity Balancing	ESS	Upper Class E Service Supplier
DHS	Department of Homeland Security	DEP	Distributed Electric Propulsion	ETM	Upper Class E Traffic Management
DOD	Department of Defense	ERAM	En Route Automation Modernization	FAA	Federal Aviation Administration
EMS	Emergency Management Service	eVTOL	Electric Vertical Take-Off and Landing	FIMS	Flight Information Management System
ERAM	En Route Automation Modernization	FAA	Federal Aviation Administration	FIR	Flight Information Region
FAA	Federal Aviation Administration	HOTL	Human-on-the-Loop	FL	Flight Level
FIMS	Flight Information Management System	HOVTL	Human-over-the-Loop	FLM	Front Line Manager
GCS	Ground Control Station	HWTL	Human-within-the-Loop	GA	General Aviation
ICAO	International Civil Aviation Organization	ICAO	International Civil Aviation Organization	GCS	Ground Control Station
JARUS	Joint Authorities for Rulemaking on Unmanned Systems	IFR	Instrument Flight Rules	HALE	High Altitude Long Endurance
KCLE	Cleveland Hopkins International Airport	L-L	Lost Link	IFR	Instrument Flight Rules
L-L	Lost Link	LOA	Letter of Agreement	LOA	Letter of Agreement
LAANC	Low Altitude Authorization and Notification Capability	NAS	National Airspace System	LTE	Long Term Evolution
NAS	National Airspace System	NASA	National Aeronautics and Space Administration	MARSA	Military Authority Assumes Responsibility for Separation of Aircraft

NASA	National Aeronautics and Space Administration	NOTAM	Notice to Airmen	NAS	National Airspace System
NOTAM	Notice to Airmen	NPSU	Network Provider of Services for UAM	NASA	National Aeronautics and Space Administration
OOP	Operations over people	PIC	Pilot in Command	NOTAM	Notice to Airmen
PIC	Pilot in Command	PSU	Provider of Services for UAM	NPSU	Network Provider of Services for UAM
RID	Remote Identification	RID	Remote Identification (ID)	PIC	Pilot in Command
PIREP	Pilot Report	RPIC	Remote Pilot in Command	PSU	Provider of Services for UAM
RNP	Required Navigation Performance	SAA	Special Activity Airspace	RPIC	Remote Pilot in Command
RPIC	Remote Pilot in Command	SDSP	Supplemental Data Service Provider	SAA	Special Activity Airspace
RTT	Research Transition Team	SWIM	System Wide Information Management	SST	Super Sonic Transport aircraft
SAA	Special Activity Airspace	TFR	Temporary Flight Restriction	SUA	Special Use Airspace
SDSP	Supplementary Data Service Provider	TRACON	Terminal Radar Control facility	TCAS	Traffic Alert and Collision Avoidance System
SUA	Special Use Airspace	UA	Unmanned Aircraft	TFR	Temporary Flight Restriction
sUA	Small Unmanned Aircraft	UAM	Urban Air Mobility	TRACON	Terminal Radar Approach Control Facility
sUAS	Small Unmanned Aircraft System	UAS	Unmanned Aircraft System	UAS	Unmanned Aircraft System
SRFC	Surface	UOE	UAM operating environment	USS	UAS Service Supplier
STARS	Standard Terminal Automation Replacement System	USS	UAS Service Supplier	UTM	UAS Traffic Management
TCL	Technical Capability Level	UTM	UAS Traffic Management	V2V	Vehicle-to-Vehicle
TFR	Temporary Flight Restriction	V2V	Vehicle-to-Vehicle		
UA	Unmanned Aircraft	VFR	Visual Flight Rules		
UAS	Unmanned Aircraft System	VMC	Visual Meteorological Conditions		
UASFM	UAS Facility Map	VTOL	Vertical Take-Off and Landing		
UAS ID	UAS Identification				
UASSC	Unmanned Aircraft System Standardization Collaborative				
UPP	UTM Pilot Program				
UREP	Unmanned Aircraft Report				
USS	Unmanned Aircraft System Service Supplier				
USS-FPS	Federal Public Safety USS				
UTM	Unmanned Aircraft System Traffic Management				
UVR	UAS Volume Reservations				
V2V	Vehicle-to-Vehicle				
VLOS	Visual Line of Sight				

B. Table 1: Planned entry into an xTM-operated region through ATC-controlled airspace <u>without</u> ATC intervention

Category	Trigger Event	xTM Type	Use Case Description
Planned xTM flight	Planned **entry** into xTM-operated region through ATC-controlled airspace: Nominal case **without ATC intervention**	UTM	UTM vehicles are not expected to operate in ATC-controlled airspace by design in nominal operations.
		UAM	A UAM flight is departing from ATC-controlled airspace and entering a UAM Corridor/UOE to complete a desired operation. The RPIC/PIC engages a Provider of Services for UAM (PSU) to coordinate a UAM 4DT Operation Plan with the Network PSU (NPSU) to operate within the UAM Corridor/UOE airspace. The NPSU checks the Operation Plan against other traffic and replies that there are no conflictions. The RPIC/PIC then files an IFR flight plan with ATS to depart the airport and operate to a point in space where they enter the UAM Corridor/UOE airspace. The RPIC/PIC calls tower and requests taxi and departure clearance at an appropriate time to meet their proposed departure time. The ATC tower provides taxi instructions. The RPIC/PIC taxis the UAM vehicle to the runway and the tower issues the departure clearance, heading to maintain, and altitude in which to climb. The RPIC/PIC acknowledges the clearance and instructs the UAM vehicle to take-off and fly the assigned heading and altitude. The UAM vehicle takes off and the tower instructs the RPIC/PIC to contact Departure (TRACON). The RPIC/PIC switches to the Departure controller frequency. The Departure controller clears the RPIC/PIC to the UAM Corridor/UOE entry point. The RPIC/PIC rogers the clearance and instructs the UAM vehicle to fly the clearance. Upon reaching the entry point of the UAM Corridor/UOE, the RPIC/PIC notifies ATC that they are cancelling IFR and entering the UAM Corridor/UOE. ATC acknowledges the IFR cancellation and clears the RPIC/PIC to leave the frequency. The RPIC/PIC instructs the UAM vehicle to fly the Operation Plan.
		ETM	A HALE balloon Operator is planning to send a vehicle into Upper Class E airspace to provide broadband internet service as part of an emergency response effort for a region with an earthquake damaged ground-based communications infrastructure. To control the vehicle's trajectory, pressurization controls enable operating altitude adjustments that take advantage of prevailing winds. The vehicle is equipped with ADS-B and/or a transponder, and primary/redundant communications equipment for connection to the Operator's control station. The Operator subscribes to third-party services for support with flight planning, weather/atmospheric data, and other information pertinent to the operation. Initial planning information, including current weather forecasts for the launch and ascent, atmospheric forecasts for high-altitude airspace, and available cooperative intent and flight information for other Operators that may be in proximity to the balloon at operating altitude and upon initial phase of flight are obtained (assumed via Upper Class E Service Supplier or ESS/Network-ESS like UTM/UAM). The Operator plans the initial portion of the flight, focusing on the launch and ascent phase, and identifying the optimal altitude for the initial operating phase. Adjustments are made to the plan (within ESS) to ensure no operational conflicts exist with other cooperative Operators. Once planning is complete, the Operator shares relevant intent information (via ESS/Network-ESS) with other Operators that are participating in cooperative separation. The Operator also notifies ATC in accordance with 14 CFR Part 101.37(a) requirements, providing required information (e.g., balloon identification,

