Identifying Information Needs and Tools to Support Interactions between Upper Class E Traffic Management (ETM) Operations and the Air Traffic System (ATS)

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With the introduction of high-altitude long endurance (HALE) vehicles and balloons designed to operate above 60,000 feet, the frequency and duration of operations in Upper Class E airspace are expected to increase. In response to the need for scalable traffic management for these diverse operations at higher altitudes, the FAA introduced the Upper Class E Traffic Management (ETM) concept. Like the successful demonstration of Uncrewed Aircraft System (UAS) Traffic Management (UTM), the ETM concept is also designed as a community-based, industry-driven cooperative approach to traffic management. As these vehicles and balloons ascend to/descend from ETM Cooperative Areas in Upper Class E, they will transit through Class A controlled airspace where they will interact with various entities of the conventional Air Traffic System (ATS) (e.g., Air Traffic Control (ATC)). This work explores tools that will help support ETM-ATS interactions for users throughout the ATS, as well as ETM Operators. An information needs analysis using ETM-ATS interaction use cases, revealed that the needed functionalities generally grouped themselves into two main themes, the visualization of flights and airspace designations, and digital communication capabilities across various human users. In this paper, we describe two envisioned tools, 1) an Integrated Visualization Tool to display flight information and airspace designations, and 2) an Integrated Digital Communication Tool to facilitate two-way information exchange between users about vehicle position information, the coordination of airspace approvals, and notifications. The tools we describe create an integrated visual representation of vehicles and airspace designations with a set of communication capabilities to consolidate information into a single display interface. These tools may be used to guide the development of prototype tools for demonstrations at the National Aeronautics and Space Administration (NASA) Ames Research Center to further explore ETM-ATS interactions within the ETM concept.

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I. Introduction

New and innovative vehicles, designed to operate above 60,000 ft (Flight Level (FL) 600), include a variety of uncrewed, high-altitude long endurance (HALE) vehicles and balloons with a wide range of performance capabilities and mission profiles. These vehicles are expected to utilize the airspace in the stratosphere, above FL600, known as Upper Class E, to provide telecommunications services, internet connectivity, and earth observation [1]. While Upper Class E has primarily been used by military operations, it is regarded as an underutilized airspace as civil operations generally have not operated above FL600 [2].

As the development of these vehicles evolves and the market demand for their services continues, the frequency and duration of HALE operations in Upper Class E are expected to increase [1,3,4]. However, the current air traffic management (ATM) system is not able to support operations in the Upper Class E environment at scale and operations like these may not be suited to conventional Air Traffic Control (ATC)-managed separation services. As a result, a new form of traffic management is needed to safely accommodate these operations at scale [1,2].

A. Upper Class E Traffic Management (ETM)

Recognizing this need, the Federal Aviation Administration (FAA), along with input from the National Aeronautics and Space Administration (NASA) and industry partners, published Version 1.0 of the Upper Class E Traffic Management (ETM) Concept of Operations (ConOps) [2]. Unlike conventional ATM, which relies on ATC to provide separation services, the initial ConOps for ETM utilizes the Uncrewed Aircraft System (UAS) Traffic Management (UTM) precedent of a "community-based, cooperative traffic management system, where the Operators are responsible for the coordination, execution, and management of operations, with rules of the road established by FAA" [2].

In the ETM concept, **cooperative operations** are enabled by:

1. *Information sharing*, and
2. A *service-oriented information architecture*, referred to here as the ***ETM Service Supplier (ESS)***. The ESS is a communication bridge between the ETM Operator and others in the ETM environment that provide tools, automation, or services to monitor the region, execute safe missions, store operational data, etc. The ESS could potentially support operations planning, vehicle deconfliction, conformance monitoring, and other airspace management functions [2]. Additionally, there would be a discovery and synchronization service (DSS) within the automation process that connects multiple ESSs together to share information and provide a cooperative framework for Operators to share situational awareness with each other. Collectively, the amalgamation of ESSs is referred to in this paper as the ***ESS Network.*** The ESS Network is expected to provide a communication bridge to ***Air Traffic Services (ATS)*** on the FAA side to support the exchange of information between the ETM system and the conventional ATM system.

It is envisioned that Operators will share their ***Operation Plan*** (consisting of comprehensive operator, vehicle, and mission information) and ***Operational Intent*** (consisting of the 4D aspects of their predicted trajectory, estimated latitude, longitude, altitude, and time) with the ESS Network [2]. The ESS Network will ingest this information and use it to support common situation awareness among Operators, conflict detection, and communication between Operators in ***Cooperative Operating Environments (COEs)***. These bounded ***Cooperative Areas*** will be in Upper Class E airspace above FL600 and, possibly, in Class A airspace (FL180–FL600), as well. Industry-defined, FAA-approved practices, or "rules of the road", that address how Operators will cooperatively manage their operations are known as ***Cooperative Operating Practices (COPs)***. COPs will be used to define how operations will be conducted with other stakeholders to address the equitable use of the airspace, demand/capacity balancing, operational intent sharing, the identification and resolution of conflicts, as well as operator responsibilities and procedures for any required interactions with ATC as vehicles transition in/out of Cooperative Areas. Regarding phraseology in the ETM domain:

- **Operator** refers to the company as a whole, or a person at the company (e.g., dispatcher), who is responsible for the vehicle and planning.
- **Remote-pilot-in-command (RPIC)** for uncrewed vehicles, or **pilot-in-command (PIC)** for crewed vehicles, refers to the person who is piloting/controlling the vehicle.

The image in Fig. 1 depicts a general overview of the cooperative ETM system with *information sharing* supported by a *service-oriented information architecture*. An Operator/RPIC with one, or more, uncrewed vehicles, or a PIC, in the case of crewed aircraft like a supersonic aircraft or business jet, use their ESS to create and share their Operation Plan/Operational Intent with the ESS Network. The ESS Network uses that information to provide a variety of services, including, conflict detection, conformance monitoring for both Operational Intent volumes and the ETM Cooperative Area, as well as communication back to the Operator/RPIC/PIC, through their ESS. Fig. 1 also shows the ESS Network providing a communication bridge to the Air Traffic Services (ATS) on the FAA side.

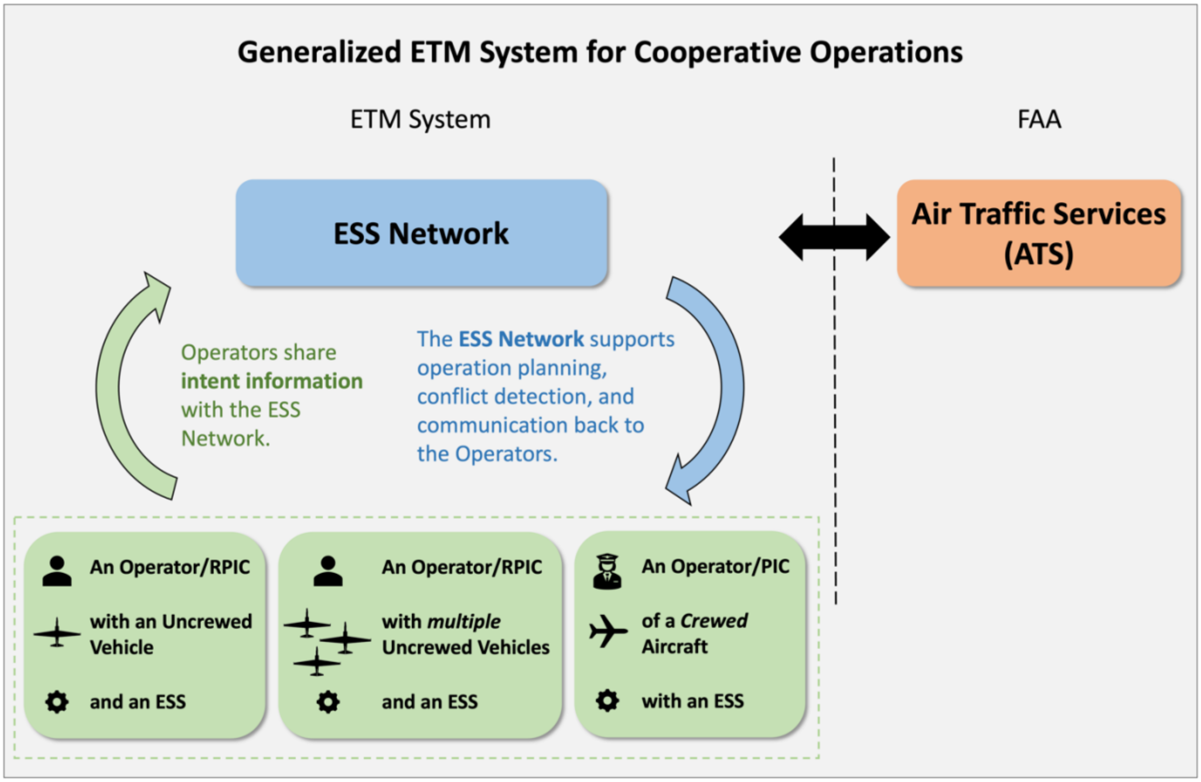

Fig. 1 Generalized ETM system for cooperative operations enabled by Operators sharing intent information with an ESS Network. The ESS Network is also expected to provide a communication bridge to Air Traffic Services (ATS).

B. ETM Research and Industry Engagement

Since Version 1.0 of the ETM ConOps [2] was published, the ETM concept has continued to evolve through research and collaboration. For example, NASA Ames Research Center has recently developed several technologies that will assist operators in a cooperative environment; these include a prototype simulation platform to assess cooperative separation [5,6,7] and the calculation of conflict probability [8].

Over the past five years, workshops with NASA, the FAA, ETM industry stakeholders, and other government agencies have been held to discuss cooperative traffic management, COPs, and operator interactions with ATC and other operators [9,10]. Last year, NASA held a virtual tabletop to solicit feedback from industry about NASA-developed technologies for strategic conflict detection and resolution [11] and, more recently, the FAA and NASA held an in-person tabletop to discuss Operational Intent information sharing with ETM industry members.

More broadly, there is an effort by the Air Traffic Organization (ATO), as part of the FAA, to support the successful operational integration of three areas with increasing/emerging demand: Space Launch/Reentry Operations, Vertical Transiting Operations To and From Upper Class E, and Upper Class E Operations. The ATO refers to this effort as the NAS Integration of Transiting and Higher Airspace Operations (NITRO). With respect to Upper Class E, NITRO aims to increase access for operations transiting to/from Upper Class E and enable Upper Class E operations with safety and efficiency for all National Airspace System (NAS) users [12]. To achieve these goals, they identify a variety of objectives, including policy changes, safety requirements, collaboration with industry, data sharing, the use of automation to improve safety, and the implementation of decision support [12].

C. Integration into the NAS

Of the many areas in which development and research are advancing the ETM concept, our focus herein will be on ***ETM-Air Traffic System (ATS) interactions*** – that is, those instances in which an ETM vehicle, Operator, RPIC, or PIC will interact with some entity of the ATS, for example, an ATC controller, supervisor/Traffic Management Coordinator (TMC) at an Air Route Traffic Control Center (ARTCC), or the Air Traffic Control System Command Center (ATCSCC) as the ETM vehicle transits through ATC-managed airspace. In this paper, we describe how we used previously developed ETM-ATS interaction use cases to identify ***information needs*** and envision ***visualization and communication tools*** to support ETM-ATS interactions.

The following sections are presented in this paper:

- In Section II, an overview of the progression of our ETM-ATS Interaction work, including, how ETM vehicles are categorized by capabilities in this discussion.
- In Section III, a description of the methodology we used to identify ETM-ATS Interaction information needs.
- In Section IV, a description of the envisioned **Integrated Visualization Tool for Flight Tracking and Airspace Designations Tool** including, potential users, functionality, and information needs.
- In Section V, a description of the envisioned **Integrated Digital Communication Tool**, including potential users, functionality, and information needs.
- The Appendix includes an Acronym List and a detailed description of the specific procedural steps described in the paper.

