AIAA AVIATION Forum
June 27-July 1, 2022, Chicago, IL & Virtual
AIAA AVIATION 2022 Forum

10.2514/6.2022-3910

Identifying Common Coordination Procedures across Extensible Traffic Management (xTM) to Integrate xTM Operations into the National Airspace System

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New categories of missions and vehicle types, such as drone delivery services, on-demand air taxi, and high-altitude long-endurance (HALE) vehicles are being proposed to operate using a novel, highly automated information exchange infrastructure and a community-based, cooperative traffic management concept. Collectively, these new operations are called Extensible Traffic Management (xTM). As these xTM vehicles become more prevalent, their operations will increasingly overlap with existing conventional aircraft and with each other. In order to seamlessly co-exist with current conventional aircraft operations, new coordination procedures, tools and services will be needed to integrate xTM into the future National Airspace System (NAS). In our prior work, we have identified a set of use cases for xTM interactions with air traffic control (ATC), categorized across different xTM operations based on trigger events. Events consisted of ones such as nominal xTM vehicle transition into the ATC environment or an off-nominal emergency landing situation. In this paper, we have extended the prior work to identify commonalities in the coordination procedures across xTM, as well as differences that are specific to the individual xTM operations. The overall results showed that two types of xTM-ATC interactions were prevalent: 1) xTM vehicles transitioning between xTM and ATC operational environments; 2) xTM vehicles being allowed to continue xTM operations in areas that are normally controlled by ATC. The results also suggested that emergency and rare off-nominal events may need specialized procedures for each vehicle type. The overall results suggest that there is a pathway to define a common method of handling and integrating diverse xTM operations in the future NAS, but there need to be procedures for individualized handling of xTM vehicles in infrequent, safety-critical events.

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I. Introduction

There has been a surge of interest in novel, non-traditional vehicles and missions introduced by new industry stakeholders. Innovative missions, such as small Unmanned Aircraft Systems (sUAS) performing infrastructure inspections and delivering goods, electric Vertical Takeoff and Landing (eVTOL) vehicles carrying passengers while remotely piloted, and high-altitude long-endurance (HALE) aircraft providing communications services while loitering in the stratosphere, are expected to come onboard and grow exponentially [1-4].

Some of these new missions seek to access previously underutilized airspace, such as airspace below 400 feet for sUAS or above 60,000 feet for HALE aircraft. Given the lack of existing air traffic management (ATM) infrastructure in these altitudes, frequent operations in this airspace would require a significant new investment in ATM infrastructure and air traffic control (ATC) support that does not exist today. Other vehicles, such as eVTOLs, are expected to operate in urban regions near existing ATM infrastructures, but they are expected to operate at a very high traffic density such that it would likely overload the ATC's ability to maintain safe operations if they relied on existing ATM infrastructures.

In order to tackle these issues, the National Aeronautics and Space Administration (NASA) has been performing research and development in coordination with the Federal Aviation Administration (FAA) and stakeholder communities to develop a new air traffic management concept and technologies while minimizing the impact to current ATM. NASA recently completed the UAS Traffic Management (UTM) project, demonstrating the feasibility of safe, efficient, and scalable operations of small UAS under 400 feet [5,6], and it has been working to generalize UTM architecture to serve other vehicles and missions [7]. These new traffic management system architectures for the new vehicles are collectively referred to as Extensible Traffic Management, or xTM [8].

One of the key design thrusts of the xTM architecture is a novel, 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. Fig. 1 illustrates the UTM architecture, which represents an instantiation of the xTM architecture.

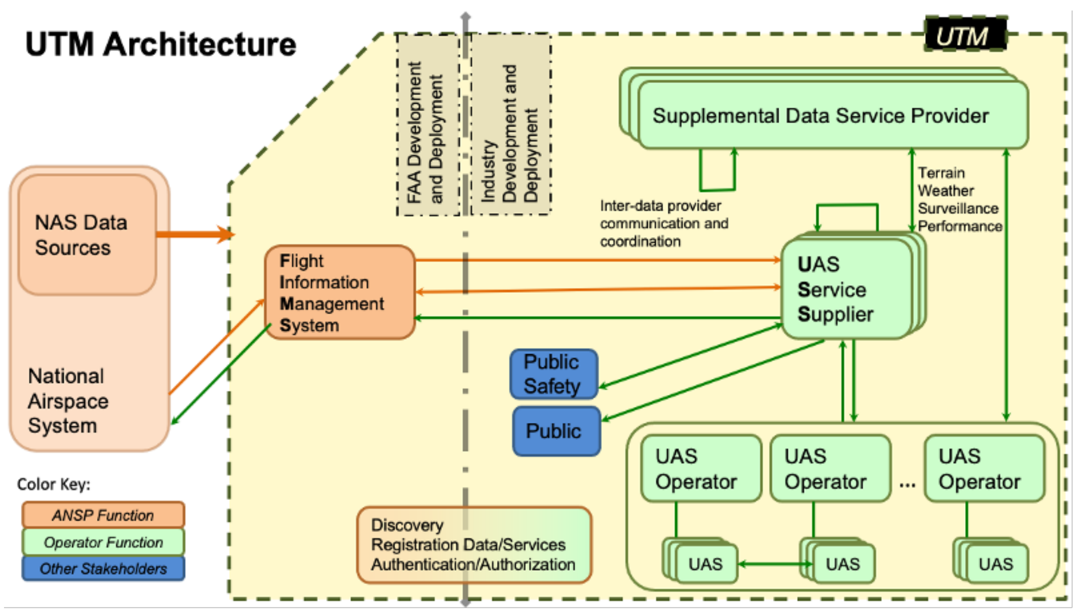

Figure 1. UTM Architecture

In this architecture, UTM operations are supported by federated service suppliers, developed mainly by industry partners, for coordinating, monitoring, and executing vehicle operational intent. For UTM, the coordination and data exchange are handled through a gateway called Flight Information Management System (FIMS) between UTM (and more generally, xTM) and Air Traffic Services (ATS), which provides the data infrastructure for conventional air traffic in the National Airspace System (NAS) [5-7]. Other xTM systems are expected to have gateways that are similar to the FIMS structure for information exchange between xTM and ATS.

The innovative approach employed in xTM architecture 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. Industry stakeholders have proposed generalization of UTM architecture to apply to other vehicle types and to rethink the concept of ATM for all users [3]. New missions, such as Advanced or Urban Air Mobility (AAM/UAM) flying eVTOL vehicles [9,10] and Upper-Class E Airspace Traffic Management (ETM) flying HALE fixed-wing aircraft and balloons at or above 60,000 feet [11-13], have been proposed. Other new missions, such as commercial space operations and large autonomous freighter operations using remote pilots, may also utilize xTM architecture to facilitate access to a sustainable ATM infrastructure in the future.

II. Integration of xTM Operations into the National Airspace System

In the FAA's vision for the future aviation, xTM (i.e., UTM, AAM/UAM Traffic Management, and ETM) operations are part of a larger ATM operation and are expected to operate seamlessly in the NAS [4]. However, given different sets of missions and flight profiles for a diverse set of xTM vehicles, xTM operations are envisioned to be introduced gradually during early implementations. Initial introduction of xTM operations will likely occur in airspace that is sparsely populated and often segregated by altitude, allowing the new xTM vehicles to operate relatively independent of conventional air traffic. Fig. 2 illustrates how the xTM operations for different vehicles could ramp up from initial to more mature implementations with higher traffic levels and overlapping xTM operations. In the left image in Fig. 2, UTM, ETM, and AAM/UAM vehicles fly in designated airspace below 400 feet, above 60,000 feet, and in special operational corridors, respectively. As xTM infrastructures mature and xTM traffic levels ramp up, the network of xTM-operating regions is likely to multiply, creating a complex web of overlapping operations, as shown in the right image in Fig. 2.

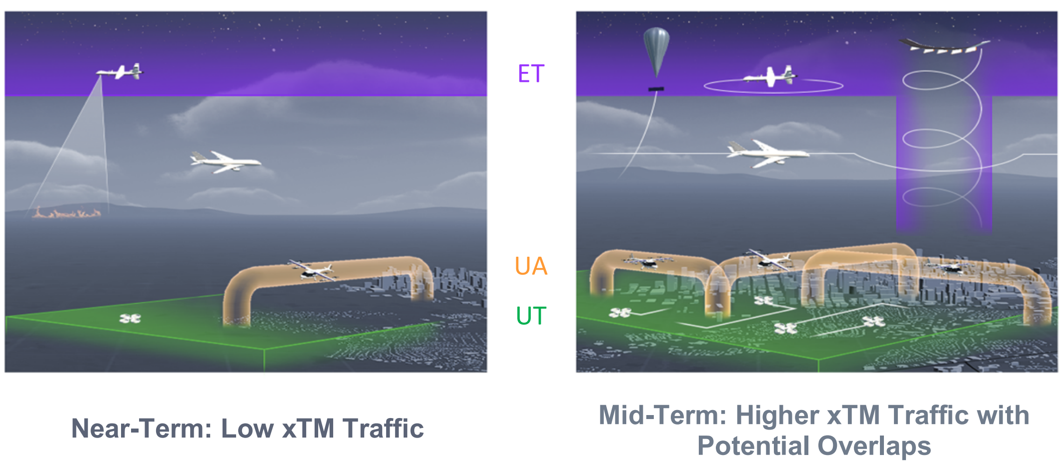

Figure 2. Characteristics of Various Traffic Levels of xTM Operations in Near to Mid-term Integration

As xTM traffic grows and a greater overlap of diverse operations occur in the same airspace, sufficient airspace access for all vehicle types will become paramount. Need for airspace access and efficient airspace usage will necessitate more harmonized, seamless integration of all vehicle types in the future, Fig. 3 illustrates the gradual evolution from initial, segregated operations of different xTM vehicles on the left to full integration of diverse vehicle operations on the right. Given the fundamental differences between xTM operations using automated, coordinated traffic management services and conventional ATM operations based on existing human-centric system, the transition and interactions of vehicles between xTM and ATC will need to be handled seamlessly to realize the full integration of two diverse types of operational systems. In addition, given the possibility of differences between each xTM operation (i.e., differences between UTM, AAM/UAM, and ETM), it is also important to identify commonalities across the xTM operations. This will enable better synergy of new procedures, services, and information exchanges across the xTM operations.

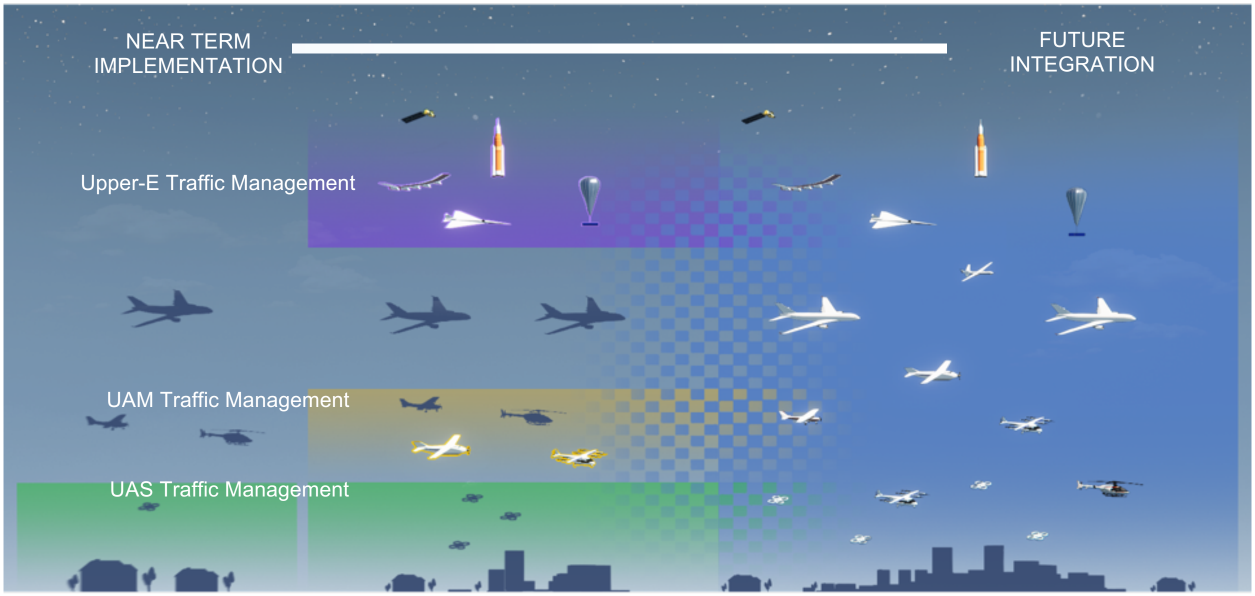

Figure 3. Integration of xTM and Conventional ATM Environment

Our approach to identifying interaction scenarios between xTM and conventional ATM operations has been to collect and categorize use cases across the three different xTM operations in which the interactions could occur. The use cases were then developed to identify step-by-step procedures for the interactions for each type of xTM vehicle and grouped together to identify common procedures that generalize the operations for all types of xTM vehicles. The exercise of developing common procedures allowed us to gauge how many commonalities exist across the different xTM operational procedures and how many cases remained that required specialized handling of the individual xTM vehicles under certain scenarios. The following sections describe the identification / categorization of common use cases, development of common procedures, and our insights gained during the development process.