			estimate launch date/time, launch location, trajectory/ascent time to operating altitude). ATC utilizes this notification information to evaluate the feasibility of managing the operation at the requested time and, if necessary, notifies the Operator to alter launch time. Upon launch of the balloon, the Operator notifies ATC in accordance with 14 CFR Part 107.37(d). The balloon transmits via ADS-B and/or transponder, in accordance with applicable operating requirements. Once the balloon is in controlled airspace, ATC manages any traffic that is in proximity of it during its ascent and ensures separation is maintained. When the time arrives to enter ETM-operated region, the Operator notifies ATS that the vehicle is leaving Class A airspace and transitioning into ETM-operated airspace. The balloon eventually reaches its operating altitude (AOA FL600), levels off, and begins its initial operating phase. **General Ascent Capability for ETM Vehicles:** **Balloon/Airship Ascent:** Balloons and High-Altitude Airships ascend freely with little to no maneuvering ability. Operators provide ATC with an estimated flight path (not a conventional flight plan) and notify ATC prior to launch. Position reports are provided to ATC throughout the ascent. Neither lateral positioning nor rate of ascent can be controlled, very susceptible to winds. HALE balloons have limited ability to respond to unforeseen events due to lack of maneuverability; therefore, ATC segregates other traffic from them. **HALE Slow Fixed-Wing Ascent:** HALE slow-speed, uncrewed, fixed-wing Operators transiting to upper Class E file an IFR flight plan based on forecasted winds for their ascent through controlled airspace. Ascent is performed via a spiral pattern climb. Since the vehicle is susceptible to winds, route flexibility is often an important aspect of transit. ATC segregates the HALE from other traffic during transit. The HALE vehicle can hold altitude, if necessary. ATC may terminate radar services and revert to non-radar procedures should surveillance capability become inadequate (e.g., radar contact lost). **HALE Fast Fixed-Wing Ascent:** HALE high-speed, uncrewed, fixed-wing aircraft are expected to operate like conventional crewed aircraft through Class A airspace (like current subsonic operations), usually flying to (or within) an sUAS. **Supersonic Ascent:** Supersonic aircraft are expected to operate like conventional crewed aircraft through Class A airspace (like current subsonic operations), however, climb rates are expected to be much greater as fuel efficiency is a much larger concern. These aircraft also require greater separation distances from other aircraft due to climb and maneuverability differences from conventional aircraft. May require a dedicated route option.

C. Table 2: Planned entry into an xTM-operated region through ATC-controlled airspace <u>with</u> ATC intervention

Category	Trigger Event	xTM Type	Use Case Description
Planned xTM flight	Planned **entry** into xTM-operated region through ATC-controlled airspace **with ATC intervention for deconfliction**	UTM	UTM vehicles are not expected to operate in ATC-controlled airspace by design in nominal operations.
		UAM	A UAM flight is departing from ATC-controlled airspace and entering a UAM Corridor/UOE to complete a desired operation. The RPIC/PIC engages a Provider of Services for UAM (PSU) to coordinate a UAM 4DT operations plan with the Network PSU (NPSU) to operate within the UAM Corridor/UOE airspace. The NPSU checks the operations plan against other traffic and replies that there are no conflictions. The RPIC/PIC then files an IFR flight plan with ATS to depart the airport and operate to a point in space where they enter the UAM Corridor/UOE airspace. The RPIC/PIC calls tower and requests taxi and departure clearance at an appropriate time to meet their proposed departure time.

			The ATC tower provides taxi instructions. The RPIC/PIC taxis the UAM vehicle to the runway and the tower issues the departure clearance, heading to maintain, and altitude in which to climb. The RPIC/PIC acknowledges the clearance and instructs the UAM vehicle to take-off and fly the assigned heading and altitude. The UAM vehicle takes off and the tower instructs the RPIC/PIC to contact Departure (TRACON). The RPIC/PIC switches to the Departure controller frequency. The Departure controller clears the RPIC/PIC to the UAM Corridor/UOE entry point and to maintain the requested altitude. The RPIC/PIC rogers the clearance and instructs the UAM vehicle to fly the clearance. **ATC Manages Traffic Conflict:** Prior to entering UAM Corridor/UOE airspace, ATC needs to slow the VTOL aircraft and instructs the RPIC/PIC to vector around passing traffic to avoid potential conflict. ATC surveys traffic and notes potential conflicts with other traffic. Prior to entering UAM Corridor/UOE airspace, ATC instructs the RPIC/PIC to turn 30 deg right to avoid traffic. The RPIC/PIC acknowledges the clearance and instructs the vehicle to turn 30 deg right. After the traffic passes, ATC clears the RPIC/PIC to turn 60 deg left and rejoin the filed route. The RPIC/PIC instructs the vehicle to turn 60 deg left and rejoin the filed route. As necessary, the Operator PSU replans with the Network PSU for a more precise entry point and time that conforms to the current trajectory and is conflict free in xTM-operated region. The Network PSU shares this with RPIC/PIC and ATS. When approved to enter the UAM Corridor/UOE, the RPIC/PIC notifies ATC that they are cancelling IFR and entering the UAM Corridor/UOE. ATC acknowledges the IFR cancellation and clears the RPIC/PIC to leave the frequency. The RPIC/PIC instructs the UAM vehicle to fly the Operation Plan.
		ETM	A HALE slow-speed, uncrewed, fixed-wing vehicle ascends through Class A airspace on its way to upper Class E airspace to provide communications platforms at high altitude. Prior to launch, the Operator met all requirements relevant to flight planning, notification/authorization, and cooperative information sharing. The HALE vehicle executes a spiral ascent pattern on transit to Class A airspace. ATC has access to flight/surveillance information for the HALE vehicle, which may come from ATC systems (e.g., radar, or may be provided by the Operator (via FIMS or Network-ESS). ATC manages any nearby traffic, ensuring separation from the HALE vehicle is maintained. **ATC Manages Traffic Conflict:** During ascent, ATC needs to reroute commercial airline traffic around storm activity. As a result, ATC instructs the Operator/RPIC to temporarily halt the ascent of the HALE vehicle and hold at FL230 around waypoint 'XYZ', until traffic is clear. The Operator commands the vehicle to temporarily hold altitude while maintaining a circular flight path around a specified waypoint. Once the rerouted traffic has passed, ATC instructs the Operator to continue the ascent. The Operator resumes ascent, and then performs in-flight re-planning (via ESS) to determine when the vehicle will reach its operating altitude in upper Class E and begin its initial operating phase. As part of this re-planning, the Operator obtains any updated information on other Operators participating in

			cooperative separation and de-conflicts the operation if any issues are detected. Once re-planning is complete, updated intent is shared (via ESS/Network-ESS) with other Operators in the cooperative separation ecosystem; ATC has access to this information, if needed. **General Ascent Maneuverability for ETM Vehicles:** **HALE Slow Fixed-Wing:** Compared to balloons, slow HALE fixed-wing vehicles are powered and have directional and altitude control. However, they are very lightweight and have limited propulsion, so they are still susceptible to changing wind conditions. They also have susceptibilities to atmospheric disturbances associated with higher-speed large aircraft, such as rapid pressure changes due to passing shock waves from aircraft in supersonic flight. **Balloon/Airship:** HALE balloons and high-altitude airships, by virtue of being lighter-than-air aircraft, are comprised of less rigid structures, with minimal control capabilities. They are highly susceptible to wind conditions. They would not be able to hold the ascent for long (if at all) and would not be able to control lateral movement. They may have susceptibilities to atmospheric disturbances associated with higher-speed large aircraft, such as rapid pressure changes due to passing shock waves from aircraft in supersonic flight. ATC would have to maneuver other aircraft around the balloon/high-altitude airship if there is a conflict. **HALE Fast Fixed-Wing:** As with all aircraft, weather conditions can affect planned trajectories, however, HALE high-speed, uncrewed, fixed-wing vehicles (e.g., Global Hawk) have high-performance capabilities, and thus have a high confidence in the planned trajectory. They are expected to maneuver like other crewed subsonic flights (i.e., ATC would not have to maneuver other aircraft). In addition, the atmospheric disturbances produced by these aircraft can possibly affect lighter vehicles (e.g., balloons, airships, and slow HALE fixed-wing). **Supersonic:** As with all aircraft, weather conditions can affect planned trajectories, however supersonic vehicles have high-performance capabilities, and thus have a high confidence in the planned trajectory. When flying at supersonic speeds, their ability to maneuver for unplanned reasons (e.g., large heading changes) is limited, reducing speed requires a large amount of distance. In addition, the shock wave produced by these aircraft at supersonic speeds can affect lighter vehicles (e.g., balloons, airships, and slow HALE fixed-wing). ATC would separate supersonic vehicle from other traffic.