II. ETM-ATS Interactions

We originally began this work by developing ***ATS interaction*** use cases in each of three domains:

1) Advanced Air Mobility (AAM)/Urban Air Mobility (UAM),

2) UTM, and

3) ETM

For each use case, we developed step-by-step procedures to identify roles/responsibilities and data exchange requirements associated with ATS interactions [13]. As we developed the use cases, we tailored the procedures according to the different *vehicle types* within each domain, that is:

- In the **AAM/UAM-ATS interaction** uses cases:
  - Crewed/uncrewed Vertical Takeoff and Landing (VTOL) aircraft
- In the **UTM-ATS interaction** use cases:
  - Uncrewed aircraft systems (UAS)/small UAS (sUAS) vehicles
- In the **ETM-ATS interaction** use cases, however, because of the diverse nature of vehicles which vary in performance characteristics in the ETM domain, we considered *four different vehicle categories* while creating the step-by-step procedures for these use cases:
  - HALE Balloons (and airships)
  - Uncrewed HALE slow-speed, fixed-wing vehicles, also referred to as High Altitude Platform Station (HAPS), with missions lasting weeks to months
  - Uncrewed HALE high-speed, fixed-wing vehicles (e.g., Global Hawk)
  - Crewed, high-speed, fixed-wing aircraft (e.g., supersonics, business jets) which may also utilize ETM Cooperative Areas in Upper Class E

A. Identifying Common Coordination Procedures

After developing the ***ATS interaction*** use cases, with step-by-step procedures specific to each of the three domains and their respective vehicle types, we asked, "What procedures are *common* across domains/vehicles?" To identify *common* coordination procedures, we first sorted and grouped the use cases by their *trigger event*, that is, the event which "triggers" the interaction with ATS [13] and then identified *common coordination procedures* and, where applicable, *exceptions* to the common procedures [14, 15].

1. Key Finding within the ETM Domain

Through that exercise, we found that some of the most significant *differences* in procedures occur between different vehicle types *within the ETM domain* itself and are attributable to **balloons** [14,15]. Balloons are notably different than other ETM vehicles in that they have their own FAA Code of Federal Regulations (i.e., Title 14 CFR Part 101 regulations for Unmanned Free Balloon (UFBs)) and are not required to file an Instrument Flight Rules (IFR) flight plan because they lack the controllability to follow a predefined flight path. Balloon operations are not expected to have someone in the role of an RPIC, and the Operators themselves may not be in communication with ATC on the radio frequency, although they are required to be in contact with a supervisor/TMC at the nearest ATC facility every two hours via phone, email, or facsimile per FAA regulations. Finally, if the balloon is not equipped with a Mode C/S transponder or Automatic Dependent Surveillance-Broadcast (ADS-B) due to payload limitations, the balloon may not be visible on the ATC controller's radar display.

An example of how coordination procedures may differ between vehicles *within the ETM domain* is shown in Table 1. In the procedural step shown in Table 1 (i.e., Flight Plan Filing), the expected procedure for each of the four ETM vehicle categories is presented. The procedure is the same across vehicle types, with the exception of the balloon, which is not required to file a conventional IFR flight plan (per FAA Title 14 CFR Part 101 regulations) due to a lack of controllability for following a predefined path.

Table 1. Example of Identifying Common Coordination Procedures (and Exceptions) across ETM vehicle categories.

	ETM Vehicle Types				
Procedural Step	**HALE Balloons and Airships**	**Slow-Speed Uncrewed Fixed-Wing HALE**	**High-Speed Uncrewed Fixed-Wing HALE** (e.g., Global Hawk)	**High-Speed Crewed Fixed-Wing** (e.g., Supersonic, Business Jet)	**Common Procedures and Exceptions**
*Flight Plan Filing**	**Balloon:** The Operator provides ATC their "flight intent volumes**"** for ATC-controlled airspace, where ATC is responsible for separation services, to the entry point of the ETM Cooperative Area. **Airship:** The Operator files an **IFR Flight Plan** for ATC-controlled airspace, where ATC is responsible for separation services, to the entry point of the ETM Cooperative Area.	The Operator files an **IFR Flight Plan** for ATC-controlled airspace, where ATC is responsible for separation services, to the entry point of the ETM Cooperative Area.	The Operator files an **IFR Flight Plan** for ATC-controlled airspace, where ATC is responsible for separation services, to the entry point of the ETM Cooperative Area.	The Operator files an **IFR Flight Plan** for ATC-controlled airspace, where ATC is responsible for separation services, to the entry point of the ETM Cooperative Area. **Dependent on whether these aircraft participate in ETM.*	**Common Procedure:** The Operator files an **IFR Flight Plan for ATC-controlled airspace** to the entry point of the ETM Cooperative Area. **Exception:** **Balloon Operator does *not* file an IFR Flight Plan because of the lack of controllability to follow a predefined flight path. Instead, they provide ATC with an "flight intent volumes."**

A selected procedural step (i.e., "Filing an IFR Flight Plan**") from the "**Planned transit through ATC-controlled airspace to enter a Cooperative Area**" use case with procedures for each of four ETM vehicle categories. Common procedures are identified in the rightmost column; exceptions to common procedures are shown in blue.*

As we will describe in Section III, procedural differences such as these will have an impact on the information needs and support tools for ***ETM-ATS interactions***.

B. Background on ETM Vehicles

In the table above, we grouped ETM vehicles into four categories, in part, based on assumptions about vehicle performance and equipage.

For the discussion in this paper, we assume that **Slow-** and **High-Speed Uncrewed, Fixed-Wing HALE vehicles**:

- Will have someone in the role of RPIC, that is, someone who is remotely piloting/controlling the vehicle.
- When in, or preparing to enter, ATC-managed airspace, the RPIC will be in communication with a controller via an ATC radio frequency, assuming that the vehicle has the capability to support air-to-ground communication. (In the future, there may be acceptable alternatives for communication, such as, ground-to-ground, Controller Pilot Data Link Communications (CPDLC), or Voice over Internet Protocol (VoIP)).
- Will have some degree of performance capability/controllability (e.g., propulsion) that:
    - Enables the vehicle to develop and follow a *planned trajectory* – allowing them to submit a conventional IFR flight plan to ATC.
    - Enables the RPIC to change altitude or heading – giving them the capability to respond to ATC instructions.
- Will be equipped with a traditional Mode C/S transponder and/or ADS-B, either of which would enable the vehicle to be displayed on the ATC radar scope.

Alternatively, we assume that **balloons:**

- Will *not* have someone in the role of an RPIC.
- Given the absence of an RPIC in balloon operations, they will not be in communication with an ATC controller *via a radio frequency* when in, or preparing to enter, ATC-managed airspace (although someone from the operation (e.g., dispatcher) is required to be in contact with a supervisor/TMC at the nearest ATC facility every two hours via phone, email, or facsimile).
- Due to a lack of controllability, will:
    - Likely be *unable* to develop or follow a *planned trajectory*, making them unable to submit an IFR flight plan to ATC.
    - Be generally limited in their ability to respond to altitude or heading changes.
- And, because of payload limitations, may not be equipped with a Mode C/S transponder or ADS-B, in which case they would not be visible on the ATC radar scope.

1. Vehicle Groupings in this Discussion

Given the assumptions outlined above, for the discussion in this paper, we grouped ETM vehicles into ***two categories*** (Table 2) based on expected performance capabilities, surveillance equipage, ability to develop a planned trajectory, and whether or not they are expected to file an IFR flight plan.

Table 2. Vehicle Categories Used in this Discussion

	Vehicle Categories	RPIC (Uncrewed Vehicles)	Radio Comm with ATC	Ability to Plan and Follow a Trajectory	Controllability (Capability to respond to ATC instructions)	Surveillance Equipage (Mode C/S Transponder, ADS-B)
1.	**Balloons and other ETM vehicles that are *not* equipped with a transponder or ADS-B and are *not required* to be on an IFR Clearance in Class A airspace.**					
2.	**ETM vehicles that are equipped with a transponder and/or ADS-B and are *required* to be on an IFR Clearance in Class A airspace.** *High-speed *crewed* aircraft are included in this category.	✓	✓	✓	✓	✓

2. Variations in Future Development of ETM Vehicle Capabilities and Equipage

For the discussion in this paper, we assume the above performance and equipage characteristics for **balloons** and vehicles in the **Slow-Speed Uncrewed** and **High-Speed Uncrewed HALE** categories. However, as vehicle development continues to evolve, the industry may see a range of variation in performance capabilities and equipage within each vehicle category. For example, it is possible that some **Slow-Speed Uncrewed HALE vehicles** may have a degraded capability to effectively execute ATC instructions, making them more like **balloons**.

Alternatively, some **balloons** are getting better at predicting a flight path that they will try to follow (and, as a result, might someday be able to submit an IFR flight plan) and some may have the capacity to carry surveillance equipment, like ADS-B, enabling their display on the controller's radar scope.

Differences, like these, in vehicle performance capabilities and equipage, will impact how ATC interacts with these vehicles, how separation standards are established, and what ATC support tools may be needed – all of which should be carefully considered as the ETM concept continues to evolve.

C. Operations in Upper Class E Airspace

In the next phase of this work, we focused exclusively on further developing use cases in the ***ETM domain*** in preparation for upcoming ETM-focused simulation work at NASA Ames Research Center. Namely, we expanded the ***ETM-ATS interaction*** use cases to include *lateral* entry into/exit an ETM Cooperative Area, in addition to vertical ascent from/descent into Class A airspace. In the lateral entry/exit use cases, we explored how aircraft will operate outside of ETM Cooperative Areas in Upper Class E airspace, above 60,000 ft.

1. Near-Term Use of ALTRVs in Upper Class E

For many years, the FAA has used ***Altitude Reservations (ALTRVs)*** to manage and prioritize segregated airspace through all altitudes [16]. As defined by the FAA, an ALTRV is an "airspace utilization under prescribed conditions normally employed for the mass movement of aircraft or other special user requirements which cannot otherwise be accomplished" [17]. ALTRVs receive special handling, for example, priority over other traffic (with the exception of safety-related issues like emergencies, e.g., Lifeguard, etc.) and priority over ATC Assigned Airspace (ATCAA). The Central Altitude Reservation Function (CARF), a unit at the ATCSCC, is responsible for identifying conflicts (using a computer program called C3), approving ALTRV requests, coordinating with ATC facilities and the military, and issuing Notices to Air Missions (NOTAMs) as a means of publishing ALTRV information [4]. Two types of ALTRVs are used, *stationary*, a defined airspace volume, and *moving*, a precoordinated trajectory that advances with the vehicle(s) [4]. In addition to ALTRVs, ***Informational Only Airspace*** can also be input into the C3 program to check for conflicts, however, it is not considered an airspace reservation.

As HALE vehicle operations increase, MITRE/FAA have proposed that ALTRVs – or, in the case of balloons, Informational Only Airspace – may be used as a *near-term* mechanism to enable access for increasing civil operations in Upper Class E airspace [4]. See [18] for a discussion about this proposal and some of the associated challenges.

2. Far-Term Use of ALTRV's in Upper Class E

Based on the proposed utilization of ALTRVs in the *near-term* [4], for the purposes of our work, we also considered the possible role of ALTRVs in the *farther term*, when the full implementation of the ETM concept is realized. That is, we envision that ALTRVs may continue to be utilized for transiting to and from bounded ETM Cooperative Areas in Upper Class E airspace. In fact, during discussions with operators, some indicated that they may prefer to enter/exit ETM Cooperative Areas *laterally*, from the side, as depicted in Fig. 2.

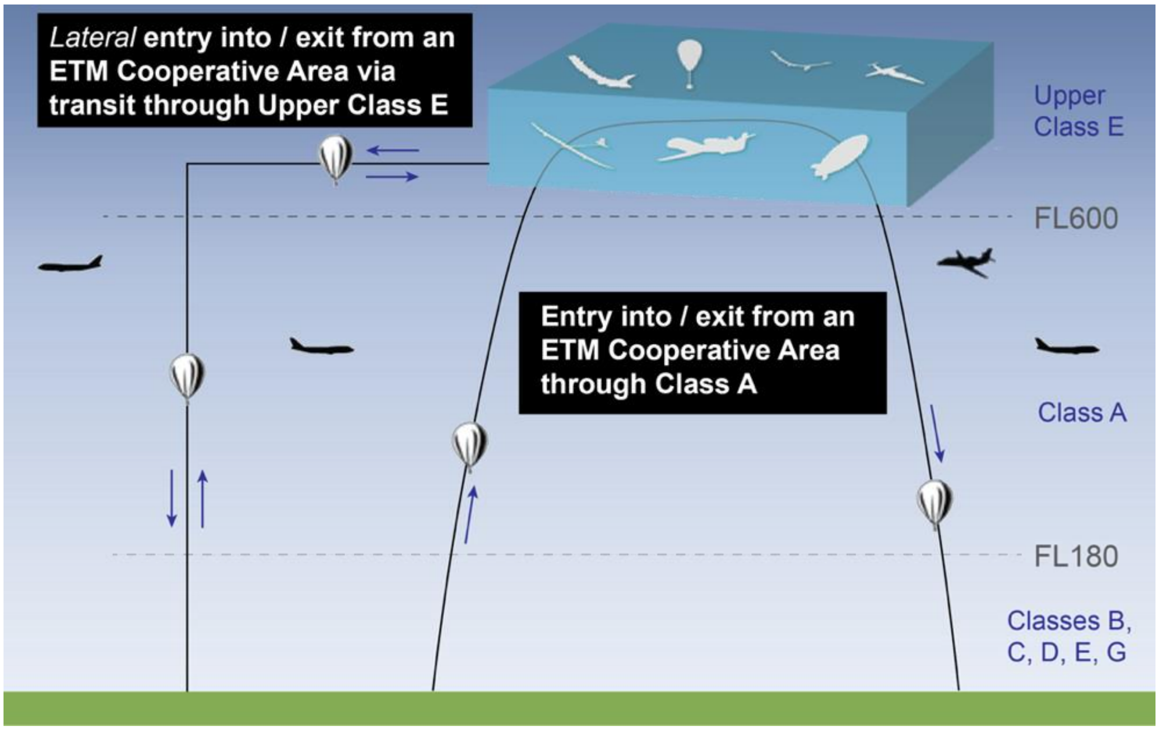

Fig. 2 Entry into/exit from an ETM Cooperative Area through Class A or, laterally, via transit through Upper Class E.