III. Identification and Categorization of Use Cases across xTM Operations

A. Use Case Collection and Categorization Approach

For the collection and identification of interaction use cases, the focus was placed on situations in which xTM vehicles, operating under xTM operations, need to interact directly with ATCs or need to enter airspace normally controlled by ATCs (i.e., xTM-ATC interactions). Situations in which xTM vehicles enter uncontrolled airspace and possible interactions between multiple xTM operations (e.g., AAM/UAM operations interacting with UTM operations) have been largely omitted from the analyses.

The potential xTM-ATC interactions across multiple xTM operations have been examined jointly to identify common themes and features in their operational procedures, ATC roles/responsibilities, and information exchange requirements, across different scenarios and under various airspace and weather constraints [14]. The interaction use cases were collected first for individual xTM operations [14] before grouping them together along commonalities. An initial set of use cases were collected from UTM, AAM/UAM, and ETM concept documents and other related published documents by the FAA, NASA, and industry stakeholders [15-20]. Additional use cases were gathered from ongoing NASA research that is still in the development stage. Additionally, numerous NASA researchers who are actively working on UTM, AAM/UAM, and ETM concepts, have been interviewed to discuss concept details that were absent from some of the published documents.

After the use cases were collected across different xTM operations, we organized them along various dimensions, such as phase of flight, different trigger events, airspace class, etc. From these dimensions, the organization by the trigger events, such as the xTM vehicles entry/exit to ATC-controlled airspace, or emergency landing due to equipment failure, seemed to align best with the goal of finding common coordination procedures across xTM operations. Following are the general categories of trigger events / scenarios that were identified across xTM:

- Planned/coordinated entry/exit into and out of ATC-controlled airspace where the xTM vehicle traverses through the controlled airspace operating under ATC control / supervision.
- Operational changes where ATC authorizes xTM operations in ATC-controlled airspace or terminates xTM operations to revert the control back to ATC operations.
- Unplanned, off-nominal entry from xTM-operating regions into ATC-controlled airspace where the xTM operations may not have adequate time to coordinate with ATC prior to entering controlled airspace and may have little to no control of where the xTM vehicle enters the controlled airspace.
    - In these use cases, ATC must take timely action in response to the xTM vehicle to ensure separation between conventional ATM aircraft and one or more xTM vehicles, which may increase controller workload.
    - A few of the identified unplanned, off-nominal entries into ATC-controlled airspace include:
        - Equipment failure
        - Command and Control (C2) lost link
        - Reroute out of an xTM-operating region due to unforeseen weather or other airspace constraints

From the use cases collected from the literature and ongoing research, it was noted that some use cases were well developed in one xTM operation type but not in the others. Thus, once the use cases were organized by similar trigger events / scenarios, the use cases that were more fully defined in one xTM operation were used to model and develop similar use cases in other xTM operations. The resulting consolidation of use cases have been developed and reported in [14].

B. Main Methods for Handling xTM Vehicles

When these use cases were compared across different xTM operations, a pattern emerged that there exist two general methods to handle xTM vehicles as they transition through ATC-controlled airspace. One method is to simply allow the xTM vehicle that is departing to or descending out of the xTM-operating region to fly with normal ATC services (depicted in the right half of Fig. 4). Prior to entry into ATC-controlled airspace, the xTM vehicle and its operator are expected to provide the ATC with the vehicle's intent, location, and other flight plan related information. Once the xTM vehicle enters ATC-controlled airspace, ATC provides separation and other air traffic services during transit. Although xTM vehicles operate under normal ATC regulations and procedures, these vehicles may have disparate vehicle performance characteristics and mission profiles that may need to be accounted for in order to facilitate the controller's handling of the vehicles. The new procedures will need to be tailored based on how ATC handles xTM vehicles during the entry into and exit from his/her control. The details on how the xTM vehicle is tracked, where and when the vehicle location appears on the ATC display, whether ATC needs to approve the vehicle's entry/exit during the transition, number of coordination steps, and the time needed for coordination, etc. will need to be specified based on the vehicle and system capabilities, roles and responsibilities, and regulations associated with xTM operations.

Although, in theory, xTM vehicles should not require different handling, communication, or separation procedures by the ATC, in reality, the different xTM vehicles are expected to operate unique missions and flight profiles, resulting in divergent vehicle performance capabilities, communication methods, and potentially different operational procedures, such that they pose significant challenges to the ATC to maintain safety within his/her controlled airspace for vehicles that behave differently from conventional aircraft and other xTM vehicles. This challenge is exacerbated when multiple types of xTM vehicles are near each other, especially if the ATC is expected to provide different types of separation services for each type of xTM vehicle. Given these challenges, ATC may need additional support tools and services for coordinating transit and maintaining situational awareness for potential conflicts and other safety risks for the new types of xTM vehicles.

A second method of handling xTM vehicle entry into and exit from ATC-controlled airspace is to extend the xTM-operating regions to be activated in areas that are nominally controlled by ATC (depicted in the left half of Fig. 4). The extension of xTM operations allow the xTM vehicles to continue to operate under xTM collaborative or cooperative rules and procedures instead of transitioning to ATC-controlled environment. Once the new xTM-operating regions are established, ATC no longer needs to provide services or maintain responsibilities for the xTM vehicles in these regions. When this method is used, coordination is done for the airspace authorization process between xTM Network service supplier automation and ATS, which provides the air traffic services to the ATC. Once the xTM-operating regions authorization process is approved, the newly authorized xTM operational area can function collaboratively like xTM operations were designed to do, without explicit ATC support. In these situations, xTM vehicles can still be tracked by ATS so that the vehicle's information and position can be accessible by the ATC to maintain his/her situation awareness. The airspace authorization process to switch between xTM and ATC operations may initially be simple and static, using pre-mapped regions of airspace that can be activated for xTM operations as needed, like many military operations (e.g., Military Operations Area (MOA) or Special Use Airspace (SUA)) are activated in current day operations. As xTM traffic tempo and complexity grows, more dynamic airspace authorization capabilities, both in terms of airspace structure (e.g., contours, busy airspace) and quicker and more agile implementation timing, may need new coordination methods for communicating and displaying the airspace structures across multiple human operators as well as xTM and ATS automation systems. A more flexible and dynamic airspace access may respond on-the-fly to the weather or other environmental constraints and coordinated digitally with all impacted ATCs, supervisors, and traffic management coordinators automatically, which could reduce workload and allow much more efficient use of airspace.

Fig. 4 illustrates the two coordination methods for xTM-ATC interactions described above for a case with xTM vehicle entering ATC-controlled airspace. The figure illustrates the decision tree for the two methods, each with a simpler and then, more advanced implementation option.

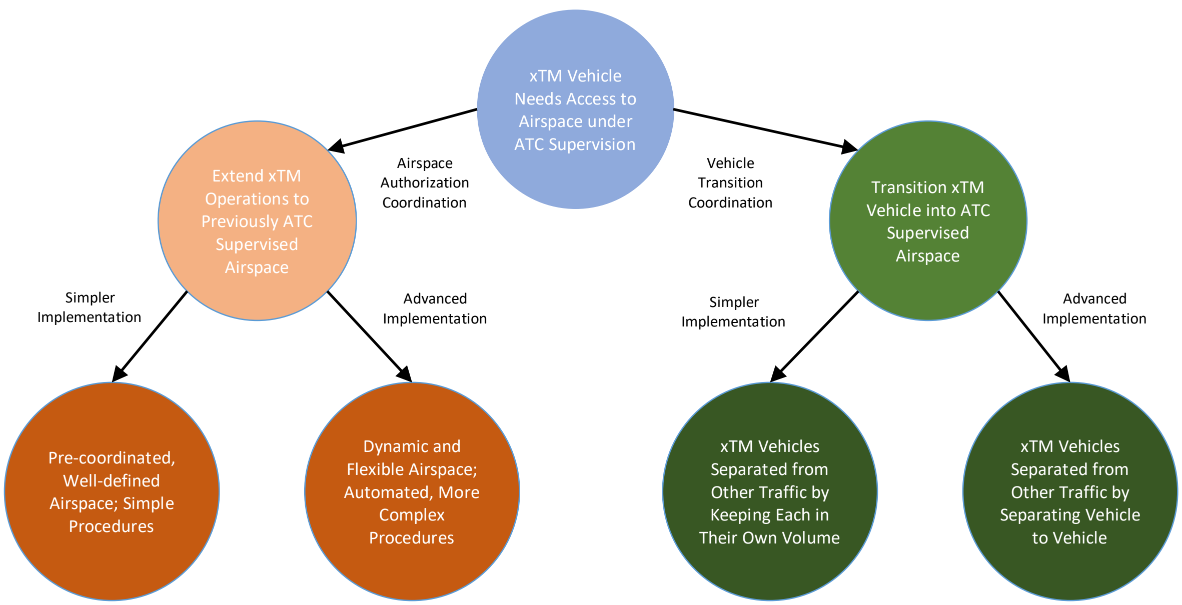

Figure 4. Two Methods for a Case with xTM Vehicle Entry into ATC Controlled / Supervised Airspace

Another large set of use cases requires a different set of methods to handle unplanned, emergency, or rare off-nominal situations that result in xTM vehicle entry into ATC-controlled airspace at an undetermined time and/or location, in which the airspace may be occupied with other traffic or require significant attention by the ATC to safely separate the xTM vehicle from the other traffic under his/her control. We have collected several unplanned, emergency / off-nominal use cases that require xTM vehicles to enter the ATC environment and land, enter the ATC environment and then re-enter xTM-operating region later, or execute a pre-defined contingency plan. The details of the use cases and their trigger events are described in [14].

These unplanned, emergency, or rare off-nominal use case situations necessitate ATC to move from standard operating procedures to using more non-standard procedures. We focused on three criteria that may need to be met to use standard procedures:

- **Control of time/location:** The operator of the xTM vehicle has control over where/when the vehicles entered ATC-controlled airspace.
- **Coordination:** From the time the operator of the xTM vehicle decides to enter ATC-controlled airspace or from the time that non-conformance is detected (e.g., due to equipment failure), there is enough time to coordinate with ATS verbally and/or digitally, prior to exiting the xTM-operating region and entering ATC-controlled airspace.
- **ATC Workload:** ATC is managing *low* traffic demand and they have the capacity to merge xTM traffic into their sector without significantly increasing his/her workload, even if s/he must move all other aircraft away from the xTM vehicle for safe transit.

The resulting non-standard procedures would be followed when:

- **Control of time/location:** The operator of the xTM vehicle has ***little to no*** control over where/when the vehicles entered ATC-controlled airspace.
- **Coordination:** From the time the operator of the xTM vehicle's non-conformance is detected (e.g., due to equipment failure), there is ***not*** enough time to coordinate with ATS verbally and/or digitally, prior to exiting the xTM-operating region thus, they may be entering ATC-controlled airspace ***without explicit approval***.
- **ATC Workload:** Even if ATC is managing *low* traffic demand, ***the encroaching xTM vehicle will create a more immediate need to move other traffic, thus significantly increasing his/her workload. ATS/ATC would not have right of refusal.***

The defined standard procedures were derived while working through the planned nominal entry/exit use cases, the non-standard procedures were formulated for the unplanned, emergency, and rare off-nominal use cases when a sense of urgency is created, and ATC must take timely action. The following sections (IV) will break down the development of the common coordination procedures and (V) will dive into the insights form the development process.

IV. Development of Common Coordination Procedures across xTM Operations

Once the use cases have been identified and categorized by trigger event, each use case (trigger event) is then expanded into step-by-step event sequences to provide a detailed description of the procedures, roles / responsibilities, and data exchange requirements during the xTM-ATC interactions across the xTM operations. The detailed procedures and roles can help us define what information ATC will need to perform his/her tasks during these interactions and identify data exchange requirements for the xTM vehicles that are entering the ATC's airspace. Following is the general approach we used to expand each of the ten use cases into step-by-step coordination procedures for each trigger event / scenario:

- For each use case (trigger event), develop step-by-step procedures for each xTM operation (UTM, AAM/UAM, and ETM).
- For each step, describe a common procedure that generalizes across UTM, AAM/UAM, and ETM operations.
- Identify the exceptions to the common procedure that need to be specified for one or more xTM vehicle types or xTM operations.

The detailed results of the common procedure development are reported in the Appendix. Common procedures and exceptions are detailed for all identified trigger events. The Appendix includes ten tables, each representing one use case (trigger event). The first four tables describe use cases in which planned/coordinated entry into / exit from ATC-controlled airspace is needed while the xTM vehicles traverse through the controlled airspace under normal ATC operations. Following is a list of descriptions for the use cases in the Appendix Tables 1–4:

Table 1	Planned entry into an xTM-operating region. Ascent/climb cases covered in the descriptions. Other types of entries have similar sets of procedures.
Table 2	Planned entry into an xTM-operating region with ATC intervention for traffic management. Ascent/climb cases covered in the descriptions. Other types of entries have similar sets of procedures.
Table 3	Planned exit from an xTM-operating region. Descent/land cases covered in the descriptions. Other types of entries have similar sets of procedures.
Table 4	Planned exit from an xTM-operating region with ATC intervention for traffic management. Descent/land cases covered in the descriptions. Other types of entries have similar sets of procedures.

The next two tables in the Appendix describe use cases in which ATC coordinates the authorization of a new xTM-operating region in an airspace normally controlled by ATC, as well as its counterpart in which ATC takes back control of an xTM-operating region that was previously authorized but now needs to revert to ATC operations. Following is a list of descriptions for the use cases in the Appendix Tables 5 and 6:

Table 5	Conversion of ATC-controlled airspace into an xTM-operating region.
Table 6	Return of an xTM-operating region back to ATC-controlled airspace.

