

Federal Aviation Administration (FAA)
Broad Agency Announcement (BAA) - Call #001

Final Project Report
For The
Contingency Management Platform (CMP)

Contract #: 692M15-20-C-00004
UAS Integration Office
Program & Data Management Branch
(AUS-410)

Version:	1.0 – Initial Version
Date:	3/29/2020
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Contract Period of Performance:	3/30/2020 – 3/29/2021



TruWeather
SOLUTIONS



ais RESILIENX



KONGSBERG



Revision History

Version	Date	Revision Details
1.0	29 March 2020	Original Release

Related Project Documents

Ref ID	Document Name	KSN Reference #
[1]	CMP Project & Analysis Plan	204 (PM Data)
[2]	CMP Requirements	197 (PM Data)
[3]	CMP System Design Document (SDD)	227 (PM Data)
[4]	CMP Interface Control Document (ICD)	75 (Op. Data)
[5]	CMP Test & Evaluation Plan	257 (PM Data)
[6]	Live Flight Risk Assessment	82 (Op. Data)
[7]	Functional Requirements Verification Procedures	96 (Op. Data)



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Executive Summary

CAL Analytics (CAL) and our team of industry partners have integrated several UTM services and technologies into a single platform for the purpose of monitoring federated Unmanned Traffic Management (UTM) ecosystem components and airspace conditions to detect and respond to contingency events. This platform is aptly called the Contingency Management Platform (CMP). Industry partners, in addition to CAL, contributing to the current CMP include: Assured Information Security (AIS), Kongsberg Geospatial, ResilienX, and TruWeather Solutions.

The CMP provides its capabilities to users through an aggregated operational airspace picture, coupled with auxiliary portals to various service interfaces, referred to as ‘web-cards.’ The operational airspace picture presents end users with all relevant airspace conditions including terrain maps, classed airspaces, advisory airspaces (NOTAMs, TFRs), UTM participant operational airspaces, live UTM participant telemetry, live radar and ADS-B target data, UTM restricted airspaces – referred to as UAS Volume Reservations (UVR), current weather conditions, and regional weather alert volumes. Services which assist in the contextualizing of UTM ecosystem reliability include monitoring of UTM component liveliness, health & integrity status, and cyber security posture.

The CMP has been designed to be utilized by a role referred to as a UTM Airspace Supervisor. A UTM Airspace Supervisor is envisioned to have some responsibility for maintaining airspace safety of UTM operations over a regional Area of Regard (AOR). Our team believes that human-in-the-loop oversight and management of UTM operations in some capacity is vital to enabling UTM operationalization in the near term. As UTM matures and automation becomes more reliable, oversight and monitoring capabilities will adapt to being conducted at a more macro-level in a human-on-the-loop capacity.

The implemented CMP provides end users with appropriate contextual information to evaluate and respond to contingency conditions. Responses are generally limited to the restriction of UTM operations in compromised airspace, although external procedural mitigations may also be triggered by CMP outputs. The CMP does however enable end users to detect a variety of contingency conditions including degraded or failed components implicating broad or geo-localized service impacts, non-conformant UTM participants, hazardous weather conditions, cyber security threats or vulnerabilities, terrain and obstacle proximity, and conflicts with both UTM participants and non-participants.

The described CMP capabilities were validated through both simulated and live flight test activities. Live flight testing was conducted in collaboration with the Northeast UAS Airspace Integration Research Alliance (NUAIR) and the New York FAA UAS Test Site (NYUASTS) at Griffiss International Airport in Rome, New York. A live flight test demonstration was observed virtually by FAA representatives on March 9th, 2021.

The resulting CMP product will continue to be matured and enhanced following closure of this FAA BAA initiative. It is currently deployed in the developing Ohio Department of Transportation (ODOT) UTM corridor in central Ohio. Our team is also pursuing additional deployments, targeting FAA UAS Test Sites and other state DOTs. Ongoing improvements to CMP partner products are currently being funded through a variety of efforts for customers such as NASA and the U.S. Air Force. Our team will continue to pursue additional opportunities for the furtherment of this product as well as UTM operationalization at large.

