Federal Aviation Administration

National Aeronautics and Space Administration

# *Cover Letter*

## UTM RTT CWG Concept & Use Cases Package #2

The Concept & Use Cases Package #2: Technical Capability Level 3 document represents the collaborative research efforts between the FAA and NASA as joint members of the Unmanned Aircraft System Traffic Management (UTM) Research Transition Team (RTT). Contained in this document are the 1) Terms and Definitions, 2) Foundational Principles, 3) Concept Narratives, 4) Use Cases, 5) Operational Views, and 6) Roles and Responsibilities of actors interacting within what is considered to be encompassed by Technical Capability Level 3 UTM operating environments. **The contents of Package #2 should NOT be considered established policy or construed as regulatory in nature.** What is presented is meant to communicate the current, agreed upon understanding between the FAA and NASA on particular features of UTM as exemplified through use cases and concept narratives for the purposes of supporting joint NASA/Industry Demonstrations and the UTM Pilot Program. It is also meant to foster discussion and refinement of the concepts and approaches being pursued by the other RTT working groups.

March 2018

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Federal Aviation Administration

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# Unmanned Aircraft System Traffic Management (UTM) Research Transition Team

## *Concept Working Group*

**Concept & Use Cases Package #2:** Technical Capability Level 3

Version 1.0

March 2018

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# 1 Introduction

## 1.1 The Need for UAS Traffic Management (UTM)

As the technical, programmatic, and operational needs associated with Unmanned Aircraft System (UAS) integration are being addressed, public and civil UAS operations are expected to increase dramatically. The small UAS (sUAS) fleet could escalate to approximately 542,500 over a five-year period. While this sounds impressive, this estimate does not include large scale beyond visual line of sight (BVLOS) operations, such as deliveries, which, once enabled, could increase the operations by millions[1]. The Federal Aviation Administration (FAA) expects that the full gamut of UAS operations will encompass everything from those that are fully contained in uncontrolled airspace, to those that require transit across the boundary between controlled and uncontrolled airspace, and finally to those that originate and operate within controlled airspace.

Integration of UAS operations into the National Airspace System (NAS) presents a variety of issues and novel challenges particularly in low altitude airspace uncontrolled airspace. The National Aeronautics and Space Administration (NASA) and the FAA have joint interests in identifying innovative, transformative integration solutions that can effectively respond to these challenges without compromising safety or efficiency of the NAS. In 2015, a Research Transition Team (RTT) was formed between NASA and the FAA to jointly develop and enable a UAS traffic management (UTM) ecosystem to provide management services to UAS operating in airspace where air traffic services are not provided.

UTM is a separate, but complementary set of services to those provided by the Air Traffic Management (ATM) system that utilizes industry's ability to supply services under FAA's regulatory authority that are currently assigned to manned flight operators/pilots. UTM is designed to support the real-time or near-real-time organization, coordination, and management of primarily low altitude (primarily < 400 ft above ground level [AGL]) multiple BVLOS UAS operations. With UTM, the FAA makes real-time constraints available to the UAS operators, who are responsible for managing their operations safely within these constraints without receiving positive air traffic control (ATC) services from the FAA. Interactions under UTM are more indirect than with the ATM system and are based on the sharing of information on airspace constraints and notification of flight intent. The primary means of communication and coordination between the FAA, operators and other stakeholders is through a distributed network of highly automated systems via application programming interfaces (API), and not between pilots and air traffic controllers via voice.

Figure 1 depicts a notional UTM system and data architecture, which includes four main entities:

- UAS Operators

1 Kopardekar, P., Rios, J., Prevot, T., Johnson, M., Jung, J., & Robinson, J.E. (2016.) Unmanned Aircraft System Traffic Management (UTM) Concept of Operations. American Institute of Aeronautics and Astronautics (AIAA 2016-3292).Paper presented at 16th AIAA Aviation Technology, Integration, and Operations Conference, Washington, D.C., 13-17 June 2016 (pp. 1-16).

- UAS Service Suppliers (USS)
- Regulator/Air Navigation Service Provider (ANSP) - *(FAA in the United States)*
- Other stakeholders (e.g. public safety, the public)

This architecture is being tested with the UAS Operator community and will be implemented in conjunction with UAS operators and third party service providers. The black line designates the demarcation between the FAA and UAS operators, their service suppliers, and public safety. The Flight Information Management System (FIMS) serves as a gateway between UTM participants (via the USS) and FAA systems. Through FIMS, the FAA can provide directives and make NAS constraint information available to UTM participants via the USS Network. Operators use the USS to organize and coordinate their operations and meet constraints and directives from the ANSP systems. The regulator/ANSPs have access to information on operations as required and are informed about any deviations that could have an impact on the NAS. Other stakeholders, such as public safety and the public, can also access UTM services via USSs.

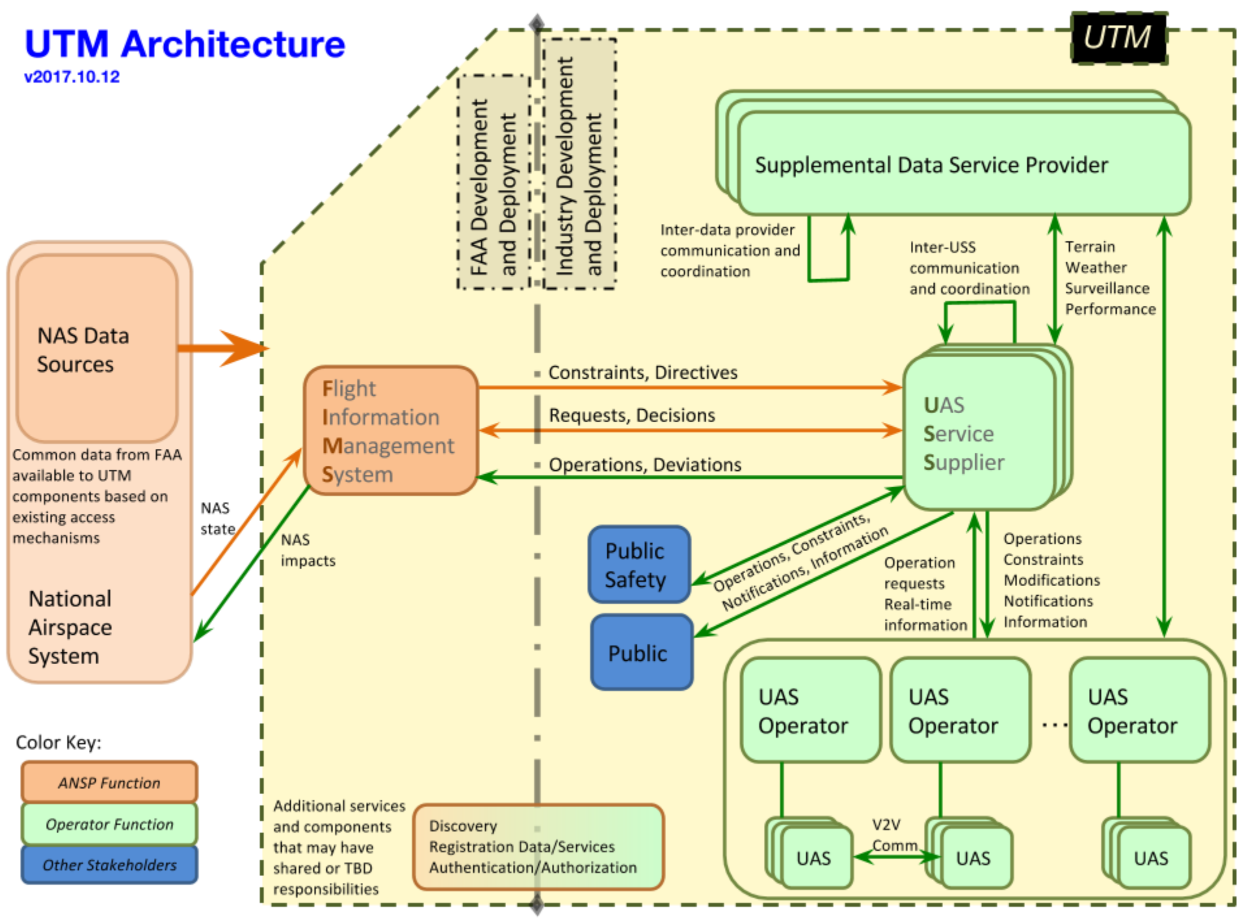



**Figure 1. High level UTM System and Data Architecture**

## 1.2 UTM RTT

The UTM RTT goals are to: 1) explore concepts, develop prototypes, and demonstrate a possible future UTM system to enable large-scale low altitude UAS operations, and 2) define the operational concept, services, roles/responsibilities, information architecture, data exchange protocols, software functions, iand performance requirements for low altitude UAS operations. The UTM RTT currently consists of four work groups (WGs) that focus on a range of technological areas to be addressed and further developed, including: (1) Concepts & Use Cases; (2) Data Exchange & Information Architecture; (3) Sense & Avoid (SAA); and (4) Communications & Navigation.

To accomplish UTM RTT goals, the UTM RTT WGs are developing products in alignment with NASA's spiral development and evaluation schedule of Technical Capability Levels (TCL), which are shown in Figure 2. Spiral development of the UTM research platform is described in terms of four successive UTM TCLs, where each new TCL extends the supporting technological architecture, number of services provided, and types of UAS operations supported. As a result, UTM development starts with TCL 1 which represents low risk, low complexity UAS operating concepts and will expand to TCL 4 which describes higher risk, more complex UAS operating concepts. As a set, the successive iterations will support development of the range of UAS operations for each operating environment - from remotely piloted aircraft to command-directed UAS and fully autonomous UAS. The TCLs are staged based upon four risk-oriented metrics: the number of people and amount of property on the ground, the number of manned aircraft in close proximity to the UAS operations, and the density of the UAS operations. Each capability is targeted to specific types of applications, geographical areas, and use cases that represent certain risk levels.

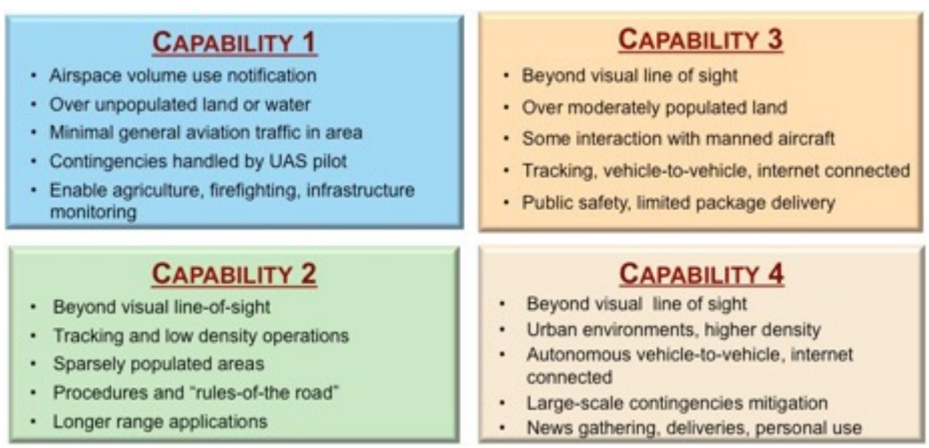



**Figure 2. UTM Technical Capability Levels**

## 1.3 Concepts and Use Cases Working Group Objectives

The overall goals and objectives of the Concepts & Use Cases Working Group (CWG) are to:

- ❖ Define and build consensus between the FAA and NASA on the concepts associated with UTM, including definitions of UTM-related terms, and principles associated with the UTM concept.

- ❖ Develop supporting use cases that will ultimately span the range of UTM operations, and identify information flows, roles and responsibilities of those entities interacting with UTM - products that will serve as input to the congressionally-mandated pilot program and all UTM RTT Working Groups as required.
- ❖ Ensure UTM Working Groups are remaining within scope and products are consistent with the UTM concept, as defined, and adhere to the operating principles in the UTM use cases.
- ❖ Support the UTM RTT Working Groups in any required further definition, and/or development of the UTM concept.

## 1.4 Scope

The foundational principles and terminology presented in this Version 1.0 are relevant to all TCLs, as they are intended to guide the overall body of work as it matures and establish a common framework for all UTM RTT development activities. Version 1.0 of UTM RTT CWG Concept & Use Cases *Package #2* Concept Narrative and Use Case documentation addresses the third UTM development phase - TCL 3, which is described in Figure 2, and at a high level, as follows:

- ❖ TCL 3 – heterogeneous BVLOS operations in uncontrolled airspace under 400' AGL over moderately populated areas

Version 1.0 of the UTM RTT CWG Concept and Use Cases *Package #1* addressed the first two UTM development phases - TCLs 1 and 2. The CWG will update this document to address TCL 4 at the end of the corresponding development cycle per the UTM RTT Joint Management Plan[2] (JMP). The final version will be a comprehensive package containing the entire compilation of TCL 1-4 products.

## 1.5 Products Overview

The CWG developed the following products for TCL 3: 1) Terms and Definitions, 2) Foundational Principles, 3) TCL 3 Concept Narrative, 4) TCL 3 Use Cases, 5) TCL 3 Operational Views (OVs), and 6) Roles and Responsibilities of actors interacting within TCL 3 environments. An overview of each product is presented in this section.

### 1.5.1 Terms and Definitions Overview

Terms and definitions (presented in Section 2) describe the terms presented throughout this document. Adoption of this terminology in other UTM RTT working groups is encouraged to ensure a consistent, common understanding of UTM related terms.

[2] FAA & NASA. (March 17, 2017). UAS Joint Management (UTM) Joint Project Management Plan v2.0.

### 1.5.2 Foundational Principles Overview

Foundational UTM principles (presented in Section 3) are based on key FAA and NASA stakeholder input and a comprehensive review of relevant literature. Foundational principles will be revisited, refined, and expanded upon, as necessary, throughout concept and use case development.

### 1.5.3 TCL 3 Concept Narrative Overview

Foundational principles and UTM literature served as inputs to the initial formulation of key concept elements central to TCL 3 (presented in Section 4). Use Cases were also analyzed for conceptual and operational consistencies that ultimately defined concept elements from an operational perspective. The Concept Narratives for TCL 3 are presented according the following structure:

- **Operational Concept:** The Operational Concept is an overview of the concept itself. This section addresses the key conceptual elements of the concept including the types of operations that will be enabled, airspace and geographical areas where the operations could conceivably occur, operation enablers, and examples of applications.

- **Prerequisite Requirements**: Prerequisite requirements are those that are imposed in order to *qualify* for UTM participation. They may not necessarily be UTM functions. They can include FAA regulatory requirements, processes, or qualifications that need to be fulfilled to be eligible to participate.

- **Sharing of Intent:** The UTM concept is largely based on sharing of information on airspace constraint data and notification of flight intent. Therefore, the processes, mechanisms, and elements of intent sharing are described specific to each TCL.

- **UTM Operation:** The UTM Operation section describes the operational portion of flights subject to UTM. Known procedures, requirements, and support services needed to support safe UTM operations in four areas are discussed:
  - Operating Conditions
  - Flight
  - Off Nominal Operations
- **Information Exchange:** The USS/FIMS and USS Information Exchange sections define the concept level data exchange requirements identified for the TCL presented. These will be further explored and refined by the UTM RTT Data Exchange and Information Requirements Working Group.

### 1.5.4 TCL 3 Use Cases Overview

A set of Use Cases were developed for TCL 3 to formulate general conceptual elements and support the derivation of systems engineering products by the UTM RTT WGs. The Use Cases cover a range of predominantly nominal operations, as well as off-nominal scenarios, and the main conceptual elements and interactions within them in a UTM environment. Each Use Case details a set of possible sequences and/or interactions between the system and its users that occur to achieve the operational goals defined for the environment being explored. Use Cases enable analyses to identify, clarify, and organize system requirements - including OVs, Information Flows and Data Exchange Diagrams, and Roles and Responsibility Allocation Tables.

Use Case scenarios do not prescribe specific solutions for how an operation should achieve a required operational goal (e.g., means by which an unmanned aircraft stays within the prescribed boundaries of the operation's associated airspace volume) but rather identify operational requirements. This allows the UTM RTT WGs to develop and ultimately specify the appropriate supporting performance requirements for each TCL.

### 1.5.5 Operational Views Overview

TCL 3 use cases were decomposed into Operational View event-trace diagrams (OV-6cs) (after each individual Use Case Narrative). These diagrams, sometimes called sequence diagrams, event scenarios, or timing diagrams, allow the tracing of actions in a scenario or critical sequence of events[3]. Each event-trace diagram has an accompanying description that defines the particular scenario or situation.

### 1.5.6 Roles and Responsibilities Tables Overview

The Use Cases, when decomposed, allow for an allocation of services and responsibilities for all entities interacting in a UTM environment. A clear allocation of responsibilities to the FAA, UTM, UAS operators, and other NAS users harmonizes airspace interactions and ensures that each party understands and fulfills their obligations for safe operations, ultimately providing an airspace management structure. TCL 3 Use Case decomposition resulted in roles and responsibility tables (Roles and Responsibilities Tables follow the Use Case Narrative and OV-6cs) for different aspects of separation, hazard /terrain avoidance, status, advisories, flight planning, and operations management and different actors, including the Remote Pilot in Command (RPIC), UAS Operator, USS, FAA, and the manned aircraft operator.

[3] Department of Defense. (May 2017). DoDAF Viewpoints and Models Operational Viewpoint OV-6c: Event-Trace Description retrieved from http://dodcio.defense.gov/Library/DoD-Architecture-Framework/dodaf20_ov6c/

# 2 Terms and Definitions

To provide a basis for establishing a clear set of terms for the UTM RTT working groups, and to ensure consistent messaging of UTM RTT efforts, UTM-related terms are defined.

## 2.1 UTM Actors

UTM actors are entities or participants that play a role in UTM operations.

- **FAA**

As the federal authority over operations in all airspace, and the regulator and oversight authority over commercial operations, the FAA grants Performance Authorizations and regulates all UTM Operations/Policies. In this document, the terms FAA and ANSP are used as general references to the FAA and do not distinguish individual lines of service, branches, systems, or functions unless directly stated.

- **Operator**

The Operator is the Person or Entity responsible for the overall management of their UTM operations including meeting regulatory responsibilities, flight/operation planning, and sharing operation Intent Information.

- **Remote Pilot in Command/RPIC**

The RPIC conducts flights per Operation Intent and is responsible for safe conduct of each UAS flight. More than one RPIC may take control of the aircraft at different but sequential times during the flight provided at least one person is responsible for the operation at any given time.

- **UAS Service Supplier/USS**

The USS is a Third Party that provides various services to Operator(s) and RPIC(s) including planning, De-confliction, Conformance Monitoring, weather, and other value-added services.

- **USS Network**

The USS Network is the amalgamation of all USSs and UAS Operators who choose to self-provision all services (i.e. the operator acts like a USS). Usage of the term typically refers to actions that need to be taken to support an operation such as when a USS is making Intent (or other) information available to all of the other USSs.

- **Flight Information Management System/FIMS**

FIMS acts as a gateway between the other FAA systems and the UAS operators. FIMS is managed by the FAA and represents the FAA's UTM component. It interfaces with the NAS systems and provides and constraints to the UAS operations via the USS Network.

## 2.2 UTM Terminology

- **UTM**

The term 'UTM' refers to a separate, but complementary set of services to those provided by the FAA's Air Traffic Management (ATM) System, designed to support the real-time or near-real-time organization, coordination, and management of primarily low altitude (primarily < 400 ft AGL) UAS operations. With UTM, the FAA makes real-time constraints available to the Operators, who are responsible for managing their operations safely within these constraints without receiving air traffic control services from the FAA. Interactions under UTM are based on the sharing of information on airspace constraints and sharing of flight intent. The primary means of communication and coordination between the FAA, operators and other stakeholders is through a distributed network of highly automated systems via application programming interfaces (API), and *not* between pilots and air traffic controllers via voice.

- **UTM Operations**

UTM operations are not managed by FAA ATC, but rather, are organized, coordinated, and managed by a federated set of actors. Information on UTM operations is available and exchanged between a USS and the Operator as needed. UTM operations take place in authorized areas of operation, as specified by the FAA. Depending on geographical area, type of operation, type of airspace, and other risk-factors, the FAA may impose different requirements and constraints including rules of the road, required information sharing, required coordination between operators, and required data exchange and coordination with the ANSP, airspace management, or directives. The fundamental difference between ATM and UTM is - with ATM, ATC directly interacts with operators while UTM is direct interaction through automated data exchange.

- **Authorized Area of Operation**

An Authorized Area of Operation is a geographical area and/or airspace, which can be spatial and temporal, that is authorized by the FAA for UTM operations. This airspace is not intended to be 'blanket coverage' nor devoid of manned aircraft operations (e.g., helicopters transiting the airspace, manned aircraft conducting agricultural operations). It is airspace where manned aircraft should anticipate a higher density of intended (and perhaps prioritized) use by UAS. The FAA would ensure, though, that certain operations, such as those conducted by Emergency Medical Services (EMS) or first responders, would be given priority access to this airspace as required. Rather than develop a universal definition of this airspace, the FAA would consider the addition of commercial UAS operators and evaluate their proposals, considering the overall effect on safety in various locations.

- **Operation Plan**

An Operation Plan is the set of data produced as a result of collaboration between the Operator and its USS while planning a flight. It includes two subsets of information: 1) Shared Information (information shared by the Operator with the USS Network) and, 2) Confidential/Proprietary Information (information that is only shared between an Operator and the USS to which the Operator subscribes). Shared information includes Operation Intent and Other Shared Information (‘Other Shared Information’ being information that also supports situational awareness between operators).

- **Operation Intent**

A set of data that is made available to all UTM participants that defines flight intent. Operation Intent data enables participants to gain situation awareness of nearby operations and supports USS provision of services (e.g., de-confliction).

- **Operation Volume**

Operation Volumes are four dimensional (4D) shapes with specified ceilings and floors that encompass the operation’s flight profile and system-based conformance/protective buffers (if applicable) within an Authorized Area of Operation. Operation Volumes may take various forms (e.g. 4D discs, tubes, or complex shapes) and can be both be stationary or moving. One single, or multiple, Operation Volume(s) may be defined for a single operation. Operation Volumes have ‘active’ times associated with them enabling USSs to de-conflict Operation Volumes prior to, and during, flight to support safe operations. Operation Volumes can be categorized as Area-Based Operation Volumes (ABOVs) or Trajectory-Based Operation Volumes (TBOVs).

# 3 Foundational Principles

The following are foundational operating principles associated with UTM, applicable across all TCLs.

1. UTM is a separate, but complementary set of services to the ATM system, based primarily on the sharing of information on airspace constraints and flight intent.
2. Participation in UTM is required for beyond visual line of sight (BVLOS) UAS operations not participating in ATM.
3. UTM services are available in uncontrolled/Class G airspace and in designated areas in controlled airspace – initially under 400 ft above ground level (AGL).
4. With UTM, Operators are responsible for the coordination, execution, and management of operations, with rules of the road established by FAA.
    - FAA interacts with UTM only for information/data exchange purposes, as required.
5. UTM requires increasing levels of engagement/interaction with services as the complexity of the operations increases.
6. UAS Operators are responsible for ensuring compliance with all FAA regulations.
    - UAS operators can use services (e.g., authentication, weather, communications, aircraft tracking, flight planning, and navigation) from third parties, but UAS operators are responsible for meeting the regulatory requirements.
7. UAS are required to meet the performance and equipage requirements established for the type of operation and associated airspace volume/route they are undertaking - including the ability to contain operations within a specified airspace volume or remain clear of a specified volume either through geo-fencing or operational control.
8. FAA has on-demand access to information regarding UTM operations, including flight status, aircraft location, and intent information.
9. Other airspace users - manned aircraft operators and UAS VLOS operators – can access information through UTM to increase situational awareness regarding nearby UAS operations..
10. FAA may require certain data to be logged / archived by Operators should the FAA and other federal entities request that information (e.g., safety, security, or post-hoc analysis of events of interest).
11. All UAS operators and/or UAS service suppliers, under UTM construct are responsible for tracking their own aircraft and sharing data with other users as required.
    - FAA does not provide track and locate services, however, FAA maintains their authority to manage airspace.

# 4 TCL 3 Product Package

TCL 3 demonstrations enable multiple BVLOS UAS operations in authorized airspace over moderately populated areas, in the vicinity of manned aircraft, under 400 ft AGL. Strategic de-confliction of airspace volumes, vehicle tracking and conformance monitoring, in-flight de-confliction of cooperative and uncooperative traffic, and the establishment of procedural rules of the road (e.g., right of way rules) enable manned/unmanned aircraft separation. Equitable airspace access among Operators is promoted through USS coordinated Operator negotiation and optimization of Operation Volume geography/design (e.g., segmented airspace volumes, Area-Based vs Trajectory-Based Operation Volumes). The navigation performance of the vehicle is highly correlated with size and geography of Operation Volumes. As a result, requirements for better navigation performance may be necessary in order to reduce conflicts between volumes during strategic de-confliction. Strategic de-confliction of airspace volumes, vehicle tracking and conformance monitoring were required to enable TCL 2 operations, therefore, TCL 3 Product Package #2 builds on TCL 1 and 2 Product Package #1 to explore: 1) manned/unmanned heterogeneous operations, 2) increasing equity of airspace access, 4) in-flight de-confliction, and 5) coordinated contingency management.

UTM participation is required for BVLOS operations not participating in ATM. For BVLOS UTM operations, FAA authorization is required via a Performance Authorization. A Performance Authorization is an FAA regulatory approval for BVLOS Operators to perform a specific type of operation in a specified volume(s) of airspace. To obtain authorization, Operators using their own or shared resources (e.g., a USS) submit a Performance Authorization Request to FAA Regulators for evaluation. The FAA reviews the Request, and if the Operator's proposed ground and air assets are sufficient to meet an established level of performance in the airspace in which they intend to operate, the FAA then authorizes an area of operation in which the UTM operations can occur. It is assumed that if an Operator has been granted an authorization to operate in an area over people, his implementation strategy for conducting operations (to include his level of services, infrastructure, flight equipment, etc.) were sufficient to meet an established level of performance for the operation

Concept Narrative, four Use Cases (see Table 1 for Use Case details), and associated Operational Views, and Roles and Responsibilities Tables are presented to demonstrate the concept, explore system interactions, allocate responsibilities, and investigate concept level requirements. A summary of key TCL 3 Use Case elements and interactions is provided in Table 2.

## 4.1 TCL 3 Concept Narrative

### 4.1.1 Operational Concept

TCL 3 demonstrations extend TCL 2 demonstration capabilities to permit BVLOS UAS operations in the vicinity of manned aircraft over moderately populated areas in suburban areas or close to airports. Moderate manned and unmanned aircraft density necessitates in-flight deconfliction of both UTM and non-UTM traffic to ensure collective safety of heterogeneous operations over moderately populated areas. Due to moderate airspace demand, equitable airspace access is optimized through USS flight planning capabilities. Coordinated contingency management is enabled through USS communications with affected UTM operations, appropriate FAA entities, and other airspace users. Prospective TCL 3 applications include public safety, suburban deliveries to delivery points, traffic monitoring, and news gathering.

In controlled airspace, UTM Operators obtain authorization from ATC through LAANC to be able to conduct flight in approved areas. Once individual operation authorization within an approved area is obtained, the information exchanges necessary to conduct an operation are similar to those for operations conducted in uncontrolled airspace (e.g., Operation Intent sharing, Dynamic Restriction notification from FIMS, etc.).

Aircraft/capability requirements to operate in a TCL 3 environment (e.g., over people) would be addressed in the Performance Authorization obtained by the Operator prior to the operation.

For TCL 3 BVLOS operations, under 400 ft AGL, in uncontrolled airspace – UAS operators are not required to notify the FAA prior to or during flights unless they experience an off-nominal event or contingency situation that requires FAA attention and/or intervention (e.g., rogue UAS – threat of entering controlled airspace). The FAA makes real-time NAS constraint data available to the USS through FIMS to support airspace management services, but it does not receive data from the USS during nominal operations.

USS operations data is available on demand through FIMS, and in Operator/USS data repositories, for FAA access upon request.

Each UTM operation will be assigned a USS status that will reflect the overall state of an operation. Use of a common set of status identifiers will enable interoperability across USSs. Operation statuses could include: 1) “Accepted” - assigned upon successful Operation Intent submission, 2) “Activated” - assigned when the flight is active, 3) “Closed” - assigned at Operation Plan close out, 4) “Non-Conforming” - assigned to an active flight that is not conforming to Operation Intent or intent is not known for some period of time, and 5) “Rogue” –assigned to an active/non-conforming flight when conformance is not expected to be restored.

Changes to operation status prompt de-confliction in some cases, and in the event of "Non-Conforming or "Rogue" statuses, immediate availability/distribution of that change of status information to other USSs so they may respond effectively.

USSs can access Supplemental Data Service Providers (SDSPs) via the USS network for essential or enhanced services (e.g. terrain and obstacle data, specialized weather data). SDSPs may also provide information directly to Operators through non UTM network sources (e.g., public/private internet sites).

The majority of the responsibilities within a TCL 3 demonstration environment are expected to be managed by a central operator with regulatory responsibility. However, in instances where an operation is not managed by a single operator, the RPIC assumes these responsibilities.

### 4.1.2 Operation Intent Sharing

When an Operator wants to perform a TCL 3 operation in an Authorized Area of Operation, they are required to submit flight intent to the USS Network via an Operation Plan. An Operation Plan is the set of data produced by the collaboration of the Operator and its USS while planning a flight; it includes subsets of the following information:

- Shared Information: Shared information is Information shared by the Operator with the USS Network. Shared information includes Operation Intent and 'Other Shared Information' ('other shared information' is information that also supports situational awareness between operators).
- Confidential/Proprietary Information: Confidential/proprietary information is information that is only shared between an Operator and the USS to which the Operator subscribes.

All Operation Plans have a start and end time and can be updated real-time.

Operation Intent is a common data set that defines the spatial, temporal, and other elements of an operation. This information allows USSs to provide support services (e.g., de-confliction of operations). Intent information is also made available to all UTM Participants to promote situational awareness. Intent is submitted prior to flight, during planning stages, but can be modified during flight as well. The Operation Plan includes *some or all* of the following information about the intended operation.

- <u>Type of Operation</u>: Data relevant to the type of operation is required to determine service/operation requirements. For example, the Operator needs to indicate, at minimum, whether the flight is VLOS or BVLOS, but other data pertinent to service/operation requirements may be solicited.
- <u>Duration/Times</u>: The day and planned start time of the operation is submitted along with the expected duration of the flight.
- <u>Operation Volume</u>: Operation Volumes are volume(s) of airspace within an Authorized Area of Operation that the operation is intended to remain within, and the associated times the volume(s) will be active. When operating in areas of increased demand, Operators consider airspace

efficiency when defining Operation Volume(s). Requirements for more sophisticated navigation performance may be necessary in order to reduce, or solve, conflicts between Operation Volumes during strategic de-confliction.

- An Operation Volume is built using Operator-defined flight geography information and other information; the Operation Volume boundary encompasses the limits of the geographies calculated using these information sets. The Operation Volume and any associated geographies are used to facilitate various services, including strategic de-confliction, conformance monitoring, etc.

- Operation Volumes may take various forms (e.g. 4D discs, tubes, or complex shapes) and may be either stationary or moving.

- An Operation Volume can be of two different types designed to support different needs:

  - Area-Based Operation Volume (ABOV): ABOVs are larger volumes where a block of airspace encompasses a mission profile because the projected route may be too complex (e.g., survey operation) or dynamic (e.g., search and rescue mission) to describe or if the UAS has minimal navigation capabilities (cannot handle trajectories with small margins of in-flight error).

  - Trajectory-Based Operation Volume (TBOV): TBOVs are volumes based on a known route or flight profile, where lateral and vertical boundaries are built around a centerline. The TBOV includes any geographical buffer required to account for the UAS' ability to maintain flight along the centerline (navigation performance capabilities, environmental factors, etc.).

  ABOVs and TBOV structural definitions and requirements enable differentiation between the two. TBOVs have performance expectations associated with them that allow them to be smallest possible area that can be tolerated by established performance. Associated rules of the road would need to be established by the FAA.

- Multiple Operation Volumes, or segmented volumes, could be defined for a single operation. Segmentation of airspace volumes divides Operation Volume(s) into consecutive, time-based segments that collectively encompass the operation. These segments are scheduled to allow release of unused volumes. Segmentation promotes airspace efficiency for long duration flights or operations requiring large volumes of airspace.

- <u>RPIC Information</u>: RPIC contact information for the duration of the operation will be required. Other relevant RPIC information may also be requested.