To explore the procedures and information needs around such a scenario, we developed ETM-ATS interaction use cases in which the ETM vehicle utilizes an ALTRV – or, in the case of a balloon, Informational Only Airspace – to transit through Upper Class E airspace on its way to *laterally entering*, or after *laterally exiting*, an ETM Cooperative Area. We used *current-day* ALTRV procedures (e.g., CARF identifies potential ALTRV conflicts) to help inform the development of step-by-step procedures in these *far-term* use cases. A summary and discussion of all finalized *ETM-ATS interaction use cases* are presented in [18].

For the remainder of this paper, we discuss identifying information needs as they relate to ***ETM-ATS interactions***, as well as tools to help support these interactions.

III. Identifying ETM-ATS Interaction Information Needs

The goal of this work was to identify information/communication needs for ETM-ATS interactions (described in this section) and then use those needs to formulate a vision for tools that will help support ETM-ATS interactions, specifically:

- an **Integrated Visualization Tool** (described in Section IV), and
- an **Integrated Digital Communication Tool** (described in Section V).

A note about terminology, as described earlier, in the ETM concept, the ESS Network is expected to provide a communication bridge to ***Air Traffic Services (ATS)*** on the FAA side**,** to support exchange of information between the ETM system and the conventional ATM system. As we developed the use cases and procedural steps, we broadened the definition of ***Air Traffic Services (ATS)*** to include both the *automation* and the *humans* involved in the information exchange between ETM and conventional ATM. The reason for expanding the definition is that we envision that communication exchanges that center on human operators today, such as TMCs, may eventually be supplanted by *automation* in future interactions with ETM, though it is unclear when such a change will take place. Therefore, we describe ***Air Traffic Services (ATS)*** handling these information exchanges and coordination with an understanding that it may be done by *automation* or in conjunction with a *human* service provider. For the purpose of defining roles/responsibilities and information exchange in our use cases, we broke down "**Air Traffic Services (ATS)**" into two entities:

- **Command Center Air Traffic Services (ATS)** refers to the services and air traffic service providers at the NAS-wide level, akin to the Command Center function.
- **Facility-level Air Traffic Services (ATS)** refers to the services and air traffic service providers at the ATC facility-level, akin to the Area Supervisor or TMC.

A. Methodology for Identifying ETM-ATS Interaction Information Needs

The first step in this process was to review the previously developed ***ETM-ATS interaction use cases***, specifically, the eight use cases that involve the transition into/out of an ETM Cooperative Area, through either Class A airspace or Upper Class E airspace, which are summarized in [18]. From each of these eight use cases, we selected the individual procedural steps that were specifically related to an *interaction* between the ETM Operator/ESS and ATC controllers, facility-level ATS, Command Center ATS, or CARF.

We further refined that list of procedural steps to include only procedures that require information exchange/communication support ***beyond what existing, and currently planned, tools can provide***. The examples in Table 3 illustrate this process.

1. In the first procedure, we considered **ETM vehicles that are equipped with a transponder and/or ADS-B and are required to be on an IFR Clearance in Class A airspace.** In this procedural step, the ETM Operator/RPIC is responsible for communicating with the ATC controller and adhering to clearances as they ascend/descend through ATC-controlled airspace. We asked, *is a new tool needed to support this procedure?* Like conventional aircraft, ETM vehicles with a transponder and/or ADS-B will be displayed on the ATC controller's scope, enabling the controller to have awareness of their position and track their ascent/descent. Furthermore, like conventional aircraft, these vehicles are expected to have an RPIC that communicates with the ATC controller via the radio frequency. So, for the purposes of this exercise, we ***excluded*** **this interaction procedure on the basis that existing tools already support the task.**
2. In the second procedure, we considered **balloons and other ETM vehicles that are *not* equipped with a transponder or ADS-B and are not required to be on an IFR Clearance in Class A airspace.** In this procedural step, the ATC controller is responsible for providing separation for safety, possibly in the form of safety advisories to other aircraft in the area, for example. If balloons are not equipped with a transponder or ADS-B, they will not be displayed on the ATC controller's radar scope. As a result, the controller will not have awareness of the balloon's position. We asked, *is a new tool needed to support this procedure?* **In this case, yes, a new visualization/communication tool may be needed to display vehicles using alternate position-reporting methods. So, for the purposes of this exercise, we *included* this interaction procedure on the basis that a new tool(s) may be needed to support this task.**

Applying this criterion narrowed the list to seven procedural steps – each one with information exchange/communication needs *beyond what existing, and currently planned, tools can provide*. For each of these seven procedural steps, we identified the information needs and support tools that could help fill these gaps (see the Appendix for a description of each of the seven ETM-ATS interaction procedures and the associated information needs).

Table 3. Examples of a Procedure that Will Not Require New Tools vs. One that May Require New Tools

	Vehicle Category (Equipage Type)	ETM-ATS Interaction Procedural Step (Roles/Responsibilities)	Is a New Tool Needed to Support this Procedure?
1.	**ETM vehicles that are equipped with a transponder and/or ADS-B and are *required* to be on an IFR Clearance in Class A airspace.**	The ETM Operator/RPIC is responsible for communicating with the ATC controller and adhering to clearances.	Like conventional vehicles, Operators/RPICs of these vehicles and ATC controllers communicate via the radio frequency and the vehicles are displayed on the ATC controller's scope, So, no new tools are needed to support this ETM-ATC interaction.
2.	**Balloons and other ETM vehicles that are *not* equipped with a transponder or ADS-B and are *not required* to be on an IFR Clearance in Class A airspace.**	The ATC controller may be responsible for separation for safety (e.g., providing safety advisories) for these vehicles.	**Yes, a new tool may be needed to support the ATC controller because balloons and other vehicles not equipped with transponders or ADS-B are not displayed on the ATC radar scope. A new visualization/communication tool may be needed to display vehicles using alternate position-reporting methods.**

Various tool functionalities and information exchange/communication needs were identified across multiple service provider entities and vehicle Operators, but these functionalities generally grouped themselves into two main themes, which we describe in two types of integrated tools:

1) an ***Integrated Visualization Tool for Flight Tracking and Airspace Designations,*** and

2) an ***Integrated Digital Communication Tool***.

These two tools are described with a tentative assumption that the functionalities needed for different scenarios and human Operators can be provided by integrated tools for visualization and communication needs, respectively. However, the assumption is an initial starting point, as each of these tools may turn out to be a collection of tools with similar functionalities for different service provider entities and vehicle Operators.

IV. Integrated Visualization Tool for Flight Tracking and Airspace Designations

A. Purpose

This tool is intended to create an integrated visual representation of all vehicles that transit through different categories of airspace and that utilize different types of cooperative and conventional air traffic operations from takeoff to landing, as well as the location and boundaries of designated airspaces. The goal is to fill the gap that exists in today's vehicle surveillance and airspace information tools/systems and to create a common platform that allows users to access relevant information.

B. Background

Two main gaps were identified in current-day tools, first, flight vehicle tracking across different surveillance conditions and, second, the visualization of designated airspaces (e.g., an ALTRV, Special Use Airspace (SUA), or ETM Cooperative Area) across Class A and Upper Class E airspace.

1. Flight Tracking Background

For flight tracking, vehicles with Mode C/S position data information (i.e., equipped with a transponder) or ADS-B can be tracked and displayed on current air traffic displays, such as the En Route Automation Modernization (ERAM) system, in much of Class A airspace. However, ETM operations may include vehicles that are not equipped with a conventional transponder or ADS-B and ATC would have to rely on alternate position reporting methods, such other Global Positioning System (GPS) sources, or reports via phone, internet, or data link. Operations at higher altitudes (e.g., above FL600 in Upper Class E) include challenges such as, not all airspace being covered by conventional radar and barometric altitude readings being less accurate at higher altitudes.

Given the diversity of surveillance information across vehicles and airspaces, it is likely that air traffic service providers would have to examine multiple data sources to gather an integrated picture of the traffic situation. For example, a mixture of balloons and slow HALE vehicles transiting through Class A airspace may require the ATC controller to track the transponder-equipped vehicles via an ERAM display, while tracking balloons (which may not be equipped with a transponder or ADS-B) on a separate display that shows their position using an alternative data source(s). When these vehicles transit into Upper Class E, Mode C/S data may also be unavailable, such that their positions would need to be tracked with a combination of alternative position data sources.

In Upper Class E, altimeter readings that are based on conventional barometric pressures will deviate significantly from GPS altitude readings as the vehicles reach higher altitudes, so identifying the source of the altitude data (i.e., barometric pressure altitude vs. geometric altitude) presented on a traffic display would be crucial. Therefore, a tool that provides common situation awareness of all vehicles across all types of airspace and operations would be useful. The Integrated Visualization Tool that we describe here is intended to allow all users to share a visual representation of all active and proposed flight information, including current position information and future intents.

2. Designated Airspaces Background

For designated airspaces and ETM Cooperative Areas, this tool is intended to provide all users with a visual representation of all active and proposed airspace and Cooperative Area constructs in Upper Class E and Class A airspace.

Currently, the FAA publishes airspace designations in graphical and text form, such as SUA, Military Operation Area (MOA), Temporary Flight Restriction (TFR), and ATC Assigned Airspace (ATCAA), on public-facing websites (see examples later in Section IV). The FAA may already, or soon will, be able to publish graphical mapping of designated airspaces *above FL600 in Upper Class E airspace,* as well. CARF publishes ALTRV information in the form of text-based NOTAMs, including those located in Upper Class E airspace. CARF plans to further enhance the C3 program, and possibly introduce other automation changes, to facilitate the ALTRV request, coordination, and approval processes.

With the introduction of ETM Cooperative Areas in Upper Class E, there needs to be an additional function to delineate the ETM Cooperative Areas from the conventional Upper Class E airspace. If the ATS entity that is responsible for approving ETM Cooperative Areas is separate from CARF, which approves ALTRVs, then shared knowledge of approved airspaces is necessary. CARF personnel will need awareness of the location and activation status of ETM Cooperative Areas and knowledge of any other approved operations (e.g., a Certificate of Authorization (COA)) that utilize the airspace, unless that operation is conducted under “due Regard” rules. This visual information could then be made available to Operators and ATC for information and planning purposes. Given that Command Center ATS and CARF might each have a standalone tool for managing ETM Cooperative Areas and ALTRVs, respectively, a capability may be needed for both Command Center ATS and CARF to deconflict all new requests for airspace from all active and approved airspace constructs across Upper Class E. Additionally, ETM and ALTRV airspace constructs in Class A should be viewable to Operators for planning purposes and to ATC for operational awareness. Even if CARF and the ETM/ATS function ultimately become fully integrated in the future, integrating that information along with military airspace and other traffic and airspace information would also be useful.

Currently, ALTRVs are approved 24–72 hours in advance, and initially, ETM Cooperative Areas may also be designated in a similar time horizon. As such, we can assume that the airspace/Cooperative Area visualization is to be well-known and relatively stable for the real-time tracking/visualization. From the ETM Operator’s point of view, all flight planning that requires ALTRV approval will also need to be done 24–72 hours in advance.

C. Potential Users and Tool Needs

In Table 4, we list the individual procedural steps from the ETM-ATS use cases that require visualization capabilities *beyond what existing, and currently planned, tools can provide*. For a further description of each of these procedural steps, see the Appendix. As Table 4 shows, some of these information needs are driven by vehicle differences, that is, vehicles that are not required to file an IFR flight plan or that are not equipped with a transponder or ADS-B (possibly balloons), while others are based on the need for information sharing and common situation awareness in ETM operations.