Introduction

CAL Analytics and our Partners conceived the CMP based on the identification of functional gaps in the FAA endorsed NASA UTM Architecture. Although the desired end state of UTM is a fully autonomous and self-regulated environment of interconnected services, the industry has yet to establish a persistent representative operational environment for solutions providers to conduct rigorous Operational Test & Evaluation (OT&E) to mature requisite autonomous capabilities. Furthermore, it would be unwise to allow developing services to perform freely in a live operational environment prior to a point in which sufficient confidence in service reliability is achieved. Figure 1 depicts this interdependency and paradox the start-up rich UTM industry finds itself in.

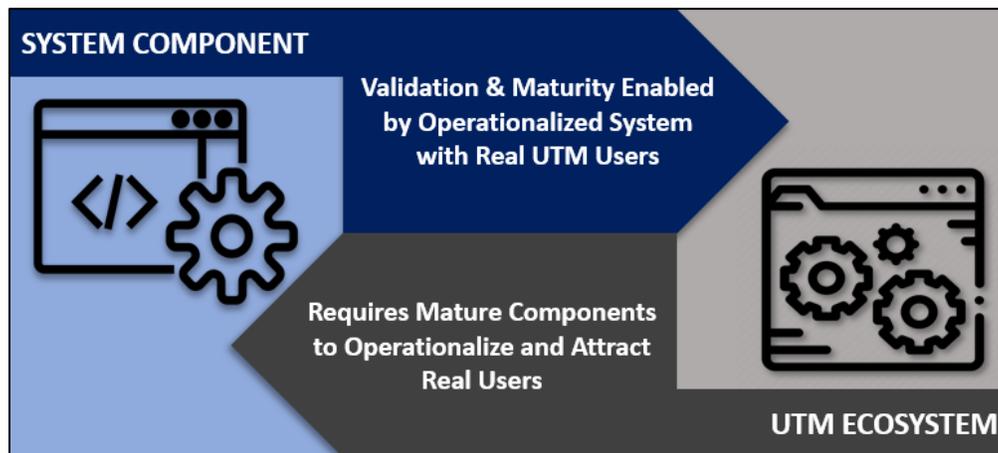


Figure 1: UTM Maturation Interdependency

To mitigate this situation, the CMP aims to inject supervisory oversight capabilities and behavior influencing mechanisms (contingency mitigations) into the UTM ecosystem. These elements will help ensure that both UTM services and operators are complying with system and regulatory requirements, as well as performing to their expected levels. These capabilities will be critical to operationalizing UTM safely. The functional gaps filled by the CMP include:

- Aggregated UTM Data Collection & Conditioning
- Supervisory-Level Airspace Situational Awareness
- UTM Service/Component Health & Integrity Monitoring
- UTM Component Cyber Security Monitoring
- Micro-Weather Observations, Analysis, Forecasts & Alerting
- Supervisory Mitigation Mechanisms for Contingency Events

Our team believes that effective implementation of these functions will enable a heterogeneous set of UTM services and components to attain similar reliability and safety as the homogenized Air Traffic Management (ATM) system. These functions are expected to evolve over time, commensurate with the maturity and dependability of autonomous services and aircraft, however, they are not likely to ever become fully obsolete. The most advanced, automated factories and production plants in the world are abundant with sensing and monitoring capabilities to detect and respond to off-nominal conditions. While those environments largely do so to protect financial profits, UTM must do so to protect the safety of the National Airspace System (NAS) and those on the ground.



Project Objectives

The overarching goal of this CMP project was to evaluate how confidence in the safety of UTM operations can be improved through implementation of advanced UTM airspace and ecosystem supervisory and oversight capabilities. The CMP was designed for this intent through integration of existing commercial UTM products from five (5) industry partners. These UTM solution providers, their products, and associated service offerings to the CMP are identified in Table 1.