- <u>Equipment Information</u>: UAS characteristics and capabilities that could impact ATC handling in the event of unplanned presence in controlled airspace may be requested.

- Contingency Plans: The Operator details required contingency responses for the flight (e.g., lost link profile information, alternative landing location). In the case of a multi-segmented flight, the Operator may need to specify a response for each segment (or volume) of flight.

- Additional Intent Information: Additional Intent Information may also be required. This information may be USS provider specific or could include other unidentified information relevant to the operation (e.g. payload information).

Operator supplied Operation Plan data is not verified with agency records at the time of submission (e.g., pilot certifications, use of specified equipment/technologies reportedly supporting the operation) but Operator accounts and records are subject to FAA auditing at the agency's discretion.

Figure 3 illustrates the elements of the Operation Plan and their relationships.

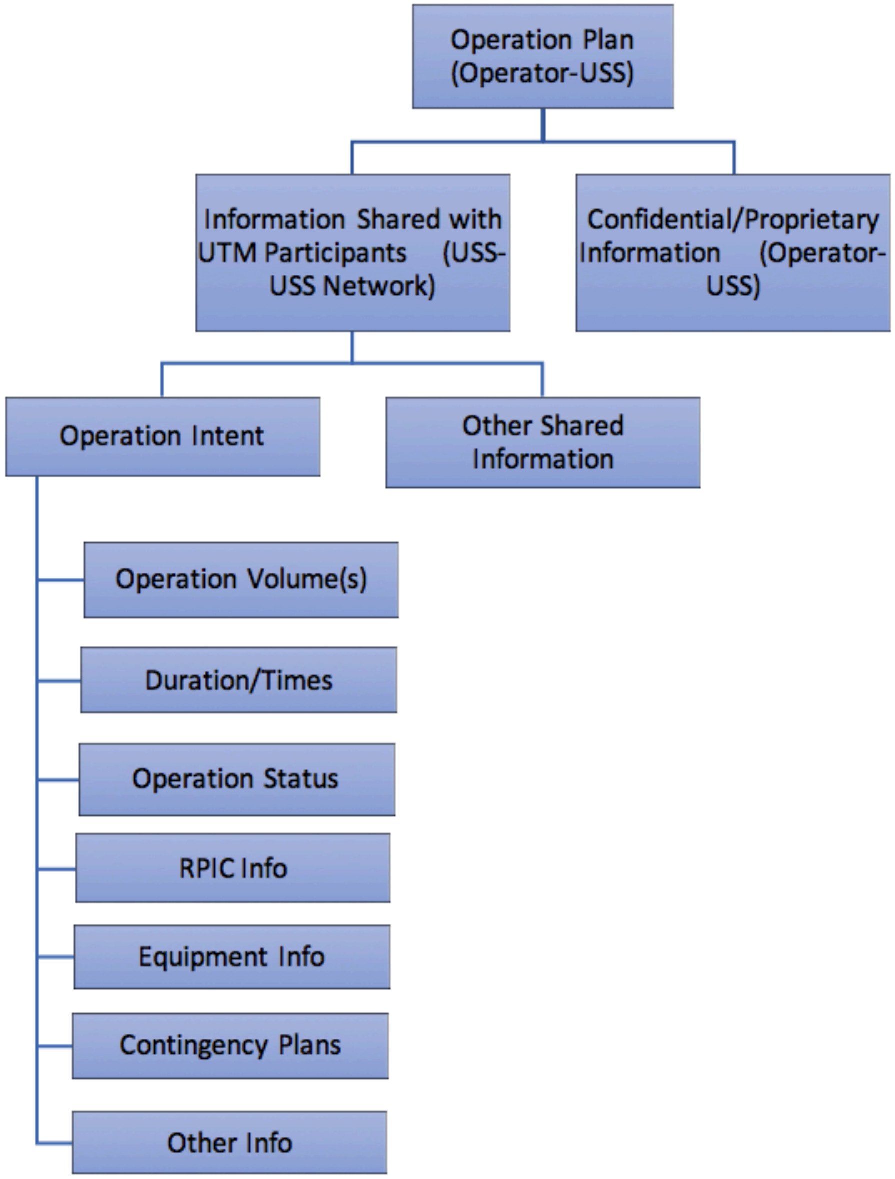



**Figure 3. Flight Planning Terminology and Relationships**

The USS checks the prospective Operation Volume(s) against the larger USS network of proposed and active plans to identify any Operation Volume conflicts. Conflicts are handled in one of three ways:

- Operator alters their Operation Plan to eliminate volume overlap
- Operator continues with their plan using equipment to separate from other aircraft
- Operator elects to continue with their original plan understanding that they are responsible for safely separating from other aircraft

If the Operator chooses to alter their proposed plan to eliminate volume overlap, the operator: 1) utilizes the USS to amend spatial or temporal elements of the plan based on his preferences (e.g., changes date), 2) Operators coordinate/negotiate via USSs to eliminate conflicts, or 3) the Operator selects USS generated de-confliction options (e.g., USS offers temporal or spatial suggestions to de-conflict volumes). USSs maximize airspace efficiency and access when developing system generated Operation Volumes for Operator consideration (e.g., segmentation, altitude block configuration, etc).

When reconfiguration and/or negotiation fails to eliminate Operation Volume overlap, Operators can alter the type of Operation Volume to optimize airspace access provided the nature of the operation or navigation performance of the vehicle allows for reduction of the size/geography of Operation Volumes. An Operator using an ABOV may choose to fly within a TBOV in order to minimize the impact of sharing airspace. When this happens, the Operator in the ABOV takes on responsibility for maintaining separation from the UAS operating in the TBOV.

The USS compares the volume against known airspace restrictions to make Operators aware of any NAS constraints or preemptive airspace restrictions that could affect the proposed flight.

- NAS Airspace Constraints: The USS also accesses the FAA generated NAS real-time airspace constraint data, made available via FIMS, to identify whether there are any NAS constraints or restrictions on the airspace at the flight times requested. If an official source of constraint data is accessible outside of FIMS then the USS may pull the data directly from an already established source of information (e.g., Notice to Airmen [NOTAMS]). If NAS constraints exist, they are made available to the Operator who has the option to alter their flight intent to ensure de-confliction of airspace constraints.
- Preemptive Airspace: Many states have passed laws that regulate or prohibit the flight, weaponization, and surveillance use of UAS in select airspace to preserve the rights of its citizens. To de-conflict Operation Volume(s) from airspace constraints unassociated with FAA requirements, the USS works with states, municipalities, and other entities as required to ensure local airspace access restrictions, or preemptions, are incorporated into, and maintained in, the USS Network and Operation Volumes are de-conflicted from these areas during the intent sharing processes.

Additional information and services (e.g., weather, hazard/obstacles awareness) are provided per the Provider’s protocol.

Operation intent sharing results in an “Accepted” status and Operation Plan/Intent Data is incorporated into the USS Network.

The USS checks for conflicts any time there is a change to Operation Intent and notifies impacted Operators of any changes or conflicts that could affect their flight. Notified Operators acknowledge the messages, assess the potential impacts to their operation, and choose whether to make changes to their operation based on their assessment.

### 4.1.3 Flight Operations

#### 4.1.3.1 Operating Conditions

Operators are responsible for ensuring operating conditions are within bounds of rules and regulations set forth for the operation (e.g., daytime Visual Meteorological Conditions [VMC]). The Operator will ensure aircraft tolerance of expected operating conditions (e.g., winds speed, temperature). Allowable maximum aircraft impact energy categories may be imposed. Aircraft noise requirements may also be imposed when operating near people.

#### 4.1.3.2 Flight

During flight, the Operator is responsible for complying with all rules and regulations associated with the operation including avoiding other aircraft, complying with airspace restrictions, and avoiding terrain and obstacles. UAS Operators share separation responsibility with other UAS operators (BVLOS and VLOS), manned, and other airborne traffic. When UAS operate over people or in areas where manned aircraft are more prevalent, Operators will be capable of identifying and maintaining separation from all low-altitude-operating aircraft, including both UTM participants and non-participants. This may be done using USS in-flight de-confliction services designed to identify and alert Operators of airborne traffic or through ground-based or airborne technological solutions (e.g., position sharing, Vehicle to Vehicle equipment, ground-based radar detection data, ADS-B in or out, sense and avoid capabilities). USSs can further assist Operators with separation responsibilities by: 1) performing strategic de-confliction of Operation Volumes prior to flight, 2) providing services that assist Operators with staying within the bounds of their volume (e.g. conformance monitoring services), 3) providing position information of surrounding UAS and participating manned aircraft to support the operator's conflict avoidance capability, and 4) coordinating with affected airspace users to facilitate effective airspace management responses in the event of a contingency. Operators follow established right of way rules or procedures when encountering low-altitude operating aircraft. UAS Operators may be required to equip with conspicuity equipment to make the UAS more visible to manned aircraft and other UAS with see and avoid requirements.

Low-altitude manned aircraft pilots share responsibility with BVLOS UAS operators for maintaining separation from each other. Manned aircraft operating near or below 400 feet AGL, are not required to participate in UTM but they have access, and are encouraged, to utilize UTM services, either through passive participation (e.g. using UTM information during planning and/or flight) or active participation (e.g. sharing manned aircraft flight intent with the USS Network, position information, etc.).

The Operator notifies the USS of flight activation and the USS shares the operation status with the USS Network (e.g., "Activated" status). The RPIC remains within the bounds of his/her Flight Volume(s) for all phases of flight, tracking the aircraft location. The Operator ensures 'near real-time' position reports are sent to the USS to enable USS conformance monitoring capabilities. The Operator maintains a continuous connection with the USS to support data exchange pertaining to aircraft tracking, weather constraints and/or notifications or directives regarding airspace constraints, known traffic, or other hazards that could affect the flight. In the case of a notification or alert, the RPIC responsible for the overall safety of the flight acts accordingly. For example, upon receiving an alert, the RPIC can exercise the option to take action (e.g., land) or continue his/her operation with increased awareness to the potential threat. In the event of a directive (e.g., dynamic restriction [described in Airspace Constraint Data definition below]), the RPIC is responsible to comply with the directive, unless waived. In the event that sharing of alternate intent information could help increase situation awareness or support planning of safe, conflict-free responses between impacted users, Operators may be asked to share their contingency intent information as soon as practical so that the USS can share this information.

Operators are responsible for ensuring actual or reserved endurance and/or fuel levels are maintained to remain compliant with rules or regulations or to support safe operations. Endurance/fuel levels (actual or reserves) may be provided to the USS to enable monitoring and alerts for endurance level checks and/or to track levels in the event of a contingency (e.g., estimation of fuel/endurance levels when aircraft is rogue). The UAS (e.g., UA GCS, associated systems equipment) has capabilities to monitor for, and alert the Operator of, on-board equipment failures or degradation (e.g., lost link, engine failure); the aircraft enacts a predictable response in such an event.

The USS monitors numerous data streams throughout the flight to identify potential hazards to the operation.

- Conformance Monitoring: The BVLOS Operator will be required to share near-real time tracking data to the USS (VLOS not required) so that the USS can provide services that enable Operators to monitor the unmanned aircraft's (UA's) conformance to applicable system-based boundaries and track the UA's position during off-nominal events.
    - A vehicle that is not operating per the Operation Intent (such as exceeding the Operation Volume boundary or system-based buffer boundaries while still in the Operation Volume) will transition from an "Activated" Operation Status to "Non-Conforming". Contingency measures associated with an instantiated geo-fence may be triggered prior to or upon the vehicle exceeding applicable boundaries. The RPIC may, at this point, receive a notification or alert from his/her USS that the operation is not performing as expected. The RPIC can take corrective actions to bring the vehicle back within the bounds of the Flight Geography and return the Operation Status to "Activated".
    - If a vehicle exceeds the Operation Volume or system-based boundaries within the Operation Volume, and is not expected to regain conformance to the Operation Intent or may be in a position such that other Operators no longer have situational awareness of the current state of the operation, the Operation Status is transitioned from "Non-Conforming" or "Activated" to "Rogue". For off-nominal situations requiring FAA attention or intervention, the USS notifies the FAA of the event via FIMS.
        - Other situations exist that could result in an Operation Status of "Rogue", for example, 1) a UA experiences a lost-link event in which the position (relative to the Operation Volume) is unknown; 2) a vehicle has numerous non-

conformance events; 3) a vehicle remains in a 'Non-Conforming' state for an extended period of time; or 4) the operator is unable to provide position reports at required rate.

- UTM Operations Data: The USS monitors UTM data for information that warrants alerts or directives be sent to the RPIC.

  Operators are encouraged to share observed weather phenomena, traffic (manned and unmanned), and other aviation information that could affect UTM operations with the USS Network (e.g., UAS Reports [UREPs]) so that this information can be shared with other potentially affected subscribers (e.g., similar to manned Pilot Reports [PIREPs]).

  UTM operation status changes are monitored for potential conflicts/or contingencies that could impact the operation. Changes that could impact the operation prompt a notification or alert to the RPIC. At minimum, the following status changes could trigger de-confliction to identify/notify any potentially impacted users of the flight, including: 1.) New "Activated" or "Accepted" Operation Intent data, 2.) "Activated" flight status change to "Non-Conforming", and 3.) "Activated" or "Non-Conforming" flight status change to "Rogue". For example, a nearby non-conforming aircraft that has potential to breach the active Operation Volume prompts an alert to the RPIC.

- Airspace Constraint Data: The USS accesses real-time NAS airspace constraint data via FIMS to ensure said data is distributed to impacted users so they can reevaluate their Operation Intent ("Accepted" status users) or take action/increase vigilance ("Active" status users). This data could include information regarding flight anomalies, airspace changes, published emergencies, or other airspace constraint issues.

  In the event of exigent circumstances, the FAA may issue a Dynamic Restriction. The FAA may define and activate the restriction. Additionally, authorized entities (e.g., law enforcement, fire department, etc.) may submit a Dynamic Restriction Request to the FAA, possibly through a USS or some other method of transmittal. If the request is approved, the FAA defines and activates the Dynamic Restriction. Once activated, the FAA notifies the USS Network of said restriction via FIMS. Each USS notifies affected subscribing UTM participants of the restriction; UAS not approved for the restriction must vacate the applicable airspace.

- Weather Data: Weather services - provided through weather sensors, manual inputs UREPs, and models – will equip the Operator with moderate resolution winds, temperatures, pressure, precipitation, and visibility data throughout the flight.

The FAA has on-demand access to information regarding UTM operations, including flight status, aircraft position, and intent information.

Upon completion of the operation, the Operator provides timely notice to the USS that operation is completed. The USS shares the operation status with the USS Network (e.g., "Closed"). Pertinent flight data is captured and stored in USS historical databases.

#### 4.1.3.3 Off Nominal Operations

Operator contingency procedures or protocols are defined and made available by the Operator to the USS. When possible, pertinent contingency responses to events, such as loss of command and communications (C2) link, are shared with the USS during the intent sharing process. If intent for a contingency cannot be predictable or is entirely situational, the operator updates their intent or provides projected trajectory at the time of the contingency in order to facilitate USS Network-wide de-confliction of affected flights (e.g., loiter for 20 seconds then return to base). UTM contingency and operation data may also be shared with the FAA and other impacted-entities if the off-nominal event or contingency situation requires their attention and/or intervention (e.g., rogue UAS – threat of entering controlled airspace).

The Operator is responsible for notifying affected airspace users in the event of a contingency; a USS can support/assist the Operator in meeting this obligation. As part of support activities, the USS coordinates with affected airspace users to facilitate effective airspace management by providing information related to the event via automated data exchange or other appropriate channels (e.g., emails). The USS notifies the USS Network and other airspace users (e.g., potentially affected public/private entities) of off nominal or potentially hazardous situations in a timely manner, providing all known data required to manage the situation effectively (e.g., new intent data, tracking information, pre-programmed contingency procedure, RPIC contact information, etc.). Parties to be notified could include the USS Network, appropriate public/private entities, and in the event the ATM system could be impacted, the FAA. Impacted parties directly enact necessary measures to respond to and/or coordinate with affected persons/entities. In the event the ATM operations could be impacted, the USS Network sends notice to the FAA via FIMS. The FAA FIMS gateway provides a continuous connection through which the USS Network can provide necessary UTM operation data, including flight status, aircraft location, and intent information. The USS sends the notification along with required data to FIMS, which parses and routes the data to the appropriate ATC facilities/entities to enact appropriate airspace management responses.

Once the event is contained and safety is restored, the USS provides notice of recovery to affected entities. The USS notifies the USS Network to enable distribution to airspace users. Other airspace users are contacted through appropriate/agreed upon channels (e.g., automated phone calls). The USS Network notifies the FAA via FIMS, providing data required to restore nominal operations and comply with FAA facility/agency reporting requirements and procedures. FIMS routes the data according to established protocol.

In the event of an unexpected airspace restriction (e.g., dynamic restriction), the Operator is responsible for remaining outside the restricted area until it is lifted, unless waived. USSs utilize their continuous Operator connection to provide real-time notifications of unexpected restrictions to impacted users. When a restriction is enacted, Operators are provided time to prepare for the restriction prior to its established effective time (e.g., plan and submit new intent, re-program new contingency response, etc.). Operators use USS situation awareness displays and planning tools to meet their responsibility for ensuring they remain outside the restricted area. Operators are capable of responding to the operational demands that can result from these unforeseen events. Equipment, capabilities, and/or USS services can assist Operators in meeting these requirements. Operators with vehicles following a pre-programmed route must be capable of avoiding restricted airspace along their route (e.g., manual intervene, capability to re-program in-flight vehicle to prevent intrusion in restricted airspace). Operators whose Operation Intent is not feasible due to airspace restrictions must reformulate their intent, or adjust the active times of planned Operation Volumes, to account for redirects, delays, or impacts that make their intent infeasible. Pre-programmed vehicle responses (e.g., programmed lost link contingency response) that would violate an airspace restriction must be amended to avoid airspace conflicts. Operators requiring in-flight changes to their operation intent are subject to the same intent and separation requirements they were prior to the restriction. Operators can utilize de-confliction support services to make real-time adjustments to their operation intent utilizing the same advanced tools used in the Operation Intent Sharing process (e.g., Operation Volume de-confliction, Operator negotiation, optimized airspace design, as detailed in the Operation Intent Sharing section).

### 4.1.4 Information Exchange

#### 4.1.4.1 USS/FIMS Information Exchange

For TCL 3 operations, real-time NAS airspace constraint data will be available to the USS via FIMS for the purposes of de-conflicting active or proposed Operation Volumes from flight anomalies, airspace changes, emergency operations, or airspace management decisions that impact UTM operations. For off-nominal situations requiring FAA attention or intervention, the USS notifies the FAA of the events via FIMS.

The USS maintains a continuous connection to FIMS to support potential data exchange requirements as required. The FAA has access to USS operations data upon request via FIMS. The USS is capable of providing position reports to the FAA at a specified rate, if available or applicable. Operations data is captured and stored in USS historical databases for analytics, regulatory, and Operator accountability purposes.

#### 4.1.4.2 USS Information Exchange

The USS performs information exchange with numerous entities to enable services that assist operators and RPICs in meeting regulatory requirements for UAS operations. Specifically, information exchange supports deconfliction, separation, demand/capacity balancing, and archives operations data in historical databases for analytics, regulatory, and operator accountability purposes. It should be noted that USSs may also provide many other value added services to support UTM participants as market forces create opportunity to meet business needs. Given the competitive pressures of the USS market it is expected these value-added services will serve to differentiate suppliers rather than define core services. Hence, value-added services fall outside the scope of this package.

USSs connect a UAS Operator to the FAA UTM data exchange application. The USS provides connections between UAS operators, the FAA (via FIMS), SDSPs, public entities and stakeholders to share information required to manage nominal and off-nominal operations. USSs assist operators in meeting the requirements set forth for each operation either by enabling data exchange to relay safety critical information to the operator and other entities (e.g., distribution of off nominal flight operations data to FAA and other affected airspace users), provide services that enable efficient, safe operations, or to support accountability of operations. The USS coordinates and distributes to appropriate entities, operator intent, airspace constraint data, weather data, vehicle tracking and conformance data, surveillance data, and other data critical to safety of flight. This data supports numerous services including, intent sharing, de-confliction support, separation support, hazard avoidance, advisory services, FAA and public service intervention for off nominal/public safety related events, and other value-added services. To successfully complete these exchanges, USSs must have discovery to FIMS, other USSs, operators, SDSPs, and public entities (e.g., law enforcement, emergency services, Department of Defense) either directly or via a central inter-USS communication and coordination capability (e.g., the USS Network). Adherence to a common requirement for information exchange within a USS Network (USS-USS) and/or with other specified entities is necessary, along with standard protocols for publishing flight information and other data, ensures data flow and situational awareness across all participants. Publishing of flight information must include communication of, and de-confliction for, non-conforming flights or hazardous flight conditions.

USSs will assist the FAA with meeting regulatory responsibilities by archiving requested operations data sets in historical databases for FAA analytics, regulatory, and operator accountability purposes. USSs must be capable of providing this data upon FAA request

USSs also work with local municipalities and communities to gather, incorporate, and maintain non-FAA preemptive airspace restrictions and local airspace rules into airspace constraint data (e.g., preemptive airspace).

## 4.2 TCL 3 Use Cases, Operational Views, and Roles and Responsibilities

Four Use Cases, along with associated OV-6cs, and Roles and Responsibilities Tables, were developed in support of the TCL 3 concept demonstration. These products were designed to cover a broad range of TCL 3 operations including a range of nominal operations and off-nominal operations. These are attached in the following sections.

**Table 1. TCL 3 Use Case Names and Key Features**

| TCL | Use Case | Use Case Features |
|---|---|---|
| TCL 3 | TCL 3-1: One-Way BVLOS Flight, Separate Landing/Take-Off Locations | • Introduction of Operation Plan development for long distance point-to-point operation in an area of increased airspace demand<br>• De-confliction of Operation Volumes using flight planning tools<br>• Segmentation of operation volumes to optimize airspace usage |
| TCL 3 | TCL 3-2: Negotiation versus Prioritization between Operators Due to Dynamic Restriction | • Segmented flight operation on long distance, point-to-point route<br>• UAS contingency response to dynamic restriction on a segmented route<br>• Two alternative outcomes of Operator negotiation due to in-flight airspace conflict. |
| TCL 3 | TCL 3-3: UAS Interaction with Manned aircraft in Low-Altitude Uncontrolled Airspace | • Heterogeneous operations<br>• Concept level capability requirements for heterogeneous operations<br>• Procedural requirements for manned/unmanned interactions |
| TCL 3 | BVLOS Operation Lost-Link Event | • UAS on-board contingency procedures during a lost-link event<br>• Communication of Off-Nominal Event to other UTM Participants via the USS Network<br>• Communication of UAS with Unknown Intent to the FAA and other Airspace Users |

**Table 2. TCL 3 Use Case Elements and Interactions**

| Description | | TCL3-1 | TCL3-2 | TCL3-3 | TCL3-4 |
|---|---|---|---|---|---|
| Type of Operation | BVLOS Flight(s) | X | X | X | X |
| | Operations Over People | X | X | | X |
| | Over the Horizon Operation | X | X | | |
| Intent Development & Sharing | Operation Plan Development | X | X | | X |
| | Operation Intent Sharing | X | X | X | X |
| USS to USS Interaction | Single USS | | | | X |
| | Multiple USSs | X | X | X | |
| Operation Characteristics | Conformance Monitoring | X | X | X | X |
| | Conformance Violation | | | | X |
| | Manned Aircraft Interaction | | | X | |
| | Near Airport | | | | X |
| | Negotiation Between Operators | | X | | |
| | Sense/Detect Capabilities | | | X | |
| | Contingency Procedures | | | | X |
| | Interaction with the FAA | | | | X |

### 4.2.1 Use Case TCL3-1: One-Way BVLOS Flight, Separate Landing/Take-Off Locations

NOTE: This use case introduces the term Area-Based Operation Volume (ABOV). The functionality of this term, and the term Trajectory-Based Operation Volume (TBOV) are initially explored in Use Case TCL3-2. Further definition on these types of volumes are detailed in the Concept Narrative of previous sections of this document.

## Overview

### Summary: Rail Inspection using Long-Distance UAS

Nexus Track & Land Rail Road Company (NT&L RR) operates rail ways over the North Western United States, including the Miles City Sub-Division, which runs between Miles City, Montana and Glendive, Montana (a distance of about 75 miles). NT&L RR uses a small fleet of long range sUAS to monitor the road bed of their various railways; they monitor the Miles City Sub-Division on a weekly basis, flying from Miles City to Glendive and being returned to base via train.

While the typical weekly operation follows the same path, other BVLOS UAS, VLOS UAS, and manned aircraft operations occur near the rail line, in large part due to its proximity to major roadways, along which utilities, towns, and farmland run. Given the ever-changing landscape of aircraft low-altitude aircraft operations along the inspection route, NT&L RR has the option to have the USS to which they are subscribed, USS ABC, create their Operation Plan for a flight, taking into account the current state of nearby low-altitude aircraft operations (UTM, manned, etc.); USS ABC attempts to make each Operation Plan an efficient use of the airspace by minimizing the overlap of the Operation Volumes of disparate UAS Operators, releasing Operation Volumes in a timely manner (so as not to have activated volumes with no UAS actively flying in it), etc.

This use case examines a specific inspection flight, in which the RR Inspection Operator (supported by USS ABC) creates a segmented series of ABOVs for the NT&L RR RPIC to fly through (refer to Figure 4). During planning, the Rail Inspection Operator identifies three other operations that may affect his flight: a power line inspection, an agricultural survey, and a photography flight; he opts to use his USS's advanced planning tools to plan around these other operations, resulting in multiple segmented ABOVs on a timed schedule.

The ABOV segments are temporally stacked such that as the UAS flies into each new segment, previous segments go into an inactive/unoccupied state. The active times for these segments take into account the three other operations, such that overlap with the volumes of these other operations (temporal and geographical) is avoided; additionally, the segments are split where possible to also allow for quick release of unused volume airspace, allowing for less need of coordination with other Operators/RPICs for any operations that may be planned after the Rail Inspection Operation Intent has been shared (promoting an efficient use of the airspace and equity of access).

During the inspection flight, the RPIC monitors the flight of the inspection UAS, taking control as necessary; Operation Volumes are considered active/occupied and inactive/unoccupied according to the Operation Intent schedule. Through strategic planning of the operation, the Rail Inspection Operation is separated from the other operations in the area.

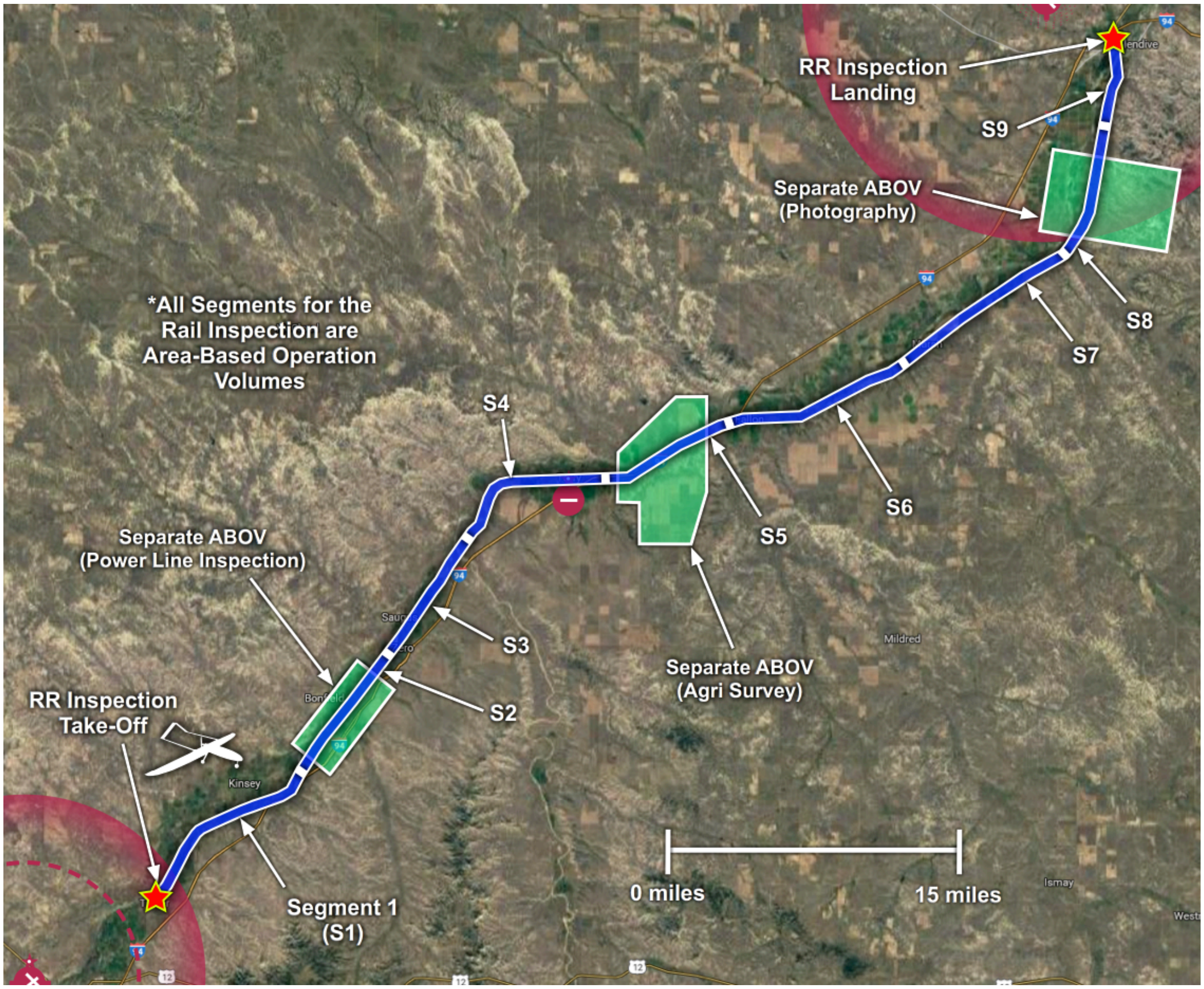



**Figure 4. Rail Inspection Overview**

## Summary Table

**Table 3. Summary - Use Case TCL 3-1**

| Operation Name | Authorization | Operational Description | Environmental Description |
|---|---|---|---|
| Rail Bed Inspection[1] | - Operation Intent Made available<br>- Operator can only perform flights within an Authorized Area of Operations | - BVLOS<br>- Segmented ABOVs<br>- Below 250 ft AGL<br>- Position Reporting<br>- Ops Over People | - Class G only<br>- Non-towered airports nearby<br>- Near Class E (SRFC)<br>- Calm Weather |
| Power Line Inspection[1,2] | | - BVLOS<br>- Single ABOV<br>- Below 400 ft AGL<br>- Position Reporting<br>- No Ops Over People | - Class G only<br>- No Airports nearby<br>- Calm Weather |
| Agricultural Survey[1,2] | | | |
| Photography[1,2] | | | |

1. Performance Authorization approval was obtained by these Operators from the FAA prior to the events of the narrative below; these processes are not discussed in this use case.
2. Operation Plan/Intent development by these Operators with their respective USS occurs prior to the events of the narrative below; these processes are not discussed in this use case.

## Equipment

### NT&L RR

The UAS being used by NT&L RR for the inspection operation is a commercially available, off the shelf UAS with upgraded avionics, sensor, endurance, and conspicuity equipment. It is a fixed-wing, fixed-landing gear, electrically-powered small UAS. It has a cruising air speed of 39 kts (~45 mph), with a maximum endurance of 4 hours at cruising power. Normal operation is via waypoint to waypoint operation, and the UAS has an auto-land capability. As landing takes place in suburban areas, the UAS has sensor capabilities that allow it to detect ground-based obstacle, as well as the ability to abort the automated landing if an obstacle is detected.

The UAS uses satellite/GPS for tracking/navigation. Direct command or override is via radio communication, as is sensor data transmission; NT&L RR has its own radio communications network to communicate with train engineers along the rail line, and it has expanded the capability of this network to include their UAS needs (sensor data reporting, autonomous flight data updates, direct control, etc.). NT&L RR's radio communications network ensures a consistent connection with their in-flight UAS. In the event of a situation where the UAS must land but cannot safely land in normal fashion, an on-board parachute is available for deployment (deployment can be commanded manually or automatically in accordance with automated procedures).

The vehicle has capability to monitor for on-board equipment issues, such as lost link, motor failure, unexpected battery depletion, etc. Additionally, the UAS has capability to act in accordance with pre-programmed contingency procedures in the event an equipment issue occurs. Standard procedures are programmed and can also be modified (or new procedures added) by the Operator and/or RPIC pre-flight and in-flight.