Table 4. ETM-ATS Interaction Procedures that Require New Visualization Capabilities

Vehicle Category (Equipage Type)	Appendix	ETM-ATS Interaction Procedural Step	How a New Visualization Tool Might be Helpful
Balloons and other ETM vehicles that are not equipped with a transponder or ADS-B and are not required to be on an IFR Clearance in Class A airspace.	*Appendix #1*	The **Operator** is responsible for providing their "flight intent volumes" to the **facility-level ATS (i.e., Supervisor/TMC at an ATC facility).**	It would be helpful for **facility-level ATS personnel** to be able to visualize the "flight intent volumes."
	Appendix # 2	The **Operator** is responsible for providing **facility-level ATS (i.e., Supervisor/TMC at an ATC facility)** with real-time updates on the vehicle's location.	It would be helpful for **facility-level ATS personnel** to be able to visualize the position information of vehicles not equipped with a transponder or ADS-B.
	Appendix # 3	The **ATC controller** may be responsible for some kind of separation for safety (e.g., they would provide safety advisories).	It would be helpful for **ATC controllers** to be able to visualize the position information of vehicles not equipped with a transponder or ADS-B.
	Appendix # 5	The **Balloon Operator** files an *Informational-only airspace* request with the **CARF.**	It would be helpful for the **Command Center ATS and other entities** to be able to visualize the location/boundaries of *Informational-only airspaces.*
	Appendix # 6	The **Operator** is responsible for providing **facility-level ATS (i.e., Supervisor/TMC at an ATC facility)** notification of transition into the ETM Cooperative Area.	It would be helpful for **facility-level ATS personnel** to be able to visualize the position information of vehicles not equipped with a transponder or ADS-B and receive notifications about transition points (e.g., ascending above FL600).
ETM vehicles that are equipped with a transponder and/or ADS-B and are required to be on an IFR Clearance in Class A airspace.	*Appendix # 4*	The **Operator** files a *Moving ALTRV* request with the **CARF.**	It would be helpful for the **Command Center ATS and other entities** to be able to visualize the location/boundaries of ALTRVs.
	Appendix # 6	The **Operator** is responsible for providing **ATC** notification of transition into the ETM Cooperative Area.	It would be helpful for **ATC controllers** to visualize and receive notifications about when vehicles cross a transition point (e.g., ascending above FL600).
All Vehicle Types	*Appendix # 7*	While operating in ETM Cooperative Areas, **Operators** define their intent using Operation Plans, Operational Intents, or waypoint plans.	It would be helpful for **other users** to be able to visualize active/planned ETM Cooperative Area boundaries and ETM intent information.

** Numbers correspond to the tables in the Appendix.*

Multiple users could benefit from an integrated visualization tool, for example:

- **CARF –** CARF would use a visualization tool to promulgate all approved ALTRVs to ATS, ATC, and ETM Operators. CARF may also use the tool to visualize the locations and boundaries of ETM Cooperative Areas and various airspace boundaries in relation to proposed and active ALTRVs.
- **Command Center ATS –** ATS would use a visualization tool to promulgate all approved ETM Cooperative Areas to CARF, ATC, and ETM Operators. ATS may use the tool to visualize the location and boundaries of approved ALTRVs in relation to the ETM Cooperative Areas and other airspace/sector boundaries. A tool like this may also give ATS the capability to deconflict new Cooperative Area requests for airspace usage from other existing airspaces. CARF-approved ALTRV information, as well as flight data information, in a common visual representation, may be useful to ATS to gain a complete picture of the traffic scenario.

- **Facility-level ATS –** Facility-level ATS (i.e., supervisor/TMC at the ATC facility) could use a visualization tool to depict a balloon's "flight intent volumes", current vehicle position information for balloons and other vehicles not equipped with a transponder or ADS-B, and for situation awareness when a vehicle transitions above FL600.
- **ATC –** ATC controllers would use a visualization tool to have general awareness of current, active airspace with integrated traffic information for vehicles with a Mode C/S transponder, as well as for vehicles with position information from an alternate source, overlayed on airspace-related information, such as sectors, ALTRVs, and ETM Cooperative Areas.
- **ETM Vehicle Operators –** Operators would use a visualization tool to have the overall picture and awareness of current airspace usage and approvals to help in planning their operations.

We used these information needs to formulate a vision for an Integrated Visualization Tool for Flight Tracking and Airspace Designations. The tool would allow users to benefit from integrating flight and airspace data, from multiple sources, into a single display to enable a "big picture" view of each flight, from takeoff to landing.

D. Current Technologies

There are several examples of current data-sharing tools that depict airspace designation information. The FAA provides information about SUAs in the form of graphical depictions on a map, and in a text list, on a public-facing website site [19]. This site includes three categories of airspace designations: 1) Special Activity Airspace (SAA) for ATCAA, MOA, national security area (NSA), etc., 2) Military Training Route (MTR)/Aerial Refueling (AR) route, and 3) TFR for hazards, emergencies, security, etc. (see example in Fig. 3).

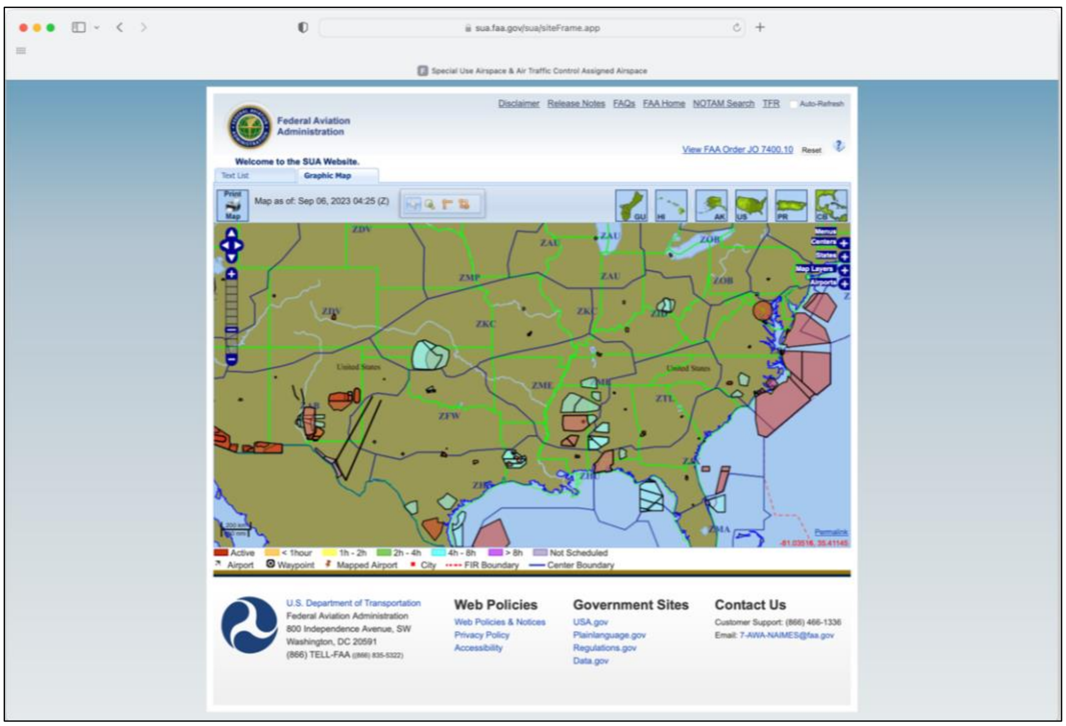

Fig. 3 FAA SUA website with SAAs, MTR/ARs, and TFRs (https://sua.faa.gov/sua).

Similarly, another public-facing FAA site provides information about TFRs, a type of Notice to Air Missions (NOTAM) [20]. Information can be viewed graphically on a map or in list form (see example in Fig. 4).

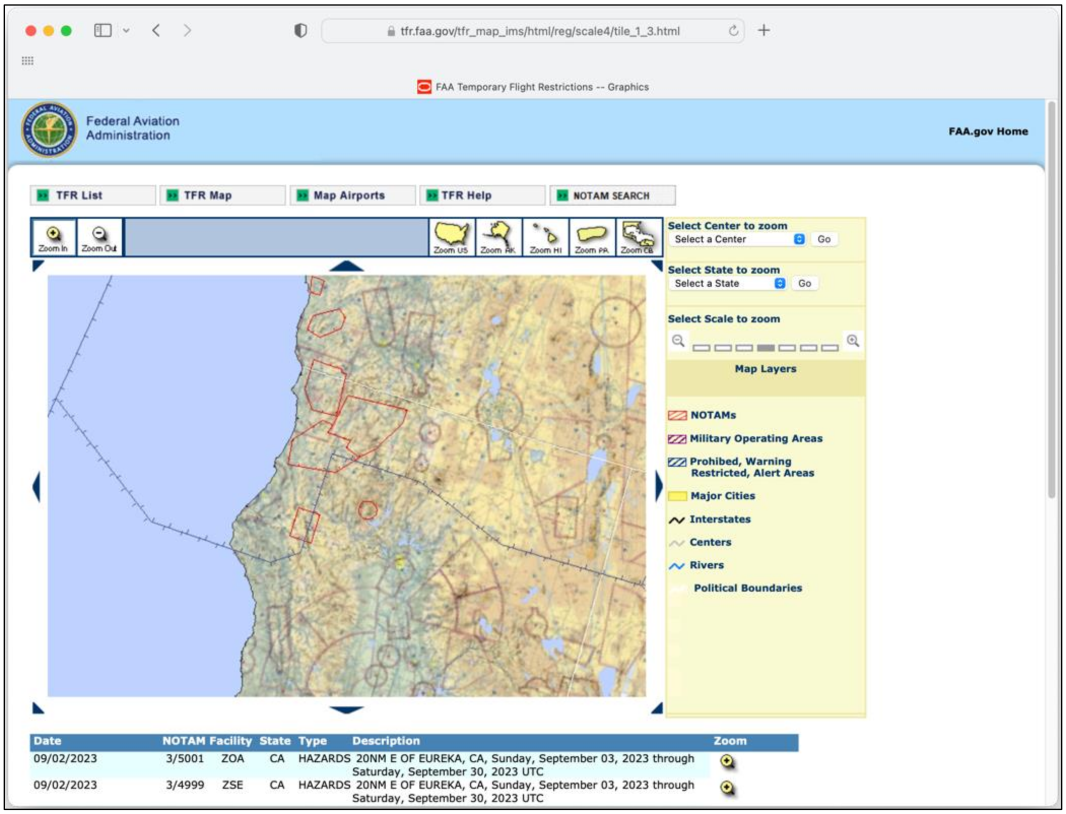

Fig. 4 FAA TFR website (https://tfr.faa.gov/tfr_map_ims/html/index.html).

CARF personnel use a computer program called C3 with a graphical user interface to identify potential airspace conflicts before approving an ALTRV (see example in Fig. 5) [4,21].

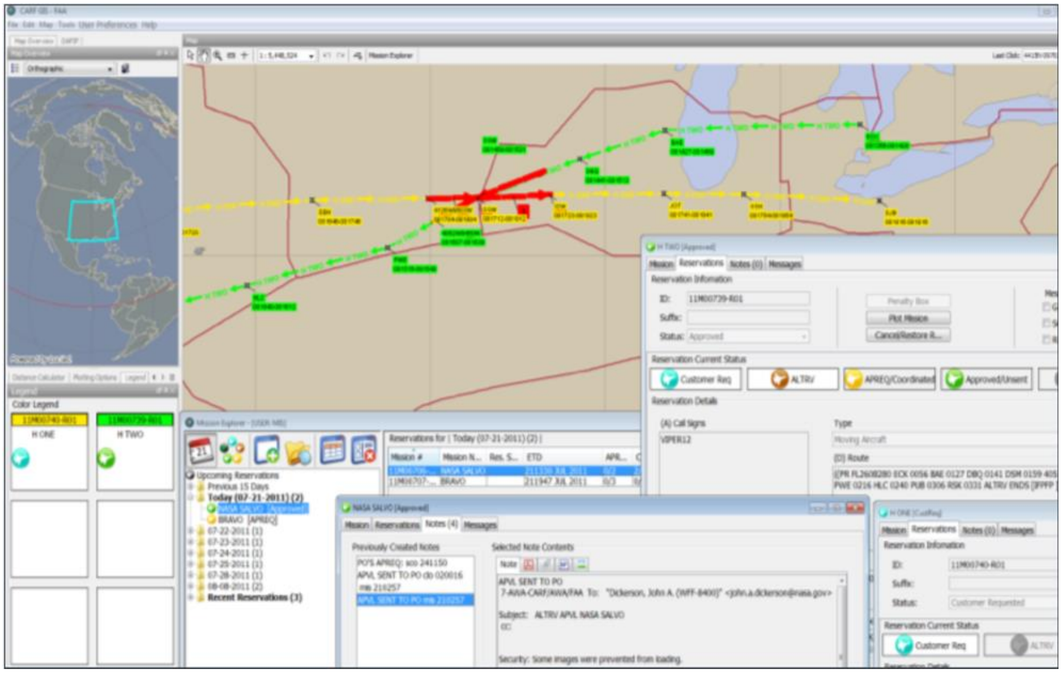

Fig. 5 FAA CARF C3 tool (http://www.azuleng.com).