The final four tables in the Appendix describe use cases in which unplanned, off-nominal entry into ATC-controlled airspace takes place and where the xTM operation may not have adequate time to coordinate with ATC prior to entering controlled airspace and may have little, to no, control of the location of the xTM vehicle's entry point into ATC-controlled airspace (e.g., situations such as equipment failure, lost link, or rerouting to avoid weather). In these use cases, ATC must take timely action in response to the unplanned events to ensure separation between conventional ATM aircraft and one or more xTM vehicles in potentially complex situations. Following is a list of descriptions for the use cases in the Appendix Tables 7–10, which represents broad categories of different emergency / off-nominal event types that could occur. Unlike nominal use cases, there exists large possible variations for each use case, depending on the type and severity of the events, equipment failures, etc., and vehicle types, each requiring selective responses by the ATC.

Table 7	Unplanned entry into ATC-controlled airspace requiring non-standard ATC procedures: xTM operation desires to land and end their mission. Event sequences focus on xTM vehicles entering ATC's airspace but not returning to xTM-operating region.
Table 8	Unplanned entry into ATC-controlled airspace requiring non-standard ATC procedures: xTM operation desires to return to xTM-operating region. Event sequences focus on xTM vehicles entering ATC's airspace and returning back to xTM-operating region at a later time.
Table 9	Unplanned entry into ATC-controlled airspace requiring non-standard ATC procedures: xTM vehicle has lost command and control (C2) link, xTM Operator/Remote Pilot does not have control of vehicle.
Table 10	Unplanned entry of <u>many</u> xTM vehicles into ATC-controlled airspace requiring non-standard ATC procedures: The use case in this example details such event due to a SIGMET weather advisory. Multiple xTM vehicle entry requires additional procedures focused on coordinating the traffic flow in addition to handling the individual vehicle.

The ten use cases listed above cover ten general categories of trigger events that we identified and grouped together. Some similar use cases that were variations of the listed use cases have been omitted for conciseness, as they result in similar sets of procedures as the ones covered in this paper. The individual step-by-step procedures for each xTM domain and for different vehicle types have been omitted from this paper for brevity. The exercise of developing individual procedures and combining them to generate the common procedures has resulted in various insights into the feasibility and challenges of finding common procedures. The insights are detailed in the following section.

V. Insights from Common Procedure Development Process

The overall goal of developing common procedures for xTM across UTM, AAM/UAM, and ETM operations was to examine if there were common features across these operations that could be generalized such that a common set of principles could guide the development of each xTM operation to ease the eventual integration efforts that will arise when the operational tempo increases, and the operations overlap more frequently.

As the use cases were collected and developed across xTM operations, a pattern emerged that suggested that there are two main options for handling xTM vehicles transiting through airspace controlled by ATC, as described in section III. Once the transitions are completed, there are no "xTM-ATC interactions" per se, since the xTM vehicles operate either like any other aircraft under ATC supervision in the first option or continue to operate like xTM vehicles in the xTM environment in the second option.

Besides these two transition options, the remaining use cases centered mostly around unplanned, emergency or off-nominal events that require additional handling above and beyond the transition steps described in the first two options. Detailed step-by-step procedures for each xTM operation and individual vehicle types were developed for each use case, and then synthesized into a common set of procedures. From this process, several insights emerged about the potential feasibility of developing a common framework across the xTM domains and potential barriers to that goal. Following are some insights that were gained through this process.

1. Most xTM vehicle access to ATC-controlled airspace is predictable and can be structured to have common features across various xTM operations.

Use cases in UTM, AAM/UAM, and ETM operations in which the vehicle transitions from the ATC environment into an xTM-operating region, or vice versa, had a similar set of procedures for coordinating across xTM Operator service suppliers and ATS on the information exchange side and across the xTM vehicle operator / remote pilot and ATC on the human operator side. The procedures could be generalized to a common set, in terms of the overall structure, but some of the details vary due to the differences in the vehicle characteristics, airspace that they operate in, and some differences in rules and regulations. Similarly, authorizing ATC-controlled airspace to operate under xTM systems showed a similar set of procedures across xTM operations. Again, some of the details vary, mainly due to the differences in the type of airspace and the level of nearby traffic in the area, as well as differences in regulations that govern different types of vehicles (e.g., small vehicles under 12 lbs., balloons, and other vehicle types operate under different rules than conventional aircraft).

Although it was expected that nominal use cases would be generalizable into common procedures, it was a surprise to discover that many of the non-emergency off-nominal scenarios could also be captured mostly through a similar set of procedures. Off-nominal events generally require additional coordination and planning at the beginning to respond to the trigger event (e.g., equipment issue, weather avoidance), but once the additional coordination is completed, xTM vehicles generally will need to either transition to the ATC environment or request authorization of the airspace to extend xTM operations similar to the nominal scenarios.

2. During unplanned emergency and/or severe off-nominal events, the responses tend to be specific to the situation and likely need individualized handling, but these situations are likely to occur infrequently.

When emergency or severe off-nominal events occur where immediate responses to highly reactive scenarios are required, xTM vehicles may need to transition through a non-idyllic ATC environment, such as highly congested areas or near a busy airport, all without much pre-planning or coordination. These situations may require significant additional ATC workload to manage separation so that the xTM vehicles are safely away from other traffic. They may also require additional procedures that deviate significantly from the nominal ones and tailored responses for each xTM vehicle type and different categories of scenarios. For emergency situations, such as equipment failures for example, a sense of urgency to take timely actions results in non-standard procedures. The reasons are described for the three factors outlined in section III:

- *Control of Time / Location:* The xTM vehicle operator / remote pilot has little to no control over where or when the vehicle enters the ATC-controlled airspace (e.g., due to equipment failure or urgency to land).
- *Coordination:* xTM service supplier automation or vehicle operator / remote pilot does not have adequate time to coordinate with ATS or ATC prior to entering the ATC-controlled airspace. Based on various concept documents, xTM Network service supplier automation may detect the xTM vehicle's trajectory toward ATC's airspace and communicate with ATS which in turn can alert ATCs ahead of time. However, it is possible that the vehicle will enter ATC's airspace without an explicit approval. It may also enter without having a clear flight plan or an operational intent, which may result in additional coordination between the operator of the xTM vehicle and ATC, after the vehicle enters ATC's airspace to coordinate a flight plan.
- *ATC Workload*: Unplanned entry of xTM vehicles may create an immediate need to move other traffic, thus increasing ATC workload. Unlike nominal scenarios, circumstances of an off-nominal/emergency event may be such that ATC does not have the option to refuse or delay vehicle entry, which may create difficult situations that will require additional sets of procedures to manage the situations.

One of the vital off-nominal events that need to be handled for uncrewed / remotely piloted aircraft across xTM operations is a loss of Command and Control (C2) of the vehicle due to the degradation or loss of the data communication link between the vehicle and the remote operator. In such situations, there needs to be well-established contingency plans that are coordinated across xTM and ATS systems and across xTM vehicle operators and ATC. Due to the different vehicle characteristics, the contingency plans and associated procedures are likely to be specific to the vehicle types and situations, and therefore not likely to be generalizable.

Overall, the emergency and severe off-nominal events probably need to be handled differently for each vehicle type and situation. However, they are likely to occur infrequently and not be a part of ATC's daily handling of the xTM vehicles. In many ways, ATCs deal with all types of emergency situations for conventional aircraft today, which also need to be handled differently for each situation and vehicle type. Therefore, the special handling of these emergency / off-nominal cases may be just an extension of existing ATC responsibilities.

3. Large commonalities exist in the step-by-step procedures between AAM/UAM and ETM operations, but the procedural steps for UTM often differ from the other two xTM operations.

The goal of the paper was to identify common procedures across all xTM operations but often there were significant difference in UTM operations as compared to AAM/UAM or ETM operations. The differences seemed to be due to various factors. First, UTM operates mostly below 400 feet, which is seldom occupied by other types of conventional aircraft. Natural segregation of its operations helps to reduce the potential interactions that may occur in other xTM operations. A UTM vehicle also differs in vehicle and sensor characteristics from others due to its small size and performance. Small drones in UTM are difficult to separate from other vehicles using either visual flight rule (VFR) or instrument flight rule (IFR) procedures under ATC supervision due to the difficulty of spotting them in a visual line of sight for VFR and the potential lack of surveillance or other sensor equipages onboard for proper IFR separation.

Therefore, finding a common set of procedures might yield promising results between AAM/UAM and ETM operations but less so for UTM operations. However, since UTM operations are likely to be more segregated than the others, the differences may have only a small impact. It would be desirable for UTM and AAM/UAM procedures and information exchange to share a common framework, but more development and analysis is needed to determine if the differences can be overcome.

4. Differences in procedures occur often between different xTM vehicle types within the same xTM operation as well as between different xTM operations.

Although there are significant differences between AAM/UAM and ETM operations, there are commonalities in the procedures that can be generalized. However, some of the larger differences and challenges occur within ETM operations between different vehicle types, such as balloons, slow- and fast-speed fixed-wing HALEs, and supersonic aircraft. Balloons are significantly different in that they do not file an IFR flight plan, do not communicate with ATC on the radio frequency, and have limited controllability, thereby needing significantly different procedures than other vehicles.

There are other differences between ETM vehicles that add to the challenge. Some vehicles can use standard ATC IFR separation while transiting through the ATC environment while others require a separate airspace volume using mechanisms such as COAs, LOAs, and/or NOTAMs. Even prior to departure, there are differences in flight planning procedures, where some vehicles are required to provide notice to ATC several hours prior to the start of the operation, while others are required to provide notice up to 24 hours in advance.

It would be desirable to modify the overall procedures in future implementations to reduce the differences between vehicle types, if possible. For example, balloons currently do not file IFR flight plans and are separated from other traffic in ways that do not require IFR separations, but if a balloon can file a flight plan based on its predicted future trajectories and can be integrated into the ATC data stream, it may be possible to have common procedures for balloons and other vehicle types.

5. Further development in xTM concepts and assumptions are needed to determine if there exists a common set of procedures for handling non-xTM vehicles transiting through an xTM-operating region with ATC supervision.

During the use case development, there were many scenarios in which non-xTM vehicles under ATC supervision enter an xTM-operating region. On the surface, they seemed to pose very different scenarios but a deeper look suggested that they have similar underlying features. Some use case examples include:

- xTM vehicle loses their access to the xTM network service supplier automation and must fly as a non-participating vehicle within the xTM-operating region with ATC support but without full xTM operations capabilities.
- Supersonics, business jets, or other non-xTM vehicles need to traverse through, instead of around an xTM-operating region due to the large route deviation needed to fly around the xTM-operating region.
- General aviation aircraft need to transit through UAM corridors due to the impracticality of deviating around the corridor structure.

In each case, new mechanisms and coordination procedures need to be developed to allow non-xTM vehicles, which cannot fully participate in cooperative xTM operational practices, to transit through the xTM-operating region with ATC support and supervision while maintaining a safe distance from xTM vehicles.

Although many of these use cases emerged from the use case and procedure development process, the details about the exact scenarios in which they would occur would depend heavily on how each xTM concept decides to handle the potential interactions (e.g., Are non-xTM vehicles allowed to penetrate through xTM operations or do they have to go around? Is there a minimum equipage level to transit through xTM operations and if so, what is required? Etc.). Because there are still a lot of questions surrounding this xTM-ATC interaction, more research and answers are needed to determine which assumptions and scenarios are likely in future xTM operations.

VI. Conclusions

An exciting new future of aviation traffic management is being researched and implemented for novel types of vehicles and missions, such as drone delivery services, on-demand air taxi, and HALE aircraft / balloons. UTM, AAM/UAM, and ETM operations, collectively called xTM operations, are being proposed to use an innovative, highly automated information exchange infrastructure and a community-based, cooperative traffic management concept. Given both the similarities and the differences between different xTM operations, this paper aims to find a common set of procedures across xTM operations, especially in situations where they need to transit through ATC-controlled airspace.

A general approach to finding common procedures was to identify a set of use cases for xTM-ATC interactions for individual xTM operations and to categorize them based on common trigger events. Use cases were then developed further as step-by-step procedures, which were then generalized along common features in the coordination procedures. Individual differences emerged for different xTM operations as well, which were captured as exceptions to common procedures. The details of the effort are shown in the Appendix.

The overall effort resulted in identifying two main types of xTM-ATC interactions: 1) xTM vehicles transitioning between xTM and ATC operating environments; and 2) xTM vehicles being allowed to continue xTM operations in areas that are normally under ATC management. These two interactions have commonalities across xTM operations in their procedures and are likely to be generalizable, as shown in the Appendix (Tables 1–4). In contrast, emergency and rare off-nominal events will likely need specialized procedures for each vehicle type that may be difficult to generalize (Tables 7–10 in the Appendix). In addition, the differences in the procedures were likely to be due to different vehicle characteristics and performance as much as the differences between the xTM operations. Due to the small size and segregated operations, UTM use cases and procedures seemed to have fewer commonalities with AAM/UAM and ETM operations in general. Finally, there are xTM-ATC interactions that result from non-xTM vehicles transiting through xTM-operating regions requiring ATC services but the xTM operations need to mature further and open questions need to be researched which will be needed to identify a likely set of use cases and the potential commonalities across them.

The results suggest a pathway to define a common method of handling and integrating diverse xTM operations into the NAS, while also identifying scenarios in which individualized handling is needed for the xTM vehicles. If common procedures can be identified early and used as guidance for the development of detailed procedures, roles and responsibilities, and potential tools / services for each xTM operation that will work consistently across all xTM operations, it will help the future integration of multiple xTM operations into overlapping operations with each other and with existing conventional air traffic, thereby enabling seamless integration of xTM operations into the future NAS.