### Other UAS Operations

The other UAS Operations occurring near the Rail Inspection Operation use various aircraft systems:

- The Power Line Inspection is using an off the shelf commercial quad copter, with long range and extended endurance capabilities to enable BVLOS operation.
- The Agricultural Survey is using a fixed wing, electrically powered UAS, with endurance capabilities that allow BVLOS flights of up to 30 miles.
- The Photography operation is using an off the shelf quadcopter with a shorter range than that of the other operations, but far enough that the UAS will likely be in BVLOS flight for portions of the operation.

None of the UAS systems for the above three operations have any advanced on-board sense and avoid capabilities; however, each UAS has conspicuity equipment for easier visual tracking.

## Actor Details

### Operator and RPIC

The Rail Inspection Operator has been granted a Performance Authorization that encompasses the area in which the rail bed inspection flights occur. Authorized operation types include, but are not limited to, BVLOS flight, over the horizon flight, and operations over people. Management personnel responsible for maintenance of the rails and road bed act as the Operator in this use case, while a specific employee with the necessary pilot certifications acts as the RPIC.

The other Operators likewise have been granted Authorized Areas of Operation. The Operators are not directly mentioned in the narrative (they have already shared the Operation Intent for their specific operations). The RPICs do actively fly their respective UAS during the narrative.

### USS

Three USSs are servicing UAS Operators along the route of the Rail Inspection:

- USS ABC is servicing the Rail Inspection Operation

- USS XZY is servicing the Power Line Inspection Operation and the Agricultural Survey Operation
- USS 123 is servicing the Photography Operation

Operators and RPICs develop and Operation Plan with each of their respective USSs; the Operation Intent (developed as part of the planning process) is made available by each Operator (through their USS) to the USS Network, enabling shared situational awareness across all UTM participants.

### FAA

The FAA interacts with UTM as follows:

- The FAA has previously provided each Operator with the approval of a Performance Authorization, each of which includes the geographical area over which the Operation Volumes indicated in Figure 4.

The FAA has the ability to access any information related to the operations as required (though this does not occur in the narrative below).

## UTM Interaction

### UTM Participation

All of the Operators identified in the narrative below are required to participate in UTM, given that some or all of their Operation Intent includes BVLOS flight.

### Shared Information Across Actors

**Table 4. Shared Information - Use Case TCL 3-1**

| Type of Information | Actor Providing Information | Actors with Access to Information | Applicable to this Use Case? |
|---|---|---|---|
| Operation Plan Parameters/Inputs | Operator | USS | Yes |
| Operation Plan | USS | Operator | Yes |
| Operation Intent, pre-flight (and other shared data) | USS | USS Network | Yes |
| Operation Data Relevant to Regulator Information Requirements | USS | FAA | Yes |
| In-Flight Modification to Intent | RPIC | USS, USS Network | No |
| Externally-originated data (surveillance, NOTAM, Wx, etc) | USS or SDSP | USS and/or Operator & RPIC | Yes |
| Operationally-derived environmental data | RPIC, USS or SDSP | USS | Yes |
| Relevant Flight Data (e.g., position data) | RPIC and/or Operator | USS | Yes |
| | USS | USS Network | No |

| | | | |
|---|---|---|---|
| | | FAA (if applicable) | |
| Operation Intent, in-flight (and other shared data) | USS | USS Network | Yes |
| Operation Status | USS | USS Network | Yes |
| Spectrum Management | USS | USS Network, RPIC and Operator | No |
| Dynamic Restriction Request | Operator/USS | FAA | No |
| Dynamic Restriction Approval | FAA | Operator/USS | No |
| Dynamic Restriction Distribution | FAA | USS Network and other NAS users | No |
| Negotiation Request | USS ABC | USS XYZ | No |
| Negotiation Response | USS XYZ | USS ABC | No |
| UREP | RPIC | USS | No |
| | USS | USS Network | No |
| UAS Flight Information | UAS | RPIC<br>Manned Aircraft | No |
| Manned Aircraft Flight Information | Manned Aircraft | UAS | No |
| Manned Aircraft Information | USS/SDSP | Operator/RPIC | No |

# Narrative

**NOTE:** The narrative of this use case focuses on the perspectives of the Rail Road Inspection Operator and RPIC. References to processes and actions of other Operators/RPICs are limited to the scope in which they contribute to the narrative.

**NOTE:** It is understood that many of the functions, communications and decision-making occurring in the narrative below are likely to be automated by the USSs and FAA. Explicit callout to automation is avoided to allow focus on the information exchange and flow of operations.

## Rail Inspection Planning

An employee of NT&L RR, acting as the Operator (hereafter referred to as the Rail Inspection Operator), utilizes USS ABC's services for regular planning of the weekly inspection flights of the rail's road bed.

On those days in which there are no other UTM-participating VLOS/BVLOS operations planned that could affect the Rail Inspection UAS (overlapping Operation Volumes, priority operations, etc.), the Rail Inspection Operator uses a boilerplate Operation Plan, with only minor adjustments to it to take into account issues such as wind direction/speed. On those days in which there are other UAS operations along the Rail Inspection UAS flight path, the Rail Inspection Operator has an option to have USS ABC-provided tools maximize the efficiency of his/her Operation Intent, which may include adjusting the shape and times of the Operation Volumes to minimize or eliminate overlap of other UAS Operation Volumes.

At 6:00 AM on the day of the weekly inspection, the Rail Inspection Operator uses USS ABC's planning tools/services to check the weather, check for any restriction on the airspace that might affect the operation, check what other operations are occurring in the area throughout the day, etc.

> **NOTE:** The Operator does not have access to intent information of UAS operators who are not participating in UTM (VLOS commercial/hobby operators who opt not to use USSs to fulfill applicable regulatory requirements).

The weather shows fair conditions and there are no posted restrictions on the airspace; however, the Rail Inspection Operator identifies three separate operations that occur along the flight path for the rail inspection during times of interest:

- a BVLOS power line inspection, active from 7:00 AM to 8:00 AM, per shared Operation Intent
- a BVLOS agricultural survey, active from 7:00 AM to 8:30 AM, per shared Operation Intent
- a BVLOS photography flight, active from 10:30 AM to 11:30 AM, per shared Operation Intent

The Rail Inspection Operator notes in each of these shared Operation Intent packages that the capabilities of the UAS do not include on-board sense and avoid of other aircraft. The Rail Inspection Operator prefers to minimize/eliminate interaction with other UAS for this flight (e.g. overlapping Operation Volumes); he prefers less burden on the RPIC conducting the flight, given the cost of the company's UAS package. The Rail Inspection Operator opts to not use the boilerplate Operation Plan today, and instead uses USS ABC's planning services to optimize the plan for today's flight.

The Inspection Operator submits to USS ABC flight geography information (a trace of the railroad path being inspected), required volume characteristics to support the operation, performance characteristics/capabilities of the UAS being used for the flight, etc. Part of the submitted information includes a request to create Operation Intent that, where possible, avoids other Operation Volumes currently known in the USS Network that lie along their intended flight path; it is indicated that the operation must still occur on the planned day, but that volume segment shapes/times can be adjusted to help in achieving the primary goal (avoiding other volumes).

USS ABC-provided tools use the Rail Inspection Operator-submitted information, as well as known UTM operation information (previously identified above), to build a set of segmented Operation Volumes, with the goal being to avoid overlapping volumes of different operations; the toolset is able to find a successful solution. Figure 4 depicts the nine (9) Operation Volume segments (in addition to other operation factors), Table 5 provides the active times for each segment, and Figure 5 provides a visualization of the active times of the segments.

The volume segments include any performance-associated buffers to minimize the chance of the UAS reaching a non-conforming state during flight; these buffers are used internally by the Operator and/or his USS and are not part of the shared Operation Intent.

> **NOTE:** Some volume segment pairs seen in Figure 4, such as S3/S4 and S6/S7, could potentially be combined into one volume, and still achieve the goal of avoiding the volumes of the known operations. However, these pairs are split by USS ABC to minimize the consumed airspace of active/planned volumes so that future UAS operations (not currently planned/known within the USS Network) can plan with a reduced potential for overlapping times.

The proposed segmentation schedule is sent to the Rail Inspection Operator for review and approval; the Operator approves.

**Table 5. Rail Inspection Operation Volume Details per Operation Plan/Intent**

| Operation Volume | Volume Active State Start | Volume Active State End | Floor (ft AGL) | Ceiling (ft AGL) | Volume Type |
|---|---|---|---|---|---|
| Segment 1 | 7:55 AM | 8:26 AM | 0 | 150 | ABOV |
| Segment 2 | 8:16 AM | 8:40 AM | | | |
| Segment 3 | 8:30 AM | 8:54 AM | | | |
| Segment 4 | 8:44 AM | 9:12 AM | | | |
| Segment 5 | 9:02 AM | 9:26 AM | | | |
| Segment 6 | 9:16 AM | 9:44 AM | | | |
| Segment 7 | 9:34 AM | 10:04 AM | | | |
| Segment 8 | 9:54 AM | 10:18 AM | | | |
| Segment 9 | 10:08 AM | 10:26 AM | | | |

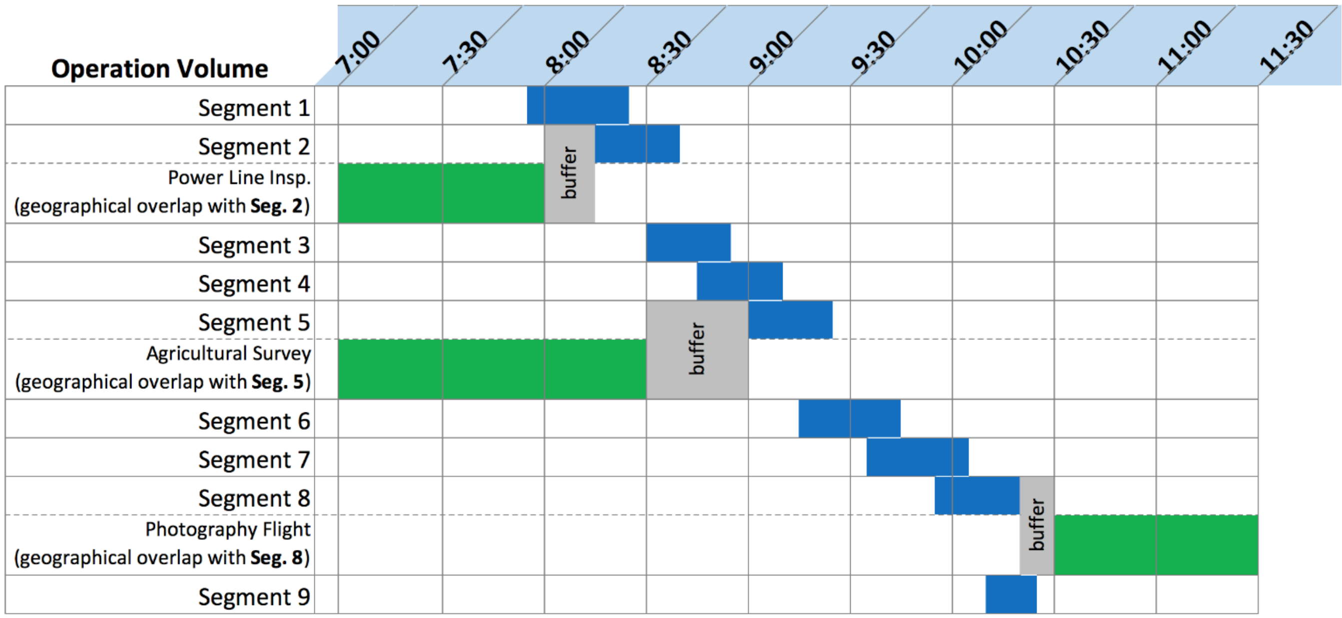



**Figure 5. Operation Volume Schedule Visualization**

**NOTE:** In Figure 5 above, the BLUE strips indicate the active status of an Operation Volume segment for the Rail Inspection operation (Volume Status = "Occupied"). The GREEN strips indicate the active status of the other Operation Volumes that lie along the inspection flight path. The GREY strips highlight the time buffer that has been designed into the Operation Volume segments to avoid temporal overlap with geographically overlapping volumes of the other operations.

With planning activities complete, USS ABC uses the approved Operation Volumes, as well as other Operator-provided or USS-calculated information, to build the proposed Operation Intent package for the rail inspection flight; the package is reviewed and approved by the Operator. Once the Rail Inspection Operator has indicated approval of the Operation Intent package, the USS sends a message to the Operator similar to the following:

> *"Thank you for completing your Operation Plan. The Operation Intent for BVLOS Operations is required to be shared with the larger USS Network (which includes USS ABC's other subscribers). Please confirm that your plan is complete, and that you are ready to share with the USS Network at this time. You also have the option to go back and update your plan or cancel this planned operation."*

At 6:30 AM, the Rail Inspection Operator indicates that he is ready to share his Operation Intent. USS ABC sets the Operation Status to "Accepted and makes the Operation Intent available to the USS Network such that other Operators can now plan their own flights with awareness of the Rail Inspection Operation.

**Notification to Other Operators -** USS XYZ and USS 123 have access to the Rail Inspection Operation Intent once it is made available by USS ABC. Each USS identifies any nearby operations (geographical and temporal) and send notification of the new operation. USS XYZ sends notification to the Power Line Inspection and Agricultural Survey Operators, while USS 123 sends notification to the Photography Operator. All three Operators send acknowledgement of the notification to their respective USS, review the Operation Intent of the Rail Inspection, determine it will not affect them, and make no changes to their planned operations.

### Take-Off

Prior to the RPIC'S arrival at the Rail Inspection Take-Off location, the Power Line and Agri-Survey Operations have changed to an "Active" state, and the Operation Volumes for each are active/occupied. The Photography Operation is not yet flying.

The Rail Inspection RPIC arrives at the launch location and prepares for flight; he determines that the airspace surrounding the take-off location is clear of manned aircraft and non-UTM participating operations, and he can see the "Active" Power Line Inspection and Agri-Survey Operations on his GCS tools. At 7:55 AM, the Rail Inspection RPIC turns on UAS position reporting to USS ABC and notifies the USS he is about to take off. The USS sets the Operation Status to "Activated" and makes this update available to the USS Network. The Power Line Inspection and Agri-Survey RPICs have the ability to see the Rail Inspection Operation Volume segments, both active and planned, on their GCS tools (if they so choose to display it). At this point, the Segment 1 Operation Volume is considered to be in the active/occupied state by the USS Network, given the scheduled times presented in Table 5.

At 8:00 AM, the Rail Inspection RPIC initiates flight and the UAS begins flying near the rail line, taking video and photographs necessary to complete the inspection; the UAS flies autonomously, according to the pre-programmed flight schedule, and makes adjustments to power, control surfaces, etc. as necessary to keep to said schedule.

During the entire flight, USS ABC receives the "real-time" UAS position information so that it can verify the UAS against applicable performance boundaries contained within the Operation Volume it is currently flying within.

## Flight

The UAS flies along its programmed route, as noted above, with the Rail Inspection RPIC monitoring the flight progress to determine if manual over-ride is required. The RPIC maintains connection to the UAS through use of the NT&L RR communications network; as the UAS approaches the performance/operational limits of one communication tower (whether due to horizon limits or structure/environmental obstruction/noise) it connects to another tower.

Operation Volumes are considered activated/occupied and inactive/unoccupied in accordance with the times noted in Table 5. As the end times for each volume are reached (at which point the UAS has already exited said volume), that particular Operation Volume is considered inactive/unoccupied. If there are no other active times for that volume for the remainder of the operation, it is no longer considered by other operators/USSs while planning new/modifying current operations.

As previously noted, the other Operators/RPICs whose operations lie along the path of the rail inspection can see the currently active and planned Operation Volume segments (if they choose to display them), allowing them to maintain situational awareness around their operation area.

At 10:30 AM, the Photography Operation is set to a status of “Activated” by USS 123 and its Operation Volume is in an active/occupied state; this information is made available to the USS Network. The Rail Inspection RPIC can see this active volume on his GCS display tools, but ignores it, as the Rail Inspection UAS is already in Segment 9, and Segment 8 became inactive prior to the activation of the Photography Operation.

No anomalies occur during flight that necessitate any updates to the Operation Intent. Additionally, no other new operations are shared with the USS Network that would necessitate re-evaluation of the Rail Inspection Operation Intent or any coordination with new UAS Operators/RPICs.

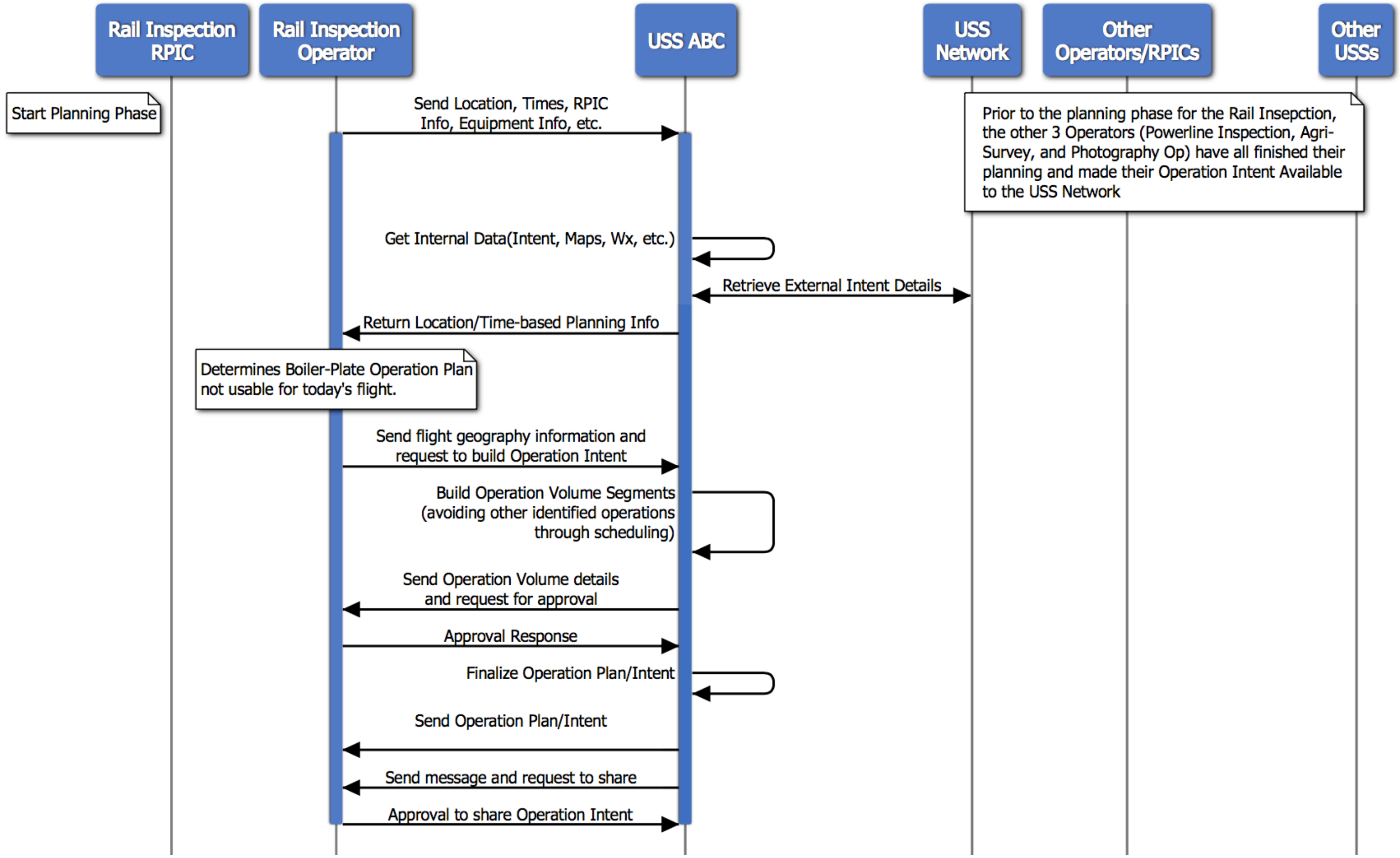
## Landing

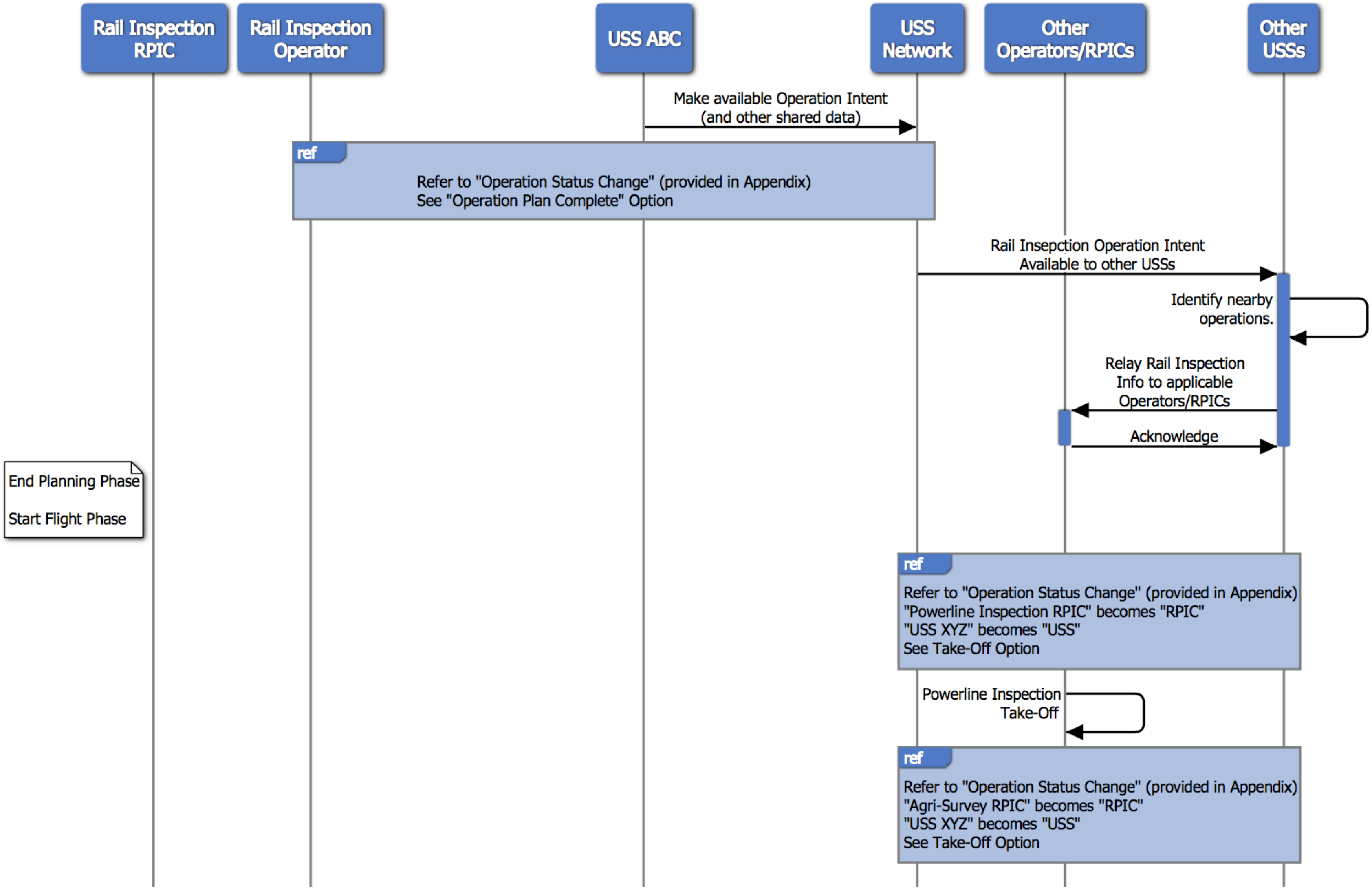
The Rail Inspection UAS reaches its destination and automatically lands within Segment 9, at a facility maintained by NT&L RR. The Rail Inspection RPIC indicates to USS ABC that his operation is concluded; the USS sets the Rail Inspection Operation Status to “Closed” (all volumes are considered inactive and closed at this time) and the updates to the Operation Intent are made available to the USS Network.

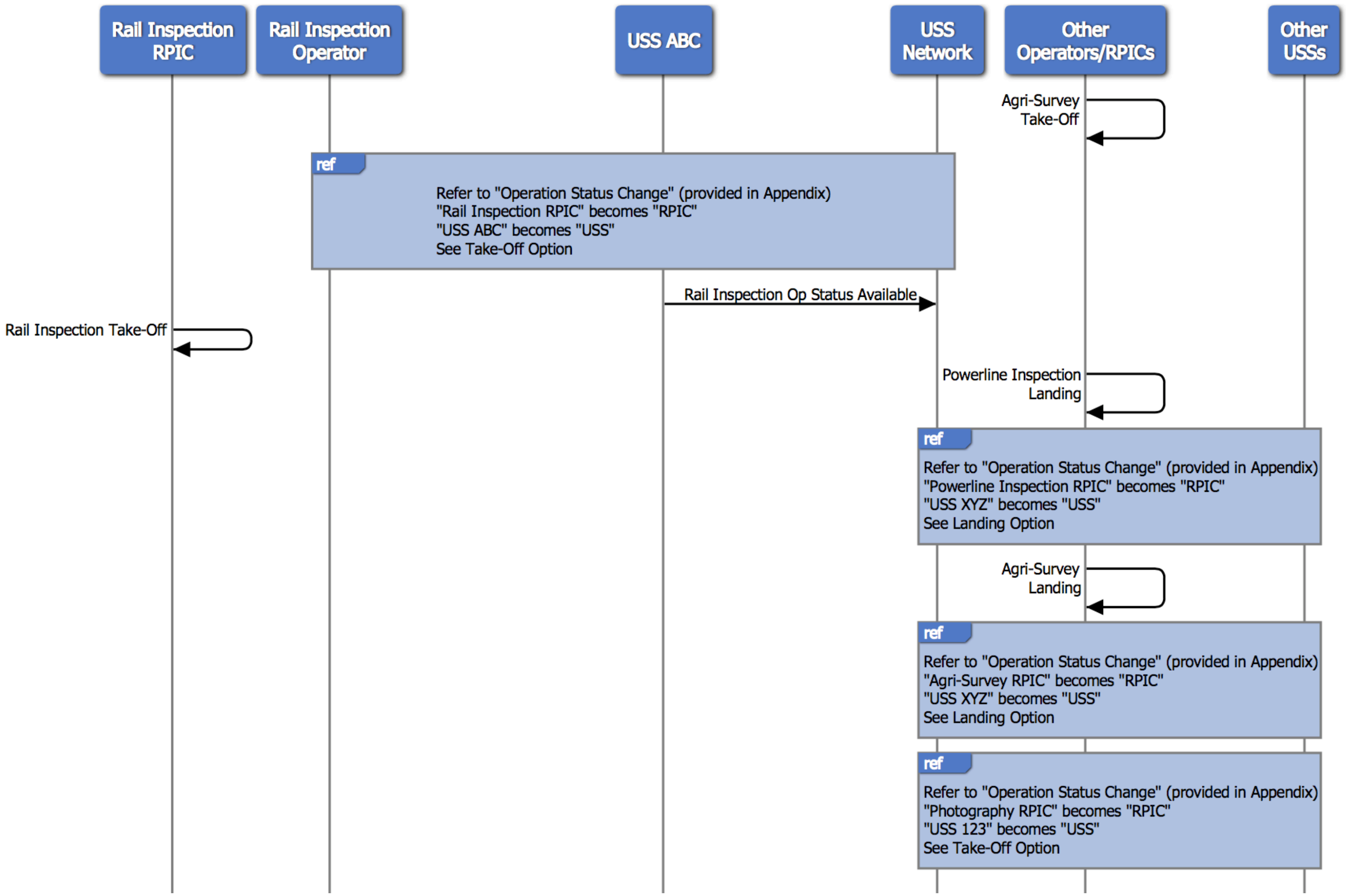
USS ABC maintains records of the Operation Plans/Intent, including the original plan and any modifications before and during flight, in the event that the FAA determines a need to review said information.

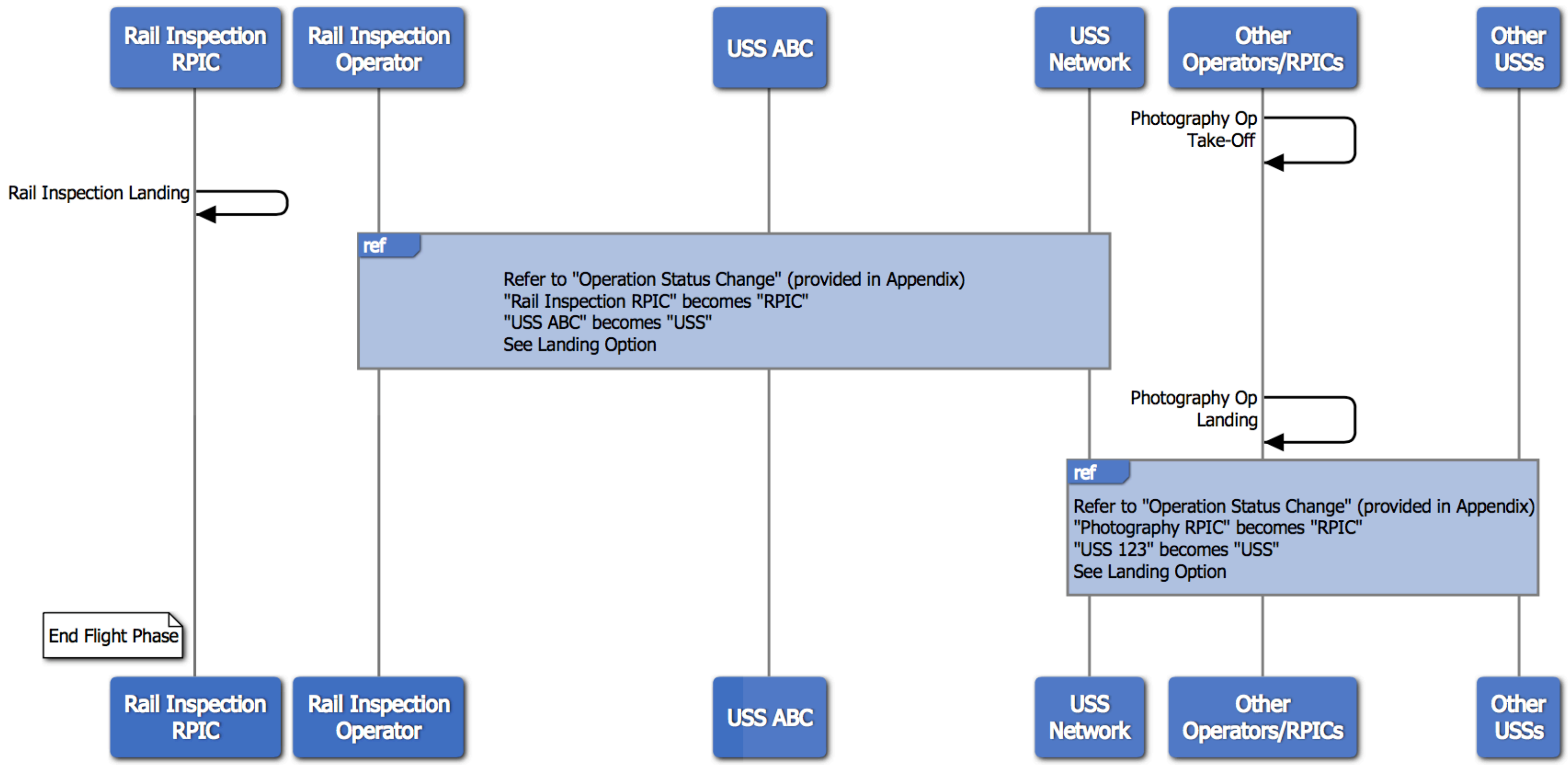
### 4.2.2 Operational Views

The following pages provide operational views of the scenario narrative. Referenced diagrams for sub-activities can be found in the Appendix.