There are also examples from other domains of new capabilities for the visualization of flight and airspace information, enabled through data sharing.

For example, the FAA's Space Data Integrator (SDI) is a prototype tool for tracking space vehicles during launch and reentry [22]. SDI receives vehicle state data from Operators, enabling FAA traffic managers to track a vehicle's actual trajectory and mission status, and view a graphical depiction of Aircraft Hazard Areas (AHAs) [23]. Real-time tracking information reduces the volume of airspace that needs to be closed during launch and reentry events [23].

In the UAS domain, the Low Altitude Authorization and Notification Capability (LAANC) is a collaboration between the FAA and UAS service suppliers to provide drone Operators access to ATC-controlled airspace, below 400 ft [24]. Drone pilots use applications provided by industry service suppliers to view a graphical depiction of available airspace and associated regulations, and request authorization to use these precoordinated areas [25]. Subsequently, data sharing allows the FAA to monitor drone flights in these areas.

These are several examples of tools and applications that use the graphical depiction of designated airspaces and data sharing to improve situation awareness and shared knowledge. The Integrated Visualization Tool that we describe here – designed to support the information needs of ETM-ATS interactions – aims to integrate airspace designation information, as well as flight tracking information, into a single display interface. A consolidated display is intended to enhance situation awareness across multiple ATS entities and ETM Operators by providing users with a "big picture" view of each flight to support end-to-end planning.

1. System Wide Information Management (SWIM)

The FAA's System Wide Information Management (SWIM) program is an information-sharing platform that facilitates the digital exchange of ATM information between different systems [27]. Users can access and subscribe to aeronautical, flight, and weather information. An **Integrated Digital Communication Tool** may utilize SWIM to gather real-time information.

E. Tool Functionality

The information/visualization needs we describe below were informed by procedural steps in the ETM-ATS use cases that require information *beyond what existing, and currently planned, tools can provide* (listed in Table 4 above).

1. Types of Information

We envision that the Integrated Visualization Tool will support situation awareness and coordination by providing users (the ETM Operator, ATC, Command Center ATS, facility-level ATS personnel, and CARF) with Flight Tracking and Airspace Designation information.

Flight Tracking. To increase the users' situation awareness of traffic, the tool should display a visual representation of *predicted* and *real-time* flight information.

- *Predicted* flight information is intended to provide users with a "big picture" view of each flight and support end-to-end planning. This includes the planned takeoff, ascent through ATC-controlled airspace, transit through Upper Class E (if applicable), operation within the ETM Cooperative Area (if applicable), descent through ATC-controlled airspace, and landing.
    - For ascent/descent through ATC-controlled airspace, predicted flight information may be displayed based on an IFR Flight Plan or "flight intent volumes" for vehicles that do not file an IFR Flight Plan (e.g., balloons).
    - For ETM Cooperative Area operations, predicted flight information may be based on an ETM Operation Plan, Operational Intents, or possibly a waypoint plan.
    - Predicted flight information may also include the flight's planned flight path within ALTRV.
- *Real-time traffic surveillance* information should be displayed for both conventional and ETM vehicles – whether the vehicle is equipped with a traditional Mode C/S transponder or an alternate position-reporting method, like ADS-B. Real-time traffic surveillance is intended to include vehicles operating *below* FL600 in ATC-controlled airspace (e.g., Lower Class E, Class A); yet to be determined, however, is whether real-time traffic surveillance of vehicles operating *above* FL600 in Upper Class E would also

be useful. For ETM operations, flights above FL600 are likely to be operating *within* an ALTRV or ETM Cooperative Area.

Airspace Designations. To increase the user's situation awareness of airspace-related information, the tool could display a visual representation of the location, altitude range, and boundaries of designated airspaces, possibly in a three-dimensional representation. Airspace designations that are, both, *currently active* and those that are *scheduled* should be displayed. The display could include several different types of airspace information:

- Fixed (permanent) airspace boundaries, such as, sector and ATC facility boundaries.
- ETM Cooperative Area boundaries, whether in Upper Class E or Class A.
- Airspace designations approved through CARF, including, ALTRVs and Informational-only airspaces (for balloons).
- Other airspace designations, such as SUAs, MOAs, and TFRs.

2. Display Components

We envision the Integrated Visualization Tool to include two primary display components, each described in more detail below:

- A **configurable map display** to provide a visual display of predicted flight information, real-time flight surveillance information, and the location and boundaries of designated airspaces.
- A **text-based flight list** of both scheduled and active flight information.

Configurable Map Display. The first component of the tool is the ***configurable map display***. Users at CARF, ATS, ATC, and possibly ETM vehicle Operators should be able to tailor their display to meet their information needs, as well as save their preferences and settings. Users should be able to resize and rotate the map, zoom in/out, and configure text size. Visual cues like color coding and icons may be integrated into the map display. Both flight tracking information and airspace designations are to be displayed on the map.

- **Flight Tracking Information on the Map.** The map should display a visual representation of predicted flight information and real-time flight surveillance to support situation awareness. Users should be able to configure and filter which flights are displayed – for example, depending on their information needs, a user may choose to display only conventional vehicles or only vehicles operating within an ETM Cooperative Area. The information elements in flight data tags (e.g., call sign, altitude, etc.) should also be configurable and each individual flight should be selectable to allow the user to access additional details (e.g., vehicle information, performance constraints, operator information, mission duration, etc.).
- **Airspace Designations on the Map.** In addition to flights, the map should display the location and boundaries of designated airspaces. Users should be to configure and filter the display of airspaces – for example, a user may choose to display ALTRVs and ETM Cooperative Areas below FL600, but not above FL600, or a user may want to view ETM Cooperative Areas, but not SUAs or MOAs. The information elements in airspace data tags (e.g., airspace type, activation/deactivation time, etc.) should also be configurable and each airspace should be selectable to allow the user to access additional details about that airspace (e.g., authorizing facility).

While some users may filter and configure the map to view *selected* information, the map should also aggregate *all* information about each flight – that is, the predicted flight information, real-time flight surveillance information, and the location and boundaries of designated airspaces – so that a complete, "big picture" view, from takeoff to landing, is available for each flight. For example, when a user selects an ETM flight currently ascending through ATC-controlled airspace that plans to utilize an ETM Cooperative Area in Upper Class E airspace, a complete view of the flight would include:

1. Real-time traffic surveillance to indicate the flight's current location/altitude.
2. Predicted flight information, including the remainder of the IFR Flight Plan up to FL600, a predicted trajectory through an ALTRV to traverse Upper Class E airspace, planned Operational Intents in the ETM Cooperative Area, and the IFR Flight Plan for descent (when available).

3. And, the location and boundaries of designated airspaces that the flight plans to utilize, such as, the ALTRVs in Upper Class E and ETM Cooperative Area.

Other types of information, such as weather or winds, should also be considered for the map display. Providing contact information, such as the nearest ATC sector's radio frequency/phone number or an ETM Operator's phone number, may be beneficial to some users.

Text-Based Flight List. The second component of the tool is a collapsible/expandable ***text-based flight list***. Users – CARF, Command Center ATS, facility-level ATS personnel, ATC, and ETM vehicle Operators – should be able to tailor the list to meet their information needs, as well as save their preferences and settings.

- **Flight Tracking Information in List Form.** Both active and planned flights should be included in the list. Depending on their information needs, a user should be able to configure and filter which flights are displayed in the list – for example, a user may choose to display only flights above a particular altitude or only certain vehicle types, for example, only ETM vehicles. The information presented for each flight in the list should also be configurable and each individual flight in the list should be selectable, allowing the user to access additional details about that flight.

Users should be able to collapse/expand the list and configure text size. Visual cues like color coding and highlighting may be integrated into the list.

3. *User Interface Features*

Where relevant, flight tracking and airspace designation information may be used together to provide notifications to users. For example, a Class A controller may find it useful to receive a notification when a vehicle transitions above FL600 into an ALTRV or when a vehicle transitions into/out of an ETM Cooperative Area. The visualization of flight-specific notifications may be enhanced by automatically highlighting the relevant flight on the display.

Interactions between the two display components, the map and the flight list, should be thoughtfully designed and tested to ensure they align with user expectations, for example:

- If the same filtering and configuration settings apply across both the map and flight list, then user actions should be reflected across both the map and list. That is, when the user selects a flight on the map, the same flight should be highlighted in the list and vice versa.
- However, if the map and flight list are configured independently of one another, user actions in the map should not impact the flight list display, and vice versa.
- Airspace designations depicted on the map should be selectable. When the user selects an airspace designation (e.g., an ETM Cooperative Area), flights that are currently operating in the Cooperative Area or that are scheduled to operate in that Cooperative Area should be highlighted.

F. Information Needs

We envision that an Integrated Visualization Tool would support situation awareness and coordination by providing users with Flight Tracking and Airspace Designation information. Specific data elements and potential sources of information are described in this section.

1. *Flight Tracking*

Flight tracking information includes both *predicted* flight information and *real-time surveillance* information. Vehicle equipage and performance capabilities impact the type of information that is available.

Predicted Flight Information (Intent Information):

- For balloons and other vehicles not required to be on an IFR clearance in Class A airspace (i.e., not equipped with a transponder or ADS-B), the **flight intent volumes** may be used to understand their intent.
- For vehicles that are required to be on an IFR clearance while in Class A airspace (i.e., equipped with a transponder and/or ADS-B), their **IFR Flight Plan** may be the best indicator of their intent.
- When a vehicle plans to utilize an ETM Cooperative Area, the **Operation Plan** which includes comprehensive operator, vehicle, and mission information, **Operational Intents** which are comprised

of the spatial (lateral and vertical aspects of the estimated trajectory) and temporal (duration of estimated trajectory) elements of a planned operation, or the **waypoint plan** may be used to understand their intent.

- When a vehicle plans to utilize an ALTRV in either Class A or Upper Class E airspace, the planned flight path through the ALTRV may be described in **lat/long/altitude**, similar to a **waypoint plan**.

Real-Time Flight Tracking for Situation Awareness:

- For balloons and other vehicles not required to be on an IFR clearance in Class A airspace (i.e., not equipped with a transponder or ADS-B), an alternate form of tracking information may be needed, such other Global Positioning System (GPS) sources, or reports via phone, internet, or data link.
- For vehicles that are required to be on an IFR clearance while in Class A airspace (i.e., equipped with a transponder and/or ADS-B), ADS-B or conventional radar coverage using the transponder could be used to track the flight in real-time.

2. Airspace Designation

Airspace designation information includes both permanent and temporary airspace boundaries, and associated activation/deactivation times. The tool should have the most up-to-date information about:

- Permanent ATC sector and facility boundaries, as well, as facility contact information (e.g., radio frequency, phone number).
- Temporary airspace designations from ATS/ATC, such as, SUA, MOA, and TFR.
- ETM Cooperative Area boundaries.
- Airspace designations approved through CARF, including, ALTRVs and Informational-only airspaces (for balloons).

3. Other Information

Other types of information may also be useful to users. For example, weather and wind information from a commonly accepted source could also be ingested and displayed by the tool.

Finally, in conjunction with the Integrated Visualization Tool, it would be ideal to integrate a second tool, a two-way Integrated Digital Communication Tool to facilitate information sharing between the different entities, such as CARF, Command Center ATS, facility-level ATS personnel, ATC, the ESS Network (automation), and ETM vehicle Operators. We will describe the Integrated Digital Communication Tool in Section V.

V.Integrated Digital Communication Tool

A. Purpose

The Integrated Digital Communication Tool is intended to create a set of communication capabilities that allows all parties to efficiently transmit data on a common platform, via a protected network. The goal is to improve communications and streamline coordination between the ETM Operator/ESS, ATC, Command Center ATS, facility-level ATS personnel, and CARF. Information exchange may be either one-way to two-way and some communication functions may be directly integrated within the Integrated Visualization Tool to allow users to input their information and visualize information from other users.

B. Background

There are several communication connections that need improvement and/or development to streamline the ETM process.

1. One-Way Communication Needs

- **Balloon Operators to Facility-level ATS/ATC Controllers –** Currently in Class A airspace, balloon Operators are required to communicate with ATS/ATC every two hours to provide position updates. Today this is done by making a phone call or sending a message directly to the ATC facility responsible for the airspace in which they are operating. Further, this communication is directed to staff personnel (e.g., supervisor/TMC) who must then relay the information to active ATC positions.

2. *Two-Way Communication Needs*

- **Balloon Operators to Facility-level ATS Personnel –** Currently, balloon Operators are required to communicate with facility-level ATS personnel and receive approval to conduct operations. Today this is usually accomplished using emails and/or text messages containing all relevant information. Digitizing this two-way communication will improve this process.