D. Table 3: Planned exit out of an xTM-operated region into ATC-controlled airspace <u>without</u> ATC intervention

Category	Trigger Event	xTM Type	Use Case Description
Planned xTM flight	Planned **exit** out of xTM-operated region into ATC-controlled airspace: nominal case **without ATC intervention**	UTM	UTM vehicles are not expected to operate in ATC-controlled airspace by design in nominal operations.
		UAM	A UAM VTOL vehicle wants to fly through UAM Corridor/UOE airspace and into ATC airspace to a private airstrip. The RPIC/PIC must file an Operation Plan with their PSU-Provider of UAM services (PSU-like USS for UTM) for approval to operate within the UAM corridor/UOE and a IFR flight plan to operate in ATC-controlled airspace. Current FAA regulations require UAS beyond visual line-of-sight (BVLOS) aircraft to operate on an IFR clearance. As the UAM VTOL nears ATC airspace, the RPIC/PIC turns on the transponder and ADS-B Out and contacts the proper sector and requests to "pick up" their IFR clearance. If ATC is unable to quickly provide the IFR clearance, the UAM

			VTOL can hover at a Corridor Control Point (CCP) within the UAM Corridor/UOE. ATC identifies the vehicle by assigning the discrete beacon code from the IFR flight plan. ATC ensures that the UAM VTOL is at an appropriate IFR altitude to obtain a clearance. ATC surveys traffic to ensure no conflictions and issues the IFR pick up clearance to the secondary airport. RPIC/PIC instructs the UAM vehicle to fly the assigned route and altitude. As the UAM vehicle nears the airport, ATC issues the RPIC/PIC a minimum available IFR altitude to maintain until established on the approach and an IFR approach clearance to the airport. ATC then cancels radar coverage and instructs the RPIC/PIC to contact the private tower for landing clearance. RPIC/PIC acknowledges and contacts the tower for clearance to land. Tower issues the landing clearance and the RPIC instructs the UAM vehicle to land as cleared.
		ETM	A HALE Communications balloon, on station for several months (at FL600) to support ground communication infrastructure repair after an earthquake, must descend for required maintenance. In accordance with 14 CFR Part 101 requirements, the Operator notifies ATS with descent information (e.g., current position/altitude, estimated descent flight path). ATC acknowledges the notification and approves the request. At the agreed upon time, the Operator initiates descent, monitoring the vehicle, re-calculating the trajectory and location of landing at regular intervals as it descends, and providing updates to ATC as appropriate. The Front Line Manager (FLM) responsible for the Air Route Traffic Control Center (ARTCC) area where the balloon will land and balloon Operator communicate periodically via telephone, as necessary. The Operator is able to provide the estimated latitude and longitude, along with a radius from the identified point, within which the balloon will land. The FLM shares this information with the sectors where the balloon is descending. ATC provides clearance for the vehicle to descend, and segregates traffic from the vehicle during descent, if required. The balloon envelope and payload separate at a predetermined altitude and each section deploys a parachute for soft landing. **General Descent Capability for ETM Vehicles:** **Balloon/Airship Descent:** Prior to descent for landing, Operators notify ATC, providing information such as intended descent time, estimated exit point, and predicted trajectory from upper Class E through Class A. ATC may delay the start of the requested descent due other traffic or restrictions within the block of airspace. ATC provides clearance for the vehicle to descend, and segregates traffic from the vehicle during descent. Once the Operator initiates the descent, the vehicles have limited to no ability to respond to unforeseen events due to maneuverability limitations. Parachutes are deployed to slow the rate of the balloon's descent. **HALE Slow Fixed-Wing Descent:** On descent, the HALE slow-speed, uncrewed, fixed-wing Operator provides notification to ATC with an intended descent time and estimated exit point from upper Class E to Class A airspace. The Operator files an IFR flight plan. ATC provides the Operator with a clearance to descend into Class A airspace and segregates traffic from the HALE vehicle. The vehicle can hold altitude, if necessary. The HALE vehicle executes a spiral descent pattern. **HALE Fast Fixed-Wing Descent:** HALE high-speed, uncrewed fixed-wing Operators interact with ATC like conventional aircraft that are at subsonic speeds; though some maneuverability characteristics may require ATC handle them differently at different portions of descent. Operators are on IFR flight plans that contain all information required by ATC, including specified routes and aircraft performance-related data. Prior to descent from operating altitude, ATC provides the Operator with a clearance to descend via the filed route for a

			specific window. ATC provides separation and may provide an updated route that vectors the aircraft around potential conflicts. **Supersonics Descent**: Supersonic aircraft Operators interact with ATC like conventional aircraft when at subsonic speeds; though maneuverability characteristics may require ATC handle them differently at different portions of descent. Operators are on IFR flight plans that contain all information required by ATC, including specified routes and aircraft performance-related data. Prior to descent from operating altitude, ATC provides the Operator with a clearance to descend via the filed route for a specific window. ATC provides separation and may provide an updated route that vectors the aircraft around potential conflicts. May require a dedicated route option.

E. Table 4: Planned exit out of an xTM-operated region into ATC-controlled airspace with ATC intervention

Category	Trigger Event	xTM Type	Use Case Description
Planned xTM flight	Planned **exit** out of xTM-operated region into ATC-controlled airspace **with ATC intervention for deconfliction**	UTM	UTM vehicles are not expected to operate in ATC-controlled airspace by design in nominal operations.
		UAM	A UAM VTOL vehicle wants to fly through UAM Corridor/UOE airspace and into ATC airspace to a private airstrip. The RPIC/PIC must file an operations plan with their PSU-Provider of UAM services (PSU-like USS for UTM) for approval to operate within the UAM corridor/UOE and a IFR flight plan to operate in ATC-controlled airspace. Current FAA regulations require UAS beyond visual line-of-sight (BVLOS) aircraft to operate on an IFR clearance. As the UAM VTOL nears ATC airspace, the RPIC/PIC turns on the transponder and ADS-B Out and contacts the proper sector and requests to "pick up" their IFR clearance. If ATC is unable to quickly provide the IFR clearance, the UAM VTOL can hover at a Corridor Control Point (CCP) within the UAM Corridor/UOE. ATC identifies the vehicle by assigning the discrete beacon code from the IFR flight plan. ATC ensures that the UAM VTOL is at an appropriate IFR altitude to obtain a clearance. **ATC Manages Traffic Conflict:** Prior to entering ATC-controlled airspace, ATC needs to slow the VTOL aircraft and instructs the RPIC/PIC to hold/hover at a Corridor Control Point (CCP) to avoid conflict with passing traffic. The RPIC/PIC instructs the UAM vehicle to hold altitude and wait for further clearance. The RPIC/PIC notifies their PSU that they are holding at the CCP for 5 minutes. The PSU coordinates with the NPSU that the CCP will be occupied for 5 minutes. As traffic clears, ATC issues the IFR pick up clearance to the secondary airport. RPIC/PIC instructs the UAM vehicle to fly the assigned route and altitude. As the UAM vehicle nears the airport, ATC issues the RPIC/PIC a minimum available IFR altitude to maintain until established on the approach and an IFR approach clearance to the airport. ATC then cancels radar coverage and instructs the RPIC/PIC to contact the private tower for landing clearance. RPIC/PIC acknowledges and contacts the tower for clearance to land. Tower issues the landing clearance and the RPIC instructs the UAM vehicle to land as cleared.
		ETM	A HALE slow-speed, uncrewed, fixed-wing vehicle that has been orbiting on station providing commercial high-speed internet communications services to a remote/rural area for several months, must land for scheduled maintenance. Due to the vehicle's descent characteristics, and to minimize airspace usage, the Operator coordinates with ATC to arrange a spiral descent over the course of