Rail Inspection RPIC
Rail Inspection Operator
USS ABC
USS Network
Other Operators/RPICs
Other USSs
Start Planning Phase
Prior to the planning phase for the Rail Insepction, the other 3 Operators (Powerline Inspection, Agri-Survey, and Photography Op) have all finished their planning and made their Operation Intent Available to the USS Network
Send Location, Times, RPIC Info, Equipment Info, etc.
Get Internal Data(Intent, Maps, Wx, etc.)
Retrieve External Intent Details
Return Location/Time-based Planning Info
Determines Boiler-Plate Operation Plan not usable for today's flight.
Send flight geography information and request to build Operation Intent
Build Operation Volume Segments (avoiding other identified operations through scheduling)
Send Operation Volume details and request for approval
Approval Response
Finalize Operation Plan/Intent
Send Operation Plan/Intent
Send message and request to share
Approval to share Operation Intent


Rail Inspection RPIC
Rail Inspection Operator
USS ABC
USS Network
Other Operators/RPICs
Other USSs
Make available Operation Intent (and other shared data)
ref
Refer to "Operation Status Change" (provided in Appendix)
See "Operation Plan Complete" Option
Rail Insepction Operation Intent Available to other USSs
Identify nearby operations.
Relay Rail Inspection Info to applicable Operators/RPICs
Acknowledge
End Planning Phase
Start Flight Phase
ref
Refer to "Operation Status Change" (provided in Appendix)
"Powerline Inspection RPIC" becomes "RPIC"
"USS XYZ" becomes "USS"
See Take-Off Option
Powerline Inspection Take-Off
ref
Refer to "Operation Status Change" (provided in Appendix)
"Agri-Survey RPIC" becomes "RPIC"
"USS XYZ" becomes "USS"
See Take-Off Option


Rail Inspection RPIC
Rail Inspection Operator
USS ABC
USS Network
Other Operators/RPICs
Other USSs
Agri-Survey Take-Off
ref
Refer to "Operation Status Change" (provided in Appendix)
"Rail Inspection RPIC" becomes "RPIC"
"USS ABC" becomes "USS"
See Take-Off Option
Rail Inspection Op Status Available
Rail Inspection Take-Off
Powerline Inspection Landing
ref
Refer to "Operation Status Change" (provided in Appendix)
"Powerline Inspection RPIC" becomes "RPIC"
"USS XYZ" becomes "USS"
See Landing Option
Agri-Survey Landing
ref
Refer to "Operation Status Change" (provided in Appendix)
"Agri-Survey RPIC" becomes "RPIC"
"USS XYZ" becomes "USS"
See Landing Option
ref
Refer to "Operation Status Change" (provided in Appendix)
"Photography RPIC" becomes "RPIC"
"USS 123" becomes "USS"
See Take-Off Option


Rail Inspection RPIC
Rail Inspection Operator
USS ABC
USS Network
Other Operators/RPICs
Other USSs
Photography Op Take-Off
Rail Inspection Landing
ref
Refer to "Operation Status Change" (provided in Appendix)
"Rail Inspection RPIC" becomes "RPIC"
"USS ABC" becomes "USS"
See Landing Option
Photography Op Landing
ref
Refer to "Operation Status Change" (provided in Appendix)
"Photography RPIC" becomes "RPIC"
"USS 123" becomes "USS"
See Landing Option
End Flight Phase
Rail Inspection RPIC
Rail Inspection Operator
USS ABC
USS Network
Other Operators/RPICs
Other USSs

### 4.2.3 Roles and Responsibilities Table

| Service/Function | | Actors: X=direct responsibility \| S=support role | | | | Explanatory Notes |
|---|---|---|---|---|---|---|
| | | RPICs | Operator | USS | FAA | |
| Separation | VLOS UAS from VLOS UAS | | | | | Not Explored in Use Case |
| | VLOS UAS from BVLOS UAS | | | | | Not Explored in Use Case |
| | BVLOS UAS from BVLOS UAS | S | X | S | | Planning stage – strategic (Operator)<br>Flight – strategic/tactical (RPIC) |
| | VLOS UAS from Low-Altitude Manned A/C | | | | | Not Explored in Use Case |
| | BVLOS UAS from Low-Altitude Manned A/C | | | | | Not Explored in Use Case |
| Hazard/ Terrain Avoidance | Weather Avoidance | | X | S | | |
| | Terrain Avoidance | | X | S | | |
| | Obstacle Avoidance | | X | S | | |
| Status | UTM Operations Status | | | X | | |
| | Flight Information Archive | | X | S | | |
| | Flight Information Status | | | X | | |
| Advisories | Weather Information | | | X | | USSs likely to be primary distributor of information. Possible they may pull from other sources and make available to subscribers. |
| | Hazard Information (Obstacles, terrain, etc) | | | X | | |
| | Alert Affected Airspace Users of UAS Hazard | | | | | |
| | UAS-Specific Hazard Information (Power-Lines, No-UAS Zones, etc) | | | X | | |

| Service/Function | | Actors | | | | Explanatory Notes |
|---|---|---|---|---|---|---|
| | | X=direct responsibility \| S=support role | | | | |
| | | RPICs | Operator | USS | FAA | |
| Planning, Intent and Authorization | Priority Status Notification (emergency declaration, public safety, etc.) | | | | | Not Explored in Use Case |
| | Operation Plan Development | | X | S | | |
| | Operation Intent Sharing (pre-flight) | | X | S | | |
| | Operation Intent Sharing (in-flight) | S | X | S | | |
| | Dynamic Restriction Request | | | | | Not Explored in Use Case |
| | Operation Intent Negotiation | | | | | Not Explored in Use Case |
| Operations Management | Demand Capacity Management | | | | | Not Explored in Use Case |
| | Airspace Access Management | | | | | Not Explored in Use Case |
| | Control of Flight | X | | | | |
| | Airspace Allocation & Constraints Definition | | | | | Not Explored in Use Case |

## 4.2.4 Use Case TCL3-2: Negotiation between Operators Due to Dynamic Restriction

### Overview

**Variation of TCL3-1 Use Case:** This use case is a variation of Use Case TCL3-1 (see §4.2.1). In the prior use case, the Rail Inspection Operator was able to separate from other operations occurring along the inspection route (at the same time) by planning and scheduling his Operation Volumes against the shared Operation Intent of these other Operations. Direct coordination/communication with these other Operators/RPICs was not required, due to the planning of segmented Operation Volumes.

To avoid unnecessary repetition in this use case, references to sections, figures and tables of the previous use case may be made throughout this use case (TCL3-2).

### Summary: Off-Nominal Events during Long-Distance Rail Inspection (Dynamic Restriction)

Nexus Track & Land Rail Road Company (NT&L RR) operates rail ways over the North Western United States, including the Miles City Sub-Division, which runs between Miles City, Montana and Glendive, Montana (a distance of about 75 miles). NT&L RR uses a small fleet of long range sUAS to monitor the road bed of their various railways; they monitor the Miles City Sub-Division on a weekly basis, flying from Miles City to Glendive and being returned to base via train.

An employee of NT&L RR is acting as the RPIC for the weekly inspection of the Mile City to Glendive road bed. The Rail Inspection Operator previously built the Operation Plan and made the Operation Intent available to the USS Network; the Operation Volumes (all ABOVs) of the inspection have been segmented and scheduled during the planning stage to avoid overlap of any Rail Inspection volume with that of the volumes of other operations occurring that day (overlap being bother geographical and temporal). While the UAS is in flight, a Dynamic Restriction is issued that lies along the inspection route, causing a disruption to the operation (see Figure 6).

The Rail Inspection RPIC receives notification of the Dynamic Restriction and enacts contingency procedures to allow him to plan around this unforeseen issue. There is still one other operation along the inspection route for which it will not be possible to avoid overlap of volumes unless something is altered (a Photography Operation). The Rail Inspection RPIC does not desire to operate in a shared airspace (overlapping volumes) due to equipage concerns of the other UAS, but he still desires to complete the inspection, rather than fly around the other Operation Volume.

Two scenarios for the Rail Inspection RPIC are explored in this use case:

- **Scenario 1:** Through negotiation with the Photography Operator (facilitated by their respective USSs), the Operation Volumes for both operations are modified to maintain separation (no overlap), and the rail inspection is able to be completed after the Dynamic Restriction is lifted by the FAA.
- **Scenario 2:** A request by USS 123 (on behalf of the Rail Inspection RPIC) to negotiate with the Photography Operator is rejected. USS 123 modifies the segment 8 ABOV, changing it to a TBOV (based off of preferences submitted by the Rail Inspection Operator during the planning phase) to minimize volume overlap with the Photography Operator. The Photography Operator is notified by his USS of the new overlapping TBOV, and he then chooses to modify his ABOV to avoid the overlap.

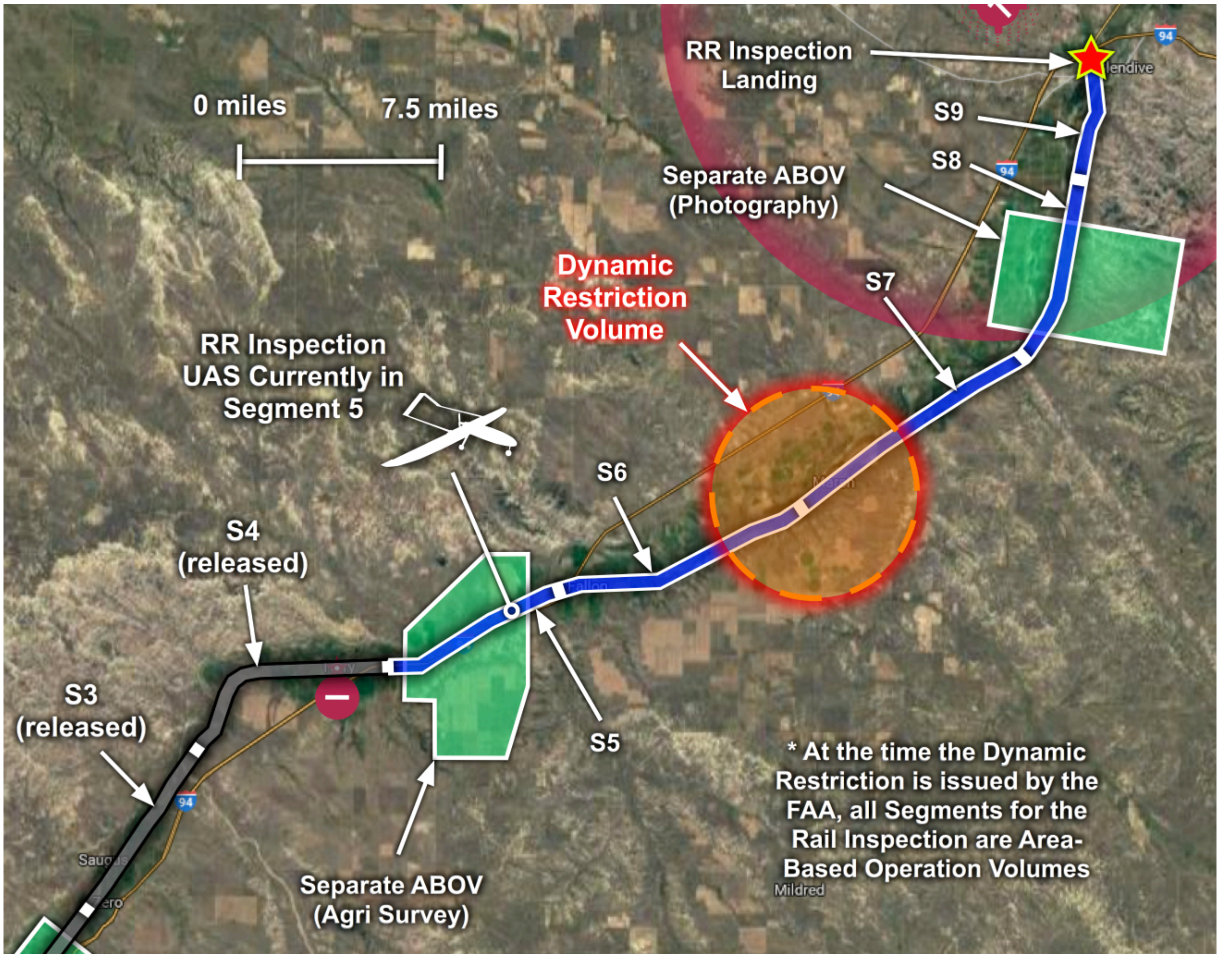



**Figure 6. Dynamic Restriction Overview**

**NOTE:** The Dynamic Restriction is not known by the USS Network (and by extension the Rail Inspection Operator and RPIC) until the Rail Inspection UAS is flying within the Segment 5 Operation Volume.

## Summary Table

*Summary Table is identical to TCL 3-1 Summary Table. Refer to §4.2.1.*

# Equipment

*Equipment Section is identical to TCL 3-1 Equipment Section. Refer to §4.2.1.*

# Actor Details

## Operator and RPIC

The Rail Inspection Operator has been granted an Performance Authorization that encompasses the area in which the rail bed inspection flights occur. Authorized operation types include, but are not limited to, BVLOS flight, over the horizon flight, and operations over people. Management personnel responsible for maintenance of the rails and road bed act as the Operator in this use case, while a specific employee with the necessary pilot certifications acts as the RPIC.

The other Operators likewise have been granted Performance Authorizations. The Operators are not directly mentioned in the narrative (they have already shared the Operation Intent for their specific operations). The RPICs do actively fly their respective UAS during the narrative.

## USS

Three USSs are servicing UAS Operators along the route of the Rail Inspection:

- USS ABC is servicing the Rail Inspection Operation
- USS XZY is servicing the Power Line Inspection Operation and the Agricultural Survey Operation
- USS 123 is servicing the Photography Operation

Operators and RPICs develop and Operation Plan with each of their respective USSs; the Operation Intent (developed as part of the planning process) is made available by each Operator (through their USS) to the USS Network, enabling shared situational awareness across all UTM participants.

## FAA

The FAA interacts with UTM as follows:

- The FAA has previously provided each Operator with the approval of a Performance Authorization, each of which includes the geographical area over which the Operation Volumes indicated in Figure 6 lie.
- The FAA receives Dynamic Restriction Requests from applicable stakeholders, approves or disapproves them, and distributes definition of approved Dynamic Restrictions to the USS Network for dissemination to affected Operators.

The FAA has the ability to access any information related to the operations as required (though this does not occur in the narrative below).

# UTM Interaction

## UTM Participation

All of the Operators identified in the narrative below are required to participate in UTM, given that some or all of their Operation Intent includes BVLOS flight.

## Shared Information Across Actors

| Type of Information | Actor Providing Information | Actors with Access to Information | Applicable to this Use Case? |
|---|---|---|---|
| Operation Plan Parameters/Inputs | Operator | USS | Yes |
| Operation Plan | USS | Operator | Yes |
| Operation Intent, pre-flight (and other shared data) | USS | USS Network | Yes |
| Operation Data Relevant to Regulator Information Requirements | USS | FAA | Yes |
| In-Flight Modification to Intent | RPIC | USS, USS Network | Yes |
| Externally-originated data (surveillance, NOTAM, Wx, etc) | USS or SDSP | USS and/or Operator & RPIC | Yes |
| Operationally-derived environmental data | RPIC, USS or SDSP | USS | Yes |
| Relevant Flight Data (e.g., position data) | RPIC and/or Operator | USS | Yes |
| | USS | USS Network<br>FAA (if applicable) | No |
| Operation Intent, in-flight (and other shared data) | USS | USS Network | Yes |
| Operation Status | USS | USS Network | Yes |
| Spectrum Management | USS | USS Network, RPIC and Operator | No |
| Dynamic Restriction Request | Operator/USS | FAA | No |
| Dynamic Restriction Approval | FAA | Operator/USS | No |
| Dynamic Restriction Distribution | FAA | USS Network and other NAS users | Yes |
| Negotiation Request | USS ABC | USS XYZ | Yes |
| Negotiation Response | USS XYZ | USS ABC | Yes |
| UREP | RPIC | USS | No |

| | | | |
|---|---|---|---|
| | USS | USS Network<br>FAA (if applicable) | No |
| UAS Flight Information | UAS | RPIC<br>Manned Aircraft | No |
| Manned Aircraft Flight Information | Manned Aircraft | UAS | No |
| Manned Aircraft Information | USS/SDSP | Operator/RPIC | No |

# Scenario Narrative

**NOTE:** The narrative of this use case focuses on the perspectives of the Rail Road Inspection Operator and RPIC. References to processes and actions of other Operators/RPICs are limited to the scope in which they contribute to the narrative.

**NOTE:** It is understood that many of the functions, communications and decision-making occurring in the narrative below are likely to be automated by the USSs and FAA. Indication of automation is avoided where possible to allow focus on the information exchange and flow of operations; for this use case, automation is called out during examination of USS to USS negotiation on the behalf of subscribing Operators/RPICs.

## Rail Inspection Planning

The planning events are similar to that found in Use Case TCL 3-1 Rail Inspection Planning Section, but have the following additions:

During the planning phase for the Rail Inspection Operation, the Operator provides information to USS ABC regarding preferences on how certain issues that the USS addresses in an automated fashion should be handled. In particular, the Rail Inspection Operator indicates to USS ABC that they should monitor for potential interruptions to their operation and recommend solutions to handle said interruptions; some solutions, such as negotiation with another Operator, are expected to be handled automatically by USS ABC.

The other Operators also provide similar preference information to their USSs; in the case of the Photography Operator, a preference to accept and have USS 123 handle Negotiation Requests is assumed in Exploration 1, while a preference to reject Negotiation Requests is assumed in Exploration 2.

## Take-Off

*Take-off Section is identical to Use Case TCL3-1 Take-Off Section; refer to §4.2.1.*

# Flight

The UAS flies along it's programmed route, as noted above, with the Rail Inspection RPIC monitoring the flight progress to determine if manual over-ride is required. The RPIC maintains connection to the UAS through use of the NT&L RR communications network; as the UAS approaches the performance/operational limits of one communication tower (whether due to horizon limits or structure/environmental obstruction/noise) it connects to another tower.

Operation Volumes are considered activated/occupied and inactive/unoccupied in accordance with the times noted in Table 5 (see previous use case). As the end times for each volume are reached (at which point the UAS has already exited said volume), that particular Operation Volume is considered inactive/unoccupied. If there are no other active times for that volume for the remainder of the operation, it is no longer considered by other operators/USSs while planning new/modifying current operations.

As previously noted, the other Operators/RPICs whose operations lie along the path of the rail inspection can see the currently active and planned Operation Volume segments (if they choose to display them), allowing them to maintain situational awareness around their operation area.

## Dynamic Restriction

While the Rail Inspection UAS is flying in Segment 5, a Dynamic Restriction (DR) is issued by the FAA through FIMS to the USS Network at 9:05 AM. The definition of the DR indicates an effective/activated time of 9:20 AM, ending at 10:20 AM; the shape of the DR volume is shown in Figure 6, with a floor of 0 ft AGL and a ceiling of 500 ft AGL. Additional definition in the DR includes a list of permitted/waived UAS for the DR Volume (only emergency medical service UAS).

USS ABC receives the DR definition from FIMS; it searches for affected or nearby operations of its subscribing operators and identifies the Rail Inspection Operation. At 9:07 AM, USS ABC sends notification to the Rail Inspection RPIC of the DR, with a message similar to the following:

> *"A Dynamic Restriction has been issued in the vicinity of your operating area, and is in effect from 9:20 AM to 10:20 AM. The Dynamic Restriction Volume overlaps, in both time and space, with at least one of your Operation Volumes. UAS are not permitted to operate within the bounds of a Dynamic Restriction Volume, unless previously authorized or waived. Refer to map information provided by us, USS ABC, on your GCS equipment or other compatible devices to review the details of this restriction. UAS Operators and RPICs are responsible for acting in accordance with all applicable regulations."*

The Rail Inspection RPIC notes on his GCS tools that the Dynamic Restriction overlaps (geographically and temporally) the Segment 6 and Segment 7 Operation Volumes, and he determines that an update to his Operation Intent is necessary (refer to Table 6 for an overview of the effect on the schedule). The Rail Inspection RPIC first enacts a contingency procedure, commanding his UAS to continue flying into segment

6, without flying into the restriction area, and then begin a holding pattern by flying in a tight circle while staying within the Operation Volume bounds.

**Table 6. Rail Inspection Operation Volume Disruption upon Activation of the Dynamic Restriction**

| Operation Volume | Volume Active State Start | Volume Active State End | Comments |
|---|---|---|---|
| Segment 1 | 7:55 AM | 8:26 AM | Volumes inactive/unoccupied |
| Segment 2 | 8:16 AM | 8:40 AM | |
| Segment 3 | 8:30 AM | 8:54 AM | |
| Segment 4 | 8:44 AM | 9:12 AM | |
| Segment 5 | 9:02 AM | 9:26 AM | Volume active/occupied |
| Segment 6 | 9:16 AM | 9:44 AM | Volume active/occupied<br>Volume affected by Dyn. Restr. |
| Segment 7 | 9:34 AM | 10:04 AM | Volumes affected by Dyn. Restr. |
| Segment 8 | 9:54 AM | 10:18 AM | |
| Segment 9 | 10:08 AM | 10:26 AM | |

**NOTE:** The Dynamic Restriction Active times are 9:20 AM to 10:20 AM. The definition is communicated to the USS Network by the FAA at 9:05 AM.

By 9:10 AM, the UAS has been updated with the contingency procedure and is in en route to the location for the holding pattern. The Rail Inspection RPIC begins reviewing potential updates to the Operation Intent to account for the Dynamic Restriction. It is determined that the Rail Inspection UAS has enough endurance left to continue the hold pattern until the DR is lifted, and then fly the remainder of the segments to the landing location. However, the Photography Operation will be active during those times in which the UAS would be flying through the same airspace as the Photography Operation Volume; the schedule cannot be adjusted for the remaining segments while still avoiding 4D overlap of Segment 8 and the Photography Operation Volume (another change is necessary to maintain separation). The Rail Inspection RPIC prefers to finish the rail inspection, rather than update his Operation Intent to fly around the Photography Operation Volume; he requests his USS to determine a solution that falls within his submitted preferences for the operation.

> **NOTE:** Two different narratives to this situation are explored in the 'Scenario 1: Negotiation between USSs' and 'Scenario 2: Use of a Trajectory-Based Operation Volume' Sections that follow; both of these approaches have a similar result in which both the Rail Inspection RPIC and Photography Operators update their respective Operation Intent and separation of each operation is maintained. The 'Updated Operation Details' Section reviews the resulting schedule update.

## Scenario 1: Negotiation between USSs

> **NOTE:** This narrative examines a more automated method of negotiation, handled by each Operator's USS based on Operator-submitted preferences. It is assumed that functionality for negotiation communication directly between Operators/RPICs could be facilitated by USSs as well, though this would result in a longer, more manual process (and is not examined in this narrative).

At 9:15 AM, the Rail Inspection RPIC requests USS ABC to find and implement a solution that updates the Operation Intent, taking into account the effects of the Dynamic Restriction. USS ABC uses various preferences submitted by the Operator and available information to determine a solution, which in this case includes:

- A preference to finish the inspection of the rail, if battery levels and other factors still allow for this
- A preference to avoid interaction with other UAS in a shared airspace (e.g., overlapping Operation Volumes)
- The battery level of the UAS is sufficient to complete the rail inspection after the Dynamic Restriction is lifted (in approximately 65 minutes)

USS ABC determines a potential solution that requires negotiation with the Photography Operator. USS ABC identifies USS 123 as the USS handling the Photography Operator and sends a Negotiation Request. Included with the Negotiation Request are details of the proposed Rail Inspection Segment 8 ABOV (see Figure 7), with new active times of 10:44 AM to 11:08 AM.

USS 123 receives the Negotiation Request and proposed 4D ABOV information; the USS checks the Photograph Operator preferences and other available information, which in this case includes:

- The operation goal is to complete aerial photography of the ground encompassed by the lateral boundaries of the ABOV
- A preference to Negotiate with other Operators when possible
- A preference for the USS to handle Negotiation Requests

USS 123 reviews the request and determines that allowing the rail inspection to take a small portion of the Photography Operation Volume does not adversely affect the photography operation or the Operator's preferences. USS 123 sends a response to USS ABC, accepting the proposed Rail Inspection Operation Volume cut-through. At the same time, USS 123 calculates a solution that segments the Photography Operation Volume into 3, with all 3 volumes scheduled to be active from 10:30 AM to 11:30 AM (see Figure 7). USS 123 updates the Operation Intent for the photography operation and makes the update available to the USS Network; the USS also sends a message to the Photography Operator, informing them of the changes to the Operation Intent.

USS ABC receives the response from USS 123; with a successful solution for the Segment 8 ABOV, USS ABC updates the Operation intent for the Rail Inspection with the new times for the remaining volumes (see Figure 9 and Table 7). By 9:17 AM, USS ABC makes the updated Operation Intent available to the USS Network, and sends a message to the Rail Inspection RPIC of the changes made.

**NOTE:** Another solution by USS 123 could have been the creation of a 4th segment, equal in boundary definition to the space cut out of the original Photography Operation Volume by Segment 8. It could have active times of 10:30 AM-10:44 AM and 11:08 AM-11:3 AM. However, since the loss of this airspace is not in opposition to the preferences of the Photography Operator, this solution is not pursued.

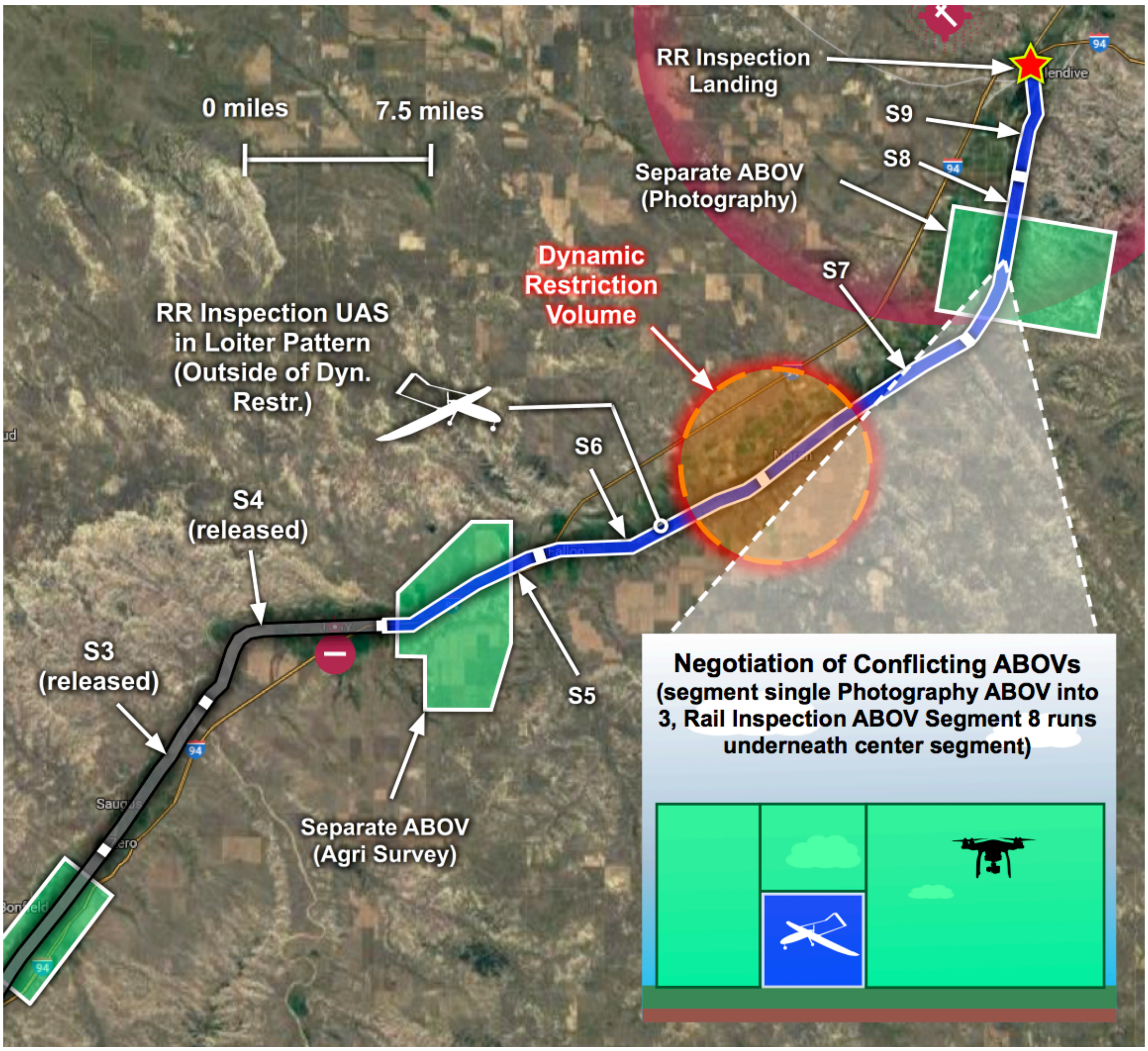



**Figure 7. Negotiated Solution between USSs**

## Scenario 2: Use of a Trajectory-Based Operation Volume

At 9:15 AM, the Rail Inspection RPIC requests USS ABC to find and implement a solution to update the Operation Intent, similar to the previous Scenario. USS ABC identifies USS 123 as the USS servicing the Photography Operator and, again in similar fashion to the previous Scenario, sends a Negotiation Request to USS 123.

USS 123 receives the Negotiation Request and proposed 4D ABOV information; the USS checks the Photograph Operator preferences and other available information, which in this case includes:

- The operation goal is to complete aerial photography of the ground encompassed by the lateral boundaries of the ABOV
- A preference to be able to operate very low to the ground within the Operation Volume (for special photography requirements)
- A preference to Negotiate with other Operators when possible
- A preference for the USS to handle Negotiation Requests

USS 123 reviews the request and determines that the proposed 4D ABOV for the rail inspection cannot work with Photography Operator’s preferences. USS 123 sends a response to USS ABC, indicating the proposed solution is not accepted. USS ABC receives the response and determines that no other solutions involving an ABOV of similar size as the original for Segment 8 are possible, while still adhering to the Rail Inspection Operator’s preferences.

USS ABC determines that modifying Segment 8 from an ABOV into a TBOV is the next-best solution. USS ABC updates Segment 8 definition to conform to a TBOV (see modification details in Figure 8, Figure 9, and Table 7). The boundaries of the Operation Volume are modified to be only as large as is required to achieve the primary operational goal (rail bed photography/videography) while accounting for the ability of the UAS (i.e. performance capabilities, environmental constraints, etc.) to maintain a trajectory aligned with said goal while staying within the volume boundaries. USS ABC also updates the schedule of Segments 6 through 9 to account for the time that the DR is planned to be lifted (see Table 7). By 9:17 AM, USS ABC makes the updated Operation Intent available to the USS Network, and sends a message to the Rail Inspection RPIC of the changes made.

**NOTE:** ABOVs used by the rail inspection allow for more maneuverability around locations of interest that are identified along the rail bed, such that different viewing angles can be achieved when needed. The TBOV used is significantly smaller in cross-sectional area than the ABOVs, limiting maneuverability. However, as the UAS has less endurance due to the DR, getting videography along the new route while still returning to base is acceptable.

When USS 123 becomes aware of the update of Segment 8 from an ABOV to a TBOV, it notifies the Photography Operator of the TBOV, and sends a message similar to the following:

"A Trajectory-Based Operation Volume (TBOV) has been created that overlaps with one or more of your Area-Based Operation Volumes (ABOVs) (available for viewing on your USS 123-provided tools). Per your submitted records to us, your UAS does not have Sense and Avoid capabilities, and third-party UAS tracking is not available in this area. It is recommended that you maintain separation from this TBOV while it is in an active state, minimizing your chance of encountering the UAS flying inside of it."

The Photography Operator prefers not to fly in a shared airspace with other UAS, due to the limitations of his UAS; he modifies his ABOV, segmenting it into 3 ABOVs (see Figure 8) to avoid geographical overlap with the Segment 8 TBOV. By 9:35 AM, USS 123 makes this updated Operation Intent available to the USS Network.