- **CARF to Facility-level ATS Personnel/ATC –** When CARF receives a request for an ALTRV located in Class A airspace, they coordinate manually with the affected ARTCC for approval. The request often is sent to an office function at the ARTCC (Airspace and Procedures, Military Coordinator, Traffic Management Unit (TMU)). This means the teletype (or other) message may not be seen on weekends, resulting in a delayed response. Digitizing this two-way communication process will make coordination more efficient. This communication capability may be included in a software tool/automation that CARF develops.

- **ATC Controller to ETM Operator –** Any vehicles that do not have an RPIC (e.g., balloon) do not communicate with an ATC controller via a radio frequency. Today, the ATC controller would, first, need to communicate to facility-level ATS personnel (i.e., supervisor/TMC), who would then convey the information to the ETM Operator, via a phone call. In the future, there is a need for a digital communication/messaging method (e.g., free text or data link) to provide more direct and timely communication between the ATC controller and the Operator.

- **CARF to Command Center ATS –** As discussed above for the visualization tool, there is a need for CARF and Command Center ATS to have common knowledge of all approved airspace constructs. A two-way, digital communication method could be utilized when it is necessary to alert the other facility of a change to an airspace construct (e.g., ALTRV) across Class A and Upper Class E airspace.

- **ETM Operator/ESS Network to Command Center ATS (and/or Other Service Providers) –** Current concepts of operation envision an ETM "entity" (e.g., the ESS) requesting activation of, receiving approval for, and promulgating information about an ETM Cooperative Area through the Command Center ATS. However, it might also be possible that an ETM Operator could coordinate directly with Command Center ATS to request approval for an ETM Cooperative Area. In either case, there is a need for a two-way communication tool that allows this request and approval process to take place between Operators, the ESS, and Command Center ATS.

There is also a need for more timely processing of changes to ETM airspace to increase efficiency. However, if 24 hours is still required for processing, then planning for ETM usage changes would be limited.

C. Potential Users and Tool Needs

In Table 5, we list the procedural steps from the ETM-ATS Use Cases that require communication capabilities *beyond what existing, and currently planned, tools can provide*. For a further description of each of these procedural steps, see the Appendix. As Table 5 shows, some of these communication needs are driven by vehicle differences, that is, vehicles that are not required to file an IFR flight plan or that are not equipped with a transponder or ADS-B (possibly balloons); others are based on the need for information sharing and common situation awareness in ETM operations.

Table 5. ETM-ATS Interaction Procedures that Require New Communication Capabilities

Vehicle Category (Equipage Type)	Appendix	ETM-ATS Interaction Procedural Step	How a New Integrated Digital Communication Tool Might be Helpful
Balloons and other ETM vehicles that are not equipped with a transponder or ADS-B and are not required to be on an IFR Clearance in Class A airspace.	*Appendix # 1*	The **balloon Operator** is responsible for providing their "flight intent volumes" to the **facility-level ATS (i.e., Supervisor/TMC at an ATC facility).**	*Two-way communication:* It would be helpful for the **balloon Operator** to be able to communicate *digitally* with **facility-level ATS personnel** about their "flight intent volumes", rather than by phone.
	Appendix # 2	The **Operator** is responsible for providing **facility-level ATS personnel (i.e., Supervisor/TMC at an ATC facility)** with real-time updates on the vehicle's location.	*One-way communication:* It would be helpful for **facility-level ATS personnel** to receive real-time position information about non-transponder equipped vehicles.
	Appendix # 3	The **ATC controller** may be responsible for some kind of deconfliction for safety (e.g., providing safety advisories) with respect to non-transponder equipped vehicles that cannot provide Mode C/S position data.	*Two-way communication:* For vehicles without an RPIC, it would be helpful to have a digitized communication channel or messaging method (e.g., free text) to enable communication between the **ATC controller** and the **Operator**.
	Appendix # 5	The **balloon Operator** files an *Informational-only airspace* request with the **CARF.**	*Two-way communication:* It would be helpful for **CARF** and the **Command Center ATS** to have a digital communication channel to alert the other of changes and to discuss changes via direct messaging.
	Appendix # 6	The **Operator** is responsible for providing **facility-level ATS personnel (i.e., Supervisor/TMC at an ATC facility)** notification of transition into the ETM Cooperative Area.	*Two-way communication:* It would be helpful for the **balloon Operator** to be able to communicate *digitally* with **facility-level ATS personnel** about when they cross a transition point (e.g., transitioning into an ETM Cooperative Area).
ETM vehicles that are equipped with a transponder and/or ADS-B and are required to be on an IFR Clearance in Class A airspace.	*Appendix # 4*	The **Operator** files a *Moving ALTRV* request with the **CARF.**	*Two-way communication:* It would be helpful for **CARF** and the **Command Center ATS** to have a digital communication channel to alert the other of changes and to discuss changes via direct messaging.
	Appendix # 6	The **Operator** is responsible for providing **ATC** notification of transition into the ETM Cooperative Area.	*Two-way communication:* Even though they are in radio contact with the controller, it may be helpful for the **ETM Operator** to be able to communicate *digitally* **ATC** about when they cross a transition point (e.g., transitioning into an ETM Cooperative Area).
All Vehicle Types	*Appendix # 7*	While operating in ETM Cooperative Areas, **Operators** define their intent using Operation Plans, Operational Intents, or waypoint plans.	*Two-way communication:* It would be helpful for **other users** if the **ETM Operator/system** could digitally share information about their Cooperative Areas and intended operations.

**Numbers correspond to the tables in the Appendix.*

Following are more details about how a digital communication tool could be used by various users.

- **ETM Operators –** Operators would use the communication tool for two primary purposes. First, Operators who do not have a RPIC in direct communication on a radio frequency with an ATC controller could use the tool to provide position updates and other information to the controller or facility-level ATS personnel. Second, Operators could use the tool to share Operational Intents and carry out other necessary communications with facility-level ATS personnel.

- **ESS Network –** The ESS Network would use the communication tool to provide requests to Command Center ATS for ETM Cooperative Area approvals. The ESS Network could also use the tool to promulgate ETM Cooperative Area information and ETM flight intent (e.g., Operation Plan, Operational Intents, waypoint plan) with other users.
- **CARF –** CARF processes requests, and approves, ALTRV usage. CARF could use the tool when coordination is necessary with facility-level ATS personnel to resolve conflicts with airspace requests or usage (for example, an emergency requiring cancellation of a previously approved designated airspace). It would also be advantageous to have a method to share cancellations and/or changes to ALTRVs with other users. CARF has requested the development of a digital communication tool for coordinating ALTRVs with both ETM Operators and facility-level ATS personnel.
- **Command Center ATS –** Command Center ATS would use the tool to coordinate approvals for ETM Cooperative Areas with the ESS Network/Operators. Additionally, they could use the tool for coordination with CARF, if necessary. In cases where an ETM Cooperative Area request is within Class A airspace, they could also use the tool to coordinate with the facility-level ATS personnel.
- **Facility-level ATS –** Facility-level ATS personnel (i.e., supervisor/TMC at an ATC facility) could use the tool to coordinate with both CARF and Command Center ATS for airspace approvals (ALTRVs and ETM Cooperative Areas) in Class A airspace.

D. Current Technologies

As mentioned above, ATC controllers communicate with IFR flights in Class A airspace via direct radio communications. In addition, there is ongoing use in Terminal Radar Approach Control Facilities (TRACONs) and testing in ARTCCs of controller pilot data link communications (CPDLC) between controllers and pilots.

Today, balloon Operators must utilize **telephone or email/text** options to communicate with ARTCCs to coordinate approval of their mission, provide required position updates every two hours during the mission, and coordinate their descent back to the ground. During operations, coordination takes place with a supervisor/TMC, who then must relay the information to ATC controllers.

Operations in Upper Class E, in particular, the *upper altitudes* of Upper Class E, may require different communication channels than conventional aircraft. With limitations on altitude, it is thought that conventional air-to-ground voice communication may be an option in Upper Class E, however, data communications (e.g., DataComm) may offer another communication option [26].

Likewise, the CARF at the ATCSCC coordinates with ARTCCs via **teletype, telephone, or email** when requesting ALTRV approval in Class A airspace. ARTCC approvals are via the same communication channel. When an ALTRV is approved the ARTCC specialist usually provides **printed copies** of the ALTRV to controllers that they place at their sector position for reference.

Currently, there is neither an ATS function, nor ESS capability, that would facilitate coordination with each other or with CARF. However, even if these capabilities did exist, there is currently only **telephone, teletype, and email/text** messages available for communication purposes.

E. Tool Functionality

We envision that the Integrated Digital Communication Tool will provide a "*visualized communication capability*", enabling a one- or two-way communication channel between users, including, the ETM Operator/ESS Network, ATC, Command Center ATS, facility-level ATS personnel, and CARF. Communication functions will be supported through the user interface, allowing users to input information, such as, flight intent or direct messaging, and enabling the notification/visualization of information for recipients.

The communication needs we describe below were informed by procedural steps in the ETM-ATS use cases that require communication capabilities *beyond what existing, and currently planned, tools can provide* (listed in Table 5 above).

- **Flight intent for vehicles that do not file an IFR Flight Plan.** Because some ETM vehicles will not file a conventional IFR Flight Plan due to performance constraints (e.g., balloon), a different method for communicating flight intent would be useful. The communication tool should support shared awareness of flight planning by enabling two-way communication between the **ETM Operator** who does not file an IFR Flight Plan (e.g., balloon) and **facility-level ATS personnel (supervisor/TMC at an ATC facility)** who need information about the vehicle's intent.

Prior to the planned flight, the Operator should be able to enter their "flight intent volumes" through the user interface and use the tool to send that information to facility-level ATS personnel. For convenience, the Operator should be able to load previously used flight trajectories and save any new flight paths for future reference.

Facility-level ATS personnel, like the supervisor/TMC, may be alerted to new flight information through an audio/graphical cue in the user interface. The "flight intent volumes" may be displayed in the form of text and/or depicted graphically. To assess potential conflicts, facility-level ATS users should be able to display the flight's predicted flight path along with the *real-time* and *predicted* flight information of other flights.

In turn, facility-level ATS personnel should be able to acknowledge receipt of the information and provide approval, if necessary, via pre-programmed response buttons. If changes are requested, the supervisor/TMC should be able to communicate via direct messaging (free text) with the ETM Operator.

- **Real-time vehicle position information for *non-transponder equipped* vehicles. Operators** of non-transponder equipped vehicles are responsible for providing **facility-level ATS personnel (i.e., supervisor/TMC at an ATC facility)** with updates on the vehicle's location. However, because these vehicles will not be visible on the ATC radar scope and may not have an RPIC to communicate via a radio frequency, an alternate method for communicating/displaying surveillance data could be useful. We envision that the communication tool could fulfill this need by using a one-way communication channel to provide vehicle position data to facility-level ATS personnel/the ATC controller.

  These data could be used to depict a visual representation of flights on the map, improving situation awareness for the facility-level ATS personnel/ATC controller, as well as for other users. Vehicle position information from an alternate source is intended to be used for situation awareness, not to support separation services. Vehicle position information would likely be automatically transmitted and not require manual input by the Operator.

  A communication channel for non-radar based vehicle position information may also serve to fill gaps in conventional radar coverage, as well. That is, in parts of the country where radar does not reach above FL600, an alternate method of providing vehicle position information may be leveraged when *transponder-equipped vehicles* are outside the coverage area.

  The ESS Network may also play a role in communicating vehicle position information through a communication bridge to ***Air Traffic Services (ATS)*** on the FAA side.

- **Coordination for designated airspaces.** As discussed in the Integrated Visualization Tool section, it will be useful for all users to see a graphical depiction of designated airspaces on the map, including ALTRVs and Informational-only airspaces, both of which are approved by **CARF**.

  In addition to a visualization tool, a two-way, digital communication channel would help facilitate communication between **CARF** and **Command Center ATS**. A communication channel would be useful if a change is required within 24 hours of the planned activation of the ALTRV/Informational-only airspace. A two-way channel would allow either CARF or Command Center ATS to initiate a notification/alert, through the user interface, to the other entity and use a direct messaging function in the interface to discuss the change with the other facility.

- **Notifications, advisories, free text, etc.** In one of the procedural steps in the ETM-ATS interaction use cases, we identify the **ETM Operator** as being responsible for notifying the **ATC controller/facility-level ATS personnel** when the vehicle transitions above FL600.

  A two-way, digital communication channel would facilitate communication between ETM Operators that do *not* have an RPIC communicating with a controller on a radio frequency and the ATC controller/facility-level ATS personnel. While vehicles that have an RPIC will already be in verbal communication with the controller via a radio frequency, they, too, may benefit from having a digital communication mechanism with the ATC controller/facility-level ATS personnel.