			10–12 hours. Since the vehicle requires segregation from other traffic during descent, ATC requests a nighttime descent to minimize disruption to the NAS. **ATC Manages Traffic Conflict:** During descent, ATC needs to reroute commercial airline traffic around storm activity. As a result, ATC instructs the Operator/RPIC to temporarily halt the descent of the HALE vehicle and hold at FL380 around waypoint 'XYZ', until traffic is clear. The Operator/RPIC acknowledges the clearance and instructs the vehicle to hold altitude while maintaining a circular flight path around the specified waypoint. After the traffic passes, ATC clears the Operator/RPIC to continue descent. The Operator/RPIC acknowledges the clearance and instructs the vehicle to continue descent. The Operator tracks the descent and remains in communication with ATC as required, which may include supplementing ATC surveillance data via digital means and/or maintaining voice communication. The HALE is handed off to the low-altitude sector responsible for the non-towered destination airport. With traffic being light, the low-altitude controller immediately clears the HALE for approach. Once the HALE is sufficiently close to the airfield, radar service is terminated, and its flight concludes without further incident. **General Descent Maneuverability for ETM Vehicles:** **HALE Slow Fixed-Wing:** On descent, the HALE Operator provides notification to ATC with an intended descent time and estimated exit point from upper Class E to Class A airspace. The Operator provides ATC with IFR flight plan. ATC issues the Operator a clearance to descend into Class A airspace and segregates traffic from the vehicle. On descent, the HALE can hold altitude, if necessary. Therefore, ATC may provide the Operator with a stepped clearance on descent allowing ATC to efficiently route traffic. It is possible that a case may arise where the vehicle is low on energy and may not be able hold altitude prior to a clearance, thus requiring ATC to make special accommodations. **Balloon/Airship:** HALE balloons and high-altitude airships cannot be held for traffic to pass once descent has started. The balloon can slow its rate of descent, if necessary, but to hold altitude would be difficult. Based on winds they could have lateral control issues. Prior to descent for landing, Operators notify ATC, providing information such as intended descent time, estimated exit point, and predicted trajectory from upper Class E through Class A. ATC may delay the requested descent due other traffic or restrictions within the airspace. ATC provides clearance for the vehicle to descend, and segregates traffic from the HALE balloon during descent. Once the Operator initiates the descent, the vehicles have limited to no ability to respond to unforeseen events due to maneuverability limitations. Parachutes are deployed to slow the rate of the balloon's descent. **HALE Fast Fixed-Wing:** A high-speed, uncrewed, fixed-wing aircraft would be maneuvered around like other traffic or asked to maintain a certain altitude for longer period. Aircraft Operators interact with ATC like conventional aircraft that are at subsonic speeds; though some maneuverability characteristics may require ATC handle them differently at different portions of descent. Operators are on IFR flight plans that contain all information required by ATC, including specified routes and aircraft performance-related data. Prior to descent from operating altitude, ATC provides the Operator with a clearance to descend via the filed route for a specific window. ATC provides separation and may provide an updated altitude or route that vectors the aircraft around potential conflicts. **Supersonics:** A high-speed, crewed, fixed-wing aircraft would be maneuvered around like other traffic. Supersonic aircraft Operators interact with ATC like conventional aircraft when at subsonic speeds; though maneuverability

			characteristics may require ATC handle them differently at different portions of descent. Operators are on IFR flight plans that contain all information required by ATC, including specified routes and aircraft performance-related data. Prior to descent from operating altitude, ATC provides the Operator with a IFR clearance to descend via the filed route for a specific window. ATC provides separation and may provide an updated altitude or route that vectors the aircraft around potential conflicts.

F. Table 5: Planned airspace authorization: Change ATC-controlled airspace into xTM-operated region

Category	Trigger Event	xTM Type	Use Case Description
Planned Airspace Authorization	Planned conversion of **ATC-controlled airspace into xTM-operated region**	UTM	USS Network requests additional airspace for a UTM area from FAA ATS. The USS Network is managing an FAA-authorized UTM area. Due to UA volume the USS Network determines that additional airspace would be of use to reduce delays for flight operations. The USS Network identifies a pre-coordinated area of airspace to the east of the current UTM-operated region and requests FAA ATS to authorize its usage from 1800–2200z. (The airspace could be pre-mapped as in the Low Altitude Authorization Notification Capability (LAANC)-enabled airspace.) ATS would then coordinate with the Air Traffic Control (ATC) TRACON which controls the requested airspace to see if they can release control of additional airspace to the UTM System. Both ATS and ATC TRACON would have access to mapping of the subject airspace. ATC TRACON approves the release of the airspace from 1800–2200z to the UTM area. Certain airspace may be pre-approved for UTM operations, in which case the ATS can automatically approve and alert the ATC TRACON instead of waiting for the approval. ATS notifies the UTM Network that the additional airspace is approved. ATC must display the new airspace to ensure that they do not allow any traffic to penetrate the UTM Area. UTM must re-configure its assigned airspace to reflect the new area as eligible for usage. The USS Network notifies all operators of the additional airspace parameters. The ATC Controller may see the authorized airspace volume and Remote ID information, but in a nominal scenario, the USS Network may not share real-time location information with ATS via the USS Network --> Flight Information Management System (FIMS).
		UAM	NPSU requests additional airspace for a UAM area from FAA ATS. A NPSU is managing several FAA-authorized UAM corridors. Due to forecast weather, the NPSU determines that an additional corridor would be of use to reduce delays for UAM flight operations. The NPSU identifies a pre-coordinated corridor to the east of the current UAM corridor and requests FAA ATS to authorize its usage from 1800–2200z. (The airspace corridor could be pre-mapped, similar to what is done in UTM under the Low Altitude Authorization Notification Capability (LAANC)-enabled airspace). ATS would determine which ATC facilities control airspace along the requested corridor and then coordinate with them to obtain approval for releasing control of the airspace to the UAM System. Both ATS and ATC control facilities would have access to mapping of the subject corridor airspace. The ATC facilities approve the release of the airspace from 1800–2200z to the UAM. Certain airspace may be pre-approved for UAM operations, in which case the ATS may automatically approve the airspace change.

			ATS notifies the UAM that the additional UAM corridor is approved. ATC must display the new airspace to ensure that they do not allow any traffic to penetrate the UAM corridor. The UAM must re-configure its assigned airspace to reflect the new area as eligible for usage and monitoring. The NPSU notifies all PSUs of the additional airspace corridor availability from 1800–2200z.
		ETM	Network ESS requests additional airspace for ETM from FAA ATS. A Network ESS is cooperatively managing a large area of Upper Class E airspace, due to some good prevailing winds at lower altitudes (FL500–FL590), several Balloons in the area would like to drop down and take advantage to move themselves. The Balloon operator ESS identifies an area of good prevailing wind patterns and requests, through the Network ESS, to ATS (via FIMS or some digital platform), an area of Flexible floor airspace for XXXXz–XXXXz, in which they can continue to operate cooperatively and take advantage of the winds. (The Flexible Floor airspace could maybe be pre-defined in areas of high ETM traffic as in the UTM Low Altitude Authorization Notification Capability (LAANC)-enabled airspace concept). ATS would determine which ATC facilities control airspace along the requested Flexible Floor area and then coordinate with them to obtain approval for releasing control of the airspace to the ETM system. Both ATS and ATC control facilities would have access to mapping of the subject Flexible Floor airspace. The ATC facilities notify the ATS that they can approve the release of the airspace from XXXXz–XXXXz. Certain airspace may be pre-approved for ETM Flexible Floor airspace authorization, in which case the ATS may automatically approve the airspace change. ATS then provides approval to the ETM Network ESS. The Network ESS notifies the Balloon operator's ESS that the additional ETM Flexible Floor airspace is approved. ATC must display the new airspace to ensure that they do not allow any traffic to penetrate the Flexible Floor airspace. ETM must re-configure its assigned cooperative airspace to reflect the new Flexible Floor area as eligible for usage and monitoring. The Network ESS notifies all Operator ESSs of the additional airspace availability from XXXXz–XXXXz. The Balloon operator must notify and/or request authorization from ATC prior to entry (e.g., ascent if on transit to flexible floor area or descent if descending from upper Class E). An Operator can manually coordinate with ATC, or provide notification, and receive authorization, via an automated means (i.e., Datalink).