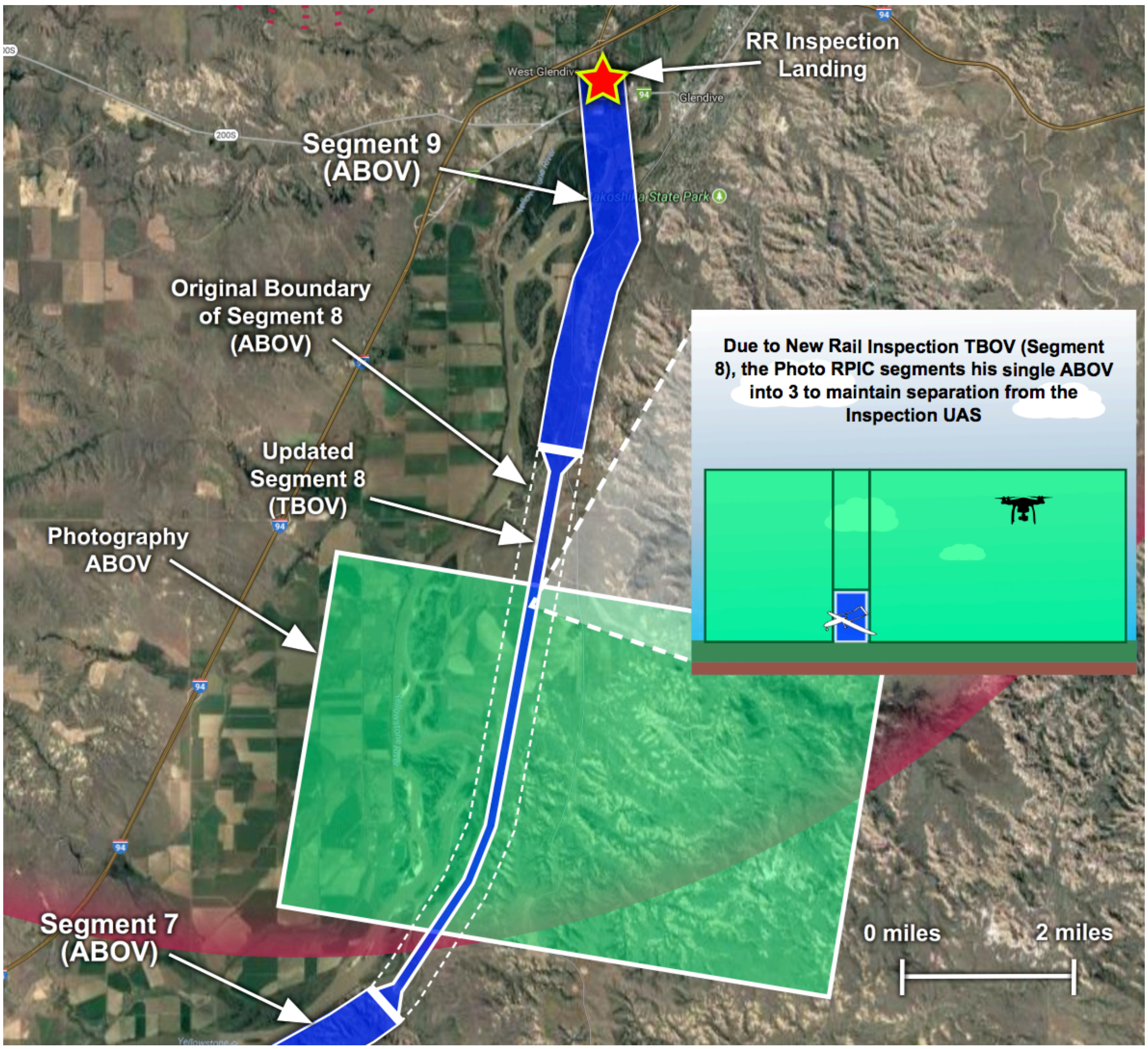



**Figure 8. Use of TBOV by Rail Inspection**

## Updated Operation Details

Table 7 provides the detailed overview of the new Rail Inspection Operation Intent. The times for Segments 6 through 9 are adjusted to account for the DR. Segment 8 has additional modifications, such as the ceiling and the type of Operation Volumes (ABOV vs TBOV), depending on the Scenario. For additional details on the modifications to Segment 8, compare Figure 7 and Figure 8.

Figure 9 provides a visualization of the new schedule for Segments 6 through 9.

**Table 7. Updated Rail Inspection Volumes**

<table>
<tr><th>Operation Volume</th><th>Volume Active State Start</th><th>Volume Active State End</th><th>Floor (ft. AGL)</th><th>Ceiling (ft AGL)</th><th>Volume Type</th><th>Comments</th></tr>
<tr><td>Segment 1</td><td>7:55 AM</td><td>8:26 AM</td><td rowspan="10">0</td><td rowspan="7">150</td><td rowspan="7">ABOV</td><td rowspan="5">Start and End times unchanged</td></tr>
<tr><td>Segment 2</td><td>8:16 AM</td><td>8:40 AM</td></tr>
<tr><td>Segment 3</td><td>8:30 AM</td><td>8:54 AM</td></tr>
<tr><td>Segment 4</td><td>8:44 AM</td><td>9:12 AM</td></tr>
<tr><td>Segment 5</td><td>9:02 AM</td><td>9:26 AM</td></tr>
<tr><td>Segment 6</td><td>9:16 AM</td><td>10:34 AM</td><td>Start time unchanged, end time updated</td></tr>
<tr><td>Segment 7</td><td>10:24 AM</td><td>10:54 AM</td><td rowspan="4">Start and End Times updated</td></tr>
<tr><td rowspan="2">Segment 8</td><td rowspan="2">10:44 AM</td><td rowspan="2">11:08 AM</td><td>150 (Scenario 1)</td><td>ABOV (Scenario 1)</td></tr>
<tr><td>75 (Scenario 2)</td><td>TBOV (Scenario 2)</td></tr>
<tr><td>Segment 9</td><td>10:08 AM</td><td>10:26 AM</td><td>150</td><td>ABOV</td></tr>
</table>

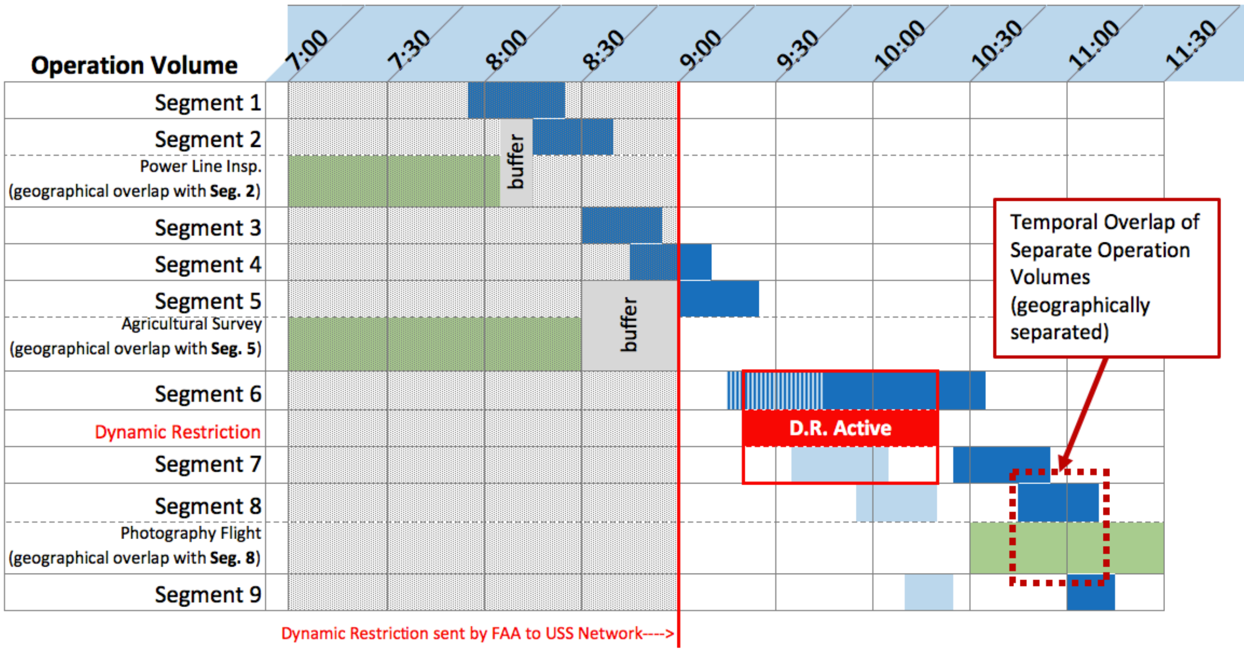



**Figure 9. Volume Schedule Visualization (after either Scenario)**

## Remainder of Rail Inspection Flight

At 10:30 AM, the DR is lifted, and the Rail Inspection UAS continues its flight. Operation Volumes are considered active/occupied and inactive/unoccupied in accordance with the times noted in Figure 9. As the end time for each volume is reached (at which point the UAS has already exited said volume), that particular Operation Volume is considered inactive.

The Photography Operation is activated at 10:30 AM. As both operations are separated geographically, neither UAS operates near the other such that they cause a hazard to one another.

The Rail Inspection UAS eventually enters Segment 9, completes the remaining photography/videography of the rail bed, and prepares to land.

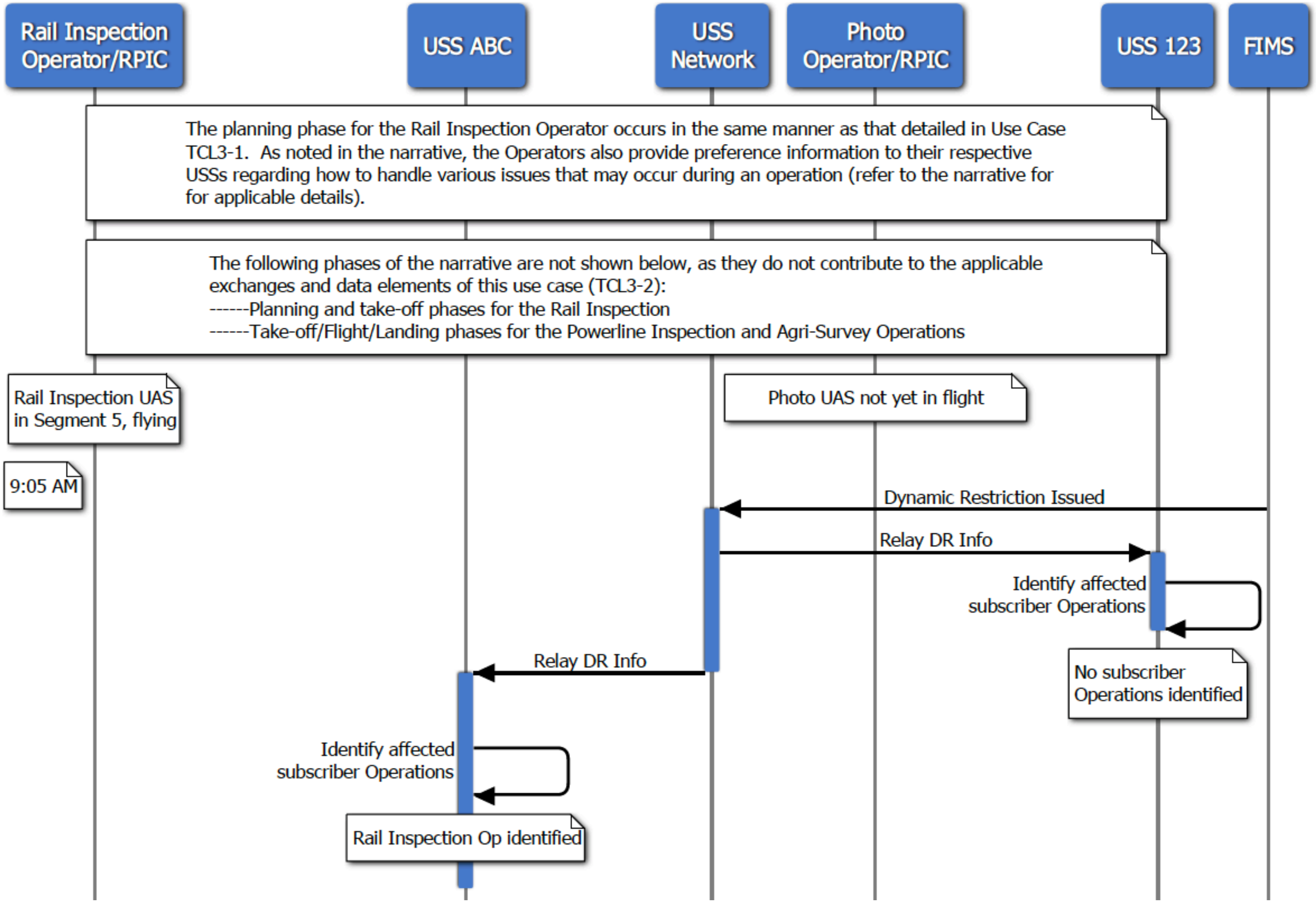
# Landing

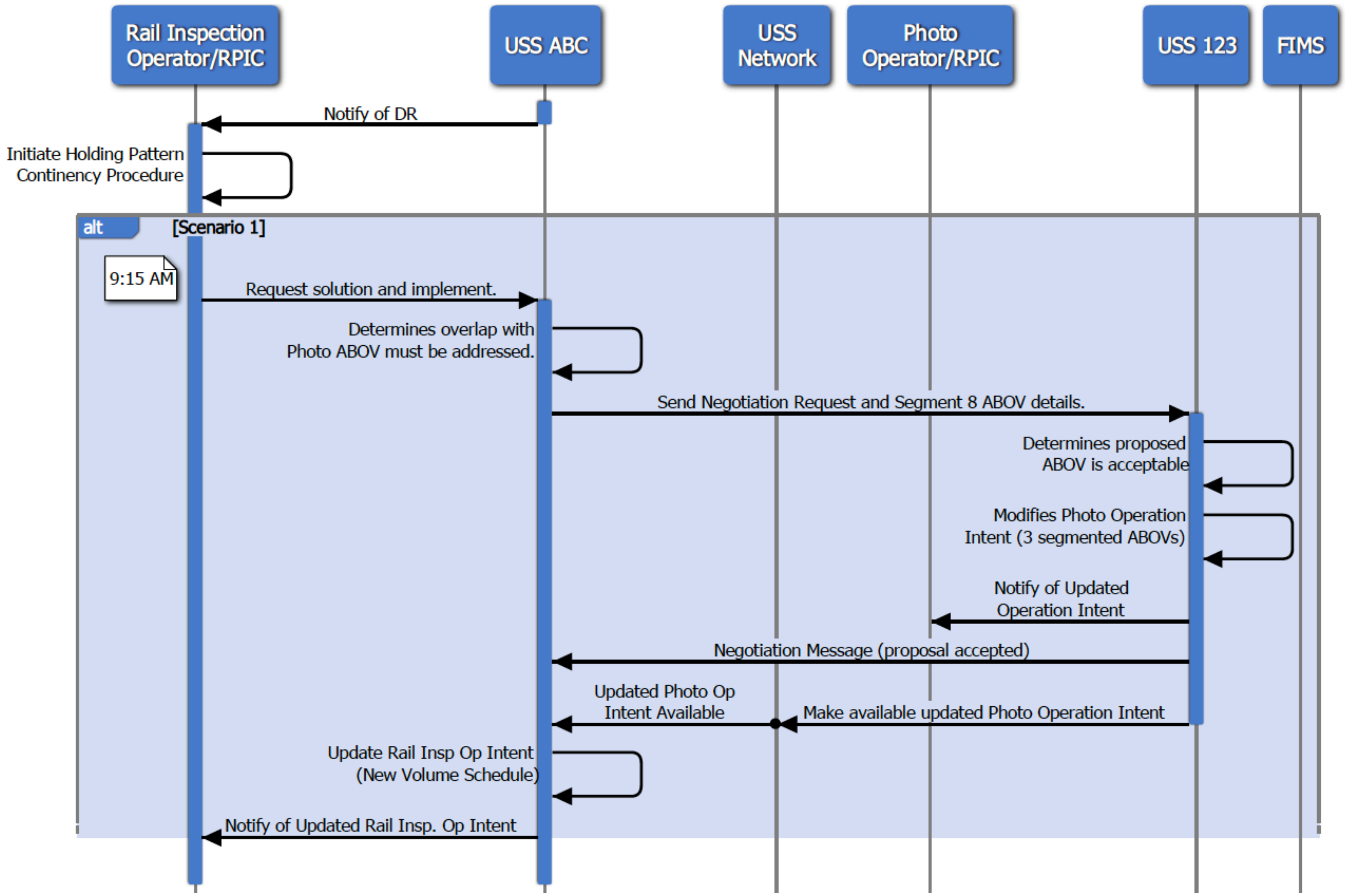
The Rail Inspection UAS reaches its destination and automatically lands within Segment 9, at a facility maintained by NT&L RR. The Rail Inspection RPIC indicates to USS ABC that his operation is concluded; the USS sets the Rail Inspection Operation Status to “Closed” (all volumes are considered inactive/unoccupied at this time) and the updates to the Operation Intent are made available to the USS Network.

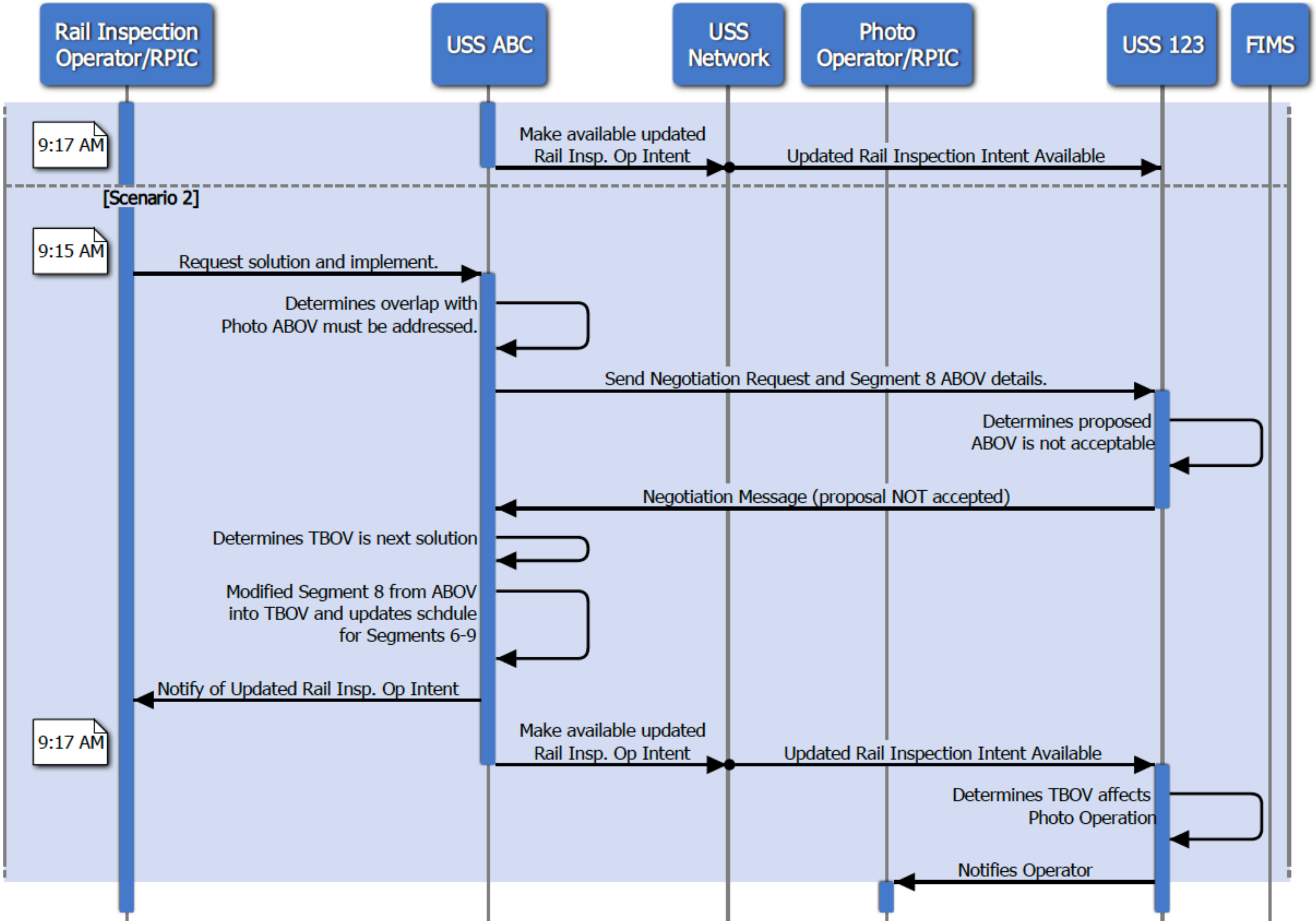
USS ABC maintains records of the Operation Plans/Intent, including the original plan and any modifications before and during flight in the event that the FAA determines a need to review said information.

### 4.2.5 Operational Views

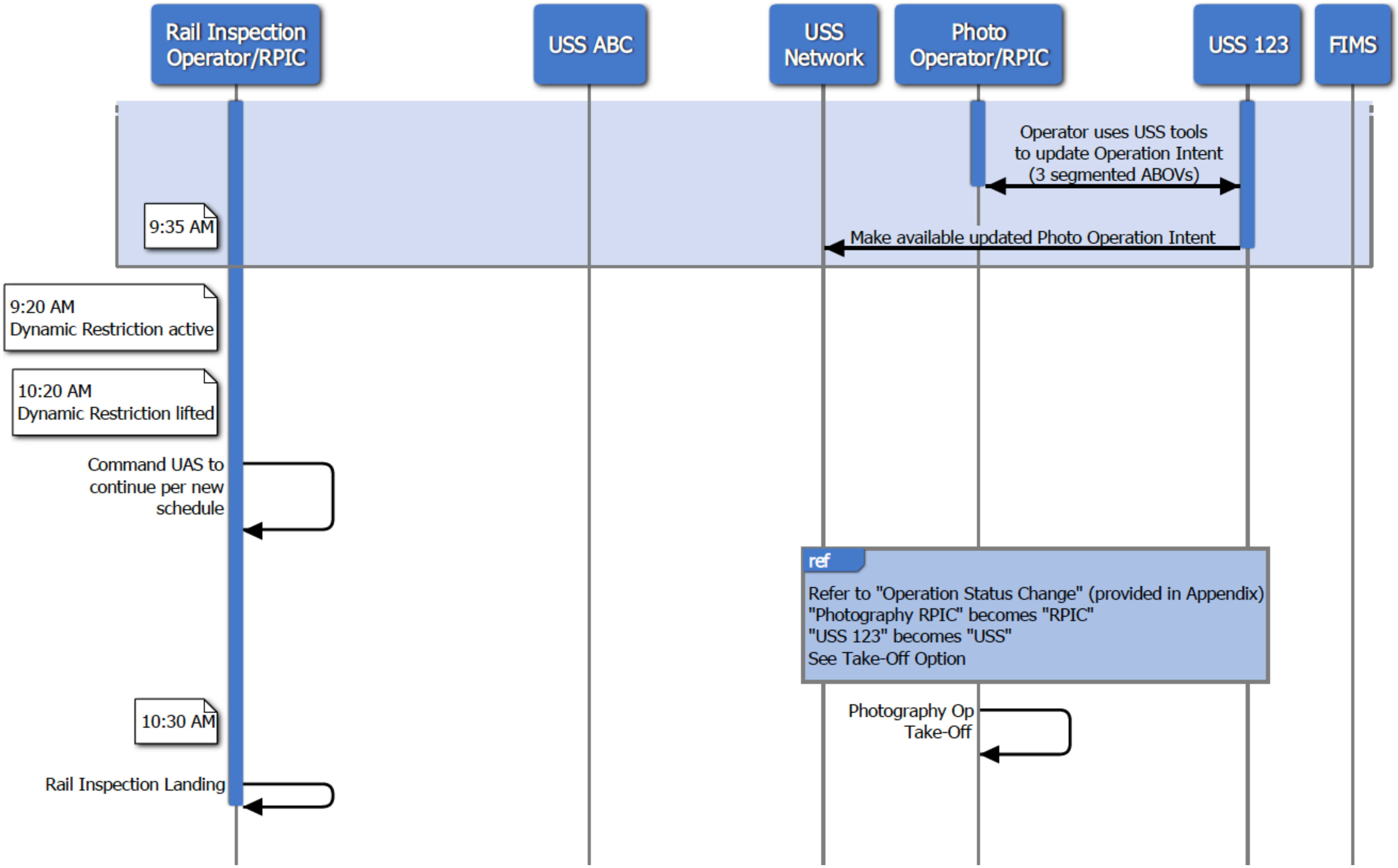
The following pages provide operational views of the scenario narrative.  Referenced diagrams for sub-activities can be found in the Appendix.

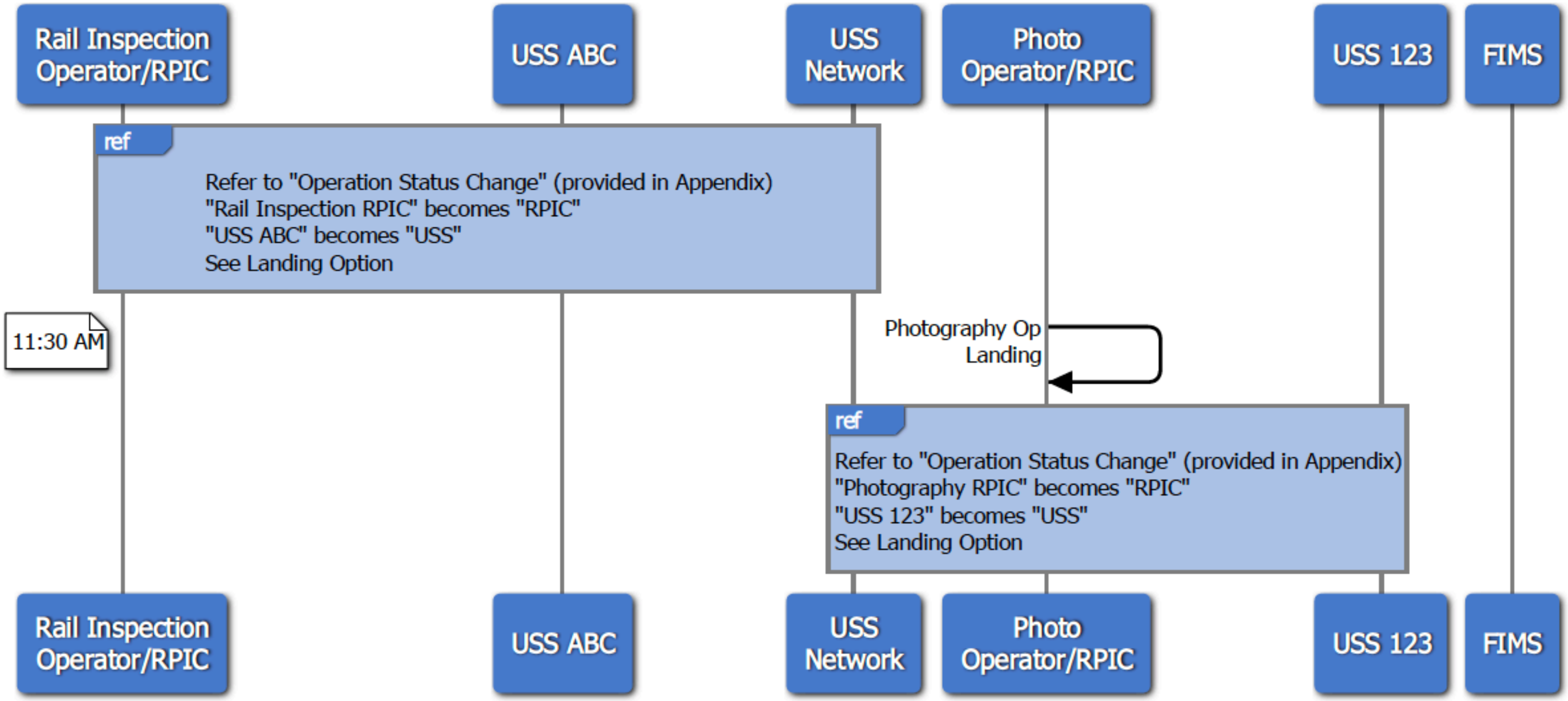

Rail Inspection Operator/RPIC
USS ABC
USS Network
Photo Operator/RPIC
USS 123
FIMS
The planning phase for the Rail Inspection Operator occurs in the same manner as that detailed in Use Case TCL3-1. As noted in the narrative, the Operators also provide preference information to their respective USSs regarding how to handle various issues that may occur during an operation (refer to the narrative for for applicable details).
The following phases of the narrative are not shown below, as they do not contribute to the applicable exchanges and data elements of this use case (TCL3-2):
------Planning and take-off phases for the Rail Inspection
------Take-off/Flight/Landing phases for the Powerline Inspection and Agri-Survey Operations
Rail Inspection UAS in Segment 5, flying
Photo UAS not yet in flight
9:05 AM
Dynamic Restriction Issued
Relay DR Info
Identify affected subscriber Operations
No subscriber Operations identified
Relay DR Info
Identify affected subscriber Operations
Rail Inspection Op identified


Rail Inspection Operator/RPIC
USS ABC
USS Network
Photo Operator/RPIC
USS 123
FIMS
Notify of DR
Initiate Holding Pattern Continency Procedure
alt
[Scenario 1]
9:15 AM
Request solution and implement.
Determines overlap with Photo ABOV must be addressed.
Send Negotiation Request and Segment 8 ABOV details.
Determines proposed ABOV is acceptable
Modifies Photo Operation Intent (3 segmented ABOVs)
Notify of Updated Operation Intent
Negotiation Message (proposal accepted)
Updated Photo Op Intent Available
Make available updated Photo Operation Intent
Update Rail Insp Op Intent (New Volume Schedule)
Notify of Updated Rail Insp. Op Intent



Rail Inspection Operator/RPIC
USS ABC
USS Network
Photo Operator/RPIC
USS 123
FIMS
9:17 AM
Make available updated Rail Insp. Op Intent
Updated Rail Inspection Intent Available
[Scenario 2]
9:15 AM
Request solution and implement.
Determines overlap with Photo ABOV must be addressed.
Send Negotiation Request and Segment 8 ABOV details.
Determines proposed ABOV is not acceptable
Negotiation Message (proposal NOT accepted)
Determines TBOV is next solution
Modified Segment 8 from ABOV into TBOV and updates schdule for Segments 6-9
Notify of Updated Rail Insp. Op Intent
9:17 AM
Make available updated Rail Insp. Op Intent
Updated Rail Inspection Intent Available
Determines TBOV affects Photo Operation
Notifies Operator


Rail Inspection Operator/RPIC
USS ABC
USS Network
Photo Operator/RPIC
USS 123
FIMS
Operator uses USS tools to update Operation Intent (3 segmented ABOVs)
9:35 AM
Make available updated Photo Operation Intent
9:20 AM Dynamic Restriction active
10:20 AM Dynamic Restriction lifted
Command UAS to continue per new schedule
ref
Refer to "Operation Status Change" (provided in Appendix)
"Photography RPIC" becomes "RPIC"
"USS 123" becomes "USS"
See Take-Off Option
10:30 AM
Photography Op Take-Off
Rail Inspection Landing


Rail Inspection Operator/RPIC
USS ABC
USS Network
Photo Operator/RPIC
USS 123
FIMS
ref
Refer to "Operation Status Change" (provided in Appendix)
"Rail Inspection RPIC" becomes "RPIC"
"USS ABC" becomes "USS"
See Landing Option
11:30 AM
Photography Op Landing
ref
Refer to "Operation Status Change" (provided in Appendix)
"Photography RPIC" becomes "RPIC"
"USS 123" becomes "USS"
See Landing Option
Rail Inspection Operator/RPIC
USS ABC
USS Network
Photo Operator/RPIC
USS 123
FIMS

### 4.2.6 Roles and Responsibilities Table

| Service/Function | | Actors X=direct responsibility \| S=support role RPICs | Operator | USS | FAA | Explanatory Notes |
|---|---|---|---|---|---|---|
| Separation | VLOS UAS from VLOS UAS | | | | | Not Explored in Use Case |
| | VLOS UAS from BVLOS UAS | | | | | Not Explored in Use Case |
| | BVLOS UAS from BVLOS UAS | S | X | S | | Planning stage – strategic (Operator)<br>Flight – strategic/tactical (RPIC) |
| | VLOS UAS from Low-Altitude Manned A/C | | | | | Not Explored in Use Case |
| | BVLOS UAS from Low-Altitude Manned A/C | | | | | Not Explored in Use Case |
| Hazard/ Terrain Avoidance | Weather Avoidance | | X | S | | |
| | Terrain Avoidance | | X | S | | |
| | Obstacle Avoidance | | X | S | | |
| Status | UTM Operations Status | | | X | | |
| | Flight Information Archive | | X | S | | |
| | Flight Information Status | | | X | | |
| Advisories | Weather Information | | | X | | USSs likely to be primary distributor of information. Possible they may pull from other sources and make available to subscribers. |
| | Hazard Information (Obstacles, terrain, etc) | | | X | | |
| | Alert Affected Airspace Users of UAS Hazard | | | | | |
| | UAS-Specific Hazard Information (Power-Lines, No-UAS Zones, etc) | | | X | | |

| Service/Function | | Actors | | | | Explanatory Notes |
|---|---|---|---|---|---|---|
| | | X=direct responsibility \| S=support role | | | | |
| | | RPICs | Operator | USS | FAA | |
| Planning, Intent and Authorization | Priority Status Notification (emergency declaration, public safety, etc.) | | | | | Not Explored in Use Case |
| | Operation Plan Development | | X | S | | |
| | Operation Intent Sharing (pre-flight) | | X | S | | |
| | Operation Intent Sharing (in-flight) | S | X | S | | |
| | Dynamic Restriction Request | | | | | Not Explored in Use Case |
| | Operation Intent Negotiation | S | X | S | | RPIC initiates, USS performs |
| Operations Management | Demand Capacity Management | | | | | Not Explored in Use Case |
| | Airspace Access Management | | | | | Not Explored in Use Case |
| | Control of Flight | X | | | | |
| | Airspace Allocation & Constraints Definition | | | | X | |

## 4.2.7 Use Case TCL3-3: UAS Interaction with Manned Aircraft in Low-Altitude Uncontrolled Airspace

## Overview

**NOTE:** It is assumed for this use case that manned aircraft pilots have no additional requirements than they have under current regulation. Manned aircraft are encouraged to use UTM-based information services provided by USSs or SDSPs when they intend to fly at low altitude where interaction with UAS is likely.