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Appendix

Based on nominal, operational change, and off-nominal scenarios, ten xTM-ATC interaction use cases were created. Each use case includes narratives for the three xTM operation types (UTM, AAM/UAM, and ETM) – where ETM operations were further broken down into four different vehicle categories: a) balloons/airships, b) slow-speed, uncrewed HALE, c) fast-speed, uncrewed HALE, and d) fast-speed, crewed vehicles. Within each use case, step-by-step procedures were then developed for each xTM operation to document the procedures, roles / responsibilities, and data exchange requirements during the xTM-ATC interactions.

Each step-by-step procedure was synthesized across the three xTM operation types to identify **common procedures** – an example of a common procedure (from Table 1, Step 1) is that as part of pre-departure planning, xTM operators across *all* operations and vehicle types create a 4DT Operation Plan for their respective xTM-operating region. Any **exceptions** to those commonalities were also noted – an example of an exception to the common procedure (from Table 9, Step 3) is that all vehicles squawk a beacon code *except for sUAS vehicles in the UTM environment which are not equipped with ADS-B or a transponder.*

In this Appendix, we present the commonalities and exceptions for each procedural step in each of the ten use cases. Use cases are grouped by the following nominal, operational change, and off-nominal categories:

- Planned/coordinated entry/exit into and out of ATC-controlled airspace where the xTM vehicle traverses through the controlled airspace operating under normal ATC services.

Table 1	Planned entry (ascent) into an xTM-operating region.
Table 2	Planned entry (ascent) into an xTM-operating region with ATC intervention for traffic deconfliction.
Table 3	Planned exit (descent) from an xTM-operating region.
Table 4	Planned exit (descent) from an xTM-operating region with ATC intervention for traffic deconfliction.

- Operational changes where ATC coordinates the authorization of a new xTM-operating region or takes back control of an existing xTM-operating region from the xTM system.

Table 5	Conversion of ATC-controlled airspace into an xTM-operating region.
Table 6	Release of an xTM-operating region back to ATC-controlled airspace.

- Unplanned, off-nominal entry into ATC-controlled airspace where the xTM operation may not have adequate time to coordinate with ATC prior to entering controlled airspace and may have little to no control of where the xTM vehicle enters controlled airspace (e.g., equipment failure, lost link, or rerouting to avoid weather). In these use cases, ATC must take timely action in response to the xTM vehicle to ensure separation between conventional ATM aircraft and one or more xTM vehicles, increasing controller workload.

Table 7	Unplanned entry into ATC-controlled airspace requiring non-standard ATC procedures: xTM operation desires to land and end their mission.
Table 8	Unplanned entry into ATC-controlled airspace requiring non-standard ATC procedures: xTM operation desires to return to the xTM-operating region.
Table 9	Unplanned entry into ATC-controlled airspace requiring non-standard ATC procedures: xTM vehicle has lost command and control (C2) link, xTM Operator/Remote Pilot does not have control of vehicle.

Table 10	Unplanned entry of <u>many</u> xTM vehicles into ATC-controlled airspace requiring non-standard ATC procedures: Due to a SIGMET weather advisory.

Unless otherwise noted, each use case includes the following traffic management domains and vehicle types.

- **Upper Class E Traffic Management (ETM):**
    a) balloon/airship
    b) slow-speed, uncrewed HALE vehicle
    c) high-speed, uncrewed HALE vehicle
    d) high-speed, crewed HALE vehicle/business jet

- **Urban/Advanced Air Mobility (AAM/UAM):** electric Vertical Takeoff and Landing (eVTOL) vehicles

- **Unmanned Aircraft Systems (UAS) Traffic Management (UTM):** small UAS (sUAS)

In general, we use the term "**Operator**" to refer to the company/dispatcher who is responsible for the vehicle/planning and the terms remote-pilot-in-command ("**RPIC"**) or pilot-in-command ("**PIC**") to refer to the person piloting/controlling the vehicle/aircraft. However, for balloons/airships in the ETM domain and for sUAS in the UTM domain – where the Operator may also serve as the controlling entity – we merge these terms and refer to the "**Operator/RPIC**."

We use the following general terminology to collectively refer to third-party service suppliers:

- **xTM Operator service supplier:**
    - ETM: ETM Service Supplier (ESS)
    - AAM/UAM: Provider of Services for UAM (PSU)
    - UTM: UAS Service Supplier (USS)

- **xTM Network service supplier automation:**
    - ETM: ESS Network
    - AAM/UAM: PSU Network
    - UTM: USS Network

In general, we use the term "**xTM Operator service supplier"** to refer to a communication bridge between xTM operator and others in the xTM eco-system. xTM Operator service supplier provides tools / automation / services to monitor the airspace, execute safe missions, store operational data, etc. The term "**xTM Network service supplier automation"** is used to refer to network automation that connects multiple xTM operator service suppliers together to share information and provide a cooperative framework for the operators.

The xTM Network service supplier also provides a communication bridge to **Air Traffic Services (ATS),** which is a collection of tools / automation services that serve the conventional **Air Traffic Control (ATC)** system**.** In this document, the term **ATC** has been used to signify air traffic controllers and/or other human service providers who communicates directly with xTM vehicle Operator/RPIC/PIC.

We use the term **ATS** to signify beyond the official definition of ATS for tools / automation services that exchanges information with xTM Network service suppliers to relay the relevant xTM vehicle information to the ATC. We also use the term to refer to the broad air traffic system, including both automation and humans, who exchange air traffic information with both xTM and conventional air traffic system. The reason for expanding the definition was that we envisioned that communication exchanges that centered on human operators such as traffic management coordinators today may eventually be supplanted by ATS automation in the future interactions with xTM, but it was unclear if/when that could happen. Therefore, we described the ATS to handle these information exchanges and coordination, with an understanding that it may be done by the actual ATS or in conjunction with a human service provider.

Table 1. Planned ENTRY (ascent) into an xTM-operated region through ATC-controlled airspace without ATC intervention for traffic deconfliction.

☑ ETM ☑ AAM/UAM ☐ UTM* *Because sUAS operations are not expected to traverse ATC-controlled airspace during nominal operations, UTM was not included in this use case.		
Step	**Common Procedures**	**Exceptions**
1	**xTM Operation Plan** • The xTM Operator uses xTM Operator service supplier/xTM Network service supplier automation to create an initial 4DT Operation Plan (volume-based or trajectory-based, depending on vehicle type). • If needed, adjustments are made to the vehicle's entry time and location (methods may differ for ETM operations vs. UAM operations because of transit time and environment) to deconflict operations within the xTM-operating region. • Once deconflicted, the xTM Network service supplier approves the Operation Plan.	• No exceptions.
2	**Operator Provides Notification to ATS** • The xTM Operator notifies ATS of the intended operation and provides the required information x hours (depending on vehicle) prior to launch.	• Slow-speed HALE vehicles also request that ATC/Flight Service distribute a NOTAM (due to slow ascent rate). • UAM operations and business jets are not required to provide pre-flight notification to ATS prior to filing an IFR Flight Plan.
3	**ATS Reviews Notification** • ATS utilizes the notification information to evaluate the planned departure and, if necessary, notify the xTM Operator to alter their launch time/departure time/route (depending on vehicle type).	• UAM operations and business jets are not required to provide pre-flight notification to ATS prior to filing an IFR Flight Plan.
4	**ATS Provides Authorization** • ATS provides authorization in accordance with regulations.	• Each vehicle type may have specific authorization requirements (e.g., 14 CFR Part 101.33, Letters of Agreement (LOA)). • ATS does not provide pre-authorization to UAM operations or business jets. If needed, ATC amends the clearance in real time, like conventional aircraft.
5	**Flight Plan Filed** • The Operator files an IFR Flight Plan for ATC-controlled airspace to arrive at the boundary of the xTM-operating region to meet their Operation Plan.	• Balloon Operator does not file an IFR Flight Plan. Instead, they provide ATC with an "estimated flight path."
6	**Request Departure Clearance** • The Operator/RPIC/PIC (depending on vehicle type) requests departure clearance.	• Balloon Operator does not request a departure clearance from ATC. (Pre-flight coordination is done through ATS.)
7	**ATC Provides Departure Clearance** • ATC provides departure clearance.	• Balloon does not receive a departure clearance from ATC. (Pre-flight coordination done through ATS.)

8	**Operator/Pilot Executes Clearance** • The Operator/RPIC/PIC (depending on vehicle type) instructs the vehicle to depart, in accordance with their IFR clearance.	• Balloon launches based on coordination with ATS.
9	**ATC Separation Standards** • ATC maintains IFR separation from other aircraft.	• Balloon, airship, and slow-speed HALE vehicle: ATC manages traffic that is in proximity of the vehicle during ascent which may mean “vehicle-to-<u>volume</u>” separation (as opposed to “vehicle-to-vehicle” separation).
10	**Surveillance and Communication in ATC-Controlled Airspace** • The vehicle transmits via ADS-B and a transponder, in accordance with IFR procedures. • The Operator/RPIC/PIC (depending on vehicle type) communicates with ATC on standard frequencies.	• Balloons may transmit via ADS-B and/or transponder (may not apply to balloons under 12 lbs.). • Balloon Operators do not talk directly to Sector controllers (i.e., they are not on a radio frequency).
11	**Information on ATC Display** • For any area with radar coverage, a “tracked” target is displayed on the En Route ATC scope. • The flight datablock displays: Aircraft ID, aircraft altitude (assigned and current), ground speed, and computer ID.	• No exceptions.
12	**xTM Replanning in Nominal Scenario** • Depending on vehicle characteristics (transit time, susceptibility to wind, conformance window) xTM Operator service supplier may need to create a new Operation Plan to adjust entry time/location.	• No exceptions.
13	**Operator/RPIC/PIC Provides Notification to ATC/ATS** • The Operator/RPIC/PIC (depending on vehicle type) notifies ATC that they are nearing the xTM-operating region.	• Balloon notifies ATS when they are entering ETM-operating region.
14	**ATC Cancels IFR Clearance and Clears Operator/RPIC/PIC to Leave Frequency** • ATC acknowledges that the Operator/RPIC/PIC (depending on vehicle type) is nearing the xTM-operating region. • ATC cancels the IFR clearance. • ATC clears the Operator/RPIC/PIC (depending on vehicle type) to leave the frequency.	• Balloon does not have an IFR clearance and is not on the frequency.
15a	**Transition Complete** • Vehicle enters the xTM-operating region.	• No exceptions.
15b	**xTM Operations** • The xTM Operator/RPIC/PIC (depending on vehicle type) instructs the vehicle to fly the Operation Plan. • The xTM Operator service supplier/xTM Network service supplier automation monitors the vehicle’s conformance.	• No exceptions.

16	**Surveillance and Communication in xTM-Operating Region** • ETM vehicles continually broadcast using ADS-B.	• UAM vehicle disables ADS-B equipment.

Table 2. Planned ENTRY (ascent) into an xTM-operated region through ATC-controlled airspace with ATC intervention for traffic deconfliction.

☑ ETM ☑ AAM/UAM ☐ UTM* *Because sUAS operations are not expected to traverse ATC-controlled airspace during nominal operations, UTM was not included in this use case.		
Step	**Common Procedures**	**Exceptions**
1	**xTM Operation Plan** • The xTM Operator uses xTM Operator service supplier/xTM Network service supplier automation to create an initial 4DT Operation Plan (volume-based or trajectory-based, depending on vehicle type). • If needed, adjustments are made to the vehicle's entry time and location (methods may differ for ETM operations vs. UAM operations because of transit time and environment) to deconflict operations within the xTM-operating region. • Once deconflicted, the xTM Network service supplier approves the Operation Plan.	• No exceptions.
2	**Operator Provides Notification to ATS** • The xTM Operator notifies ATS of the intended operation and provides the required information x hours (depending on vehicle) prior to launch.	• Slow-speed HALE vehicles also request that ATC/Flight Service distribute a NOTAM (due to slow ascent rate). • UAM operations and business jets are not required to provide pre-flight notification to ATS prior to filing an IFR Flight Plan.
3	**ATS Reviews Notification** • ATS utilizes the notification information to evaluate the planned departure and, if necessary, notify the xTM Operator to alter their launch time/departure time/route (depending on vehicle type).	• UAM operations and business jets are not required to provide pre-flight notification to ATS prior to filing an IFR Flight Plan.
4	**ATS Provides Authorization** • ATS provides authorization in accordance with regulations.	• Each vehicle type may have specific authorization requirements (e.g., 14 CFR Part 101.33, Letters of Agreement (LOA)). • ATS does not provide pre-authorization to UAM operations or business jets. If needed, ATC amends the clearance in real time, like conventional aircraft.
5	**Flight Plan Filed** • The Operator files an IFR Flight Plan for ATC-controlled airspace to arrive at the boundary of the xTM-operating region to meet their Operation Plan.	• Balloon Operator does not file an IFR Flight Plan. Instead, they provide ATC with an "estimated flight path."
6	**Request Departure Clearance** • The Operator/RPIC/PIC (depending on vehicle type) requests departure clearance.	• Balloon Operator does not request a departure clearance from ATC. (Pre-flight coordination is done through ATS.)
7	**ATC Provides Departure Clearance** • ATC provides departure clearance.	• Balloon does not receive a departure clearance from ATC. (Pre-flight coordination done through ATS.)