G. Table 6: Planned airspace authorization: Release of xTM operations back to ATC-controlled airspace

Category	Trigger Event	xTM Type	Use Case Description
Planned Airspace Authorization	Planned release of temporary **xTM-operated region back to ATC-controlled airspace**	UTM	FAA ATS determines that they need to take control of all, or part, of an active UTM area. A USS is managing an FAA-authorized UTM area. Due to high winds, a non-traditional runway operation at a Class C airport requires the TRACON to take control of the northern half of the authorized UTM-operated region for arrival procedures. FAA TRACON notifies ATS that they need the subject airspace to be returned to ATC TRACON control. ATS sends a message to the UTM Network USS stating that the airspace needs to be returned to FAA control by 1000z. The USS Network notifies all operators that the subject airspace will no longer be available effective 1000z and that all flights must use the southern portion of the UTM-operated region. Operators check the operations plans of all active and proposed flights, adjust their plans, and submit them to the USS Network. The

			USS Network reviews all new operations plans and indicates to the operators if there are any conflictions. Once all flights have new Operation Plans that vacate the northern airspace, the USS Network notifies ATS that the airspace will be clear at 1000z. ATS notifies the TRACON that they have control of the northern airspace effective 1000z. ATC TRACON begins utilizing the new arrival runway configuration at 1000z.
		UAM	FAA ATS determines that they need to take control of all, or part, of active UAM corridor airspace. A NPSU is managing several FAA-authorized UAM corridors. A non-traditional runway operation at a Class C airport due to high winds requires the TRACON to take control of one specific UAM corridor for arrival procedures. FAA TRACON notifies ATS that they need the subject corridor to be returned to ATC TRACON control. ATS sends a message to the UAM NPSU stating that the airspace needs to be returned to FAA control by 1000z. The NPSU notifies all PSUs that the subject airspace will no longer be available effective 1000z and that all flights must use other corridors in the UAM-operated region. PSUs check the operations plans of all active and proposed flights and adjust their plans and submit them to the NPSU. The NPSU reviews all new operations plans and indicates to the operators if there are any conflictions. Once all UAM flights have new operations plans that vacate and release the corridor airspace, the NPSU notifies ATS that the airspace will be clear at 1000z. ATS notifies the TRACON that they have control of the specific corridor effective 1000z. ATC TRACON begins utilizing the new arrival runway configuration at 1000z.
		ETM	FAA ATS determines that they need to take control of all, or part, of an active ETM Flexible Floor airspace. A Network ESS is managing a Flexible Floor airspace with several HALE vehicles performing various communication and internet provider capabilities. Due to a convective weather cell in the area and to avoid prohibitively lengthy re-routes. ATS needs to reacquire the Flexible Floor Airspace between FL500–FL530. The monitoring FAA Enroute facility notifies ATS that they need the Flexible Floor airspace between FL500–FL530 returned to their control. ATS sends a message to the ETM Network ESS, stating that the airspace needs to be returned to FAA control by XXXXz. The Network ESS notifies all Operator ESSs that the Flexible Floor airspace will no longer be available between FL500–FL530 effective XXXXz and that all flights must climb above FL540 into the upper section of the Flexible floor or request/coordinate a new Flexible Floor airspace. Operator ESSs check the Operation Plans of all active and proposed flights and adjust their plans and submit them to the Network ESS. The Network ESS reviews all new Operation Plans and indicates to the operators if there are any conflictions. Once all ETM flights have new Operation Plans that vacate the subject Flexible Floor airspace, they can then release the airspace, the Network ESS notifies ATS that the airspace will be clear at XXXXz. ATS notifies the Enroute facility that the Flexible Floor airspace will return to Class A airspace between FL500–FL530 effective XXXXz. ATC can now begin to reroute and climb the business jets.

H. Table 7: Unplanned entry into ATC-controlled airspace: Equipment failure

Category	Trigger Event	xTM Type	Use Case Description
Unplanned (of varying degrees) xTM vehicle entry into ATC-controlled airspace.	xTM vehicle equipment failure (e.g. sensor failure, low battery, etc.)	UTM	If RPIC can maintain control of the UTM vehicle, it is not expected to intrude unplanned into ATC-controlled airspace.
		UAM	A UAM flight is operating within a UAM Corridor/UOE on an approved Operation Plan. The RPIC/PIC notes the low-battery indicator and determines that they should land as soon as possible. The RPIC/PIC coordinates with their PSU to determine where to divert. They decide the best option is a secondary airport, situated outside of the UAM Corridor/UOE in ATC lower Class E airspace. The PSU develops a new Operation Plan and coordinates with the NPSU and instructs the RPIC/PIC to fly the new route. The NPSU/PSU forwards appropriate information to ATS. For an IFR flight, the PSU forwards an IFR flight plan to ATS. As the UAM flight approaches the UOE/ATC boundary, the RPIC/PIC instructs the UAM vehicle to turn on its transponder and ADS-B Out and contacts ATC on the proper frequency to request an IFR pick up clearance. If necessary, the RPIC/PIC can instruct the UAM vehicle to hover at a Corridor Control Point (CCP) while waiting for ATC to respond. ATC identifies the proper target by issuing a beacon code to squawk from the flight plan. ATC will verify radar contact and UAM vehicle altitude. ATC will provide a clearance to the new airport which may require the aircraft to climb to a legal IFR altitude. ATC will ensure separation from known traffic during this period. As the UAM vehicle approaches the new airport, coordination must take place to allow for IFR approach and landing. ATC issues an IFR approach clearance and clears the RPIC/PIC to contact the airport for landing clearance. RPIC/PIC acknowledges the approach clearance and instructs the UAM vehicle to execute the approach. For a VFR flight, the RPIC/PIC would turn on ADS-B Out and its transponder, set to 1200, before entering ATC airspace. Assuming FAA regulations that allow UAS BVLOS to fly "VFR Like" rules and with VMC conditions, the RPIC/PIC would proceed VFR to the secondary airport. The RPIC/PIC can request VFR flight following with ATC if desired. As the UAS approaches the secondary airport, the RPIC/PIC needs to procure a clearance to land and contacts the tower. Coordination with the airport could be through the PSU or the RPIC/PIC. ATC tower would clear the RPIC/PIC to land and the RPIC/PIC would instruct the UAM vehicle to land as cleared.
		ETM	A HALE balloon is operating at FL610, providing internet and telecommunications services to remote and rural areas. At 3:00 a.m., monitoring equipment alerts the HALE Operator that the balloon is slowly losing altitude and automated controls are unable to return it to its programmed position. The Operator performs troubleshooting procedures and determines that the equipment issue cannot be fixed remotely, and contingency procedures must be enacted. The balloon is operating cooperatively, therefore, its Operator coordinates with other cooperative Operators (via ESS/Network-ESS) to identify potential conflicts resulting from the situation. Since the balloon intends to descend straight into Class A (there is no flexible floor area below FL600) without laterally deviating from its intent, no conflicts are identified. The Operator continues to monitor cooperative intent conflicts as the situation progresses. The balloon is set to squawk 7700 and ATC coordination begins. The HALE Operator uses available traffic information sources via ESS data (or other public entities such as FlightAware) to identify actions that could minimize impacts to other traffic in Class A airspace and below.

			While the airspace below the balloon's current position has light air traffic and is in a remote area, it is heading toward a more heavily populated area with higher air traffic densities. Circumstances indicate that a rapid descent via deflation would minimize impacts to NAS operations and optimize the safety of air traffic and people/structures on the ground. The balloon Operator requests ATC approval to initiate a rapid descent via deflation and advises ATC of the circumstances surrounding the event. All operational information required for ATC to manage the balloon's descent is provided, including the balloon's current location, altitude, projected descent trajectory, and procedures (e.g., rapid deflation, parachute deployment). ATC evaluates the information provided, approves the request, and prepares for the descent. The balloon Operator acknowledges and provides updated trajectory information to ATC that accounts for the new descent rate. The Operator commands the balloon to execute the deflation/descent procedure. During descent, ATC vectors aircraft under its control, as needed, based on the HALE Operator's projected trajectory and current position. The Operator works with ATC to send notifications relating to the balloon's descent to other airspace users as quickly as possible (e.g., NOTAMs, advisories, Network ESS). Upon reaching a pre-determined low altitude, the balloon deploys its recovery parachute. The vehicle makes a soft landing, and the Operator completes recovery procedures using the balloon's location data.