**NOTE:** It is assumed for this use case that BVLOS UAS Operators and manned aircraft share separation responsibilities. It is also assumed that BVLOS UAS Operators adhere to right-of-way rules similar to that of manned aircraft operating under 14 CFR Part 91 (e.g., the more maneuverable aircraft giving way, turning right when two aircraft are on course towards each other, etc.). These assumptions only apply to this use case for exploratory purposes and should not be interpreted as an established regulatory UTM solution.

### Three Scenarios Exploring UAS and Manned Aircraft Interactions

Various manned aircraft may be encountered by small UAS while operating VLOS or BVLOS below 400 feet AGL. This use case examines potential ways in which UTM-participating UAS Operators and RPICs may identify and interact with these aircraft in a safe manner. This use case focuses only on these types of interactions in uncontrolled airspace. Three different scenarios are explored and show different manned aircraft that may be encountered at low altitudes (in low-congestion or sparsely-populated areas); each scenario also shows a different manner in which a UAS Operator may identify the manned aircraft and what steps may be taken to maintain separation (through on-board systems, ground-based systems, use of USS/SDSP services, etc.).

The three scenarios are:

- **Scenario 1: UAS Interaction with a Moored Balloon**
  - A BVLOS UAS Operator conducts monitoring of several vineyards, and during flight encounters a moored balloon providing tourism services.
  - Explores a UAS Operator using on-board detection systems to avoid manned aircraft.
- **Scenario 2: UAS Interaction with a Manned Fixed-Wing Aircraft**
  - A manned fixed-wing aircraft conducting low-altitude sightseeing flies near a BVLOS UAS conducting a survey of bison.
  - Explores a UAS Operator using information from a USS to avoid manned aircraft.
- **Scenario 3: UAS Interaction with a Manned Rotor Aircraft**

- A BVLOS UAS conducting a videography operation for a film studio unknowingly flies towards a helicopter operating at low-altitudes.
- Explores a UAS that utilizes vehicle to vehicle (V2V) equipment that is cooperative with manned aircraft V2V equipment to maintain separation.

# Summary Table

**Table 8. Summary - Use Case TCL 3-3**

| Scenario | Operation | Authorization | Operational Description | Environmental Description |
|---|---|---|---|---|
| 1 | Vineyard Monitoring | See Notes Below[1,2] | Unmanned BVLOS, Below 400 ft AGL, Position Reporting, Ops Over People | Congested Area (town), Class G, Calm Weather, 10-mile visibility |
| | Moored Balloon (tourism) | N/A | Manned Flight, Tethered, Below 150 ft AGL | |
| 2 | Animal Survey | See Notes Below[1,2] | Unmanned BVLOS, below 400 ft AGL, Position Reporting | Sparsely Populated, Class G, Calm Weather, 10-mile visibility |
| | Recreational Flight (sightseeing) | N/A | Manned Fixed-Wing Flight, Below 1,000 ft AGL | |
| 3 | Film Videography | See Notes Below[1,2] | Unmanned BVLOS, below 400 ft AGL, Position Reporting | Sparsely Populated, Class G, Calm Weather, 10-mile visibility |
| | Charter Flight | N/A | Manned Helicopter Flight, Below 500 ft AGL. | |

1. Performance Authorization approval was obtained by these Operators from the FAA prior to the events of the narrative below; these processes are not discussed in this use case.
2. Operation Plan/Intent development by these Operators with their respective USS occurs prior to the events of the narrative below; these processes are not discussed in this use case.

# Equipment

## Vineyard Monitoring UAS and Moored Balloon

The Vineyard Operator is flying a fixed-wing UAS with a range/endurance capable of supporting his operation. The UAS has advanced on-board sensing capabilities, such as airborne radar or infrared sensors. The GCS has equipment/systems that allow for an increased communications range to support long-distance operations to support the primary mission goals. The UAS also has multiple cameras, allowing it to look towards the ground while also looking forward/rearward (enabling imagery to be recorded while the RPIC maintains flight awareness at the same time).

The manned balloon has no on-board equipment that relates to interaction with the UAS.

### Animal Survey UAS and Manned Fixed-Wing

The Survey Operator is flying a fixed-wing UAS with a range/endurance capable of supporting his operation. The GCS has equipment/systems that allow for an increased communications range to support long-distance operations. The UAS does not have advanced on-board sensing capabilities to identify airborne manned aircraft, but it does have conspicuity equipment to increase its visibility to manned aircraft and other UAS RPICs.

The USS to which the Survey RPIC is subscribed services many rural UAS Operators in the area. Given the presence of low altitude manned aircraft operations in the area as well (such as crop-dusters), ground-based surveillance services are available through a SDSP to detect airborne manned aircraft; any subscribing UAS Operators/RPICS who are operating near detected manned aircraft are alerted.

The manned A/C PIC flies a 1978 Cessna 152. The 152 does not have any advanced electrical equipment (transponder, ADS-B, etc.). The pilot uses a cellular-connected tablet for connection to a SDSP; the SDSP provides information on known UTM operations (Operation Intent shared with the USS Network) occurring near the 152 PIC while he flies. He uses this information for situational awareness, so that he can operate with increased awareness of active UAS areas.

### Movie Videography UAS and Manned Rotor Aircraft

The film studio flies a rotor-craft UAS with extended battery capacity to support the long-distance flights necessary for filming along the river. The GCS has equipment/systems that allow for an increased communications range to support long-distance operations. The UAS also has on-board vehicle to vehicle communication capabilities that may also used by manned aircraft. It also has conspicuity equipment to increase its visibility to manned aircraft and other UAS RPICs.

The helicopter has one of the latest avionics packages to support traffic spotting, which includes vehicle-to-vehicle/vehicle-to-ground communication equipment.

## Actor Details

### PICS

All manned aircraft PICs have appropriate certifications for operating their applicable aircraft.

The pilot of the moored balloon is referred to as the Balloon PIC. The pilot of the fixed-wing aircraft is referred to as the Sightseeing PIC. The pilot of the manned helicopter is referred to as the Charter PIC.

### Operators and RPICs

The UAS Operator in each scenario is assumed to have already been granted a Performance Authorization that encompasses the area in which their operation occurs; the types of operations authorized may include BVLOS, Ops Over People, over the horizon flight, etc. The individual conducting the unmanned flight in each scenario is the RPIC, and is assumed to have all required certifications for conducting the operation.

The RPIC of the vineyard monitoring operation is referred to as the Vineyard RPIC. The RPIC of the animal survey operations is referred to as the Survey RPIC. The RPIC of the film videography operation is referred to as the Film RPIC.

### USS

The USS supporting the Vineyard RPIC is referred to as the Vineyard USS. The USS supporting the Survey RPIC is referred to as the Survey USS. The USS supporting the Film RPIC is referred to as the Film USS.

### SDSP

The Sightseeing PIC uses a cellular-connected tablet to connect to services by a SDSP, hereafter referred to as the Sightseeing SDSP. This SDSP provides Operation Intent information to the PIC that has been shared with the USS Network by UTM-participating UAS Operators, allowing him increased situational awareness of active UAS areas when flying at low altitudes.

### FAA

The FAA interacts with UTM as follows:

- The FAA has previously provided each Operator with the approval of a Performance Authorization, each of which includes the geographical area over which the Operation Volumes indicated in Figure 4 lie.

The FAA has the ability to access any information related to the operations as required (though this does not occur in the narrative below).

## UTM Interaction

### UTM Participation

All of the Operators identified in the narrative below are required to participate in UTM, given that some or all of their Operation Intent includes BVLOS flight.

## Shared Information Across Actors

**Table 9. Shared Information - Use Case TCL 3-3**

| Type of Information | Actor Providing Information | Actors with Access to Information | Applicable to this Use Case? |
|---|---|---|---|
| Operation Plan Parameters/Inputs | Operator | USS | No |
| Operation Plan | USS | Operator | No |
| Operation Intent, pre-flight (and other shared data) | USS | USS Network | No |
| Operation Data Relevant to Regulator Information Requirements | USS | FAA | No |
| In-Flight Modification to Intent | RPIC | USS, USS Network | No |
| Externally-originated data (surveillance, NOTAM, Wx, etc) | USS or SDSP | Operator or RPIC | Yes |
| Operationally-derived environmental data | RPIC, USS or SDSP | USS | Yes |
| Relevant Flight Data (e.g., position data) | RPIC and/or Operator | USS | Yes |
| | USS | USS Network | No |
| Operation Intent, in-flight (and other shared data) | USS | USS Network | No |
| Operation Status | USS | USS Network | No |
| Spectrum Management | USS | USS Network, RPIC and Operator | No |
| Dynamic Restriction Request | Operator/USS | FAA | No |
| Dynamic Restriction Approval | FAA | Operator/USS | No |
| Dynamic Restriction Distribution | FAA | USS Network and other NAS users | No |
| Negotiation Request | USS ABC | USS XYZ | No |
| Negotiation Response | USS XYZ | USS ABC | No |
| UREP | RPIC | USS | Yes |
| | USS | USS Network<br>FAA (if applicable) | Yes |
| UAS Flight Information | UAS | RPIC<br>Manned Aircraft | Yes |
| Manned Aircraft Flight Information | Manned Aircraft | UAS | Yes |
| Manned Aircraft Information | USS/SDSP | Operator/RPIC | Yes |

# Narratives and Operational Views

**NOTE:** The narratives of each scenario focus on the interactions between aircraft. Details on the processes of Operation Intent development sharing, Operation Status changes, etc. are avoided unless they directly contribute to exchanges relating to the interaction of these aircraft.

**NOTE:** It is understood that many of the functions, communications and decision-making occurring in the narrative below are likely to be automated by the USSs and FAA. Explicit callout to automation is avoided to allow focus on the information exchange and flow of operations.

## Scenario 1: UAS and Moored Balloon

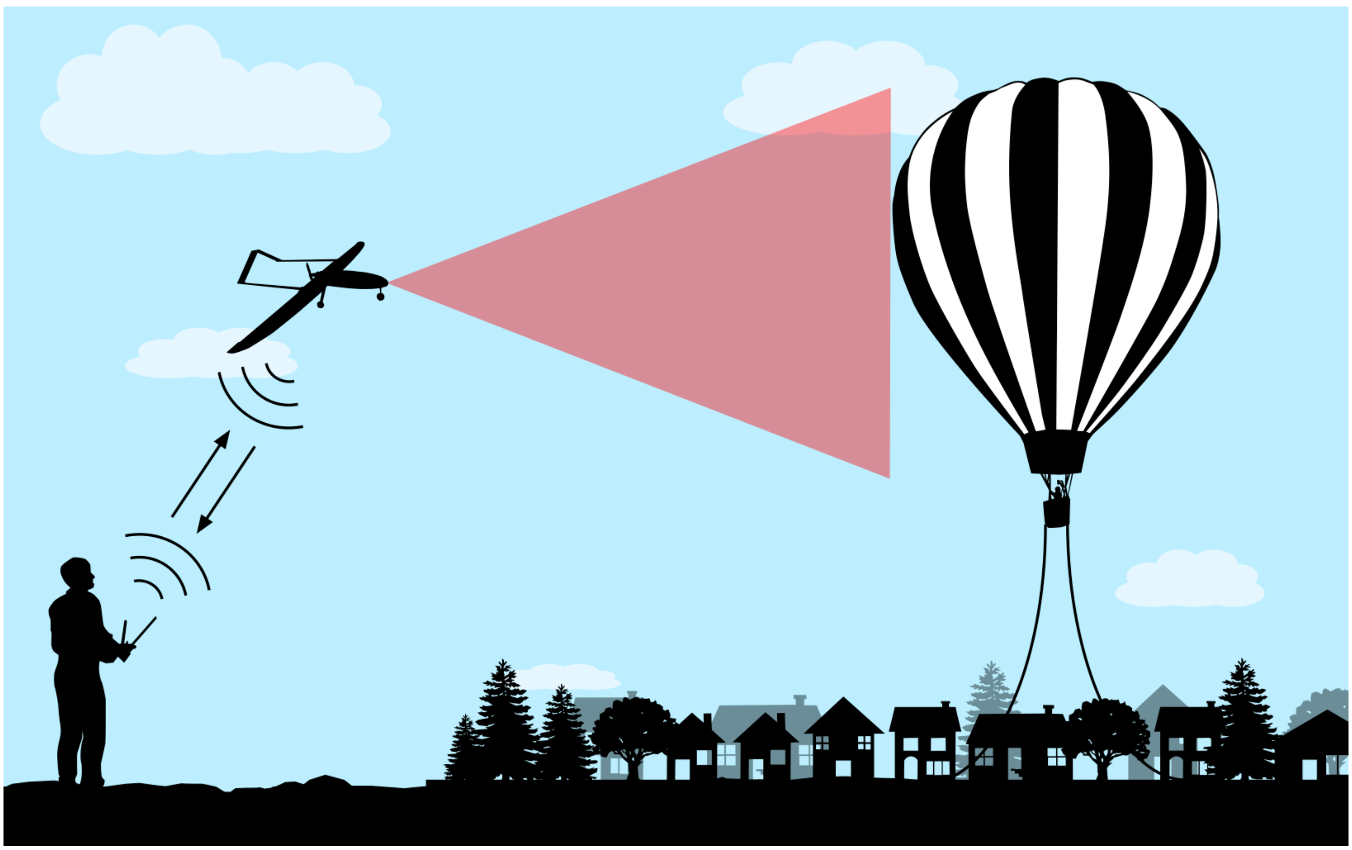


**Figure 10. Scenario 1**

### Narrative - Scenario 1

A commercial UAS Operator has been hired by multiple wineries in rural Southern California to perform regular vineyard monitoring services. The operator monitors all of these vineyards during a single BVLOS flight on a weekly basis, flying up to 30 miles for each operation. Moored balloon operations occur regularly for tourism purposes, allowing visitors views of the valley and vineyards. The commercial UAS Operator knows of these balloon operations and has on-board detection capabilities to alert him of any large aircraft (relative to small UAS sizes) operating near the UAS while in flight.

The Operation Intent for the vineyard monitoring operation is developed and shared with USS Network by the Vineyard Operator the night before the flight, using the services provided by the Vineyard USS; any other UTM-participating aircraft have the ability to identify details of the winery monitoring operation (including Operation Volumes, times, etc.). The Balloon PIC does not provide any information to, or get any from, the USS Network, and is therefore unaware of any nearby UAS operations. Additionally, the Balloon PIC operates at or below 150 ft AGL, and is therefore not required to provide notice to the FAA of their operation (refer to 14 CFR Part 101 Subpart B §101.15); there is no NOTAM data regarding this flight that could be utilized by the Vineyard Operator or his USS.

On the morning of the vineyard operation, the Vineyard RPIC sets up the GCS and also inspects the airspace near him. He sees no other UAS or aircraft nearby; the moored balloon is already in the air 10 miles away, but the view of it for the RPIC is obscured by small hills and foliage. He sends take-off notice to the Vineyard USS, who updates his Operation Status to “Activated” and makes this update available to the USS Network. The Vineyard RPIC launches his UAS at this time and begins flying.

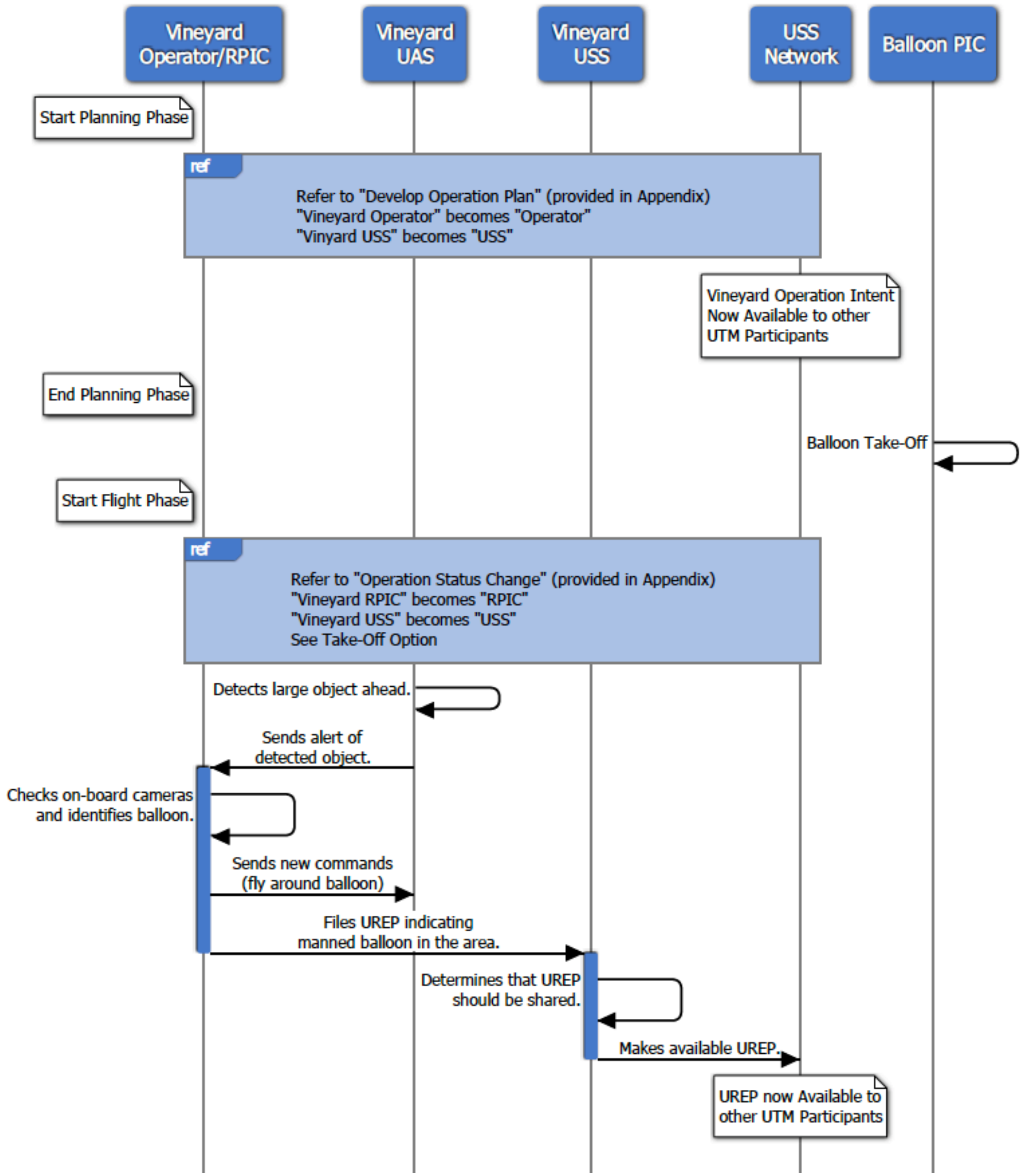
While in flight, any Operation Volumes are considered active/occupied and inactive/unoccupied in accordance with the schedule in the Operation Intent. The UAS flies along the commanded/programmed route, and the RPIC observes the video of the monitored vineyards as the UAS flies along its course.

At some point along the UAS route, the on-board sensors detect a larger airborne object (the balloon) 2 miles ahead, with an altitude of approximately 135 feet AGL; equipment capable of detecting such an object may include infrared sensors, airborne radar (assuming the balloon has reflectors that radar can detect), etc. The UAS relays this information as an alert to the Vineyard RPIC, who then focuses on the forward-facing UAS camera on his control station and visually identifies the balloon. The balloon lies along the current programmed route of the UAS; the Vineyard RPIC alters the programmed route to fly around the balloon, while remaining within his Operation Volume; the change in flight path does not adversely affect the scheduling for the Operation Volumes, such that no update to the Operation Intent is required. The RPIC maintains attention on the balloon until the UAS is no longer operating near it, allowing video-recording of the down-facing cameras to capture imagery for the vineyard monitoring while his focus is on the balloon.

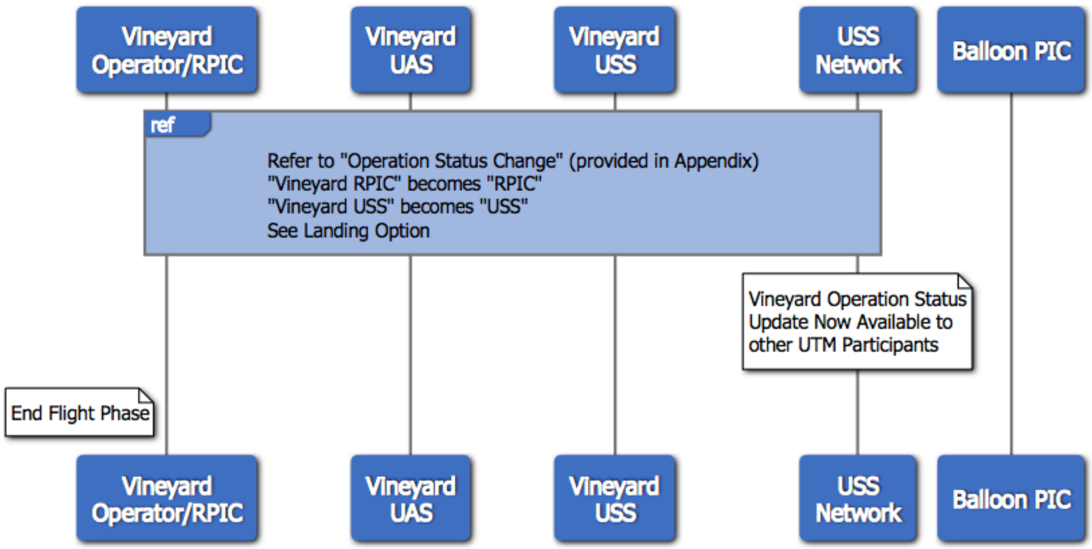
While flying around the balloon, the Vineyard RPIC uses his GCS tools to submit a UREP to the Vineyard USS, indicating the approximate location and altitude of the balloon. The Vineyard USS determines the information provided in the UREP is pertinent to UAS Operators in that area, and makes it available to the USS Network; any other UTM-participating UAS Operators in the area can see the balloon information. The UREP information will remain active across the USS Network until the end of the day.

The remainder of the UAS flight has no other incidents of note, and lands safely as planned. The Vineyard USS sets the Operation Status to “Closed” and makes the update available to the USS Network.

## Operational View - Scenario 1



**Operational View – Scenario 1, continued…**




## Scenario 2: Manned Fixed-Wing

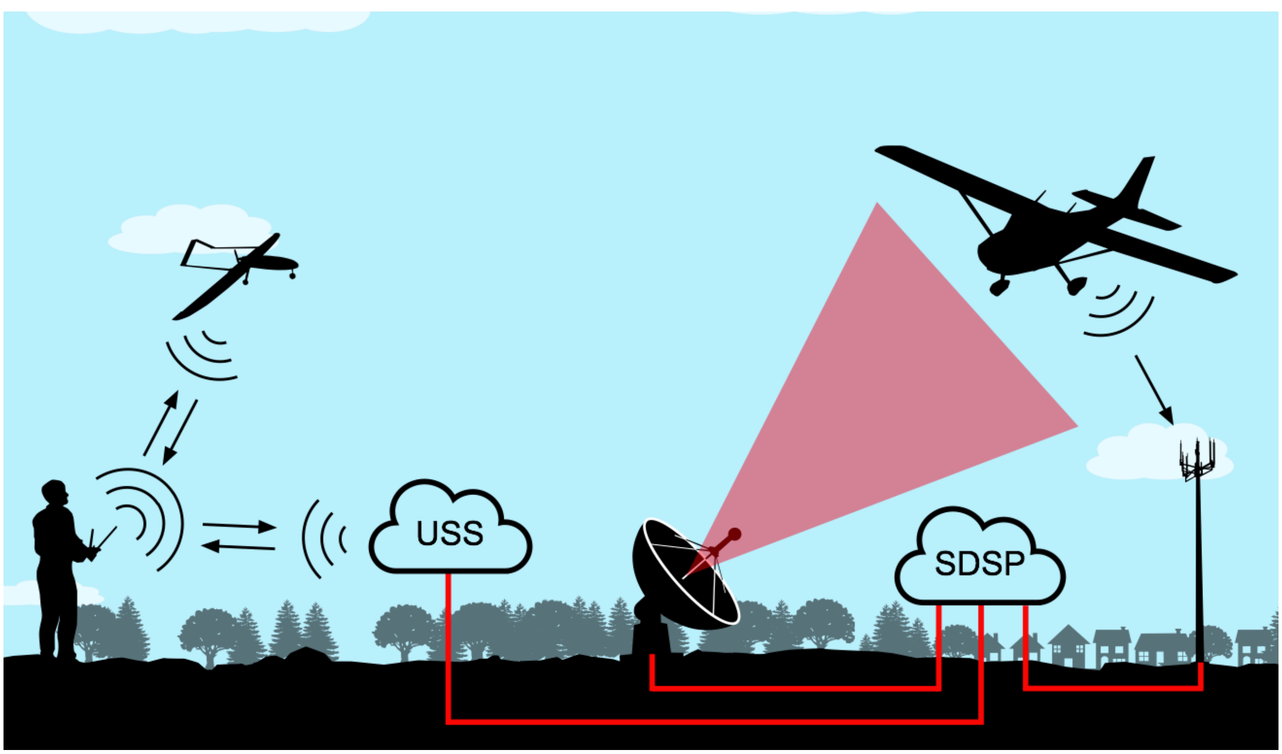



**Figure 11. Scenario 2**

## Narrative - Scenario 2

A ranch owner, acting as the Survey Operator/RPIC, uses his UAS to conduct a BVLOS survey of bison that are being re-introduced into the wild near his land in rural Oklahoma. He knows that manned aircraft often conduct low-altitude operations such that he might encounter them below 400 ft. AGL. The Operator subscribes to the Survey USS; this USS uses the services of a local SDSP to get information on non-UTM aircraft through ground-based aircraft detection. This information is used by the USS to support the Operator in maintaining separation from manned aircraft.

The Operation Intent for the survey operation is developed and shared with USS Network by the Survey Operator the morning of the flight, using the services provided by the Survey USS; any other UTM-participating aircraft have the ability to identify details of the survey operation (including Operation Volumes, times, etc.).

The Sightseeing PIC has subscribed to the services of a SDSP; the SDSP is connected to the USS Network. Using the USS services on a cellular-connected tablet, the PIC can see (while planning a flight or in the air) any nearby UAS Operation Volumes that are active or planned in the near future. He is able to identify the survey operation along his flight path and knows he will need to keep a look out for the UAS while flying through the volume.

In the early afternoon, the Survey RPIC sets up the GCS and also inspects the airspace near him. He sees no other UAS or aircraft nearby; the Sightseeing PIC has not yet taken off. The Survey RPIC sends a take-off notice to the Survey USS, who updates his Operation Status to “Activated” and makes this update available to the USS Network. The Survey RPIC launches his UAS at this time and begins flying.

While in flight, any Operation Volumes are considered active/occupied and inactive/unoccupied in accordance with the schedule in the Operation Intent. The UAS flies along the commanded/programmed route, and the RPIC takes video and photos of the bison as the UAS flies along its course. While the UAS is in flight, the Sightseeing PIC takes off and begins flying. As he approaches the Operation Volume boundary of the survey, he scans the sky for signs of the UAS; if he cannot spot it he intends to increase altitude from 400 ft. AGL to 600 ft. AGL.

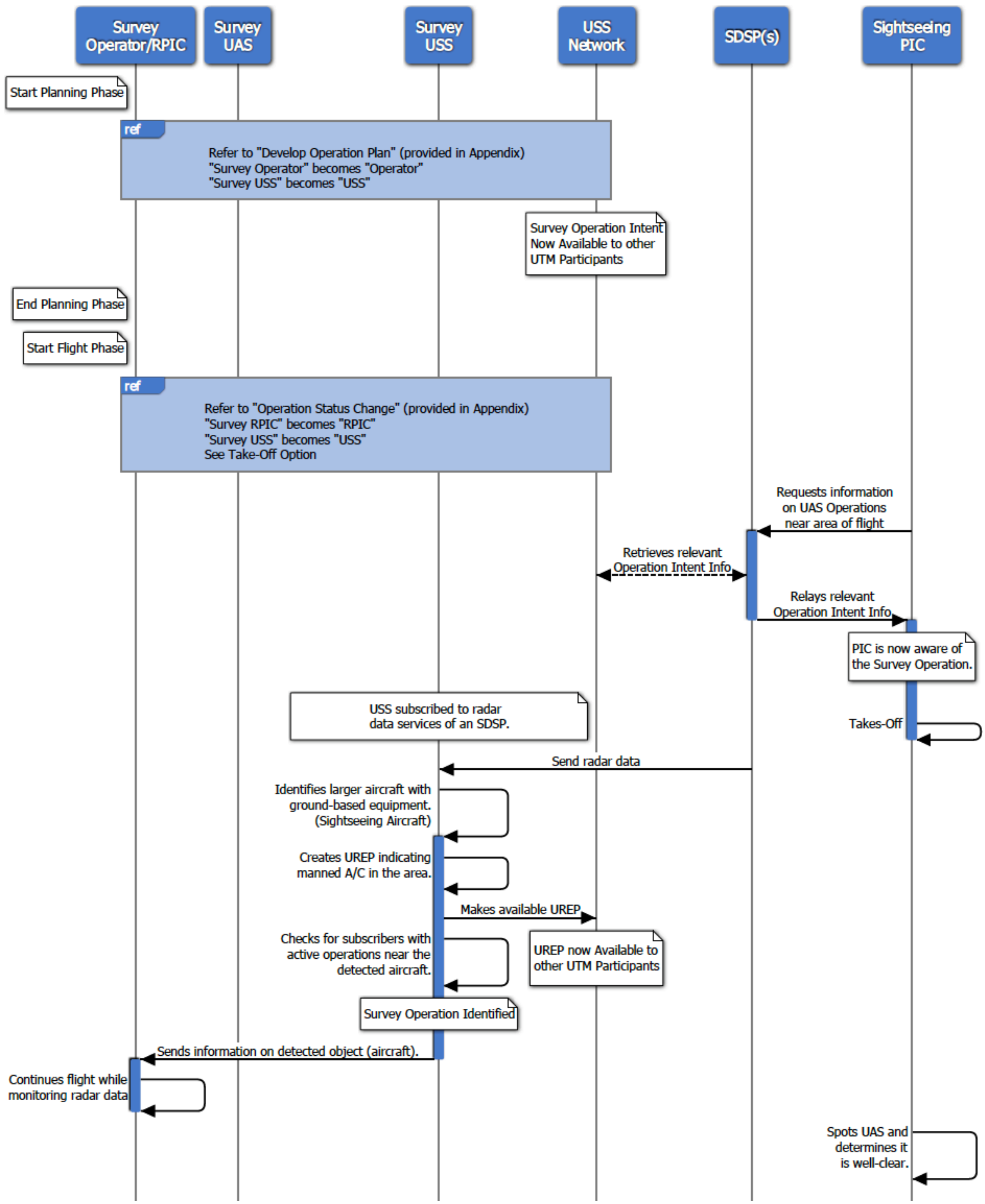
While the Sightseeing Aircraft is in flight, an SDSP supplying ground-based sensing equipment data (radar, in this case) to the Survey USS detects the aircraft as an object of significant size in the air at approximately 400 ft. AGL. The Survey USS searches for subscribing operators nearby that are in active flight and the survey operation is identified. The USS transmits tracking information on the detected object to the Survey RPIC, which is indicating a larger aircraft approaching the boundary of his Operation Volume. The Survey RPIC receives the information on his GCS and uses it to maintain separation from the detected object while continuing his operation.