8	**Operator/Pilot Executes Clearance** • The Operator/RPIC/PIC (depending on vehicle type) instructs the vehicle to depart, in accordance with their IFR clearance.	• Balloon launches based on coordination with ATS.
9	**ATC Separation Standards** • ATC maintains IFR separation from other aircraft.	• Balloon, airship, and slow-speed HALE vehicle: ATC manages traffic that is in proximity of the vehicle during ascent which may mean "vehicle-to-<u>volume</u>" separation (as opposed to "vehicle-to-vehicle" separation).
10	**Surveillance and Communication in ATC-Controlled Airspace** • The vehicle transmits via ADS-B and a transponder, in accordance with IFR procedures. • The Operator/RPIC/PIC (depending on vehicle type) communicates with ATC on standard frequencies.	• Balloons may transmit via ADS-B and/or transponder (may not apply to balloons under 12 lbs.). • Balloon Operators do not talk directly to Sector controllers (i.e., they are not on a radio frequency).
11	**Information on ATC Display** • For any area with radar coverage, a "tracked" target is displayed on the En Route ATC scope. • The flight datablock displays: Aircraft ID, aircraft altitude (assigned and current), ground speed, and computer ID.	• No exceptions.
12	**ATC Manages Traffic Conflict** • Depending on vehicle type/capabilities, ATC issues a revised clearance and instructs the vehicle to hold around a waypoint, amend the assigned altitude, or turn to avoid traffic.	• Due to vehicle control limitations, balloons and airships cannot hold during ascent. As a result, ATC vectors commercial traffic well clear of both the balloon and airship.
13	**Operator/Pilot Executes Clearance** • The RPIC/PIC (depending on vehicle type) acknowledges the clearance and instructs the vehicle per the new clearance.	• Balloons and airships do not change their ascent trajectory/clearance.
14	**ATC Resumes Flight Plan Clearance** • After the traffic passes, ATC issues the RPIC/PIC a new clearance to get them back on track to the xTM-operating region.	• Balloons and airships do not change their ascent trajectory/clearance.
15	**Operator/Pilot Resumes Flight Plan** • The Operator/RPIC/PIC (depending on vehicle type) instructs the vehicle to fly, in accordance with their IFR clearance.	• Balloons and airships do not change their ascent trajectory/clearance.
16	**xTM In-Flight Replanning Due to Altered Entry Time/Location** • Due to the revised clearance from ATC (depending on the vehicle), xTM Operator service supplier will need to replan the entry time/location and create a new Operation Plan.	• Although their ascent trajectory/IFR clearance is unchanged, given the balloons and airship's susceptibility to wind, long transit time, and conformance window, their Operation Plan may also require re-planning.
17	**xTM Receives New Entry Time/Location** • If necessary, the xTM Operator service supplier / xTM Network service supplier automation replans a new entry point and time that conforms to the vehicle's current trajectory.	• No exceptions.

	• xTM Network service supplier automation shares the new Operation Plan with the Operator/RPIC/PIC (depending on the vehicle) and ATS.	
18	**Coordination of New Flight Plan with ATC (if necessary)** • If the new Operation Plan requires a change to the current IFR Flight Plan, the Operator/RPIC/PIC (depending on the vehicle) verbally requests a change to the IFR Flight Plan to enable conformance to the xTM Operation Plan.	• Balloon Operator notifies ATS of any changes.
19	**Operator/RPIC/PIC Provides Notification to ATC/ATS** • The Operator/RPIC/PIC (depending on vehicle type) notifies ATC that they are nearing the xTM-operating region.	• Balloon Operator notifies ATS when they are entering the ETM-operating region.
20	**ATC Cancels IFR Clearance and Clears Operator/RPIC/PIC to Leave Frequency** • ATC acknowledges that the Operator/RPIC/PIC (depending on vehicle type) is nearing the xTM-operating region. • ATC cancels the IFR clearance. • ATC clears the Operator/RPIC/PIC (depending on vehicle type) to leave the frequency.	• Balloon does not have an IFR clearance and is not on the frequency.
21a	**Transition Complete** • Vehicle enters the xTM-operating region.	• No exceptions.
21b	**xTM Operations** • The xTM Operator/RPIC/PIC (depending on vehicle type) instructs the vehicle to fly the Operation Plan. • The xTM Operator service supplier/xTM Network service supplier automation monitors the vehicle’s conformance.	• No exceptions.
22	**Surveillance and Communication in xTM-Operating Region** • ETM vehicles continually broadcast using ADS-B.	• UAM vehicle disables ADS-B equipment.

Table 3. Planned <u>EXIT</u> (descent) from an xTM-operating region <u>without</u> ATC intervention for traffic deconfliction.

☑ ETM ☑ AAM/UAM ☐ UTM* *Because sUAS operations are not expected to traverse ATC-controlled airspace during nominal operations, UTM was not included in this use case.		
Step	**Common Procedures**	**Exceptions**
1	**Ending the xTM Operation Plan to EXIT the xTM-Operating Region** • The xTM Operator uses the xTM Operator service supplier/xTM Network service supplier automation to continuously update and coordinate the vehicle's operational intent conformance window (including time and location) to exit the xTM-operating region.	• No exceptions.
2	**Operator Provides Notification to ATS** • The xTM Operator notifies ATS of the intended operation and provides the required information x hours (depending on vehicle) prior to descent.	• Slow-speed HALE vehicles also request that ATC/Flight Service distribute a NOTAM (due to slow descent rate). • UAM operations and business jets are not required to provide pre-flight notification to ATS prior to filing an IFR Flight Plan.
3	**ATS Reviews Notification** • ATS utilizes the notification information to evaluate the planned descent and, if necessary, notify the xTM Operator to alter their exit point/exit time/route (depending on vehicle type).	• UAM operations and business jets are not required to provide pre-flight notification to ATS prior to filing an IFR Flight Plan.
4	**ATS Provides Authorization** • ATS provides authorization in accordance with regulations.	• Each vehicle type may have specific authorization requirements (e.g., 14 CFR Part 101.33, Letters of Agreement (LOA)). • ATS does not provide pre-authorization to UAM operations or business jets. If needed, ATC amends the clearance in real time, like conventional aircraft.
5	**Flight Plan Filed** • The Operator files an IFR Flight Plan for the portion of the flight operating in ATC-controlled airspace.	• The balloon Operator does not file an IFR Flight Plan or receive a clearance from ATC. Instead, they provide the balloon's proposed/projected descent plan to ATS.
6	**Operator/RPIC/PIC Requests IFR Clearance** • As the vehicle approaches the boundary of the xTM-operating region, the Operator/RPIC/PIC (depending on the vehicle) contacts the proper ATC sector and requests to "pick up" their IFR clearance to enter ATC-controlled airspace.	• Balloon does not request an IFR clearance from ATC. instead, ATS provides a discrete beacon code and permission to enter and operate in ATC-controlled airspace. • UAM vehicles also turn on their transponder and ADS-B Out.
7	**ATC Provides IFR Clearance** • ATC identifies the vehicle by assigning the discrete beacon code from the IFR Flight Plan and issues the IFR "pick up" clearance to the Operator/RPIC/PIC (depending on the vehicle).	• ATC scans for the balloon's discrete beacon code and, if observed, keeps everyone well clear of the balloon, to ensure no conflictions.
8a	**Transition Complete**	• No exceptions.

	• Vehicle enters the ATC-controlled airspace.	
8b	**Operator/Pilot Executes Clearance** • The Operator/RPIC/PIC (depending on vehicle type) instructs the vehicle to fly the assigned route and altitude, in accordance with their IFR clearance.	• Balloon does not receive a clearance, instead continues to provide ATS with its updated descent trajectory.
9	**ATC Separation Standards** • ATC maintains IFR separation from other aircraft.	• Balloon, airship, and slow-speed HALE vehicle: ATC manages traffic that is in proximity of the vehicle during descent which may mean "vehicle-to-volume" separation (as opposed to "vehicle-to-vehicle" separation).
10	**Surveillance and Communication in ATC-Controlled Airspace** • The vehicle transmits via ADS-B and a transponder, in accordance with IFR procedures. • The Operator/RPIC/PIC (depending on vehicle type) communicates with ATC on standard frequencies.	• Balloons may transmit via ADS-B and/or transponder (may not apply to balloons under 12 lbs.) • Balloon Operators do not talk directly to sector controllers (i.e., they are not on a radio frequency).
11	**Information on ATC Display** • For any area with radar coverage, a "tracked" target is displayed on the En Route ATC scope. • The flight datablock displays: Aircraft ID, aircraft altitude (assigned and current), ground speed, and computer ID.	• No exceptions.
12	**ATC Clears Vehicle for Approach** • As the vehicle nears its arrival airport, ATC clears the Operator/RPIC/PIC for the IFR (published) approach clearance (if applicable). • If there is not a published IFR Approach, ATC issues a minimum altitude for the flight to maintain until established on the approach.	• The balloon Operator continues to update ATS on the balloon's updated descent trajectory, information is shared with appropriate ATC sector(s) through which the balloon will descend.
13	**Operator/Pilot Acknowledges Approach Clearance** • The Operator/RPIC/PIC (depending on the vehicle) executes the approach clearance.	• No exceptions.
14	**ATC Clears Operator/Pilot to Contact the Tower** • If landing at a towered airport, ATC clears the Operator/RPIC/PIC (depending on the vehicle) to contact the tower.	• If landing at a non-towered airport, the Operator/RPIC/PIC is cleared to the Common Traffic Advisory Frequency (CTAF).
15	**Operator/Pilot Acknowledges Clearance** • If landing at a towered airport, the Operator/RPIC/PIC (depending on the vehicle) contacts the tower for clearance to land.	• Balloon does not have contact with ATC sectors or tower.
16	**Tower Clears Operator/Pilot to Land** • If landing at a towered airport, the tower issues the landing clearance. • The Operator/RPIC/PIC (depending on the vehicle) instructs the vehicle to land.	• Balloon does not have contact with ATC sectors or tower.
17	**ATC Cancels Flight Plan** • ATC cancels the IFR Flight Plan.	• Balloon does not file an IFR Flight Plan, therefore, the Operator notifies ATS when the balloon is on the ground.

Table 4. Planned <u>EXIT</u> (descent) from an xTM-operating region <u>with</u> ATC intervention for traffic deconfliction.

☑ ETM ☑ AAM/UAM ☐ UTM* *Because sUAS operations are not expected to traverse ATC-controlled airspace during nominal operations, UTM was not included in this use case.		
Step	**Common Procedures**	**Exceptions**
1	**Ending the xTM Operation Plan to EXIT the xTM-Operating Region** • The xTM Operator uses the xTM Operator service supplier/xTM Network service supplier automation to continuously update and coordinate the vehicle's operational intent conformance window (including time and location) to exit the xTM-operating region.	• No exceptions.
2	**Operator Provides Notification to ATS** • The xTM Operator notifies ATS of the intended operation and provides the required information x hours (depending on vehicle) prior to descent.	• Slow-speed HALE vehicles also request that ATC/Flight Service distribute a NOTAM (due to slow descent rate). • UAM operations and business jets are not required to provide pre-flight notification to ATS prior to filing an IFR Flight Plan.
3	**ATS Reviews Notification** • ATS utilizes the notification information to evaluate the planned descent and, if necessary, notify the xTM Operator to alter their exit point/exit time/route (depending on vehicle type).	• UAM operations and business jets are not required to provide pre-flight notification to ATS prior to filing an IFR Flight Plan.
4	**ATS Provides Authorization** • ATS provides authorization in accordance with regulations.	• Each vehicle type may have specific authorization requirements (e.g., 14 CFR Part 101.33, Letters of Agreement (LOA)). • ATS does not provide pre-authorization to UAM operations or business jets. If needed, ATC amends the clearance in real time, like conventional aircraft.
5	**Flight Plan Filed** • The Operator files an IFR Flight Plan for the portion of the flight operating in ATC-controlled airspace.	• The balloon Operator does not file an IFR Flight Plan or receive a clearance from ATC. Instead, they provide the balloon's proposed/projected descent plan to ATS.
6	**Operator/RPIC/PIC Requests IFR Clearance** • As the vehicle approaches the boundary of the xTM-operating region, the Operator/RPIC/PIC (depending on the vehicle) contacts the proper ATC sector and requests to "pick up" their IFR clearance to enter ATC-controlled airspace.	• Balloon does not request an IFR clearance from ATC. instead, ATS provides a discrete beacon code and permission to enter and operate in ATC-controlled airspace. • UAM vehicles also turn on their transponder and ADS-B Out.
7	**ATC Provides IFR Clearance** • ATC identifies the vehicle by assigning the discrete beacon code from the IFR Flight Plan and issues the IFR "pick up" clearance to the Operator/RPIC/PIC (depending on the vehicle).	• ATC scans for the balloon's discrete beacon code and, if observed, keeps everyone well clear of the balloon, to ensure no conflictions.