I. Table 8: Unplanned entry into ATC-controlled airspace: xTM vehicle entry due to environmental factors

Category	Trigger Event	xTM Type	Use Case Description
Unplanned (of varying degrees) xTM vehicle entry into ATC-controlled airspace.	Unplanned xTM vehicle entry into ATC-controlled airspace due to environmental factors	UTM	Given that UTM vehicles are expected to operate far from conventional aircraft in nominal situations, if the RPIC can maintain control of the UTM vehicle, it is not expected to deviate so far that it intrudes into ATC-controlled airspace, unplanned.
		UAM	A UAM flight is operating on an approved Operation Plan within a UAM Corridor/UOE. The UAM flight makes an unanticipated turn into ATC Class C airspace. The RPIC/PIC has regained control of vehicle and desires to return the aircraft to the UAM Corridor/UOE. The Network PSU (NPSU) notifies ATS and the Operator PSU of the UAM flight's non-conformance and potential incursion to ATC airspace. The PSU notifies the RPIC/PIC that the UAM vehicle has entered, or is about to enter, ATC-controlled airspace and provides the proper frequency for the RPIC/PIC to contact ATC. The RPIC/PIC instructs the UAM vehicle to turn on its transponder and ADS-B Out and contacts ATC on the proper frequency to request assistance returning to the UAM Corridor/UOE. ATC identifies the proper target via the assignment of a discrete beacon code. ATC verifies radar contact and vehicle altitude and asks the RPIC/PIC for their intentions. RPIC/PIC states that they want to return to the UOE airspace. ATC issues an IFR clearance with a heading to fly and altitude to maintain that will take the UAS back into the UAM Corridor/UOE. The RPIC/PIC accepts the heading and coordinates with the PSU for a new Operation Plan to re-enter the UOE. The PSU develops a new Operation Plan to re-enter the UAM Corridor/UOE and complete the flight. The PSU coordinates the new Operation with the NPSU and receives notification that there are no

			conflictions. The PSU provides the new Operation Plan to the RPIC/PIC. The RPIC/PIC notifies ATC that they have permission to re-enter the UOE on their present heading and altitude. As the UAM vehicle nears the UOE boundary, ATC cancels radar coverage and the IFR clearance and clears the RPIC to leave the ATC frequency. The RPIC/PIC acknowledges the clearance, enters the UAM Corridor/UOE and resumes UAM operations.
		ETM	An ETM flight in Upper E Cooperative airspace makes an unplanned descent into ATC-controlled airspace. As the flight is progressing, it makes an unanticipated altitude change due to a down draft and descends into Class A airspace. The RPIC/PIC has control of the vehicle and desires to return the aircraft back to the ETM-operated region. The Network ESS notifies ATS and the Operator ESS (or vice versa). The ESS then notifies the RPIC that the aircraft is entering, or has entered, ATC-controlled airspace and provides the proper frequency for the RPIC/PIC to contact ATC. The RPIC/PIC turns on their transponder and ADS-B Out and contacts ATC on the proper frequency. ATC identifies the proper target via the assignment of a discrete beacon code. ATC verifies radar contact, vehicle altitude, and asks the RPIC/PIC for their intentions. The RPIC states that they want to return to the ETM-operated region. ATC assigns a new altitude which will take the HALE back up into ETM. The RPIC accepts the altitude and coordinates with the Operator ESS for a new Operation Plan to re-enter ETM. ESS executes the new plan and advises the RPIC. The RPIC notifies ATC that they are good to re-enter ETM. As the HALE vehicle nears the ETM boundary, ATC cancels radar coverage and IFR clearance (if any) and clears the RPIC to leave the ATC frequency. Vehicle performance characteristics may change ATC and ESS interaction, that is, whether the vehicle is crewed or uncrewed, or slow or fast.

J. Table 9: Unplanned entry into ATC-controlled airspace: Lost link contingency

Category	Trigger Event	xTM Type	Use Case Description
Unplanned (of varying degrees) xTM vehicle entry into ATC-controlled airspace.	Unplanned xTM vehicle entry without authorization: Lost link contingency	UTM	A UA deviates from its intended 4D Operation Plan and is on a trajectory to enter ATC-controlled airspace or has already crossed the boundary into ATC-controlled airspace (e.g., fly-away scenario). When the UAS Service Supplier (USS) detects non-conformance, the USS alerts the Remote Pilot in Command (RPIC). The RPIC uses available technology, if any, to "detect and avoid" all other aircraft (IFR, VFR, UA). The USS begins sharing real-time location information with ATS, if known, via the USS Network --> Flight Information Management System (FIMS). If the USS is unable to track the UAV, the USS shares the UA's last known location with ATS. ATS forwards known information to the appropriate ATC facility/sectors. If the RPIC is aware of the deviation, they contact ATC by landline and indicate intent (descend, turn around). ATC uses all available information from the RPIC and ATS to determine the UA location: • If ATC can identify the actual UA target, they provide traffic advisories to other traffic to stay clear of the UA. • If ATC only has general information about the UAs geographic location, they clear sufficient airspace to avoid the geographic area and issue a general advisory to VFR aircraft containing all known information (type, last altitude, Lost-Link procedure if known, etc.).

			ATC coordinates with other sectors whose operations may be impacted by the UA: • If the UA is under the Operator's/RPIC's control, RPIC/USS notifies ATC/ATS that the UA is returning to the UTM-operated region. • If the RPIC no longer has control of the UA, the RPIC/USS notifies ATC/ATS of any known lost link procedure which the UA may execute along with known location information. Once the UA has returned to UTM-operated airspace or landed, the RPIC/Operator USS advises ATC. ATC resumes normal traffic operations. -- **xTM Vehicle Entry into Uncontrolled Airspace** A UA deviates from its intended 4D trajectory and is on a trajectory to enter uncontrolled (Class G) airspace or has already crossed the boundary into uncontrolled (Class G) airspace (e.g., fly-away scenario). When the UAS Service Supplier (USS) detects non-conformance, the USS alerts the RPIC. The RPIC uses any available technology (V2V, ADS-B In, etc.) to "detect and avoid" all other aircraft (IFR, VFR, UA). The Operator USS shares all known data with ATS, via the USS Network / Flight Information Management System (FIMS). ATS develops and issues an advisory for VFR aircraft in the vicinity of the UA (via voice, sector frequency/guard frequency; via NOTAM; etc.) or the USS could provide the notification to VFR aircraft via some type of public portal. If the RPIC can regain control of the UA, the RPIC takes action to return the UA to UTM-operated region. If the RPIC no longer has control of the UA, the RPIC/USS notifies ATC/ATS of any known lost link procedure which the UA may execute along with known location information. Once the UA has returned to UTM-operated region or landed the USS notifies ATS. ATS or USS cancel advisories to VFR flights.
		UAM	A UAM vehicle is operating within a UAM Corridor/UOE between two vertiports on an approved 4DT Operation Plan. The RPIC determines that the UAM vehicle is not responding to commands and has lost link. The NPSU/PSU/RPIC note that the UAM vehicle is out of compliance with its operations plan and notifies other actors. The last known position and course indicate the UAM vehicle will likely fly into ATC Class C airspace. The NPSU/PSU notifies ATS of the UAM vehicle status and current intent, if known. The NPSU/PSU forwards the RPIC/PIC contact information for the appropriate ATC sector which the UAM vehicle is going to enter. The RPIC contacts ATC on the appropriate frequency and states all known vehicle status information. To include vehicle's position, altitude, current course, and that the UAM vehicle is squawking 7400 per lost link protocol. ATC is able to identify the UAM vehicle radar target, squawking 7400. ATC scans for traffic and moves traffic as necessary away from the UAM vehicle. The ATC controller notifies their supervisor that they are declaring an emergency and have a fly away UAM vehicle in their airspace. ATC/ATS requests details of the UAM flight's lost-link procedure to be prepared for any changes in course or altitude. The ATC notifies other ATC positions of the aircraft's current location, course, and altitude and that the UAM vehicle is in an emergency status. All controllers move traffic as necessary. RPIC advises ATC of his/her best estimate of when the UAM vehicle will lose battery power and advises ATC that the flight is programmed to execute a landing procedure 5 minutes before loss of battery power. The ATC Controller advises their supervisor of imminent descent and landing of the UAM vehicle. ATC supervisor notifies local authorities of imminent descent and landing. ATC monitors the UAM flight for initial descent and unplanned landing. The ATC controller observes flight descend below radar coverage and marks the spot on