Additionally, the Survey USS files a UREP and makes it available to the USS Network. Once the manned aircraft is no longer detected within the USS’s sensing range, the UREP is be updated and shared to indicate the aircraft is no longer in the indicated area.

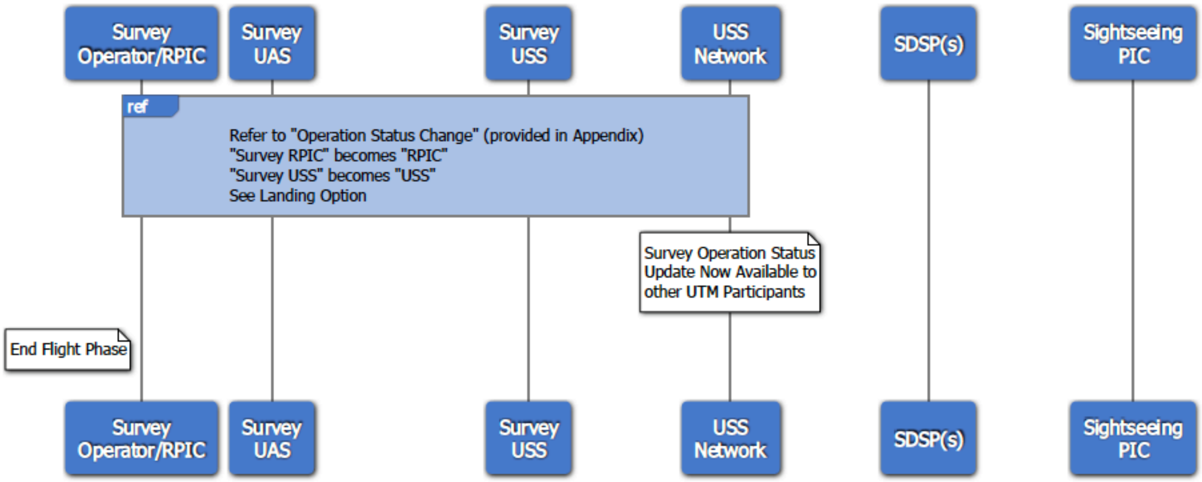
The Sightseeing PIC spots the survey UAS a distance away, and determines it is not a risk. The PIC continues with his current altitude and course.

The remainder of the UAS flight has no other incidents of note, and lands safely as planned.  The Survey USS sets the Operation Status to "Closed" and makes the update available to the USS Network.

## Operational View - Scenario 2



**Operational View – Scenario 2, continued…**




## Scenario 3: UAS and Manned Rotor Aircraft

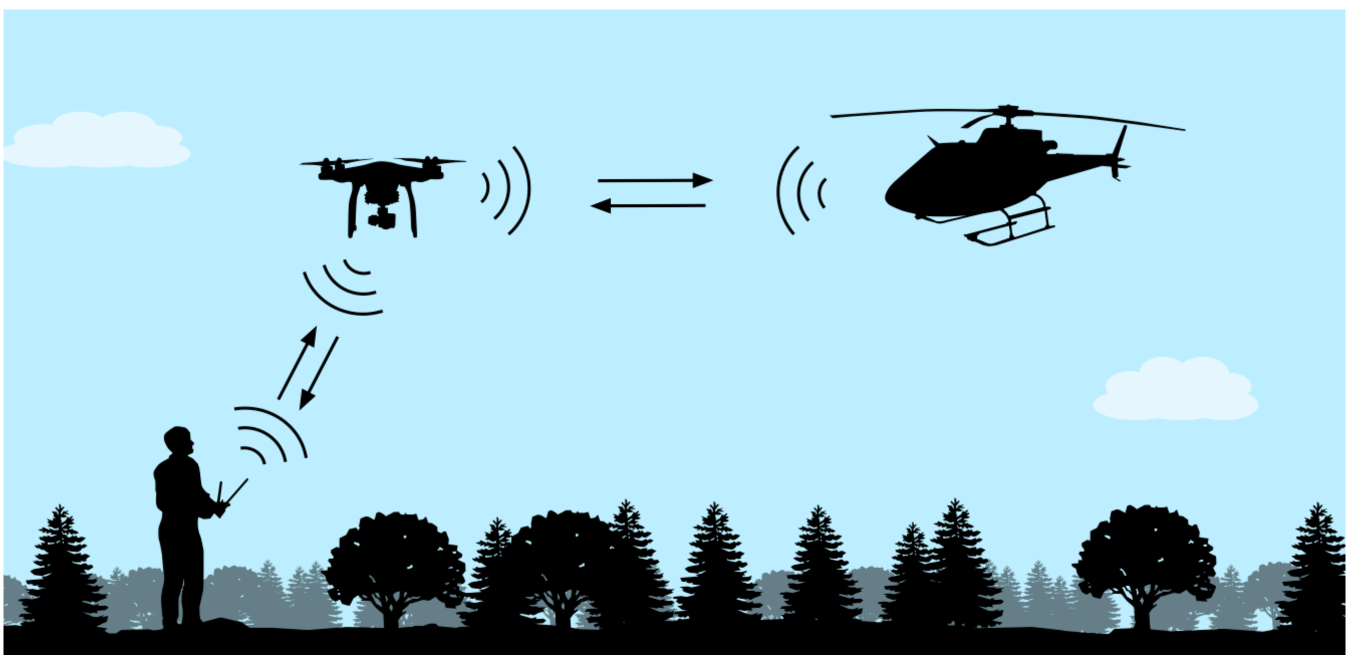


**Figure 12. Scenario 3**

## Narrative - Scenario 3

A Hollywood film studio is making a documentary about the changes to the Colorado River that have taken place over the last 50 years. The 1,800 miles of shoreline lend itself well to air videography, and the studio operates a UAS over long distances (BVLOS) to lower the cost of filming (some shots are only available using a small UAS with a mounted camera). A helicopter has also been chartered by the film studio to transport staff of the studio from McCarran Airport to the on-set location (in a remote area 35 miles east of Las Vegas near Lake Mead); these flights occur frequently, and as there are other aircraft operating at low altitudes in the area (primarily for sightseeing) the UAS has been outfitted with on-board sensors and communication equipment that is cooperative with appropriately-equipped manned aircraft (e.g, ADS-B IN/OUT, V2V technology such as DSRC, etc.). The charter helicopter also has cooperative equipment.

**NOTE:** It is not known if small UAS will actually utilize ADS-B OUT as it is currently implemented for larger aircraft. It is possible that the protocol could be used on frequencies not currently used by larger aircraft, such that traditional aircraft operation coordination and management is not affected.

It is noted that the Film Studio has an agreement with the Charter Company such that the helicopter PICs will give right of way over to the film UAS if and when the two aircraft encounter one another in flight.

The Operation Intent for the film operation is developed and shared with USS Network by the Film Operator the morning of the flight, using the services provided by the Film USS; any other UTM-participating aircraft have the ability to identify details of the survey operation (including Operation Volumes, times, etc.). The Charter PIC knows that the videography UAS performs flights in the area and uses cooperative communication technology to provide its flight information to nearby aircraft; the PIC does not use a USS or SDSP to get information from the USS Network, and therefore does not know about specific filming operation times or locations planned by the Film Operator.

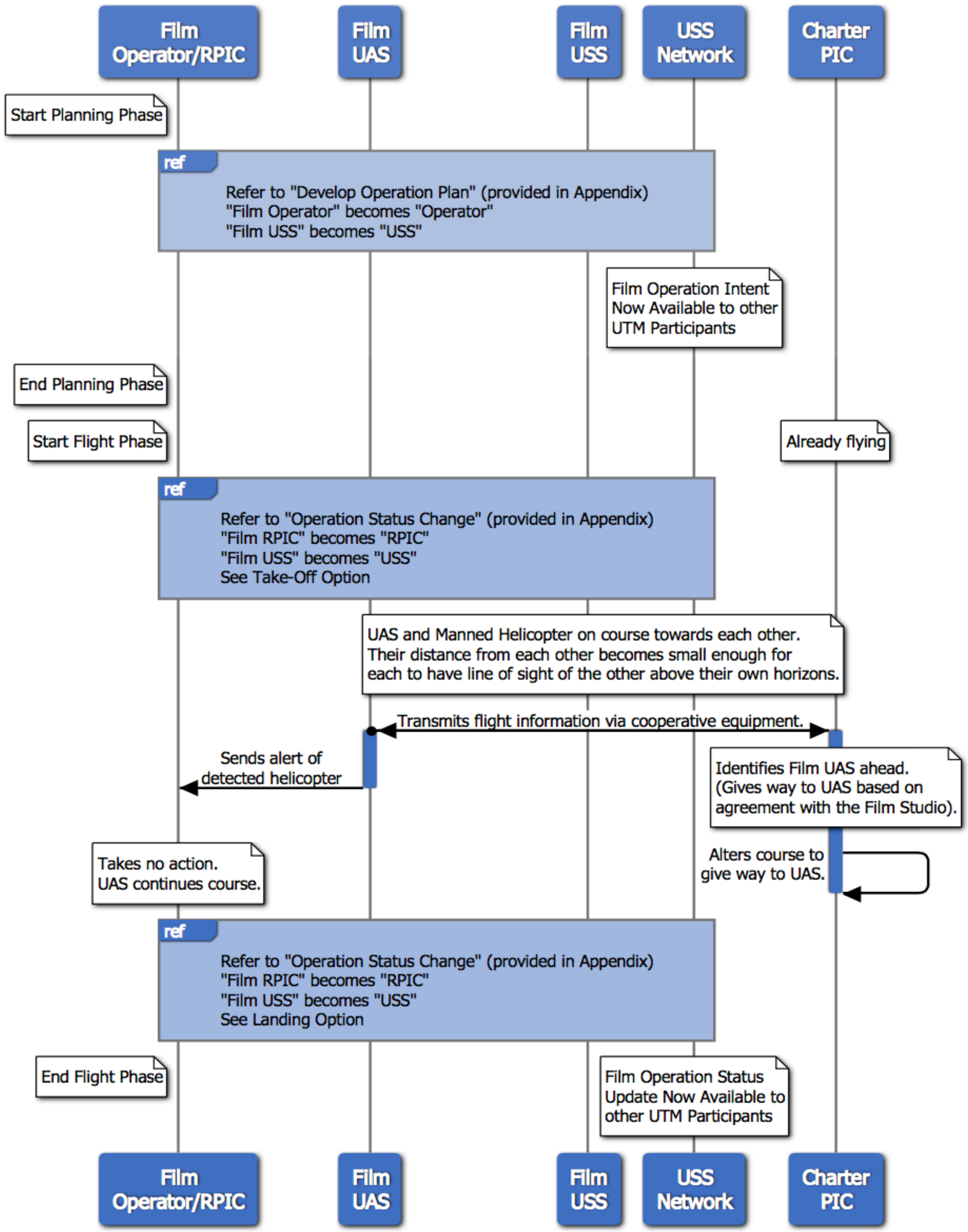
In the early afternoon, the Film RPIC sets up the GCS and also inspects the airspace near him. He sees no other UAS or aircraft nearby; the Charter PIC is currently near McCarran airport, too far away to see. The Film RPIC sends a take-off notice to the Film USS, who updates his Operation Status to “Activated” and makes this update available to the USS Network. The Film RPIC launches his UAS at this time and begins flying.

While in flight, any Operation Volumes are considered active/occupied and inactive/unoccupied in accordance with the schedule in the Operation Intent. The UAS flies along the commanded/programmed route, collecting video of the river as the UAS flies along. While the UAS is in flight, the Charter PIC begins heading to a drop-off location for ferried Film Studio personnel.

While in flight, the Charter PIC detours and flies eastward along the river at 350 ft. AGL, giving the passengers a scenic view of the area. The UAS is on a programmed route, flying westward along the river at 300 ft. AGL. As both aircraft come over the horizon of the other, communication signals begin to be picked up by each aircraft. The Film RPIC receives an alert on his GCS, showing the charter helicopter approximately 20 miles away, while the Charter PIC gets similar information about the UAS on his avionics display; the RPIC and PIC get the call signs of each aircraft through the transmitted information. Each pilot begins to pay attention to the other's location and course. As noted previously, the Charter PIC has agreed to give way to the UAS when it is in the air so that videography work is not interrupted. As helicopter approaches to within 5 miles from the UAS, the Charter PIC diverts to the right, heading South, and makes his way to the landing location on an altered course that gives a wide berth to the UAS. The Film RPIC sees the change in course of the helicopter, and takes no action, since the aircraft are no longer headed toward each other.

The remainder of the UAS flight has no other incidents of note, and lands safely as planned. The Film USS sets the Operation Status to "Closed" and makes the update available to the USS Network.

## Operational View - Scenario 3



### 4.2.8 Roles and Responsibilities Table

| Service/Function | | Actors: X=direct responsibility \| S=support role — RPICs | Operator | USS | FAA | Explanatory Notes |
|---|---|---|---|---|---|---|
| Separation | VLOS UAS from VLOS UAS | | | | | Not Explored in Use Case |
| | VLOS UAS from BVLOS UAS | | | | | Not Explored in Use Case |
| | BVLOS UAS from BVLOS UAS | | | | | Not Explored in Use Case |
| | VLOS UAS from Low-Altitude Manned A/C | | | | | Not Explored in Use Case |
| | BVLOS UAS from Low-Altitude Manned A/C | S | X | S | | Responsibilities per noted assumptions in use case. Manned aircraft share separation responsibilities with BVLOS. |
| Hazard/ Terrain Avoidance | Weather Avoidance | | | | | Not Explored in Use Case |
| | Terrain Avoidance | | | | | Not Explored in Use Case |
| | Obstacle Avoidance | S | X | S | | |
| Status | UTM Operations Status | | | X | | |
| | Flight Information Archive | | | | | Not Explored in Use Case |
| | Flight Information Status | | | X | | |
| Advisories | Weather Information | | | X | | Not Explored in Use Case |
| | Hazard Information (Obstacles, terrain, etc) | | | X | | |
| | Alert Affected Airspace Users of UAS Hazard | | | | | Not Explored in Use Case |
| | UAS-Specific Hazard Information (Power-Lines, No-UAS Zones, etc) | | | X | | |

| Service/Function | | Actors | | | | Explanatory Notes |
|---|---|---|---|---|---|---|
| | | X=direct responsibility \| S=support role | | | | |
| | | RPICs | Operator | USS | FAA | |
| Planning, Intent and Authorization | Priority Status Notification (emergency declaration, public safety, etc.) | | | | | Not Explored in Use Case |
| | Operation Plan Development | | | | | Not Explored in Use Case |
| | Operation Intent Sharing (pre-flight) | | X | S | | |
| | Operation Intent Sharing (in-flight) | S | X | S | | |
| | Dynamic Restriction Request | | | | | Not Explored in Use Case |
| | Operation Intent Negotiation | | | | | Not Explored in Use Case |
| Operations Management | Demand Capacity Management | | | | | Not Explored in Use Case |
| | Airspace Access Management | | | | | Not Explored in Use Case |
| | Control of Flight | X | | | | |
| | Airspace Allocation & Constraints Definition | | | | | Not Explored in Use Case |

## 4.2.9 Use Case TCL3-4: BVLOS Operation Lost-Link Event

### Overview

#### BVLOS Land Survey Lost-Link near Non-Towered Airport and another BVLOS Operation

A commercial UAS Operator regularly conducts rural land surveys for farm owners, land development companies, etc. across Eastern Maryland. The UAS Operator has a cluster of surveys to perform near Ocean City, MD, and has chosen to use a series of segmented ABOVs with TBOVs to perform the surveys in a single BVLOS operation. Each ABOV encompasses an individual survey area, while the TBOVs act as transit corridors between the ABOVs (see Figure 13).

While the survey UAS is in flight, a hardware failure for the communications equipment results in a lost-link event, though GPS is still active. The UAS automatically enacts pre-programmed contingency procedures, based on the current state of the vehicle and operation. The Survey Operator no longer receives information from the UAS and is unable to send commands to it. The USS servicing the Survey RPIC detects the lost link through its connection to the RPIC's GCS, and begins alerting other airspace users of the situation, which includes a nearby BVLOS Golf Course Flyover and a non-towered airport. Affected entities take appropriate actions regarding the rogue survey UAS that now has unknown intent/trajectory.

The UAS, with GPS still active, loiters at a location pre-preprogrammed as part of its contingency procedures, and then eventually makes its way back to the take-off/landing location (another pre-programmed procedure). When the UAS lands and is recovered by the Survey RPIC, he alerts his USS, who in turn let's affected airspace users know that the UAS is no longer in the air. Affected entities resume their normal operations.


**Figure 13. Survey Operation Overview**

# Summary Table

**Table 10. Summary - Use Case TCL 3-4**

| Operation | Authorization | Operational Description | Environmental Description |
|---|---|---|---|
| Land Survey | See Notes Below[1,2] | BVLOS<br>Multiple, Segmented Operation Volumes (ABOVs and TBOVs)<br>Below 400 ft. AGL<br>Position Reporting | Class G, non-towered airport nearby<br>Operations Over People |
| Golf Course | See Notes Below[1,2] | BVLOS<br>Single Operation Volume (ABOV)<br>Below 200 ft. AGL<br>Position Reporting | Class G, non-towered airport nearby<br>Not Operating Over People |

1. Performance Authorization approval was obtained by these Operators from the FAA prior to the events of the narrative below; these processes are not discussed in this use case.
2. Operation Plan/Intent development by these Operators with their respective USS occurs prior to the events of interest in the narrative below; these processes are not examined in detail below.

# Equipment

The Survey is being performed using a fixed-wing unmanned aircraft, and the golf course flyover is being performed using an unmanned quadcopter. Both UASs have position reporting capabilities; Lat-Long GPS location and altitudes are reported to the GCS at a rate sufficient to indicate the "real-time" position of the UAS. The survey UAS also has a long range battery capable of supporting flights in excess of 25 miles at cruising power.

Each UAS vehicle has capabilities to monitor for on-board equipment issues, such as lost link, motor failure, unexpected battery depletion, etc. Additionally, they each have the capability to act in accordance with pre-programmed contingency procedures in the event an equipment issue occurs. Standard procedures are programmed, and can also be modified (or new procedures added) by the Operator and/or RPIC pre-flight and in-flight.

Internet connectivity with the USS supporting the survey operation is achieved via a mobile hotspot, while the USS supporting the golf course is connected to using the Wi-Fi network for the golf course.

# Actor Details

## Operators and RPICs

For the land survey, the roles of Operator and RPIC are held by the same person: the owner of the company providing the UAS services to local customers.

For the golf course flyover, the Operator and RPIC are held by separate entities/persons. The Operator role is held by the golf course management personnel, while the role of RPIC is held by an employee with the appropriate pilot certification for the type of operation being performed.

Both Operators have been granted a Performance Authorization that encompasses the area in which their respective operations occur. Authorized operation types for the survey flight include BVLOS flight and operations over people; types for the golf course flyover include BVLOS flight.

Those persons acting as RPIC have all required pilot certifications necessary for the type of operation.

### USS

Each Operator uses a different USS: the Survey Operator uses USS ABC, while the Flyover Operator uses USS 123. Information shared across the larger USS network provides UTM participants situational awareness of planned/current operations in an area.

Operators and RPICs share their Operation Intent with their respective USSs, who then make available the intent information to the larger USS Network. USSs also share relevant data in off-nominal situations beyond that of the Operation Intent to maintain a safe operating environment.

### FAA

The FAA interacts with UTM as follows:

- The FAA has previously provided each Operator with the approval of a Performance Authorization, each of which includes the geographical area over which the Operation Volumes indicated in Figure 13 lie.
- The FAA receives alerts from UTM participants regarding issues that may affect manned traffic operating in non-UTM airspace.
- The FAA has the ability to access any information related to UTM operations as required.

## UTM Interaction

### UTM Participation

All of the Operators identified in the narrative below are required to participate in UTM, given that some or all of their Operation Intent includes BVLOS flight. Manned aircraft do not participate in UTM.

## Shared Information Across Actors

**Table 11. Shared Information - Use Case TCL 3-4**

| Type of Information | Actor Providing Information | Actors with Access to Information | Applicable to this Use Case? |
|---|---|---|---|
| Operation Plan Parameters/Inputs | Operator | USS | Yes |
| Operation Plan | USS | Operator | Yes |
| Operation Intent, pre-flight (and other shared data) | USS | USS Network | Yes |
| Operation Data Relevant to Regulator Information Requirements | USS | FAA | Yes |
| In-Flight Modification to Intent | RPIC | USS, USS Network | No |
| Externally-originated data (surveillance, NOTAM, Wx, etc) | USS or SDSP | Operator or RPIC | Yes |
| Operationally-derived environmental data | RPIC, USS or SDSP | USS | Yes |
| Relevant Flight Data (e.g., position data) | RPIC and/or Operator | USS | Yes |
| | USS | USS Network<br>FAA (if applicable) | Yes |
| Operation Intent, in-flight (and other shared data) | USS | USS Network | Yes |
| Operation Status | USS | USS Network | Yes |
| Spectrum Management | USS | USS Network, RPIC and Operator | No |
| Dynamic Restriction Request | Operator/USS | FAA | No |
| Dynamic Restriction Approval | FAA | Operator/USS | No |
| Dynamic Restriction Distribution | FAA | USS Network and other NAS users | No |
| Negotiation Request | USS ABC | USS XYZ | No |
| Negotiation Response | USS XYZ | USS ABC | No |
| UREP | RPIC | USS | No |
| | USS | USS Network | No |
| UAS Flight Information | UAS | RPIC<br>Manned Aircraft | No |
| Manned Aircraft Flight Information | Manned Aircraft | UAS | No |
| Manned Aircraft Information | USS/SDSP | Operator/RPIC | No |

# Narratives and Operational Views

**NOTE:** It is understood that many of the functions, communications and decision-making occurring in the narrative below are likely to be automated by the USSs and FAA. Explicit callout to automation is avoided to allow focus on the information exchange and flow of operations.

## Planning, Take-Off and Initial Flight

The Operation Intent for the golf course flyover operation is developed and made available to the USS Network by the Flyover Operator the night before the flight, using the services provided by USS 123; any other UTM-participants have the ability to identify details of the flyover operation (including Operation Volumes, times, etc.). The planned flight is from 8:00 AM to 9:15 AM.

At 7:00 AM on the morning of the flyover and survey operations, the Survey Operator develops his Operation Intent and shares it with the USS Network, using the services provided by USS ABC. During planning, he is able to see the flyover Operation Volume, and plans around it to avoid operating in the same airspace (Figure 13). The planned flight is from 8:15 AM to 9:45 AM. Included in the Operation Intent is an indication of the on-board contingency procedures programmed into the UAS; these are automated procedures that the UAS follows in the event the RPIC does not provide additional commands, or the UAS cannot receive RPIC commands, during an unexpected event.

At 8:00 AM, the Flyover RPIC sets up his GCS and UAS, determines the airspace above him is clear for take-off, and sends take-off notification to USS 123. USS 123 updates the Operator Status to "Activated" and makes the update available to the USS Network. The Flyover RPIC takes off and begins his flyover inspection of the golf course, landing and swapping batteries as required (a battery swap does not constitute a need for change to the Operation Intent, since the volume extends to the ground[4]). USS 123 receives "real-time" UAS location information from the Flyover RPIC's GCS, and monitors the conformance of the UAS to the Operation Intent.

At 8:15 AM, the Survey RPIC arrives at his take-off location within Segment 1 (ABOV). He sets up his GCS and UAS in preparation for flight; part of his preparation is programming the UAS with various loiter and alternate landing locations that are used as part of its pre-programmed contingency procedures (see Figure 13). The Survey RPIC determines the airspace above him is clear for take-off (he can see the active Operation Volume for the flyover operation to the South on his equipment), and sends a take-off notice to USS ABC; USS ABC updates the Operator Status to "Activated", and makes the update available to the USS Network. The Survey RPIC launches the UAS and begins the survey flight. USS ABC receives "real-

[4] A power cycle on a UAS will likely require some method of handling the interruption to any position reporting that the Operator sends from the UAS to the USS for conformance monitoring. Previous in-field testing by industry partners of the RTT has shown that a pause feature on the RPIC's GCS worked well to mitigate this issue; pausing the GCS would continue to provide the same position to the USS while the power cycle of the UAS is in process.

time" UAS location information from the Survey RPIC's GCS and monitors the conformance of the UAS to the Operation Intent.

At this point, both the Survey and Flyover RPICs can see each other's active Operation Volumes on their equipment displays.

The Survey UAS follows a pre-programmed flight path, taking videos and photos of the areas of interest. Each Operation Volume is on a schedule such that a maximum of two are in an active state at any time, allowing efficient use of the airspace so other operations can occur with minimal potential for overlap with the survey operation (for a visual example of this scheduling approach, see Use Case TCL3-1).

## Lost-Link Event

At 9:03 AM, the survey UAS is in Segment 5, and experiences a hardware failure that results in the loss of its C2 link, though GPS and other systems are still operable. Sensing the loss of C2 link, the UAS initiates a programmed contingency procedure and immediately flies to its loiter location in Segment 5 and waits for the link to re-establish. The Survey RPIC attempts to troubleshoot on his end, not knowing the link loss is due to a UAS hardware failure and is unsuccessful in re-establishing the link. The UAS waits at the loiter location until 9:08 AM and then enacts the second step of its programmed contingency procedure, starting an automated return to base (staying within the bounds of the Operation Volumes).

Also at 9:08 AM, USS ABC determines that the UAS has been out of contact too long, is in an unknown condition/has unknown intent, and may now be a hazard to nearby airspace users. USS ABC changes the survey Operation Status to "Rogue" and makes available the update to the USS Network; the last known position is also provided in the update Operation Intent.

Additionally, USS ABC determines the proximity of the last-known position of the now-Rogue UAS to nearby OXB airport (non-towered) could affect manned traffic. At 9:09 AM, USS ABC sends a notification to the FAA through FIMS, alerting them of the situation and providing the Operation Intent (including the last known position of the UAS); any changes of information are sent to the FAA by USS ABC as they become available.

Finally, USS ABC identifies the OXB FBO and the local Parachuting Jump School from publicly-available information and sends automated email and/or phone messages to these entities, notifying them of the rogue UAS. These messages are sent by 9:10 AM.

> **NOTE:** The responsibility to determine the need for, and perform the action of, notification to affected airspace users of a rogue UAS with unknown intent is with the Operator; however, it has been delegated to USS ABC through a user-agreement signed by the Survey Operator when he subscribed to their services.

## Actions Regarding the Flyover Operation

By 9:09 AM, USS 123 receives information regarding the rogue survey operation, and identifies the flyover operation as potentially affected. It sends a notification to the Flyover RPIC, who acknowledges receipt of the message and reviews the information; available to him, as part of the shared Survey Operation Intent, are the contingency procedures programmed into the Survey UAS.

The Flyover UAS does not have on-board detection equipment that could identify the rogue UAS, and so the Flyover RPIC elects to land his UAS and end the operation early. He notifies USS 123 of the landing, who updates the Operation Status to "Closed" and makes available the update to the USS Network.

## Actions Regarding Manned Aircraft

The FAA receives the notification of the rogue UAS from USS ABC through FIMS. By 9:10 AM, the notification is forwarded to Patuxent TRACON, which services Approach Control to OXB Airport.

The weather conditions this morning are VFR, and no actual IMC operations are being conducted. Because of the proximity to OXB Airport and the Instrument Approach Procedures, the TRACON Supervisor decides to curtail all practice approaches to OXB and broadcast an advisory on the local sector frequencies. A call is also made to the servicing Flight Service Station; they issue a NOTAM for OXB. Because of the proximity to the National Capitol Region, the TRACON Supervisor alerts the Domestic Events Network to the presence of a Lost Link UAS with unknown position or intentions.

The OXB FBO and the Parachuting School provide necessary messaging to affected persons/entities under their management.

# Recovery

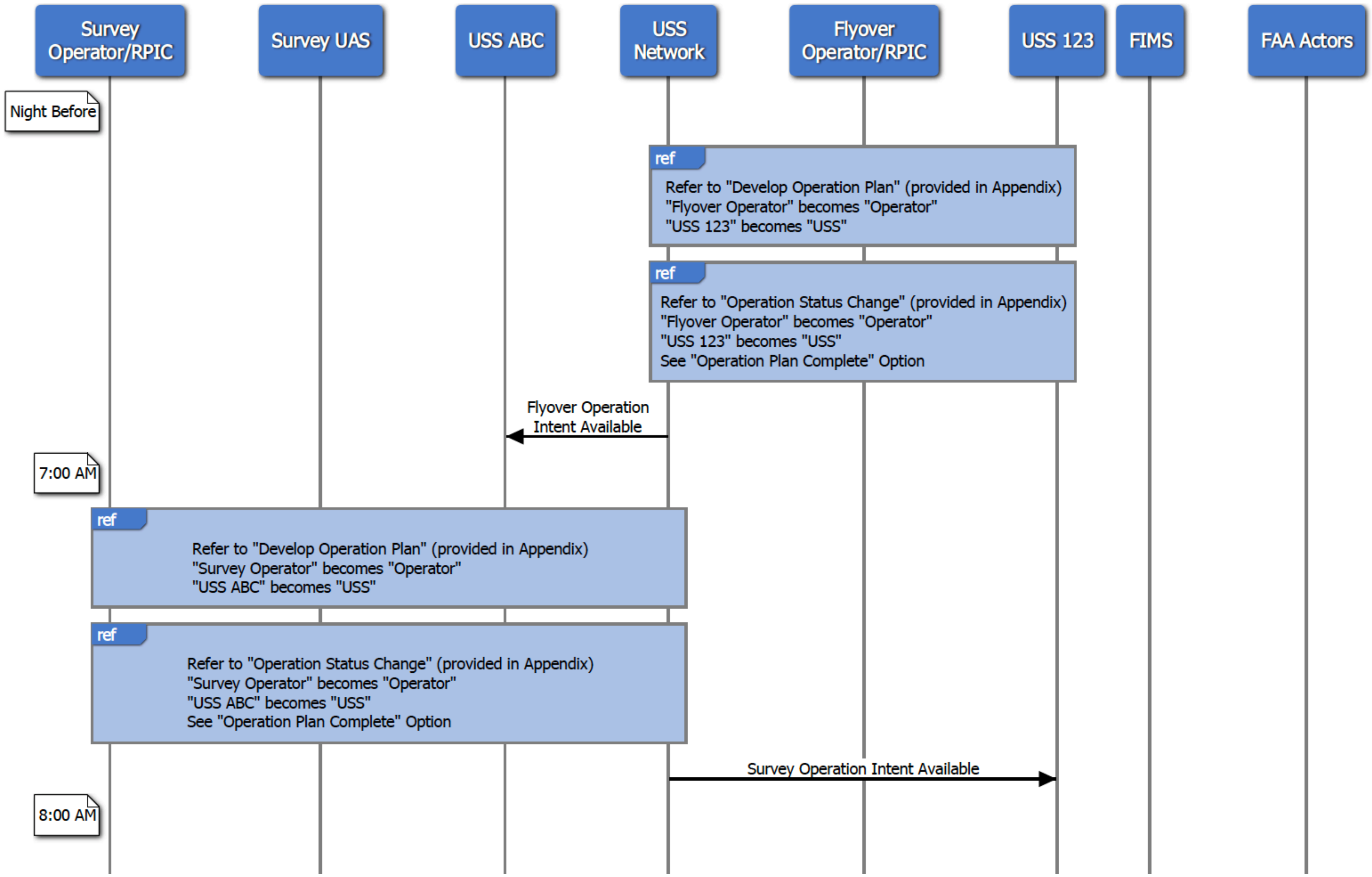
At 9:38 Am, the Survey UAS is spotted by the Survey RPIC as it re-enters Segment 1 and approaches for landing. As soon as it lands, the Survey RPIC messages USS ABC, alerting it of the UAS recovery. USS ABC immediately changes the Operation Status to "Closed", indicates a recovery of the UAS in the Operation Intent, and makes the updated Operation Intent information available to the USS Network.