8a	**Transition Complete** • Vehicle enters the ATC-controlled airspace.	• No exceptions.
8b	**Operator/Pilot Executes Clearance** • The Operator/RPIC/PIC (depending on vehicle type) instructs the vehicle to fly the assigned route and altitude, in accordance with their IFR clearance.	• Balloon does not receive a clearance, instead continues to provide ATS with its updated descent trajectory.
9	**ATC Separation Standards** • ATC maintains IFR separation from other aircraft.	• Balloon, airship, and slow-speed HALE vehicle: ATC manages traffic that is in proximity of the vehicle during descent which may mean "vehicle-to-<u>volume</u>" separation (as opposed to "vehicle-to-vehicle" separation).
10	**Surveillance and Communication in ATC-Controlled Airspace** • The vehicle transmits via ADS-B and a transponder, in accordance with IFR procedures. • The Operator/RPIC/PIC (depending on vehicle type) communicates with ATC on standard frequencies.	• Balloons may transmit via ADS-B and/or transponder (may not apply to balloons under 12 lbs.) • Balloon Operators do not talk directly to sector controllers (i.e., they are not on a radio frequency).
11	**Information on ATC Display** • For any area with radar coverage, a "tracked" target is displayed on the En Route ATC scope. • The flight datablock displays: Aircraft ID, aircraft altitude (assigned and current), ground speed, and computer ID.	• No exceptions.
12	**ATC Manages Traffic Conflict** • Depending on vehicle type/capabilities, ATC issues a revised clearance to keep the xTM vehicle clear of conventional traffic.	• Due to vehicle control limitations, balloons/airships cannot hold during descent. As a result, ATC vectors conventional traffic well clear of both the balloon and airship.
13	**Operator/Pilot Executes Clearance** • The RPIC/PIC (depending on vehicle type) acknowledges the clearance and instructs the vehicle per the new clearance.	• Balloons/airships do not change descent trajectory/clearance.
14	**ATC Resumes Flight Plan Clearance** • After the traffic passes, ATC issues clearance instructions that enable the Operator/RPIC/PIC (depending on vehicle) to rejoin the original clearance.	• Balloons/airships do not change descent trajectory/clearance.
15	**Operator/Pilot Resumes Flight Plan** • The RPIC/PIC (depending on vehicle type) acknowledges the clearance and instructs the vehicle per the revised clearance.	• Balloons/airships do not change descent trajectory/clearance.
16	**ATC Clears Vehicle for Approach** • As the vehicle nears its arrival airport, ATC clears the Operator/RPIC/PIC for the IFR (published) approach clearance (if applicable). • If there is not a published IFR Approach, ATC issues a minimum altitude for the flight to maintain until established on the approach.	• The balloon Operator continues to update ATS on the balloon's updated descent trajectory, information is shared with appropriate ATC sector(s) through which the balloon will descend.
17	**Operator/Pilot Acknowledges Approach Clearance**	• No exceptions.

	• The Operator/RPIC/PIC (depending on the vehicle) executes the approach clearance.	
18	**ATC Clears Operator/Pilot to Contact the Tower** • If landing at a towered airport, ATC clears the Operator/RPIC/PIC (depending on the vehicle) to contact the tower.	• If landing at a non-towered airport, the Operator/RPIC/PIC is cleared to the Common Traffic Advisory Frequency (CTAF).
19	**Operator/Pilot Acknowledges Clearance** • If landing at a towered airport, the Operator/RPIC/PIC (depending on the vehicle) contacts the tower for clearance to land.	• Balloon does not have contact with ATC sectors or tower.
20	**Tower Clears Operator/Pilot to Land** • If landing at a towered airport, the tower issues the landing clearance. • The Operator/RPIC/PIC (depending on the vehicle) instructs the vehicle to land.	• Balloon does not have contact with ATC sectors or tower.
21	**ATC Cancels Flight Plan** • ATC cancels the IFR Flight Plan.	• Balloon does not file an IFR Flight Plan, therefore, the Operator notifies ATS when the balloon is on the ground.

Table 5. Planned conversion of ATC-controlled airspace into an xTM-operating region: ATC authorizes ATM airspace for xTM vehicle / xTM-operating needs.

☑ **ETM*** ☑ **AAM/UAM** ☑ **UTM** *In this use case, ETM does not include Supersonics, which may or may not operate as an ETM vehicle. They may continue to operate in ATC-controlled airspace, rather than flying through existing ETM-operating regions.		
Step	**Common Procedures**	**Exceptions**
1	**Operator Requests that ATS/ATC Convert Airspace into xTM-Operating Region** • The xTM Operator service supplier/xTM Network service supplier automation sends a request to ATS to authorize the use of an xTM-operating region for a specified number of hours. • May use a pre-coordinated process like the LAANC system for UTM.	• No exceptions.
2	**xTM Network Service Supplier Automation Coordinates with ATS** • xTM Network service supplier automation coordinates with ATS for the creation of a new xTM-operating region.	• No exceptions.
3	**ATS Coordinates with ATC Facility** • ATS determines which ATC facility controls the airspace along the requested airspace and coordinates with them to transfer operational control to xTM Network service supplier automation.	• No exceptions.
4	**Information Displayed to ATS/ATC** • Both ATS and ATC control facilities have access to mapping of the proposed xTM-operating region, including ATM traffic, if needed.	• No exceptions.
5	**ATC Provides Approval to ATS** • The ATC facility checks traffic predictions and provides approval to ATS for the transfer of operational control to xTM Network service supplier automation.	• No exceptions.
6	**ATS Authorizes ATM airspace as xTM-Operating Region** • ATS authorizes the transfer of operational control to xTM Network service supplier automation.	• No exceptions.
7	**ATS Issues NOTAMs** • ATS issues appropriate NOTAMs detailing airspace status changes.	• No exceptions.
8	**ATS Notifies xTM Network Automation of the Approval** • ATS notifies xTM Network service supplier automation that the xTM-operating region has been approved for usage.	• No exceptions.
9	**xTM Network Service Supplier Automation Reconfigures Airspace**	• No exceptions.

	• xTM Network service supplier automation reconfigures its cooperative volume to reflect the new xTM-operating region as eligible for use and monitoring.	
10	**xTM Network Service Supplier Automation Shares Information about New Airspace with xTM Operators** • xTM Network service supplier automation shares geographical and time information about the xTM-operating region with all xTM Operator service suppliers.	• No exceptions.
11	**xTM Network Service Supplier Automation Manages New xTM-Operating Region** • xTM Network service supplier automation is now overseeing the reconfigured xTM-operating region.	• No exceptions.
12	**Operator(s) Creates xTM Operation Plan** • Operators use xTM Operator service supplier to create a new Operation Plan and submit it to xTM Network service supplier automation for approval.	• No exceptions.
13	**xTM Network Service Supplier Automation Approves New Operation Plan** • Once deconflicted, xTM Network service supplier automation approves each Operation Plan.	• No exceptions.
14	**Information Displayed to ATC** • ATC displays the reconfigured xTM-operating region. • ATC separates traffic from the xTM-operating region.	• No exceptions.
15	**Operator/Pilot Executes xTM Operation Plan** • The Operator/RPIC/PIC (depending on vehicle) instructs their vehicle to fly the Operation Plan within the reconfigured xTM-operating region. • The xTM Operator service supplier/xTM Network service supplier automation monitors the vehicle's conformance.	• No exceptions.
16	**Surveillance and Communication in the xTM-Operating Region** • ETM vehicles continually broadcast using ADS-B.	• UAM and UTM vehicles do not broadcast via ADS-B when in UAM/UTM-operating regions.
17	**xTM Network Service Supplier Automation Notifies ATS that the xTM-Operating Region is Clear** • As the authorization for the reconfigured xTM-operating region comes to an end, the xTM Network service supplier automation notifies ATS that all vehicles are clear of the airspace.	• No exceptions.
18	**xTM Network Service Supplier Automation Deactivates** • xTM Network service supplier automation deactivates use of the xTM-operating region.	• No exceptions.
19	**ATS/ATC Resumes Operational Control of the Airspace**	• No exceptions.

	• ATS/ATC resumes operational control of the airspace.	

Table 6. Planned airspace authorization: Release of an xTM-operating region back to ATC-controlled airspace.

☑ **ETM*** ☑ **AAM/UAM** ☑ **UTM** *In this use case, the ETM categories for balloons/airships and high-speed, crewed, fixed-wing vehicles have comparable/analogous steps and are therefore not specifically addressed.		
Step	**Common Procedures**	**Exceptions**
1	**ARTCC Facility Notifies ATS** • An ARTCC (En Route) or TRACON facility (depending on the domain), notifies ATS that they need an xTM-operating region to be returned to ATC control.	• No exceptions.
2	**ATS Notifies xTM Network Service Supplier Automation** • ATS sends a notification to xTM Network service supplier automation that the xTM-operating region needs to be returned to ATC by a designated time.	• No exceptions.
3	**xTM Network Service Supplier Automation Notifies each Operator** • xTM Network service supplier automation notifies each xTM Operator service supplier that the xTM-operating region will no longer be available, and all vehicles must vacate by the designated time.	• No exceptions.
4	**Operators Determine Replan or Complete their Mission** • xTM Operators are expected to fly into another xTM-operating region if the flight has not landed due to a short mission duration.	• UAM and UTM operations complete their mission and land before the airspace change takes place. • ETM Operators with vehicles in the ETM-operating region decide to climb to stay in other active ETM-operating regions or continue their mission under ATC services.
5	**Operators Submit New Operation Plans** • Any operations that were planned in the now-deactivated xTM-operating region will need to replan. • Actual execution will depend on whether traffic is airborne or pre-departure.	• ETM Operators/RPICs use their xTM Operator service supplier to create a new 4DT Operation Plan for the ETM-operating region and submit their Operation Plan to xTM Network service supplier automation for coordination. • ETM Operators who wish to maintain their current flight plan or descend and terminate their mission must file an IFR Flight Plan or coordinate with ATS/ATC. • Airborne UAM and UTM operations are expected to complete their mission before the operating region is terminated. • UAM and UTM Operators/RPICs check the Operation Plans of all *proposed* flights to ensure they avoid the deactivated region. • Balloon Operators who wish to operate in ATC-controlled airspace must coordinate with ATS and get approval for the desired activity.
6	**xTM Network Service Supplier Automation Deconflicts and Approves the New Operation Plan**	• No exceptions.

	• xTM Network service supplier automation reviews all new Operation Plans and identifies any conflictions. • Once deconflicted, xTM Network service supplier automation returns an Operation Plan approval message to each xTM Operator service supplier.	
7	**Operator/ Pilot Executes xTM Operation Plan.** • The Operator/RPIC/PIC (depending on the vehicle) instructs their vehicle(s) to fly the Operation Plan within the xTM-operating region. • The xTM Operator service supplier/xTM Network service supplier automation monitors the vehicle's conformance.	• No exceptions.
8	**xTM Network Service Supplier Automation Notifies ATS that All Vehicles Have Vacated the Airspace** • Prior to the designated time, xTM Network service supplier automation notifies ATS that all vehicles have vacated the airspace.	• No exceptions.
9	**ATS/ATC Issues NOTAMs** • ATS/ATC issues NOTAMs as appropriate to inform traffic flow users of the airspace changes. In positive control airspace (PCA) NOTAMs, or other means, may be used to promulgate airspace status.	• No exceptions.
10	**ATS Notifies the ATC Facility that they have Control of the Airspace** • ATS notifies the ARTCC (En Route) or TRACON facility (depending on the domain) that they have control of the airspace.	• No exceptions.
11	**ATC Begins Utilizing Airspace** • An ARTCC (En Route) or TRACON facility (depending on the domain) begins utilizing the airspace.	• No exceptions.

Table 7. Unplanned entry into ATC-controlled airspace (e.g., equipment failure, low battery) requiring non-standard ATC procedures: xTM operation desires to land and end their mission.

☑ **ETM** ☑ **AAM/UAM** ☐ **UTM***		
*Given that UTM vehicles are expected to operate far from conventional aircraft, if the RPIC can maintain control of the UTM vehicle in a situation like this (e.g., equipment failure, low battery), it is not expected to make an unplanned intrusion into ATC-controlled airspace.		
Step	**Common Procedures**	**Exceptions**
1	**Standard Operations in xTM-Operating Region** • An xTM vehicle is operating in an xTM-operating region. • The xTM Operator service supplier/xTM Network service supplier automation monitors the vehicle's conformance.	• No exceptions.
2	**xTM Vehicle Equipment Failure is Identified – Requires the Vehicle to Land** • The Operator/RPIC/PIC (depending on vehicle) observes an equipment failure. After troubleshooting, or because of SOP, they decide they must land the vehicle and end their mission as soon as possible.	• No exceptions.
3	**Operator/RPIC/PIC Instructs Vehicle** • In order to land, the Operator/RPIC/PIC (depending on vehicle) intends to descend/divert out of the xTM-operating region and enter ATC-controlled airspace.	• No exceptions.
4	**xTM Network Service Supplier Automation Detects Deviation and Notifies ATS** • xTM Network service supplier automation detects non-conformance and notifies ATS that an xTM vehicle is deviating from its Operation Plan and will enter ATC-controlled airspace. • *However, that notification may not contain complete information (e.g., intent).	• No exceptions.
5a	**xTM Network Service Supplier Automation Coordinates with other xTM Operator Service Suppliers** • xTM Network service supplier automation informs each xTM Operator service supplier of any conflicts resulting from the vehicle's deviation.	• Within the ETM environment, this would trigger Cooperative Operating Practices (COPS).
5b	**Operator/RPIC/PIC Coordinates with their xTM Operator Service Supplier to Determine Diversion Plan** • Each Operator/RPIC/PIC (depending on vehicle) coordinates with their xTM Operator service supplier to determine where to divert (e.g., alternate or secondary airport).	• The slow-speed HALE vehicle's slow descent rate will require special consideration.
5c	**ATS Notifies the ATC Facility** • ATS advises the appropriate ATC facility that an xTM vehicle is descending/deviating from its Operation Plan and will enter ATC-controlled airspace.	• No exceptions.