			the radar, obtains a lat/long for the flights last position, and notifies their supervisor. The ATC supervisor coordinates the last known position with emergency responders.
		ETM	An ETM HALE is operating within the cooperative ETM environment (>FL600) on an approved 4DT Operation Plan. The RPIC determines that the HALE is not responding to commands and has lost link. The Network ESS or Operator ESS/RPIC note that the HALE is out of compliance with its operations plan and notifies other actors. The last position and course indicate the vehicle will fly into ATC Class A airspace (<FL600). The Network ESS notifies ATS of the HALE's status and current intent, if known. The Network ESS forwards the RPIC contact information for the ATC sector the HALE is going to enter. The RPIC contacts ATC on the appropriate frequency and states all known vehicle status information, which includes vehicle position, altitude, current course, and notify ATC that the vehicle is squawking 7400. ATC can identify the HALE radar target, squawking 7400. ATC scans for traffic and moves traffic as necessary away from the HALE. The ATC controller notifies their supervisor that they are declaring an emergency and have a fly-away HALE. ATC requests details of any lost-link procedure. The ATC controller notifies other positions of the vehicle's current location, course, and altitude, and that the vehicle is in an emergency status. All controllers move traffic as necessary. The RPIC advises the ATC controller of his/her best estimate of when the flight will lose battery power and advises ATC that the flight is programmed to execute a landing procedure 'X' minutes before loss of battery power. The ATC Controller advises their supervisor of the HALE's imminent descent and landing. The ATC supervisor notifies all other impacted ATCs and the local authorities of imminent descent and landing. ATC monitors the HALE for initial descent and unplanned landing. The ATC controller observes the vehicle's descent to below radar coverage and marks the spot on the radar, obtains a lat/long for the vehicle's last position, and notifies his/her supervisor.

K. Table 10: Unplanned entry of a large number of xTM vehicles into ATC-controlled airspace: TFR or SUA

Category	Trigger Event	xTM Type	Use Case Description
Unplanned Entry of large number of xTM vehicles entry into ATC-controlled airspace.	Temporary Flight Restriction (TFR) or Special Use Airspace (SUA)	UTM	Given the UTM vehicles are expected to operate far from conventional aircraft in nominal situations, mass reroutes of UTM vehicles into ATC-controlled airspace, unplanned, is not expected.
		UAM	NOTE: There are 4 use cases here (IFR, VFR, Dynamic Airspace Change, and Point Out). This is the dynamic airspace change version. During daily operations, an Operator PSU receives notice of a TFR being activated within a UAM Corridor/UOE in which they have operations. The PSU locates the TFR and uses automation to determine that several their airborne UAM flights will need to be rerouted around the TFR. They determine that the best route will require deviation into ATC airspace for 10 miles and then return into UAM Corridor/UOE airspace. The PSU/NPSU decide to request temporarily borrowing that airspace to accommodate the UAM vehicles' new route. The full route transits through ATC airspace where a pre-coordinated and charted UOE shelf, “UOEWing1”, is located. The NPSU/PSU forwards a request to ATS to take control of UOEWing1 airspace in 10 minutes time and to utilize it for 2 hours.

			ATS coordinates with the appropriate ATC sector(s) to release UOEWing1 airspace to the NPSU/PSU. The ATC sector(s) approve the release and ensure that no IFR aircraft will utilize the UAM Corridor/UOE airspace during the allotted time. ATS issues a notification to VFR traffic of the activation and transfer of UOEWing1 airspace. ATS notifies the NPSU that the airspace transfer is approved. The NPSU activates its control of the UOEWing1 airspace and notifies Operator PSUs that it is providing de-confliction and other services in the airspace. The PSUs develop new operations plans for all UAM flights (airborne and pre-departure) through both the standard UOE/UAM Corridor and its associated UOEwing1 airspace and submits them to the NPSU to ensure de-confliction. The NPSU returns notification of no conflictions with the new routes. The PSU instructs RPICs/PICs to initiate the new operations plan. RPIC/PICs instruct their UAM vehicles to fly the new operations plan. The PSUs obtain new landing slots at vertiports for the UAM flights. Each UAM flight operates on its Operation Plan and lands at its respective vertiport. ATC can observe the individual UAM flights as they progress through the UOEWing1 airspace if desired. They continue to ensure IFR and known VFR traffic stays clear of the UOE. They also scan for unknown VFR traffic and broadcast in the blind on their frequency about the UOE airspace status. The PSU/NPSU returns the UOEWing1 airspace to ATS for ATC Control at the allotted time.
		ETM	NOTE: There are 3 use cases (IFR, Flex Floor/Dynamic Airspace Change, and Point Out). This is the Flex Floor change version. During busy operations of multiple uncrewed, fixed-wing, HALE, balloon, and airship vehicles providing surveillance, internet, and communication services over a natural disaster area, the Network ESS receives a Homeland Security-driven TFR(SUA) within the ETM cooperative environment. The ESS locates the TFR(SUA) and uses automation to determine that a number of their airborne HALE flights will need to be rerouted around or under the TFR/SUA. ESS determines that the best route will require deviation into ATC airspace down to FL500–FL550. The routes would enter ATC airspace where a pre-coordinated, existing Flexible Floor 'ZOB39A' is located. The Flexible Floor activation would need to be coordinated. The Network ESS forwards a request to ATS to take control of 'ZOB39A' airspace in ~20 minutes time and to utilize it for 3 hours. ATS coordinates with the appropriate ATC sector(s) to release 'ZOB39A' airspace to the Network ESS. The ATC sector(s) approve the release and ensure that no IFR aircraft will utilize the ETM Flexible Floor airspace during the allotted time. ATS issues a notification to other IFR traffic, as necessary, regarding activation of the Flexible Floor ETM-operated region. The Network ESS activates its control of the 'ZOB39A' Flex Floor airspace and notifies ESSs that it is providing de-confliction and other services in the airspace. The ESSs develop a new Operation Plan for each of the HALE flights expected to come down to utilize the Flex Floor area and submits them to the Network ESS to ensure de-confliction. The Network ESS returns notification of no conflictions with the new routes/altitudes. The Operator ESS instructs RPICs/PICs to initiate the new Operation Plan. RPIC/PICs instruct their HALE vehicles to fly the new operations plan.

			Once the TFR/SUA has ended, the Network ESS returns the 'ZOB39A' Flexible Floor airspace to ATS for ATC control at the allotted time.

L. Table 11: Unplanned entry of many xTM vehicles into ATC-controlled airspace: Weather

Category	Trigger Event	xTM Type	Use Case Description
		UTM	Given the UTM vehicles are expected to operate far from conventional aircraft in nominal situations, mass reroutes of UTM vehicles into ATC-controlled airspace, unplanned, is not expected.
Unplanned Entry of large number of xTM vehicles entry into ATC-controlled airspace.	Weather	UAM	NOTE: There are three use cases here (IFR, VFR, and Dynamic Airspace Change). This is the IFR version. During daily operations, a PSU receives a SIGMET from the FAA for a large thunderstorm building in the UAM Corridor/UOE and potentially affecting numerous airborne flights. The flights are currently operating northbound along the eastern edge of the UAM Corridor/UOE airspace. The PSU locates the weather cell on radar and determines that several UAM flights will not be able to safely complete their intended operations. The PSU initiates IFR Flight plans for the RPIC/PICs to pick up while airborne and proceed east to secondary airports/vertiports for landing. The PSU submits the flight plans to the FAA via standard flight planning software. The PSU halts all pre-departure flights along the impacted route. The PSU develops new Operation Plans for airborne UAM flights within the UAM Corridor/UOE and submits them to the NPSU to ensure de-confliction. The routes take the UAM flights to Corridor Control Points (CCPs) that are separated from each other. The NPSU returns notification of no conflictions with the new routes and CCPs. The NPSU notifies ATS that many UAM flights will be requesting IFR flight plans to enter ATC airspace for weather avoidance, including general geographic area. ATS determines affected ATC sectors and forwards appropriate information to them. The Operator PSUs coordinates with RPIC/PICs to have all UAM flights initiate their new Operation Plan within the UAM Corridor/UOE. The PSU also forwards the IFR flight plans and ATC contact information to the RPIC/PICs. The RPIC/PIC for each vehicle acknowledges the new routing. As each flight reaches its CCP, the RPIC/PIC instructs the UAM vehicle to hover and turn on the vehicle's ADS-B Out and transponder. Each RPIC/PIC then contacts ATC on the proper frequency to request pick up of an IFR clearance to the secondary airport/vertiport. ATC acknowledges the request and instructs the RPICs/PICs to continue to hover. As workload permits, ATC identifies the proper target either by issuing a discrete beacon code to squawk, or by having the RPIC use the ident feature of the transponder. ATC verifies radar contact and altitude and provides the RPICs/PICs with an IFR clearance to the secondary airport. This may require a climb to legal IFR altitude. RPIC/PIC acknowledges the clearance/heading and instructs the UAM vehicle to fly the assigned route and altitude. As the UAM vehicle approaches the new airport, the ATC controller issues an IFR approach clearance to each RPIC/PIC. Each RPIC/PIC instructs their respective UAM vehicle to execute the approach. ATC cancels radar coverage and clears each RPIC/PIC to contact tower/vertiport. Each RPIC/PIC contacts the tower/vertiport and receives a landing clearance. The RPIC/PIC instructs the UAM vehicle to land as instructed and closes out the IFR flight plan.