Notifications for events, such as, ascending above FL600, and other messaging would be sent via the user interface. Preset buttons for standardized messaging should be available in the interface for both the Operator to send a notification, such as, “transitioning above FL600”, and for the ATC controller/facility-level ATS personnel to provide an acknowledgment. Depending on the user’s preference, notifications may be auditory, graphical, or both. Digital communication like this may support ATC hand-off procedures, as well.

In addition to pre-programmed notifications/responses, users should also be able to send free text for communication that is not already captured through standardized, pre-programmed buttons. Free text messages should be enabled through the user interface.

It is also possible that the ESS/ESS Network may utilize this communication channel to automatically send information to the ATC controller/facility-level ATS personnel. A two-way, digital communication tool may also aid in the coordination of transitions, such as, transitioning into/out of an ETM Cooperative Area, ALTRV, or Informational-only airspace.

- **Requests/approvals for ETM Cooperative Areas and ETM flight operations information.**

  Requests/Approvals for ETM Cooperative Areas. **ETM Operators and/or the ESS Network**, could request the activation of a new ETM Cooperative Area, or modification of an existing one, from the **Command Center ATS**. A new, two-way, digital communication channel would support the approval/coordination process. The request for a new, or modified, Cooperative Area may come from an Operator who enters information manually in the user interface, or the process may be more automated and initiated by the ESS Network. The Operator’s user interface should allow them to enter specifications for the ETM Cooperative Area, for example, the requested location, size, duration, and number of planned ETM operations. Likewise, the user interface at the Command Center should support the display of that information and the visualization of the requested Cooperative Area. Through the user interface, ATS users should have the ability to modify, approve, or reject the requested Cooperative Area.

  An important part of this coordination/approval process will be the aggregated information displayed in the Integrated Visualization Tool – that is, the predicted flight information, real-time flight surveillance, and airspace designations (ALTRVs, Informational-only airspaces, SUA, TFR, etc.). Both the ETM Operator/system and ATS should be able to utilize the aggregated information to assess the safety and feasibility of a requested Cooperative Area.

  Once an ETM Cooperative Area is approved/modified, other entities, including CARF, facility-level ATS personnel, and ATC will benefit from having a common awareness of ETM Cooperative Areas through the Integrated Visualization Tool.

  ETM flight operations information. A two-way, digitized communication channel with the **Command Center ATS** will also allow the **ETM Operator** to share flight intent in the form of an Operation Plan, Operational Intents, or a waypoint plan. The Operator should be able enter, or import, this information through the user interface or the data elements should be communicated by the ESS Network. A mechanism for pulling information about the Operation Plan, Operational Intent, or a waypoint plan from the ESS/ESS Network may be the most efficient method for capturing and sending this information. If the Operator makes changes to their mission, the Command Center ATS should be alerted through their user interface.

  Like information about ETM Cooperative Areas, providing a visualization of ETM flight intent information may be useful to other entities too.

F. Information Needs

We envision the Integrated Digital Communication Tool to help fulfill communication needs between users through one- and two-way digitized communication channels. The primary categories of information for communication are notifications/advisories, flight information, requests/approvals, and free-text direct messaging.

1. *Notifications/Advisories*

   - A communication channel may be used to provide notifications/advisories between Command Center ATS and CARF about **changes to ALTRVs or Informational-only airspaces**. One entity may need to alert the other about changes, particularly changes that occur *within* 24 hours of the planned activation time.

   - A communication channel may be used to send **notifications/advisories** between the ETM Operator and the ATC controller/facility-level ATS personnel. For example, Operators may notify the ATC controller when the vehicle transitions above FL600. Notifications/advisories could also potentially be used to support transitions into/out of an ETM Cooperative Area, ALTRV, or Informational-only airspace.

2. *Flight Information*

   - **Flight intent information for ATC-controlled airspace** may be needed for vehicles that do *not* file an IFR Flight Plan. For example, a balloon Operator could provide their "flight intent volumes" the form of lat/longs/altitudes or a waypoint plan.

   - **Flight information for the ETM Cooperative Area** could be communicated to Command Center ATS. For example, the Operator/ESS Network may share the Operation Plan, Operational Intents, comprised of spatial and temporal elements, or waypoint plan.

   - **Real-time flight information** may be needed for vehicles not equipped with a transponder or ADS-B, and that do not have an RPIC in communication with the ATC controller. Non-radar based vehicle position information would use an alternate source of position information, such as, GPS-based information. Alternate position information may also fill a gap for conventional vehicles when they experience a lapse in radar coverage (e.g., above FL600 in certain parts of the country).

3. *Requests/Approvals*

   - A two-way communication channel could facilitate the coordination of requests and approvals, such as those for the **activation/modification of a new ETM Cooperative Area**. The ETM Operator and/or the **ESS Network** may request the activation/modification of an ETM Cooperative Area from Command Center ATS.

4. *Free Text (Direct Messaging)*

   - Free text (direct messaging) may be utilized between Command Center ATS and CARF to discuss and resolve **changes to ALTRVs or Informational-only airspaces.**

   - Free text (direct messaging) may also be useful for communication between the ETM Operator and the ATC controller/facility-level ATS personnel about information pertaining to a **notification or advisory**. When standardized messages are not sufficient, direct messaging may facilitate communication between the two entities.

VI. Next Steps and Conclusions

New and innovative, high-altitude vehicles will be integrated into the NAS with the conventional ATM system and will co-exist with conventional aircraft. ETM operations are expected to interact with different entities of the Air Traffic System (ATS) (i.e., ATC controller, supervisor/TMC, CARF, etc.) as they ascend/descend through ATC-controlled airspace, enter/exit ETM Cooperative Areas, and transit through Upper Class E to/from ETM Cooperative Areas. In this paper, we describe two tools to support these ETM-ATS interactions, an Integrated Visualization Tool for Flight Tracking and Airspace Designations and an Integrated Digital Communication Tool.

We used previously developed ETM-ATS interaction use cases – in which we created step-by-step procedures for entry into/exit from an ETM Cooperative Area – to identify information needs, specifically focusing on those procedures that require information/communication support *beyond what existing, and currently planned, tools can provide.* The tools we describe here create an integrated visual representation of vehicles and airspace designations with a set of communication capabilities to consolidate information into a single display interface. The information presented in the display interface is intended to enable a "big picture" view of each flight, from takeoff to landing.

Now that we have identified the visualization and communication tool requirements, next steps will include prototyping the functionalities and the user interface for these tools and evaluating them in a simulated environment. Simulations could include scenarios based on the ETM-ATS interaction use cases, which would allow participants to walk through the procedures using the prototype tools. The tools would be evaluated based on their usefulness in supporting ETM-ATS interaction procedures, as well as overall usability parameters. We hope to pursue this prototype development in future concept evaluations at NASA Ames Research Center.

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Appendix

Acronym List

Acronym	Definition
AAM	Advanced Air Mobility
AHA	Aircraft Hazard Areas
ALTRV	Altitude Reservation
ARTCC	Air Route Traffic Control Center
ATC	Air Traffic Control
ATCAA	ATC Assigned Airspace
ATCSCC	Air Traffic Control System Command Center
ATM	Air Traffic Management
ATO	Air Traffic Organization (ATO), an operational arm of the FAA
ATS	In the ETM concept, the ESS Network is expected to provide a communication bridge to ***Air Traffic Services (ATS)*** on the FAA side, to support exchange of information between the ETM system and the conventional ATM system. As we developed our use cases and procedural steps, we broadened the definition of ***Air Traffic Services (ATS)*** to include both the *automation* and the *humans* involved in the information exchange between ETM and conventional ATM. The reason for expanding the definition is that we envision that communication exchanges that center on human operators today, such as TMCs, may eventually be supplanted by *automation* in future interactions with ETM, though it is unclear when a change like that may happen. Therefore, we describe ***Air Traffic Services (ATS)*** handling these information exchanges and coordination with an understanding that it may be done by *automation* or in conjunction with a *human* service provider. For the purpose of defining roles/responsibilities and information exchange in our use cases, we broke down "***Air Traffic Services (ATS)***" into two entities: • **Command Center Air Traffic Services (ATS)** refers to the services and air traffic service providers at the NAS-wide level, akin to the Command Center function. • **Facility-level Air Traffic Services (ATS)** refers to the services and air traffic service providers at the ATC facility-level, akin to the Area Supervisor or Traffic Management Coordinator (TMC).
ATS	Air Traffic System
CARF	Central Altitude Reservation Function
COA	Certificate of Authorization
ConOps	Concept of Operations
COP	Cooperative Operating Practice
CPDLC	Controller Pilot Data Link Communications

DSS	**Discovery and Synchronization Service (DSS)** within the automation process that connects multiple ESSs together to share information and provide a cooperative framework for Operators to share situational awareness with each other.
ERAM	En Route Automation Modernization
ESS	**ETM Service Supplier (ESS)** refers to a communication bridge between the ETM Operator and others in the ETM eco-system that provides tools, automation, or services to monitor the region, execute safe missions, store operational data, etc.
ESS Network	**ETM Service Supplier (ESS) Network** refers to network automation that connects multiple ETM Operator service suppliers together to share information and provide a cooperative framework for the Operators. The **ESS Network** also provides a communication bridge to Air Traffic Services (ATS) on the FAA side. ATS is a new, FAA-provided service that enables a gateway to the ESS Network to exchange relevant ETM vehicle information between ETM and the conventional ATM system.
ETM	Upper Class E Traffic Management
FAA	Federal Aviation Administration
FL	Flight Level (e.g., FL600)
GPS	Global Positioning System
HALE	High-Altitude Long Endurance
IFR	Instrument Flight Rules (e.g., an IFR flight plan)
LAANC	Low Altitude Authorization and Notification Capability
MOA	Military Operation Area
MTR/AR	Military Training Route/Aerial Refueling
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NOTAM	Notice to Air Missions
NSA	National Security Area
OI	Operational Intent
PCA	Positive Control Airspace
PIC	Pilot-in-Command
RPIC	Remote Pilot-in-Command
SAA	Special Activity Airspace
SDI	Space Data Integrator
SUA	Special Use Airspace
TFR	Temporary Flight Restriction
TMC	Traffic Management Coordinator

TMU	Traffic Management Unit
TRACON	Terminal Radar Approach Control Facility
UAM	Urban Air Mobility
UAS	Uncrewed Aircraft System
UCE	Upper Class E airspace
UTM	Uncrewed Aircraft System (UAS) Traffic Management

ETM–ATS Interaction Procedures

Of the dozens of individual procedural steps in the ***ETM-ATS interaction use cases***, these are the seven specific procedural steps that will require information exchange/communication support ***beyond what existing, and currently planned, tools can provide***.

For each procedural step, we identified the roles/responsibilities, the current-day method, the envisioned tool, and the visualization and/or communication needs.

#1: Class A Airspace

Roles/ Responsibilities	Current Day Method	Envisioned Tool	Visualization Tool Information Need	Communication Tool Information Need	Additional Notes
Balloons and other ETM vehicles that are not equipped with a transponder or ADS-B and are not required to be on an IFR Clearance in Class A airspace: Prior to departure or descent from an ETM Cooperative Area, the **Operator** is responsible for providing their “flight intent volumes” to the **facility-level ATS (i.e., Supervisor/ Traffic Management Unit at an ATC facility)** for their ascent/descent through ATC-controlled airspace. The **facility-level ATS** can communicate this information to the ATC position(s) who are responsible for the Sector(s) that may be impacted.	Currently, a manual process by which the Operator contacts facility-level ATS (i.e., Supervisor/Traffic Management Unit at the ATC facility**)** by phone or email to communicate their predicted trajectory.	**Visualization:** It would be helpful for **facility-level ATS personnel** to visualize the “flight intent volumes.” **Communication:** It would be helpful for the **balloon Operator** to be able to communicate digitally with **facility-level ATS personnel** about their “flight intent volumes.”	Intent information, “flight intent volumes”, predicted trajectory based on the vehicle’s capabilities. May be communicated in the form of predicted waypoints, uncertainty errors, future intents, etc.	A digital communication channel to support two-way communication between the ETM Operator who does not file an IFR Flight Plan (and who does not have an RPIC communicating on a radio frequency with a controller) and facility-level ATS (i.e., Supervisor/ Traffic Manager) to communicate flight intent and approval, if necessary.	New tool/function are needed for balloons and other vehicles not required to be on an IFR Clearance in Class A airspace (i.e., not equipped with a transponder or ADS-B). There would need to be a better method than phone/email to relay flight intent information. In the future, communication may be digitized. **User Interface:** Text description/visual representation of predicted trajectory, defined by lat/longs/altitude at time x. The vehicle’s “flight intent volumes” should be available to an ATC controller once the vehicle enters their sector. The controller should be able to view the vehicle’s “flight intent volumes” to see how it impacts their sector.