	• *However, at this point, ATS may not have complete information to pass to the ATC facility.	
6a	**ATC Manager Notifies Appropriate Sector** • The ATC facility (via automation or manually) provides the information they received from ATS to the appropriate sector(s). • *However, at this point, ATC may not have complete information to pass to the sector(s).	• No exceptions.
6b	**ATS Acknowledges Notification** • ATS sends an acknowledgement of xTM Network service supplier automation's notification back to xTM Network service supplier automation.	• No exceptions.
6c	**ATC Controller Protects Airspace and Manages Traffic** • ATC sectors protect for imminent xTM vehicle incursion as necessary. This may require moving other traffic and using larger buffers than standard separation.	• No exceptions.
7a	**Operator/RPIC/PIC Squawks 7700 and makes the Initial Call to ATS/ATC** • The Operator/RPIC/PIC (depending on vehicle) switches beacon code to 7700 (to indicate an emergency, when appropriate) and initiates verbal contact with ATC to notify them of the emergency and desire to land immediately. • Note: Operator/RPIC should have knowledge of the airspace and related contact information. If they don't have contact information, the xTM Operator service supplier could forward the information.	• The UAM RPIC/PIC must <u>first</u> enable the vehicle's ADS-B and transponder. • Balloon Operator does not make radio contact with ATC sectors, they coordinate with ATC/ATS via other methods (phone, etc.)
7b	**xTM Operator Service Supplier Provides Proposed IFR Flight Plan** • The Operator (possibly done through their xTM Operator service supplier) provides the new, proposed IFR Flight Plan for the alternate airport to the Operator/RPIC/PIC (depending on the vehicle) and ATS/ATC.	• Balloon Operator does not file an IFR Flight Plan. Instead, the Operator provides the balloon's proposed/projected plan to ATS.
8	**ATC Establishes Positive Radar Contact / ATC Responds to the Initial Call and Receives Provisional Information (if necessary)** • ATC responds to the initial call from the Operator/RPIC/PIC (depending on vehicle). • ATC observes the 7700 beacon code, instructs the Operator/RPIC/PIC to IDENT, and verifies radar contact. (*ATC may already have the flight's IFR Flight Plan in ERAM at this time.) • *If ATC does not yet have the current IFR Flight Plan from the Operator, ATC asks the Operator/RPIC/PIC to provide additional information.	• Balloon Operator does not make radio contact with ATC sectors, they coordinate with ATC/ATS via other methods (phone, etc.) • Balloon Operator does not file an IFR Flight Plan. Instead, the Operator provides the balloon's proposed/projected plan to ATS.

9	**ATC Provides IFR Clearance** • ATC surveys traffic to ensure no conflictions and issues the IFR clearance to the Operator/RPIC/PIC (depending on the vehicle).	• Balloon does not receive an IFR clearance; ATC keeps other traffic well clear of the balloon, to ensure no conflictions.
10	**ATC Notifies Supervisor and Other ATC Sectors** • In case of an emergency, ATC notifies their supervisor that they have a vehicle that desires to land immediately and notifies all appropriate sectors.	• No exceptions.
11	**Operator/Pilot Executes Clearance** • The Operator/RPIC/PIC (depending on the vehicle) instructs the vehicle to fly the assigned route and altitude, in accordance with the IFR clearance.	• Balloon does not receive an IFR clearance; instead provides ATS with updated trajectory.
12	**ATC Separation Standards** • ATC maintains IFR separation from other aircraft and moves other traffic as necessary to accommodate the emergency.	• Balloon, airship, and slow-speed HALE vehicle: ATC manages traffic that is in proximity of the vehicle during descent which may mean “vehicle-to-volume” separation (as opposed to “vehicle-to-vehicle” separation).
13	**ATC Clears Vehicle for Approach** • As the vehicle nears its arrival airport, ATC clears the Operator/RPIC/PIC for the IFR (published) approach clearance (if applicable). • If there is not a published IFR Approach, ATC issues a minimum altitude for the flight to maintain until established on the approach.	• The balloon Operator continues to update ATS on the balloon’s updated descent trajectory, information is shared with appropriate ATC sector(s) through which the balloon will descend.
14	**Operator/Pilot Acknowledges Approach Clearance** • The Operator/RPIC/PIC (depending on the vehicle) executes the IFR (published) approach clearance (if applicable).	• Balloon does not receive an approach clearance.
15	**ATC Clears Operator/Pilot to Contact the Tower** • ATC clears the Operator/RPIC/PIC (depending on the vehicle) to contact the tower.	• Balloon does not contact a tower (non-towered landing site).
16	**Operator/Pilot Acknowledges Clearance** • The Operator/RPIC/PIC (depending on the vehicle) contacts the tower for clearance to land.	• Balloon does not receive a landing clearance (non-towered landing site).
17	**Tower Clears Operator/Pilot to Land** • The tower issues a landing clearance, and the Operator/RPIC/PIC (depending on the vehicle) instructs the vehicle to land.	• Balloon does not receive a landing clearance (non-towered landing site). • The balloon envelope and payload separate, and each section deploys a parachute for soft landing.
18	**ATC Cancels Flight Plan** • ATC cancels the IFR Flight Plan.	• Balloon does not file an IFR Flight Plan, therefore, the Operator notifies ATS when the balloon is on the ground.

Table 8. Unplanned entry into ATC-controlled airspace (e.g., faulty control sensor) requiring non-standard ATC procedures: xTM operation desires to return to the xTM-operating region.

☑ ETM ☑ AAM/UAM ☐ UTM* *Given that UTM vehicles are expected to operate far from conventional aircraft, if the RPIC can maintain control of the UTM vehicle in a situation like this (e.g., faulty control sensor), it is not expected to make an unplanned intrusion into ATC-controlled airspace.		
Step	**Common Procedures**	**Exceptions**
1	**Standard Operations in xTM-Operating Region** • An xTM vehicle is operating in an xTM-operating region. • The xTM Operator service supplier / xTM Network service supplier automation monitors the vehicle's conformance.	• No exceptions.
2	**xTM Vehicle Equipment/Environmental Issue is Identified / Issue Resolved and Request to Re-enter xTM-Operating Region** • The Operator/RPIC/PIC (depending on vehicle) observes an equipment issue and begins troubleshooting the problem. • The xTM vehicle may enter ATC-controlled airspace before they fully coordinate with ATC. • The Operator/RPIC/PIC prefers to return to the xTM-operating region to continue their mission.	• No exceptions.
3	**xTM Network Service Supplier Automation Detects Deviation and Notifies ATS** • xTM Network service supplier automation detects non-conformance and notifies ATS that an xTM vehicle is deviating from its Operation Plan and will enter ATC-controlled airspace. • *However, that notification may not contain complete information (e.g., intent).	• No exceptions.
4a	**xTM Network Service Supplier Automation Coordinates with other xTM Operator Service Suppliers** • xTM Network service supplier automation informs all xTM Operator service suppliers of any conflicts resulting from the vehicle's deviation.	• Within the ETM environment, this would trigger Cooperative Operating Practices (COPS).
4b	**ATS Notifies the ATC Facility** • ATS advises the appropriate ATC facility that an xTM vehicle is deviating from its Operation Plan and will enter ATC-controlled airspace. • *However, at this point, ATS may not have complete information to pass to the ATC facility.	• No exceptions.
5a	**ATC Manager Notifies Appropriate Sector** • The ATC facility (via automation or manually) provides the information they received from ATS to the appropriate sector(s).	• No exceptions.

	• *However, at this point, ATC may not have complete information to pass to the sector(s).	
5b	**ATS Acknowledges Notification** • ATS sends an acknowledgement of xTM Network service supplier automation's notification back to xTM Network service supplier automation.	• No exceptions.
5c	**ATC Controller Protects Airspace and Manages Traffic** • ATC sectors protect for imminent xTM vehicle incursion as necessary. This may require moving other traffic and using larger buffers than standard separation.	• No exceptions.
5d	**Surveillance and Communication in ATC-Controlled Airspace** • xTM vehicles continually broadcast using ADS-B/transponder.	• The UAM RPIC/PIC must enable the vehicle's ADS-B and transponder prior to entering ATC airspace.
6	**Operator/RPIC/PIC makes the Initial Call to ATS/ATC** • The Operator/RPIC/PIC (depending on the vehicle) initiates verbal contact with ATS/ATC to notify them of the situation. • The Operator/RPIC/PIC states their approximate position and altitude, and that they are troubleshooting the problem. • Note: Operator/RPIC should have knowledge of the airspace and related contact information. If they don't have contact information, the xTM Operator service supplier could forward the information.	• Balloon Operator does not make radio contact with ATC sectors, they coordinate with ATC/ATS via other methods (phone, etc.)
7	**ATC Establishes Positive Radar Contact** • ATC identifies the proper target via the assignment of a discrete beacon code and verifies radar contact. • ATC asks the Operator/RPIC/PIC (depending on the vehicle) if they need any support and to advise them of their intention as soon as they can.	• Balloon Operator does not make radio contact with ATC sectors, they coordinate with ATC/ATS via other methods (phone, etc.)
8	**Operator/RPIC/PIC Troubleshoots and Repairs the Issue, and Requests to Return to xTM-Operating Region** • The Operator/RPIC/PIC (depending on the vehicle) squawks the assigned beacon code, continues troubleshooting procedures, and determines the issue can be repaired. • They intend to return to the xTM-operating region as soon as possible.	• No exceptions.
9a	**Operator Coordinates with xTM Operator Service Supplier for New Operation Plan** • The Operator/RPIC/PIC (depending on the vehicle) coordinates with their xTM Operator service supplier to build a new Operation Plan to reenter and operate within xTM-operating region.	• If there are any conflicts within the ETM environment, this would trigger Cooperative Operating Practices (COPS).

	• The xTM Operator service supplier plans with xTM Network service supplier automation for an entry point and time that conforms to the current position/trajectory and is conflict free in the xTM-operating region. • xTM Network service supplier automation provides the approval to the xTM Operator service supplier. • *If there is a conflict, the Operator/RPIC/PIC would adjust their reentry point or time and coordinate again with xTM Network service supplier automation.	
9b	**xTM Operator Service Supplier Provides Proposed IFR Flight Plan** • The Operator (possibly done through their xTM Operator service supplier) provides the new, proposed IFR Flight Plan to the Operator/RPIC/PIC (depending on the vehicle), xTM Network service supplier automation, and ATS/ATC.	• Balloon Operator does not file an IFR Flight Plan or receive a clearance from ATC. Instead, they provide the balloon's proposed/projected plan to ATC.
9c	**Operator/RPIC/PIC calls ATC to Coordinate Reentry Into xTM** • The Operator/RPIC/PIC (depending on the vehicle) calls ATC to request a clearance to return to the xTM-operating region. • Note: If reentry into the xTM-operating region is delayed by replanning/deconflicting – causing the xTM vehicle to spend additional time in ATC-controlled airspace – ATC workload is increased due to providing holding or other instructions to the xTM vehicle and separating them from ATM traffic.	• Balloon Operator requests permission through ATS/ATC instead of requesting an IFR clearance.
10	**ATC Responds to the Call and Provides IFR Clearance** • ATC responds to the Operator/RPIC/PIC (depending on the vehicle) request for clearance, scans for traffic, and issues an IFR clearance with a heading to fly and altitude to climb to that will return the vehicle back to the xTM-operating region.	• Balloon: ATS/ATC approves the requested altitude.
11	**ATC Notifies Supervisor and Other ATC Sectors** • ATC notifies their supervisor that the vehicle is going back into the xTM-operating region.	• No exceptions.
12	**Operator/Pilot Executes Clearance** • Each Operator/RPIC/PIC (depending on vehicle type) instructs the vehicle to fly the assigned route and altitude, in accordance with their IFR clearance.	• Balloon does not receive clearance, instead continues to provide ATS with its updated ascent trajectory.
13	**ATC Separation Standards** • ATC maintains IFR separation from other aircraft.	• Balloon, airship, and slow-speed HALE vehicle: ATC manages traffic that is in proximity of the vehicle during descent which may mean "vehicle-to-volume" separation (as opposed to "vehicle-to-vehicle" separation).

14	**Operator/RPIC/PIC Provides Notification to ATC/ATS** • The Operator/RPIC/PIC (depending on vehicle type) notifies ATC that they are nearing the xTM-operating region.	• Balloon Operator notifies ATS when they are entering the ETM-operating region.
15	**ATC Cancels IFR Clearance and Clears Operator/RPIC/PIC to Leave Frequency** • ATC acknowledges that the Operator/RPIC/PIC (depending on vehicle type) is nearing the xTM-operating region. • ATC cancels the IFR clearance. • ATC clears the Operator/RPIC/PIC (depending on vehicle type) to leave the frequency.	• Balloon does not have an IFR clearance and is not on the frequency.
16a	**Transition Complete** • Vehicle enters the xTM-operating region.	• No exceptions.
16b	**xTM Operations** • The xTM Operator/RPIC/PIC (depending on vehicle type) instructs the vehicle to fly the Operation Plan. • The xTM Operator service supplier/xTM Network service supplier automation monitors the vehicle's conformance.	• No exceptions.
17	**Surveillance and Communication in xTM-Operating Region** • xTM vehicles broadcast using ADS-B while in the xTM-operating region.	• UAM vehicle disables ADS-B equipment.

Table 9. Unplanned entry into ATC-controlled airspace requiring non-standard ATC procedures: xTM vehicle has lost command and control (C2) link, xTM Operator/RPIC does not have control of vehicle.