		ETM	NOTE: There are 3 use cases (IFR, Flex Floor/Dynamic Airspace Change, and Point Out). This is the Flex Floor change version. During daily operations, the Operator ESSs receive a SIGMET from the FAA for a large thunderstorm building up into the Stratosphere and affecting numerous airborne flights in the region. The Operator ESSs activate data on the weather cell via third-party service tools and determines that several ETM flights will not be able to safely complete their intended operations. The ESSs initiate IFR flight plans for the ETM vehicles to prepare to proceed to secondary staging areas (or landing areas) to wait out the storm. The ESSs submit the flight plans to the FAA via standard flight planning software or via FIMS/Network ESS connections. The ESSs develop new Operation Plans for HALE flights within the affected ETM region and submit them to the Network ESS to ensure de-confliction. The routes take the ETM flights to the hand-off point into Class A (maybe something like-Corridor Control Points (CCPs) in UAM), ensuring that they are separated from each other. The Network ESS returns notification of no conflictions with the new routes at the handoff points. The Network ESS notifies ATS that a few ETM HALE flights will be requesting IFR flight plans to enter ATC airspace for weather avoidance. The ESSs coordinate with all HALE flights to initiate the new procedures including the IFR flight plans and ATC contact. The RPIC/PIC for each vehicle acknowledges the new routing. As each flight reaches its handoff point, the RPIC/PIC instructs the HALE vehicles to hover (depending on each vehicle's performance capability) and to turn on each vehicle's ADS-B Out and transponder. They then contact ATC on the proper frequency to request pick up of their IFR clearances to the secondary staging area or landing airport. ATC acknowledges the request and instructs the RPICs/PICs to continue to hold. As workload permits, ATC identifies the proper target either by issuing a discrete beacon code to squawk, or by having the RPICs use the ident feature of the transponder. ATC verifies radar contact and altitude and provides the IFR clearances to the secondary airport. This may require step descents or rapid descents depending on the vehicle type. The RPICs/PICs acknowledges the clearance/heading and instruct each HALE vehicle to fly the assigned route and/or altitude. As the vehicle approaches the secondary staging area, the RPIC/PIC contacts ATC for further instructions. If the vehicle is going to a secondary landing sight, as they are cleared to descend, ATC cancels radar coverage and clears the RPIC/PIC to contact tower. The RPICs/PICs contacts the airport and receive a landing clearance.

M. Table 12: ATC support needed in an xTM-operated region

Category	Trigger Event	xTM Type	Use Case Description
ATC support needed in xTM-operated region	Non-xTM aircraft entry into an xTM-operated region	UTM	Given the UTM operational region (e.g. below 400 feet), more conventional aircraft are not expected to enter a UTM-operated region.
		UAM	A VFR aircraft is operating at low altitude to remain clear of clouds and needs to cross through a UAM Corridor/UOE to get to its destination. The VFR pilot must file an approved 4DT Operation Plan to operate in the UAM-operated region. The VFR pilot engages an Operator PSU to coordinate its 4DT flight path through the UOE/Corridor. The PSU coordinates the flight’s 4DT Operation Plan with the NPSU and receives back notification that there are no conflictions with other UAM traffic. The PSU provides the VFR pilot with their course, altitude, and time constraints to maintain in the form of an Operation Plan. The VFR pilot/aircraft must be capable of meeting all operational requirements for the UAM

			corridor/UOE airspace. The VFR aircraft enters the UAM Corridor/UOE airspace and follows the operational plan. Upon reaching the boundary of UAM corridor/UOE airspace the pilot resumes VFR flight. Note: This not really an ATC interaction use case but a general use case about how this would be accomplished procedurally.
		ETM	**Case 1**: A Gulfstream 650ER flying across the country at FL510 files an IFR flight plan and will need ATS/ETM permission to transit through several ETM Flexible Floor areas. The flight will have to subscribe or participate in the ETM cooperative environment to do so. They file a flight plan through the ESS process to ensure conflict free "4D Transit Volume." Or they file an IFR flight plan that avoids the reserved Flexible Floor areas by flying around or under those airspaces. A flight operating on an IFR flight plan, referred to here as an ATC-managed operation, has the option of flying a route that avoids Flexible Floor areas or one that traverses through a Flexible Floor area. Operators that opt to fly through Flexible Floor areas are responsible for strategically de-conflicting their operations from cooperatively managed operations and filing an IFR flight plan that includes a conflict-free trajectory. When the ATC-managed flight approaches Flexible Floors along the route, ATC clears the flight to enter a conflict-free corridor/volume as filed; ATC does not provide separation services to aircraft or vehicles in flexible floor areas. ATC does have access to notification/authorization and intent/flight data for operations within flexible floor areas, should it be required. Upon exiting the Flex Floor Area, ATC resumes separation services for the Gulfstream flight. --- **Case 2:** A NASA Global Hawk heading to Edwards AFB, flying at FL610, has lost its (ESS) link to the cooperative environment and requests ATC separation services throughout its projected flight plan. The cooperative environment is notified that the Global Hawk will no longer be flying cooperatively but with ATC separation services instead. ATC accesses cooperative (ESS) and NAS system data to safely separate operations under their control. ATC sees that there are indeed balloon and HALE operations conducting research and surveillance cooperative operations near the Global Hawk's filed IFR flight plan. To ensure separation, the Global Hawk should continue to fly its original cooperative operations filed route because ATC-managed operations receive less operational flexibility than cooperative operations (e.g., fly filed route). ATC-managed operations are operationally less flexible because they are subject to the limitations imposed by airspace separation constraints and cooperative/ATC-managed traffic. --- **Case 3:** A chartered supersonic transport (SST) plans to fly from IAD to LAX, with the intent to depart from IAD in 12 hours. The Operator identifies locations along the flight path where their aircraft will overlap Flexible Floor cooperative separation environments in Class A airspace; two are identified. The SST Operator submits a flight plan for the cooperative environment via an Upper E Service Supplier (ESS). The ESS finalizes the flight plan and generates a 4D transit volume for identified flexible floor areas; details on this volume are made available to cooperative Operators as needed. SST-Ops then generates an IFR flight plan and files it via the appropriate ATS. ATC approves the flight plan. Prior to the supersonic aircraft's takeoff, a HALE Operator, whose vehicle is currently in Upper Class E airspace, begins in-flight planning for entry into one of the flexible floor areas. The HALE Operator obtains relevant planning information from other Operators, which includes the transit volume from SST-

			Ops; the HALE Operator accounts for this constraint while planning the descent time and profile, ensuring the HALE vehicle will not conflict with the supersonic operation during its transit. Once planning is complete, the HALE Operator submits a request to ATS, via the Network ESS, for authorization to enter the flexible floor area. ATC sends an approval message (maybe via digital data link) in response to the request. The supersonic aircraft takes off per the approved IFR flight plan and conducts the flight using ATC separation services until ATC clears the aircraft to enter the 4D transit volumes for each flexible floor area. The HALE Operator executes its mission in the flexible floor and the supersonic aircraft flies through each flexible floor area without issue and safely lands at LAX. ATC does not provide separation services to aircraft or vehicles in flexible floor areas. ATC does have access to notification/authorization and intent/flight data for operations within flexible floor areas, should it be required.