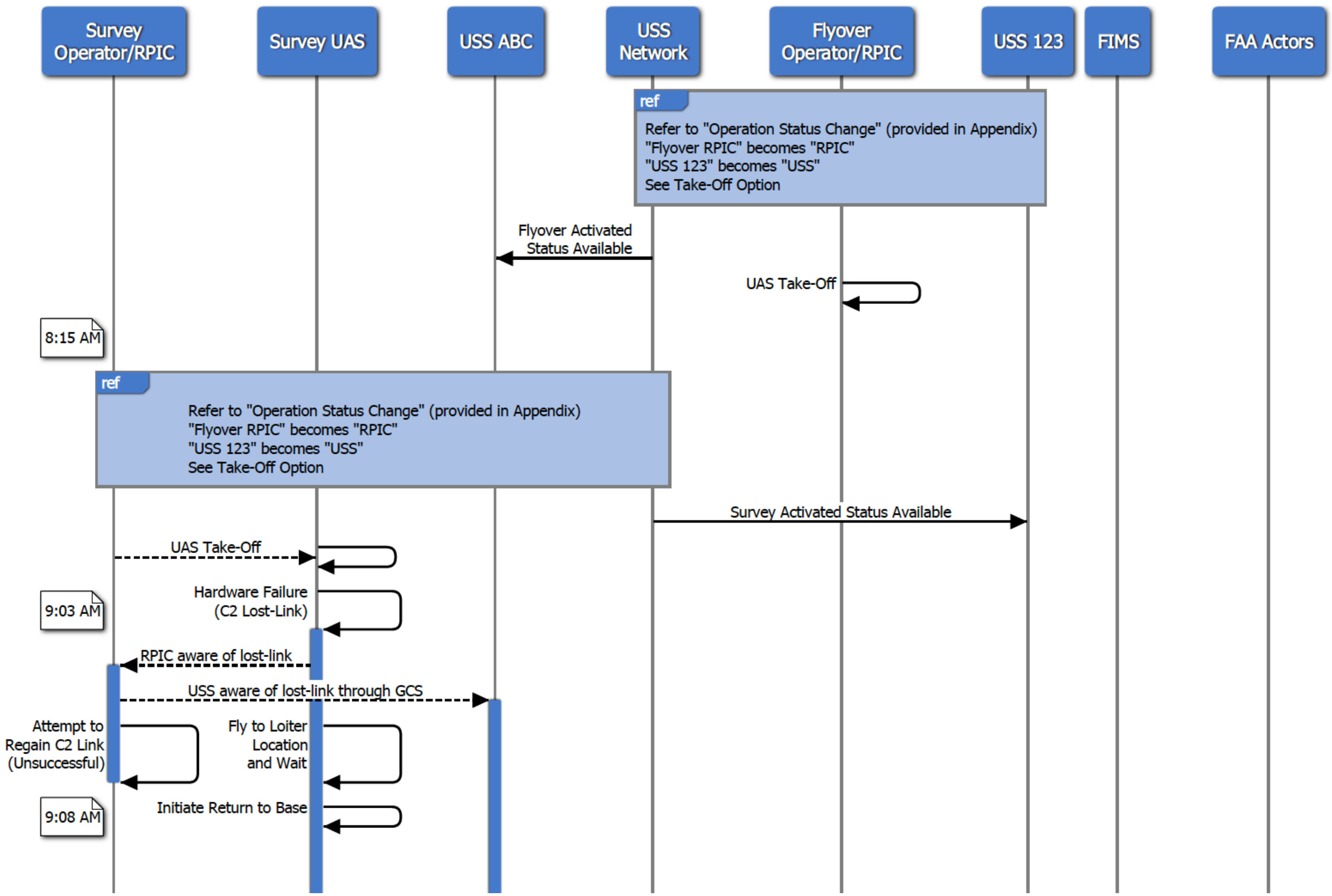
USS ABC also sends notice through FIMS to the FAA of the recovery. The FAA forwards the message to Patuxent TRACON; the TRACON Supervisor ends the advisory broadcast, notifies the Flight Service Station (who closes the NOTAM), and updates the Domestic Events Network that the UAS is no longer in the air. TRACON also completes a Mandatory Occurrence Report, pulling information from USS ABC, and the Survey Operator/RPIC as necessary (through the USS Network, email, phone, etc.).

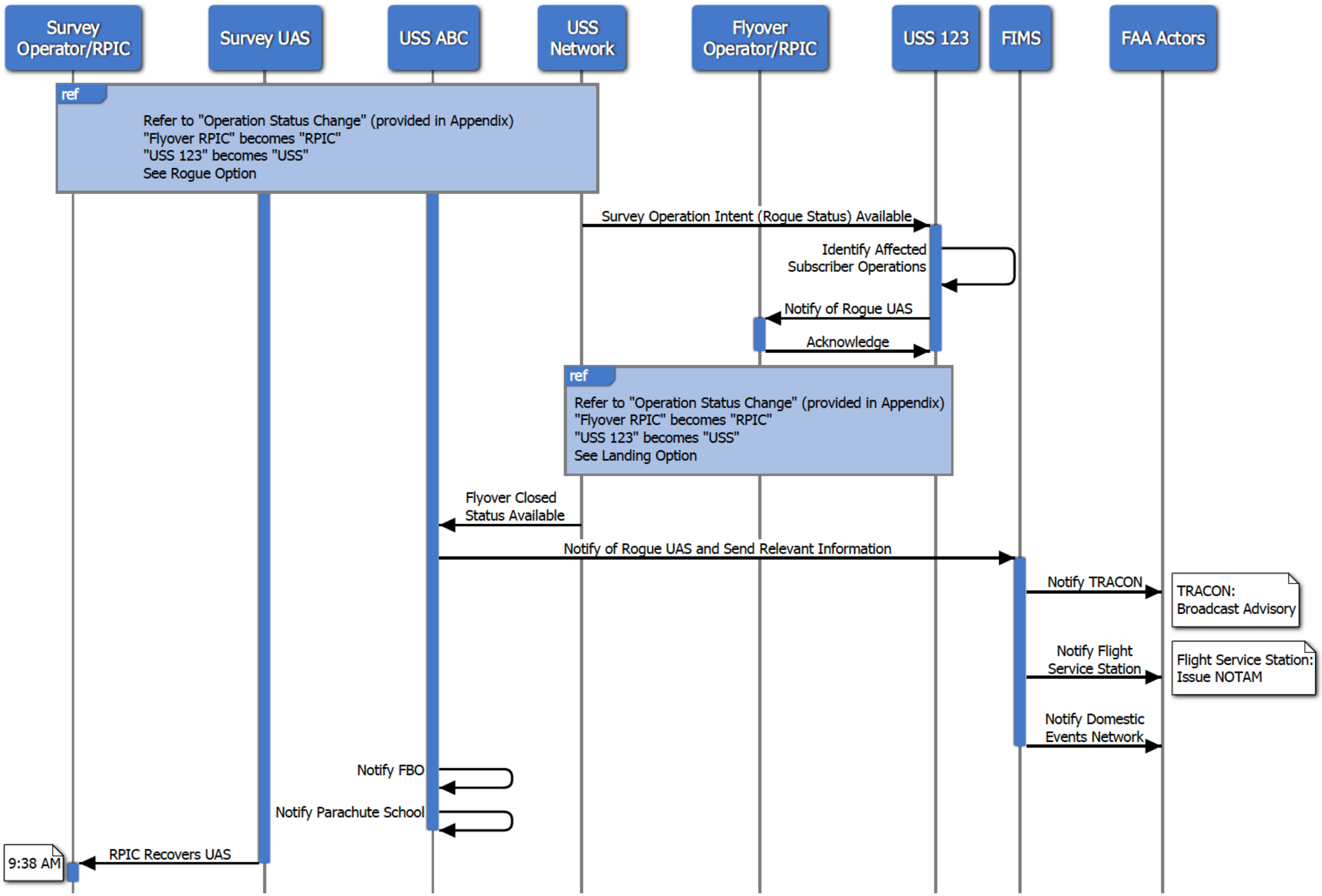
Finally, USS ABC sends automated emails and/or phone messages to the OXB FBO and Parachuting School, who each take appropriate action to update the affected persons/entities under their management.

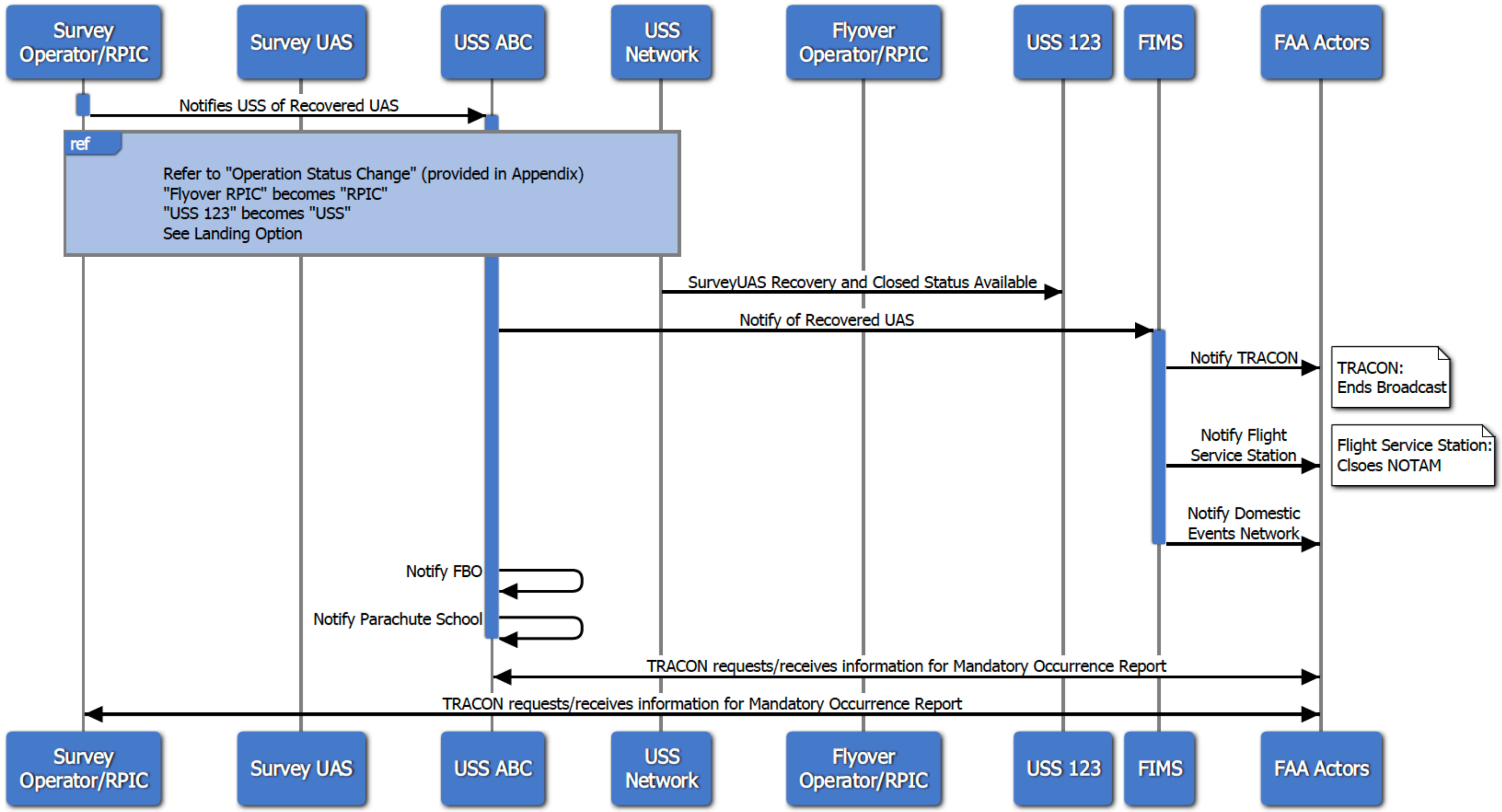
#### 4.2.10 Operational Views

The following pages provide operational views of the scenario narrative. Referenced diagrams for sub-activities can be found in the Appendix.


Survey Operator/RPIC
Survey UAS
USS ABC
USS Network
Flyover Operator/RPIC
USS 123
FIMS
FAA Actors
Night Before
ref
Refer to "Develop Operation Plan" (provided in Appendix)
"Flyover Operator" becomes "Operator"
"USS 123" becomes "USS"
ref
Refer to "Operation Status Change" (provided in Appendix)
"Flyover Operator" becomes "Operator"
"USS 123" becomes "USS"
See "Operation Plan Complete" Option
Flyover Operation Intent Available
7:00 AM
ref
Refer to "Develop Operation Plan" (provided in Appendix)
"Survey Operator" becomes "Operator"
"USS ABC" becomes "USS"
ref
Refer to "Operation Status Change" (provided in Appendix)
"Survey Operator" becomes "Operator"
"USS ABC" becomes "USS"
See "Operation Plan Complete" Option
Survey Operation Intent Available
8:00 AM


Survey Operator/RPIC
Survey UAS
USS ABC
USS Network
Flyover Operator/RPIC
USS 123
FIMS
FAA Actors
ref
Refer to "Operation Status Change" (provided in Appendix)
"Flyover RPIC" becomes "RPIC"
"USS 123" becomes "USS"
See Take-Off Option
Flyover Activated Status Available
UAS Take-Off
8:15 AM
ref
Refer to "Operation Status Change" (provided in Appendix)
"Flyover RPIC" becomes "RPIC"
"USS 123" becomes "USS"
See Take-Off Option
Survey Activated Status Available
UAS Take-Off
Hardware Failure (C2 Lost-Link)
9:03 AM
RPIC aware of lost-link
USS aware of lost-link through GCS
Attempt to Regain C2 Link (Unsuccessful)
Fly to Loiter Location and Wait
9:08 AM
Initiate Return to Base


Survey Operator/RPIC
Survey UAS
USS ABC
USS Network
Flyover Operator/RPIC
USS 123
FIMS
FAA Actors
ref
Refer to "Operation Status Change" (provided in Appendix)
"Flyover RPIC" becomes "RPIC"
"USS 123" becomes "USS"
See Rogue Option
Survey Operation Intent (Rogue Status) Available
Identify Affected Subscriber Operations
Notify of Rogue UAS
Acknowledge
ref
Refer to "Operation Status Change" (provided in Appendix)
"Flyover RPIC" becomes "RPIC"
"USS 123" becomes "USS"
See Landing Option
Flyover Closed Status Available
Notify of Rogue UAS and Send Relevant Information
Notify TRACON
TRACON: Broadcast Advisory
Notify Flight Service Station
Flight Service Station: Issue NOTAM
Notify Domestic Events Network
Notify FBO
Notify Parachute School
9:38 AM
RPIC Recovers UAS


Survey Operator/RPIC
Survey UAS
USS ABC
USS Network
Flyover Operator/RPIC
USS 123
FIMS
FAA Actors
Notifies USS of Recovered UAS
ref
Refer to "Operation Status Change" (provided in Appendix)
"Flyover RPIC" becomes "RPIC"
"USS 123" becomes "USS"
See Landing Option
SurveyUAS Recovery and Closed Status Available
Notify of Recovered UAS
Notify TRACON
TRACON: Ends Broadcast
Notify Flight Service Station
Flight Service Station: Clsoes NOTAM
Notify Domestic Events Network
Notify FBO
Notify Parachute School
TRACON requests/receives information for Mandatory Occurrence Report
TRACON requests/receives information for Mandatory Occurrence Report

### 4.2.11 Roles and Responsibilities Table

| Service/Function | | Actors<br>X=direct responsibility \| S=support role<br>RPICs | Operator | USS | FAA | Explanatory Notes |
|---|---|---|---|---|---|---|
| Separation | VLOS UAS from VLOS UAS | | | | | Not Explored in Use Case |
| | VLOS UAS from BVLOS UAS | | | | | Not Explored in Use Case |
| | BVLOS UAS from BVLOS UAS | S | X | S | | Delegated to RPIC. |
| | VLOS UAS from Low-Altitude Manned A/C | | | | | Not Explored in Use Case |
| | BVLOS UAS from Low-Altitude Manned A/C | S | X | S | | Responsibilities per noted assumptions in use case. UAS Operator delegates to RPIC. |
| Hazard/ Terrain Avoidance | Weather Avoidance | | | | | Not Explored in Use Case |
| | Terrain Avoidance | | | | | Not Explored in Use Case |
| | Obstacle Avoidance | | | | | |
| Status | UTM Operations Status | | | X | | |
| | Flight Information Archive | | | | | Not Explored in Use Case |
| | Flight Information Status | | | X | | |
| Advisories | Weather Information | | | | | Not Explored in Use Case |
| | Hazard Information (Obstacles, terrain, etc) | | | | | Not Explored in Use Case |
| | Alert Affected Airspace Users of UAS Hazard | | X | S | | Delegated to USS. |
| | UAS-Specific Hazard Information (Power-Lines, No-UAS Zones, etc) | | | | | Not Explored in Use Case |

| Service/Function | | Actors | | | | Explanatory Notes |
|---|---|---|---|---|---|---|
| | | X=direct responsibility \| S=support role | | | | |
| | | RPICs | Operator | USS | FAA | |
| Planning, Intent and Authorization | Priority Status Notification (emergency declaration, public safety, etc.) | | | | | Not Explored in Use Case |
| | Operation Plan Development | | X | S | | |
| | Operation Intent Sharing (pre-flight) | | X | S | | |
| | Operation Intent Sharing (in-flight) | S | X | S | | |
| | Dynamic Restriction Request | | | | | Not Explored in Use Case |
| | Operation Intent Negotiation | | | | | Not Explored in Use Case |
| Operations Management | Demand Capacity Management | | | | | Not Explored in Use Case |
| | Airspace Access Management | | | | | Not Explored in Use Case |
| | Control of Flight | X | | | | |
| | Airspace Allocation & Constraints Definition | | | | | Not Explored in Use Case |

# Acronyms

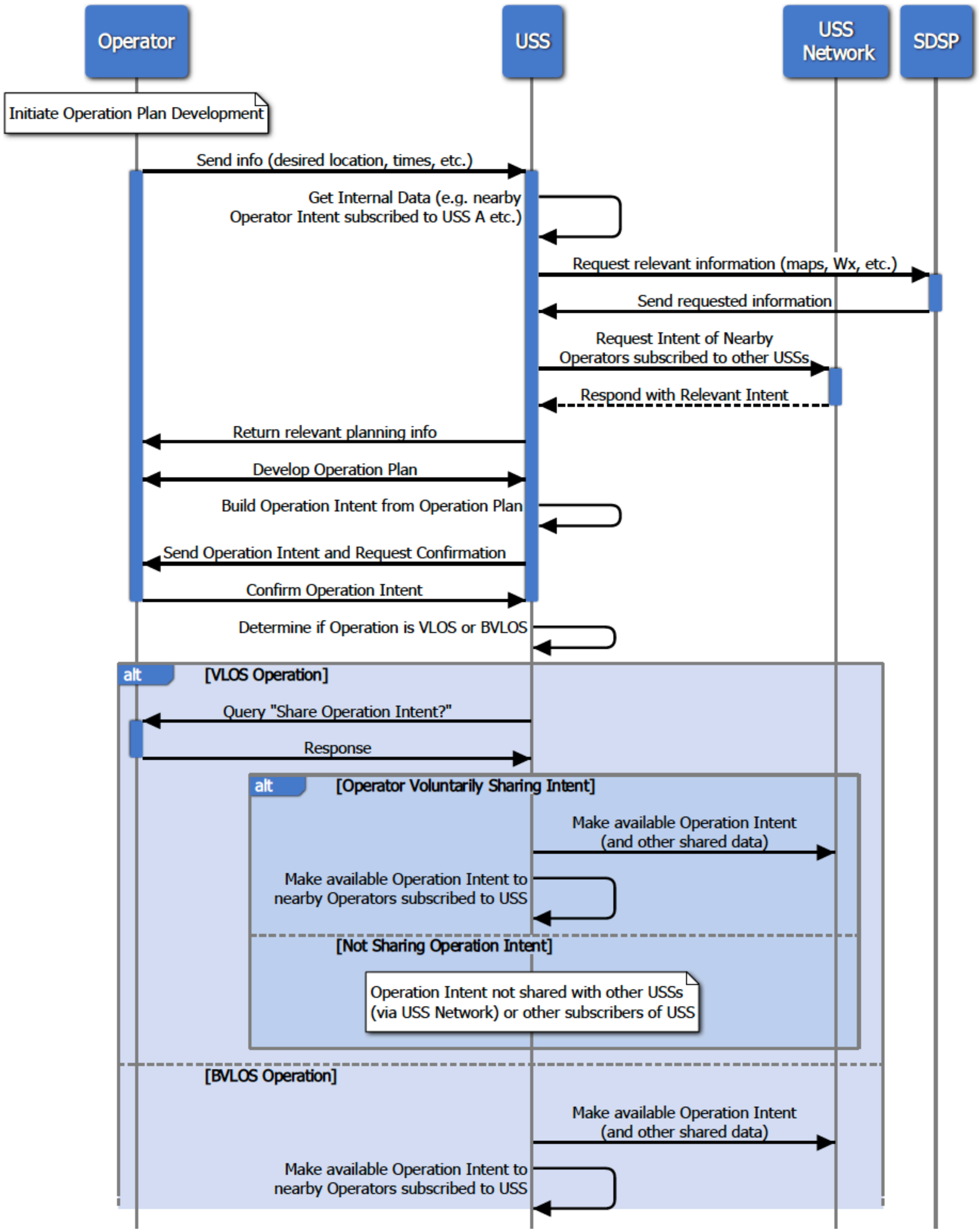
| Term | Definition |
|---|---|
| ABOV | Area Based Operation Volume |
| AGL | Above Ground Level |
| ANSP | Air Navigation Service Provider |
| API | Application Programming Interface |
| ATC | Air Traffic Control |
| ATM | Air Traffic Management |
| BVLOS | Beyond Visual Line-of-Sight |
| C2 Link | Command and Communications Link |
| CFR | Code of Federal Regulations |
| CWG | Concepts & Use Cases Working Group |
| DR | Dynamic Restriction |
| FAA | Federal Aviation Administration |
| FIMS | Flight Information Management System |
| NAS | National Airspace System |
| NASA | National Aeronautics and Space Administration |
| OOP | Operations Over People |
| OV | Operational View |
| PIC | Pilot in Command |
| RTT | Research Transition Team |
| RPIC | Remote Pilot-in-Command |
| SDSP | Supplemental Data Service Provider |
| sUAS | Small Unmanned Aircraft System |
| TBOV | Trajectory Based Operation Volume |
| TCL | Technical Capability Level |
| UA | Unmanned Aircraft |
| UAS | Unmanned Aircraft System |
| UREP | UAS Report |
| USS | UAS Service Supplier |

| Term | Definition |
| --- | --- |
| UTM | Unmanned Aircraft Systems Traffic Management |
| VLOS | Visual Line of Sight |
| VMC | Visual Meteorological Conditions |
| WG | Work Groups |

# Appendix A

The following pages of this section contains two diagrams for OV-6c sub-activities: 1.) Develop Operation Plan, 2.) Operation and Volume Status Change.

**Develop Operation Plan OV-6c**



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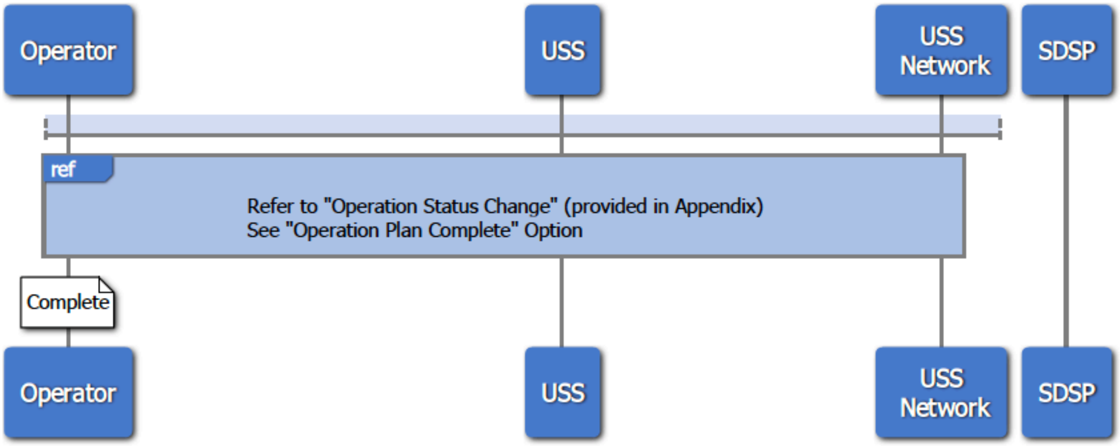
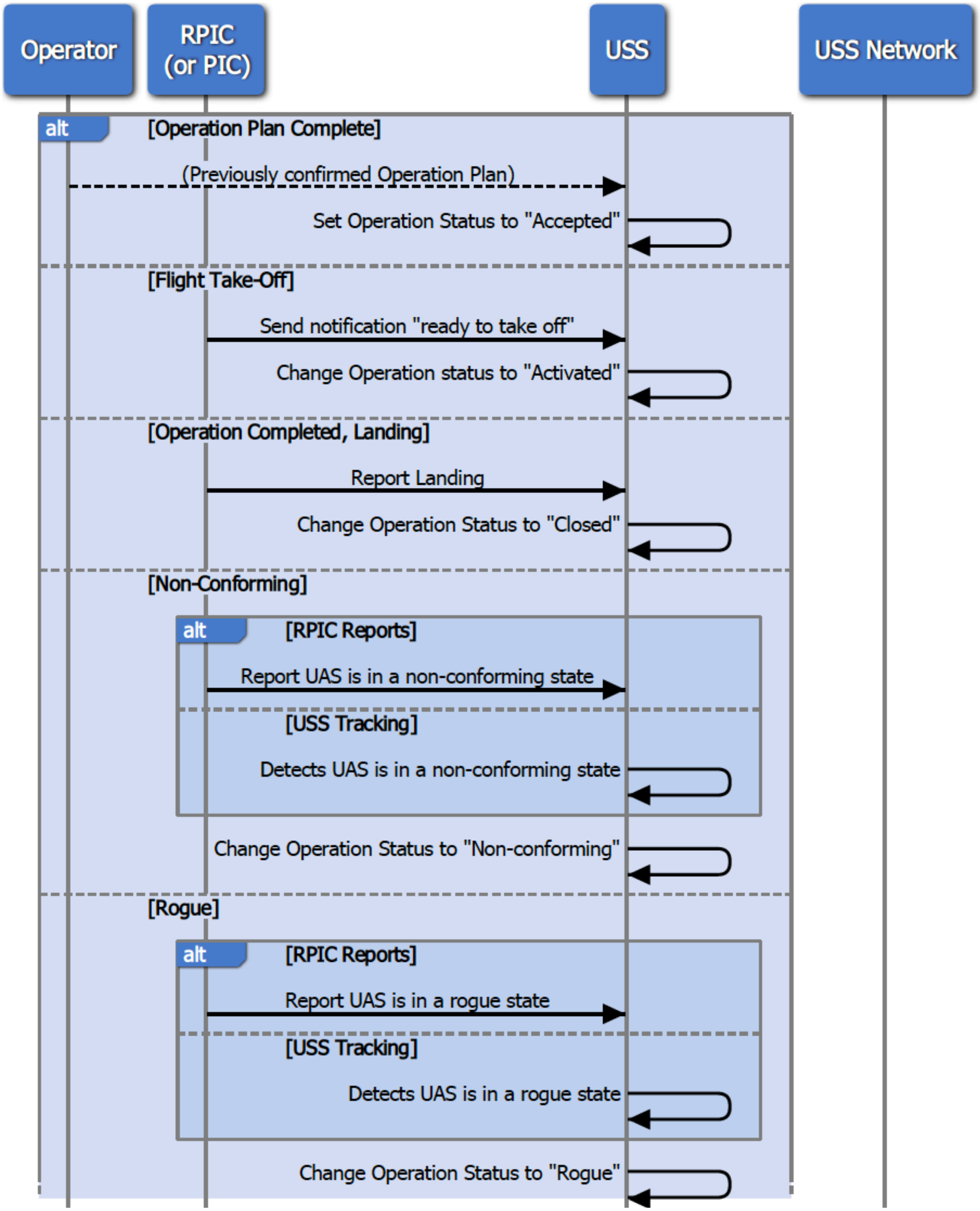

Operator
USS
USS Network
SDSP
ref
Refer to "Operation Status Change" (provided in Appendix)
See "Operation Plan Complete" Option
Complete
Operator
USS
USS Network
SDSP

**Operation and Volume Status Change OV-6c**



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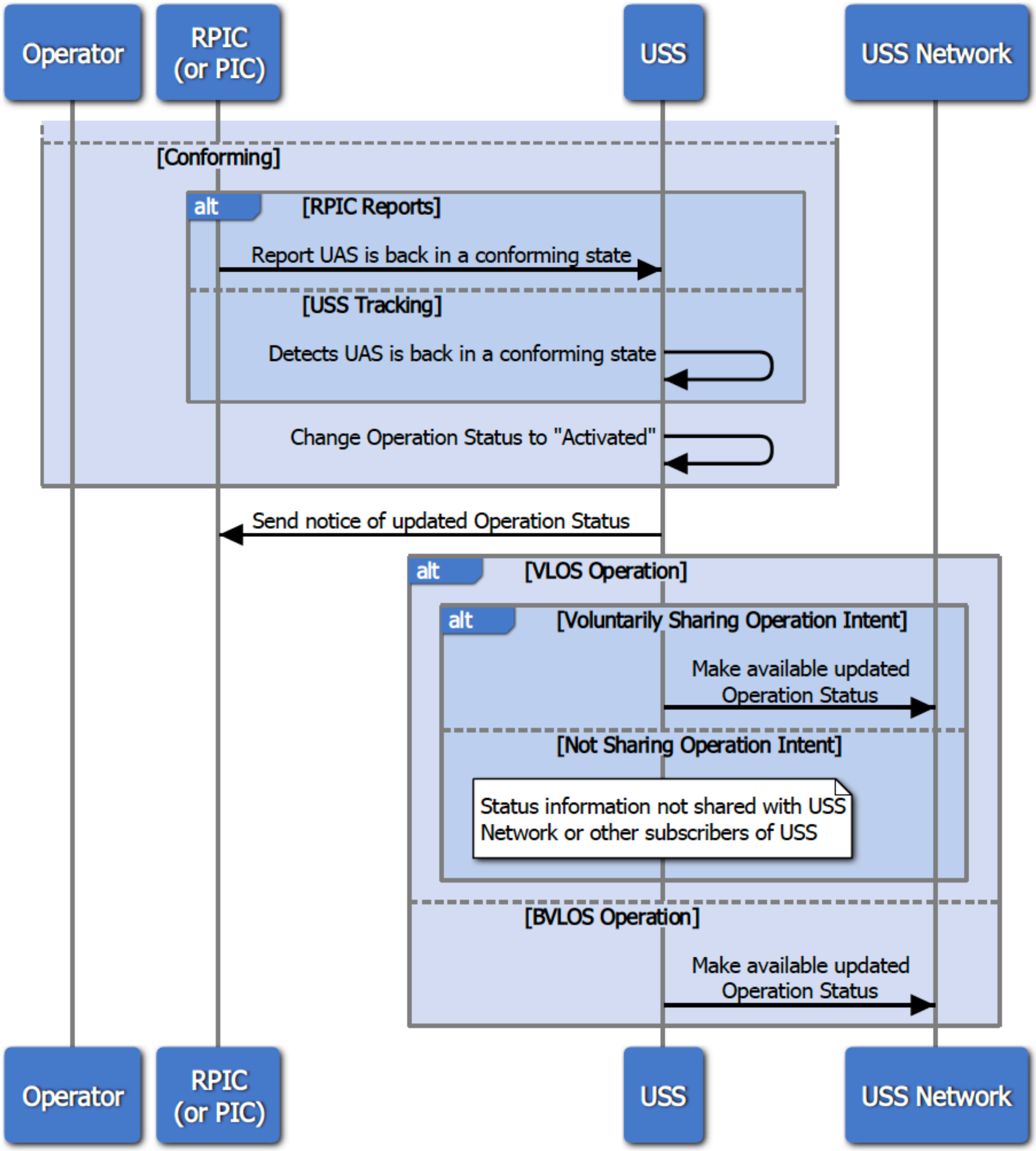
Operator
RPIC (or PIC)
USS
USS Network
[Conforming]
alt
[RPIC Reports]
Report UAS is back in a conforming state
[USS Tracking]
Detects UAS is back in a conforming state
Change Operation Status to "Activated"
Send notice of updated Operation Status
alt
[VLOS Operation]
alt
[Voluntarily Sharing Operation Intent]
Make available updated Operation Status
[Not Sharing Operation Intent]
Status information not shared with USS Network or other subscribers of USS
[BVLOS Operation]
Make available updated Operation Status
Operator
RPIC (or PIC)
USS
USS Network