#2: Class A Airspace

Roles / Responsibilities	Current Day Method	Envisioned Tool	Visualization Tool Information Need	Communication Tool Information Need	Additional Notes
Balloons and other ETM vehicles that are not equipped with a transponder or ADS-B and are not required to be on an IFR Clearance in Class A airspace: During ascent or descent from an ETM Cooperative Area, the **Operator** is responsible for providing **facility-level ATS (i.e., Supervisor/ Traffic Manager)** with updates on the vehicle's location. The **facility-level ATS (i.e., Supervisor/ Traffic Management Unit at ATC Facility)** can communicate this information to the ATC position(s) who are responsible for the Sector(s) that may be impacted.	Currently, a manual process by which the Operator communicates current location (lat/long/ altitude) by phone, teletype, fax, or email to the facility-level ATS (i.e., Supervisor/ Traffic Management Unit at ATC Facility). The current-day process is to update route and rate of climb every two hours. Note: The University of Montana currently uses phone communication for balloons. They also provide a third-party tool to ATS for awareness of a balloon's location.	**Visualization:** It would be helpful for the **facility-level ATS personnel** to be able to visualize the position information of non-transponder equipped vehicles. **Communication:** It would be helpful for **facility-level ATS personnel** to receive real-time position information for non-transponder equipped vehicles.	Current position information and altitude (e.g., based on GPS tracking information). May also include ascent/descent rate. This information will enable the visual representation of flights on the map.	One-way, digital communication channel for vehicle tracking/position information.	If ATS needs to monitor these vehicles, then a new tool/function is needed for balloons and other vehicles not required to be on an IFR Clearance in Class A airspace (i.e., not equipped with a transponder or ADS-B). Today's method is not sufficient to support these types of vehicles in the future. In the future, communication may be digitized. A new tool/display is needed to display a visual representation of these vehicles using an alternate reporting method, we would need their position info, predicted path, time information, etc. **User Interface:** Text description/visual representation of location. Notifications for Situation Awareness: Launch, above FL600, below FL600. The tool may provide functions similar to the ERAM display and voice communication typically used by conventional, transponder-equipped aircraft.

#3: Class A Airspace

Roles / Responsibilities	Current-Day Method	Envisioned Tool	Visualization Tool Information Need	Communication Tool Information Need	Additional Notes
Balloons and other ETM vehicles that are not equipped with a transponder or ADS-B and are not required to be on an IFR Clearance in Class A airspace. The **ATC controller** may be responsible for some kind of separation for safety (e.g., they would provide safety advisories). The ATC controller would communicate with the Operator to have the vehicle pause/resume climb – as vehicle capabilities allow. The **Operator** would be responsible for responding to the **ATC controller's** instructions.	(For transponder-equipped aircraft) ATC tools, including target with datablock that is displayed on the scope (enabled by transponder or ADS-B).	**Visualization:** It would be helpful for **ATC controllers** to be able to visualize the position information of non-transponder equipped vehicles. **Communication:** For vehicles without an RPIC, it would be helpful to have a digitized communication channel or messaging method (e.g., free text) to enable communication between the **ATC controllers** and the **Operator**.	Current position information and altitude (e.g., based on GPS tracking information). May also include ascent/descent rate. This information will enable the visual representation of non-transponder equipped vehicles on the map.	Two-way, digital communication channel to support communication (e.g., free-text messaging) between the ETM Operator (who does not have an RPIC using a radio frequency to communicate with ATC) and the ATC controller.	Balloons and other vehicles not required to be on an IFR Clearance in Class A airspace (i.e., not equipped with a transponder or ADS-B) are not visible on the conventional radar scope (i.e., no real-time surveillance). These vehicles may have different separation requirements/ performance characteristics than conventional vehicles – they would not move through Class A like conventional vehicles. When using alternate position reporting methods, like GPS, the accuracy of the position information cannot be guaranteed, so we cannot expect ATC controllers to use their normal separation heuristics. Non-transponder equipped vehicles would need to be handled differently by the ATC controller than conventional vehicles, for example, maybe having a larger bubble around them. Controllers may consider them as an "obstacle" for Mode C/S vehicles to work around. The visual representation on the new tool will not be for radar separation, it is not intended for real-time surveillance, rather it will support situation awareness.

#4: Upper Class E Airspace

Roles / Responsibilities	Current-Day Method	Envisioned Tool	Visualization Tool Information Need	Communication Tool Information Need	Additional Notes
ETM vehicles that are equipped with a transponder and/or ADS-B and are required to be on an IFR Clearance in Class A airspace: In order to transit through Upper Class E, the Operator will utilize an Altitude Reservation (ALTRV). The **Operator** files a Moving ALTRV request with the **Central Altitude Reservation Function (CARF)** 24–72 hours before the vehicle plans to utilize the ALTRV. If there is a conflict, they notify the Operators. Otherwise, CARF issues approval to the **Operator**.	Currently, there is no mechanism to share information about approved ALTRVs with other entities. Other facilities do not currently have the ability to visualize ALTRVs. Currently, there is no digital communication channel to support sending notifications or direct messaging between CARF and the Command Center ATS.	**Visualization:** It would be helpful for **Command Center ATS** and **other entities** to be able to visualize the location/ boundaries of ALTRVs. **Communication:** It would be helpful for **CARF** and the **Command Center ATS** to have a two-way digital communication channel to alert the other of changes and to discuss changes via direct messaging.	Location (lats/longs/ altitude) of ALTRV and start/end times to generate a graphical depiction of the airspace on the map.	Need for a two-way communication channel between CARF and the Command Center ATS in the event that a change is needed within 24 hours of the ALTRV's activation time. A two-way communication channel would allow one facility to alert the other of a change and use direct messaging capabilities to discuss any changes.	**Assumption:** CARF will already have a tool that allows them to digitally coordinate/ communicate ALTRV requests with Operators. The visualization tool we envision here supports users having common knowledge of ALTRVs through graphical depictions on the map. The communication tool that we envision supports communication between CARF and the Command Center ATS to notify the other of changes and to use direct messaging to discuss changes. Note: Currently, CARF does not actively monitor ALTRV usage, they only approve ahead of time. Right now, CARF is a "strategic" tool. In the future, there will be a need for more dynamic coordination procedures. **User Interface:** Visual representation of airspace boundaries, ALTRVs, Informational-only airspaces. Interface for sending notifications/alerts and for direct messaging.

#5: Upper Class E Airspace

Roles / Responsibilities	Current Day Method	Envisioned Tool	Visualization Tool Information Need	Communication Tool Information Need	Additional Notes
Balloons and other ETM vehicles that are not equipped with a transponder or ADS-B and are not required to be on an IFR Clearance in Class A airspace: In order to transit through Upper Class E, the **Balloon Operator** will utilize Informational-only airspace. The **Balloon Operator** files an Informational-only airspace request with the **Central Altitude Reservation Function (CARF)** 24–72 hours before the vehicle plans to utilize the airspace. If there is a conflict, they notify the Operators. Otherwise, CARF issues approval to the **Operator**.	Currently, there is no mechanism to share information about Informational-only airspaces with other entities. Other facilities do not currently have the ability to visualize Informational-only airspaces. Currently, there is no digital communication channel to support sending notifications or direct messaging between CARF and the Command Center ATS.	**Visualization:** It would be helpful for **Command Center ATS** and **other entities** to be able to visualize the location/ boundaries of Informational-only airspaces. **Communication:** It would be helpful for **CARF** and the **Command Center ATS** to have a two-way digital communication channel to alert the other of changes and to discuss changes via direct messaging.	Location (lats/longs/ altitude) of Informational-only airspaces and start/end times to generate a graphical depiction of the airspace on the map.	Need for a two-way communication channel between CARF and the Command Center ATS in the event that a change is needed within 24 hours of the Informational-only airspace's activation time. A two-way communication channel would allow one facility to alert the other of a change and use direct messaging capabilities to discuss any changes.	**Assumption:** CARF will already have a tool that allows them to digitally coordinate/ communicate ALTRV requests with Operators. The visualization tool that we envision here supports users having common knowledge of Informational-only airspaces through graphical depictions on the map. The communication tool that we envision supports communication between CARF and the Command Center ATS to notify the other of changes and to use direct messaging to discuss changes. Note: Currently, CARF does not actively monitor Informational-only airspaces usage. Right now, CARF is a "strategic" tool. In the future, there will be a need for more dynamic coordination procedures. **User Interface:** Visual representation of airspace boundaries, ALTRVs, Informational-only airspaces. Interface for sending notifications/alerts and for direct messaging.

#6: Transition Into/Out of ETM Cooperative Area

Roles / Responsibilities	Current Day Method	Envisioned Tool	Visualization Tool Information Need	Communication Tool Information Need	Additional Notes
Vehicle Exits Class A Airspace and Ascends above FL600: The Operator/RPIC is responsible for notifying ATC that the vehicle is leaving Class A airspace. **Balloons and other ETM vehicles that are not equipped with a transponder or ADS-B and are not required to be on an IFR Clearance in Class A airspace:** The notification is either: a) sent automatically to **ATS (facility level)**, or b) communicated to **ATS (facility level)** Controller by the Operator/ RPIC. **ETM vehicles that are equipped with a transponder and/or ADS-B and are required to be on an IFR Clearance in Class A airspace:** The notification is either: a) sent automatically to **ATC**, or b) communicated to **ATC** controller by the Operator/RPIC. *For transponder-equipped vehicles, this is a "nice to have" because they already have communication with the ATC controller via the radio frequency.	**Vehicles Equipped with a Transponder or ADS-B:** Verbally, via radio frequency. **Balloons and Other Vehicles Not Equipped with a Transponder or ADS-B:** Via phone call to ATS.	**Visualization:** It would be helpful for the **ATC controller/facility -level ATS personnel** to be able to visualize the position information of non-transponder equipped vehicles and receive notifications about transition points (e.g., ascending above FL600). **Communication:** It would be helpful for the **balloon Operator** to be able to communicate digitally with the **ATC controller/ facility-level ATS personnel** about when they cross a transition point (e.g., transitioning into an ETM Cooperative Area).	In combination with the visual representation of non-transponder equipped vehicles on the map, there is a need for visual/ graphical cues for notifications and transitions for the **ATC controller/ facility-level ATS personnel**.	Need for a two-way communication channel for notifications, such as ascending above FL600, and other messaging will be sent via the user interface. Preset buttons for standardized messaging should be available in the interface for both the Operator to send a notification, such as, "transitioning above FL600", and for the **ATC controller/ facility-level ATS personnel** to provide acknowledgment.	New tool/function is needed to support "airspace awareness" will be needed when the vehicle transitions from Class A into the ETM Cooperative Area. As the vehicle transitions above FL600 and into an ETM Cooperative Area, the ATC controller may have access to position information and be able to see a visual representation of the vehicle on their scope. However, if the ATC controller does not have access to position information – because coverage is not available in that part of the country or because the vehicle is not equipped with a transponder **or ADS-B** – then new tools/functions are needed. **Visualization:** The visualization tool is dependent on whether an alternate means of surveillance for vehicles that don't have conventional transponder.

#7: Transition Into/Out of ETM Cooperative Area

Roles / Responsibilities	Current Day Method	Envisioned Tool	Visualization Tool Information Need	Communication Tool Information Need	Additional Notes
All Vehicle Types: ETM Operator requests activation of an ETM Cooperative Area. ETM Operator creates an Operation Plan/ Operational Intents.	There is no current-day method for the ETM Operator/ system to digitally share airspace designation information or flight intent with other entities.	**Visualization:** It would be helpful for **other users** to be able to visualize active/planned ETM Cooperative Area boundaries and ETM intent information. **Communication:** It would be helpful for **other users** if the **ETM Operator/system** could digitally share information about their Cooperative Areas and intended operations.	Need to visualize flight intent, for example, newly created ETM Operation Plan, Revised ETM Operation Plan, or IFR Flight Plan. ETM Cooperative Area location, boundaries, and activation times.	Need for a two-way communication channel from the **ETM Operator/ ESS Network** to **facility-level ATS (i.e., Supervisor/Traffic Manager) and other users** to update ETM Cooperative Area information and provide flight intent.	A functionality that allows the ETM Operator to share the <u>full set</u> of info for their proposed flight/mission in one place. The tool would be able to distinguish the IFR Flight Plan/ Operation Plan/ ALTRV. The ETM Operator would be able to share: Operator establishes their OI and the trajectory of their vehicle through an ALTRV. Based on those, the Operator creates an IFR Flight Plan/ Departure Time. **User Interface:** At a minimum, a text description of ETM Operation Plan, IFR Flight Plan, and/or ALTRV (lat longs/altitudes/ times). Ideally a visual representation of flight information and airspace boundaries.