☑ **ETM** ☑ **AAM/UAM** ☑ **UTM*** *UTM in 1) ATC-controlled airspace and 2) uncontrolled airspace are both considered in this use case.		
Step	**Common Procedures**	**Exceptions**
1	**Standard Operations in xTM-Operating Region** • An xTM vehicle is operating in an xTM-operating region. • The xTM Operator service supplier/xTM Network service supplier automation monitors the vehicle's conformance.	• No exceptions.
2	**Loss of C2 Link** • The command and control (C2) link between the ground station and the vehicle is lost.	• Crewed UAM flights, supersonic, and business jets would not be subject to C2 losses.
3	**Vehicle Executes its Lost C2 Link Contingency Procedures** • After a predetermined amount of time with lost link, the vehicle defaults to its pre-programmed lost C2 link contingency procedure (e.g., return to base or land at the nearest airport). • The vehicle switches its beacon code to 7400 (per lost link protocol).	• UAM vehicles first need to enable their ADS-B/transponder. This would have to be automated on board vehicle. • sUAS vehicles are not equipped with an ADS-B/transponder.
4	**Operator/RPIC Continues to Receive Position Information** • The Operator/RPIC/PIC (depending on the vehicle) continues to receive vehicle telemetry information through ADS-B.	• sUAS vehicles are not equipped with an ADS-B/transponder.
5	**Last Known Position on Course for ATC-Controlled Airspace** • The flight is out of conformance with their Operation Plan and the last position and course indicate that the vehicle will fly into ATC-controlled airspace (or uncontrolled Class G airspace).	• No exceptions.
6a	**xTM Network Service Supplier Automation Detects Deviation and Notifies ATS** • xTM Network service supplier automation or the xTM Operator service supplier detects non-conformance – the vehicle is deviating from its Operation Plan. • The xTM Network service supplier automation notifies the xTM Operator service supplier and ATS that an xTM vehicle will enter ATC-controlled airspace.	• No exceptions.
6b	**Attempt to Reestablish the C2 Link is Unsuccessful**	• No exceptions.

	• The Operator/RPIC/PIC (depending on the vehicle) determines that the xTM vehicle is not responding to commands and has lost C2 link. • The Operator/RPIC/PIC attempts to re-establish the C2 link but is unable.	
7a	**xTM Network Service Supplier Automation Coordinates with other xTM Operator Service Suppliers** • xTM Network service supplier automation informs each xTM Operator service supplier of any conflicts resulting from the vehicle's deviation.	• Within the ETM environment, this would trigger Cooperative Operating Practices (COPS).
7b	**Operator/RPIC Notifies the xTM Network Service Supplier Automation** • The Operator/RPIC/PIC (depending on the vehicle) notifies xTM Network service supplier automation and ATS that the flight has lost C2 link and is executing its lost link contingency procedure.	• The slow-speed HALE vehicle's slow descent rate will require special consideration.
7c	**ATS Notifies the ATC Facility** • ATS advises the appropriate ATC facility that an xTM vehicle is now navigating according to its pre-programmed lost link contingency procedure and has/will enter ATC-controlled airspace.	• UTM (Uncontrolled Airspace): ATS/ATC develops and issues an advisory for VFR aircraft in the vicinity of the UA/sUA.
8a	**ATS Acknowledges Notification** • ATS sends acknowledgements of all notifications to xTM Network service supplier automation.	• No exceptions.
8b	**ATC Manager Notifies Appropriate Sector** • The ATC facility (via automation or manually) provides the information they received from ATS – that an xTM vehicle is now navigating according to its pre-programmed lost link contingency procedure and will enter ATC-controlled airspace – to the appropriate sector(s).	• UTM (Uncontrolled airspace): Not applicable to ATC.
8c	**ATC Controller Protects Airspace and Manages Traffic** • ATC sectors protect for imminent xTM vehicle incursion as necessary. This may require moving other traffic and using larger buffers than standard separation.	• UTM (Uncontrolled airspace): Not applicable to ATC. The RPIC uses any available technology to detect and avoid.
9	**Operator/RPIC Calls ATC** • The Operator/RPIC (depending on the vehicle) contacts ATC and informs them that the vehicle is now navigating according to its pre-programmed lost C2 link contingency procedure. • Note: Operator/RPIC should have knowledge of the airspace and related contact information. If they don't have contact information, the xTM Operator service supplier could forward the information.	• UTM (Uncontrolled airspace): Not applicable to ATC. There should be some notification to VFR aircraft of UAS known lost link routing if possible and relevant.

10	**ATC Establishes Positive Radar Contact** • ATC acknowledges, observes the 7400 beacon code and verifies radar contact.	• sUAS vehicles are not equipped with ADS-B/transponder.
11	**ATC Separation Standards** • ATC maintains safe separation from other aircraft and moves other traffic as necessary to accommodate the vehicle's lost C2 link contingency procedure.	• UTM (Controlled Airspace): UTM infrastructure provides an area of airspace to protect as radar identification is unlikely. • UTM (Uncontrolled airspace): Not applicable to ATC.
12	**ATC Notifies Supervisor and Other ATC Sectors** • ATC notifies their supervisor that they have identified the lost link vehicle and coordinates with other ATC sectors/facilities.	• UTM (Controlled Airspace): No radar contact. • UTM (Uncontrolled airspace): Not applicable to ATC.
13	**ATC Monitors Descent and Coordinates to the Ground** • ATC will provide IFR separation to the xTM vehicle until it lands, is cleared to land, or enters uncontrolled Class G airspace (depending on the vehicle).	• UTM (Controlled Airspace): ATC will protect the potential operating area of the UA/sUA until notified that the vehicle is no longer a factor. • UTM (Uncontrolled airspace): Not applicable to ATC.
14	**Operator Confirms Vehicle on the Ground and ATC Cancels the Flight Plan** • The Operator/RPIC (depending on the vehicle) advises ATS that the xTM vehicle is on the ground.	• UTM (Uncontrolled airspace): Not applicable to ATC.

Table 10. Unplanned entry of many xTM vehicles into ATC-controlled airspace requiring non-standard ATC procedures: Due to a SIGMET weather advisory.

☑ **ETM** ☑ **AAM/UAM** ☐ **UTM*** *Because sUAS operations below 400 feet are not expected to enter ATC-controlled airspace, UTM was not included in this use case.		
Step	**Common Procedures**	**Exceptions**
1	**Standard Operations in xTM-Operating Region** • Multiple xTM vehicles are operating in an xTM-operating region. • The xTM Operator service suppliers/xTM Network service supplier automation monitors the vehicle's conformance.	• No exceptions.
2	**Significant Weather Event Requires that Many Vehicles Exit the xTM-Operating Region** • Each xTM Operator service supplier receives a SIGMET from the FAA for a large thunderstorm affecting numerous airborne flights in the region. • Each xTM Operator service supplier locates the weather cell on radar and determines the flight cannot complete its intended mission within the xTM-operating region.	• No exceptions.
3	**xTM Operator Service Supplier Notifies the Operator/RPIC/PIC of the need to vacate the xTM-operating region.** • xTM Operator service supplier determines that the vehicle will need to utilize ATC-controlled airspace and notifies the Operator/RPIC/PIC (depending on the vehicle). • xTM Operator service suppliers with a pre-departure flight along the impacted route halt the flight prior to takeoff.	• No exceptions.
4a	**Operator/RPIC/PIC Coordinates with xTM Operator Service Supplier to Submit a New Operation Plan to Exit the xTM-Operating Region** • Each Operator/RPIC/PIC (depending on the vehicle) uses their xTM Operator service supplier to develop an Operation Plan to exit the xTM-operating region and submits the new Operation Plan to xTM Network service supplier automation to ensure de-confliction.	• The new Operation Plan takes each UAM flight to a holding point in the UAM Corridor/UOE where they may hover, if necessary, while awaiting the IFR clearance from ATC.
4b	**xTM Network Service Supplier Automation Coordinates with all xTM Operator Service Suppliers to Resolve any Conflicts** • xTM Network service supplier automation informs the xTM Operator service supplier of any conflicts resulting from the vehicle's new Operation Plan. If any are detected, they would de-conflict from each other.	• Within the ETM environment, this would trigger Cooperative Operating Practices (COPS).

4c	**xTM Network Service Supplier Automation Coordinates with ATS that Many xTM Flights will be Requesting Clearance into ATC Airspace** • xTM Network service supplier automation notifies ATS that multiple xTM vehicles are deviating from their Operation Plan for weather avoidance and will enter ATC-controlled airspace.	• The slow-speed HALE vehicle's slow descent rate will require special consideration.
5a	**ATS Notifies the ATC Facility** • ATS advises the appropriate ATC facility that multiple xTM vehicles are descending/deviating from its Operation Plan and will enter ATC-controlled airspace. • *However, at this point, ATS may not have complete information to pass to the ATC facility.	• No exceptions.
5b	**Each xTM Operator Service Supplier Submits an IFR Flight Plan to ATS** • Each Operator (possibly done through their xTM Operator service supplier) provides the new, proposed IFR Flight Plan to the Operator/RPIC/PIC (depending on the vehicle) and ATS.	• The balloon Operator does not file an IFR Flight Plan or receive a clearance from ATC. Instead, they provide the balloon's proposed/projected plan for proceeding to a secondary/landing area to ATS.
6a	**ATC Manager Notifies Appropriate Sector(s)** • The ATC facility (via automation or manually) provides the information they received from ATS to the appropriate sector(s). • *However, at this point, ATC may not have complete information to pass to the sector(s).	• No exceptions.
6b	**ATS Acknowledges Notification** • ATS sends an acknowledgement of the xTM Network service supplier automation's notification back to xTM Network service supplier automation.	• No exceptions.
6c	**ATC Controller Protects Airspace and Manages Traffic** • ATC sectors protect for imminent xTM vehicle incursion as necessary. This may require moving other traffic and using larger buffers than standard separation. • *However, at this point, ATC may not have complete information to pass to the sector(s).	• No exceptions.
6d	**Each xTM Operator Service Supplier Instructs the Operator/RPIC/PIC to Execute the New Operation Plan** • xTM Operator service supplier coordinates with the Operator/RPIC/PIC (depending on the vehicle) so that all vehicles in the xTM-operating region initiate their new Operation Plan. • Note: Operator/RPIC should have knowledge of the airspace and related contact information. If they don't have contact information, the xTM Operator service supplier could forward the information.	• No exceptions.

7a	**Each Operator/RPIC/PIC Executes their New Operation Plan to Exit the xTM-Operating Region** • Each Operator/RPIC/PIC (depending on the vehicle) executes the new routing to exit the xTM-operating region.	• UAM: Each RPIC/PIC instructs the UAM vehicle to turn on the ADS-B Out and transponder.
7b	**Each Operator/RPIC/PIC Contacts ATC and Requests IFR Clearance** • Each Operator/RPIC/PIC (depending on the vehicle) contacts ATC on the proper frequency and requests to "pick up" their IFR clearance to enter ATC-controlled airspace.	• Balloon Operator does not request an IFR clearance from ATC. instead, ATS provides a discrete beacon code and permission to enter and operate in ATC-controlled airspace.
8	**ATC Establishes Positive Radar Contact and Issues IFR Clearance** • ATC responds to the initial call from each Operator/RPIC/PIC (depending on vehicle). • If ATC has radar coverage, they instruct each Operator/RPIC/PIC to IDENT and verify radar contact and altitude.	• ATC scans for the balloons' discrete beacon codes and, if observed, keeps everyone well clear of the balloons, to ensure no conflictions.
9	**Each Operator/RPIC/PIC Acknowledges and Executes the ATC Clearance** • Each Operator/RPIC/PIC (depending on vehicle type) instructs the vehicle to fly the assigned route and altitude, in accordance with their IFR clearance.	• Balloon does not receive a clearance, instead continues to provide ATS with its updated descent trajectory.
10	**ATC Separation Standards** • ATC maintains IFR separation from other aircraft.	• Balloon, airship, and slow-speed HALE vehicle: ATC manages traffic that is in proximity of the vehicle during descent which may mean "vehicle-to-volume" separation (as opposed to "vehicle-to-vehicle" separation).
11	**ATC Clears Vehicle for Approach** • As the vehicle nears its arrival airport, ATC clears the Operator/RPIC/PIC for the IFR (published) approach clearance (if applicable). • If there is not a published IFR Approach, ATC issues a minimum altitude for the flight to maintain until established on the approach.	• The balloon Operator continues to update ATS on the balloon's updated descent trajectory, information is shared with appropriate ATC sector(s) through which the balloon will descend.
12	**Operator/Pilot Acknowledges Approach Clearance** • The Operator/RPIC/PIC (depending on the vehicle) executes the approach clearance (applies to airship and slow-speed HALE vehicle if they are landing at a towered airport).	• Balloon does not receive an approach clearance.
13	**ATC Clears Operator/Pilot to Contact the Tower** • If landing at a towered airport, ATC clears each Operator/RPIC/PIC (depending on the vehicle) to contact the tower.	• Balloon lands at a non-towered landing site, does not contact a tower.
14	**Operator/Pilot Acknowledges Clearance** • If landing at a towered airport, each Operator/RPIC/PIC (depending on the vehicle) contacts the tower for clearance to land.	• Balloon lands at a non-towered landing site, does not contact a tower.
15	**Tower Clears Operator/Pilot to Land** • If landing at a towered airport, the tower issues the landing clearance to each vehicle.	• Balloon lands at a non-towered landing site, does not contact a tower or receive a landing clearance.

	• Each Operator/RPIC/PIC (depending on the vehicle) instructs the vehicle to land.	• Balloon envelope and payload separate, and each deploys a parachute for soft landing.
16	**ATC Cancels Flight Plan** • ATC cancels each IFR Flight Plan.	• Balloon does not file an IFR Flight Plan, therefore, each Operator notifies ATS when their balloon is on the ground.