Table 1: CMP Partners and Service Offerings

UAS Solution Provider	Product(s)	Service Offerings
Assured Information Security (AIS)	Metasponse for CMP (MSCMP)	Cybersecurity Monitoring, Cyber Threat Mitigation
CAL Analytics (CAL)	CAL Integration Engine (CIE)	Data Collection, Translation, & Management Modeling & Simulation
Kongsberg Geospatial	IRIS UAS	Airspace Situational Awareness Display
ResilienX	FRAIHMWORK	In-time system-wide safety assurance (ISSA)
TruWeather Solutions (TWS)	Weather Data Tiles MissionCast RouteCast TruFlite Alert	Current Weather Data, Forecasting, Weather Alerting

The technical objectives of project execution were identified as [1]:

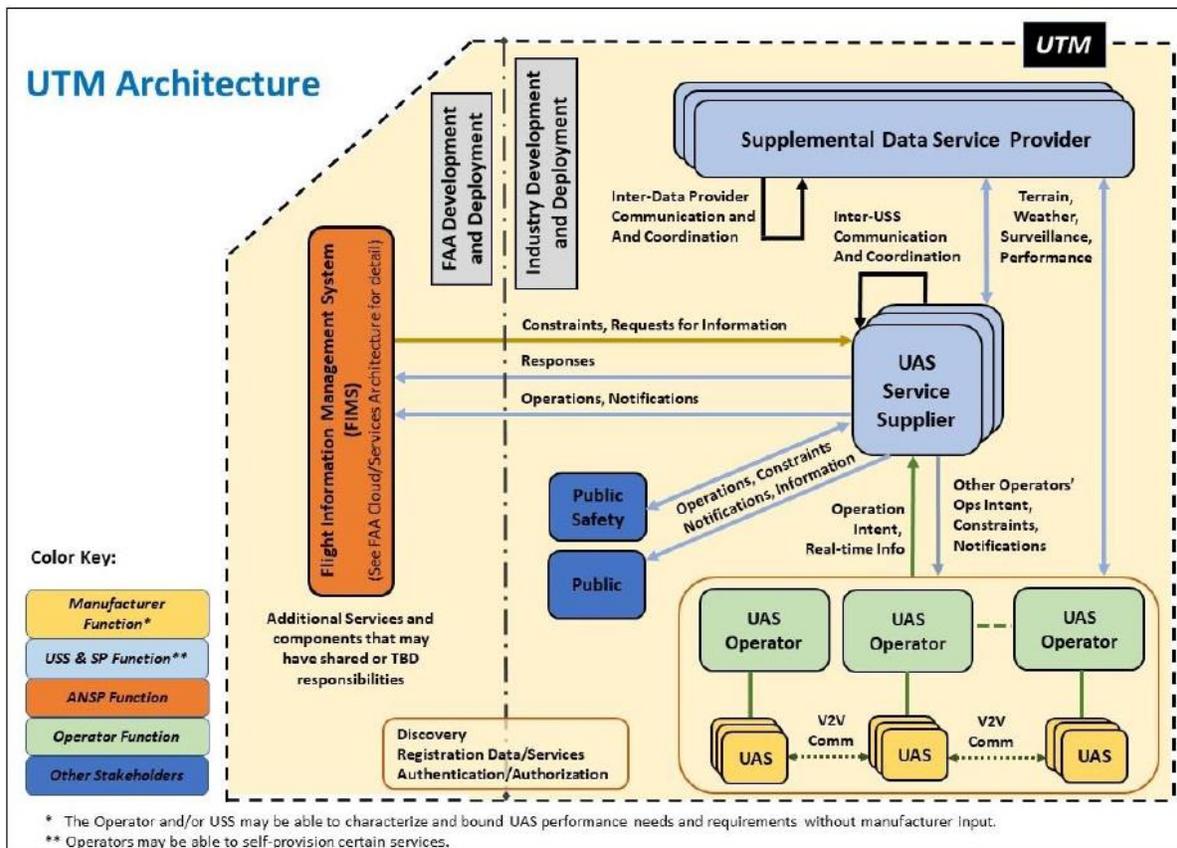
- Characterize the NYUASTS deployment environment and accessible components
- Integrate partner products into cohesive platform (the CMP)
- Test prototype CMP in M&S environment
- Deploy CMP at NYUASTS
- Conduct research and analysis to evaluate CMP performance
- Document research findings
- Conduct capability demonstration for FAA

The operational objectives of the resultant CMP product were identified as [3]:

- Support holistic assessment of UAS Traffic Management (UTM) risk mitigation system reliability
- Identify adverse conditions within a UTM environment
- Support the determination of appropriate UTM environment contingency actions in the event of adverse conditions
- Assist in the execution of contingency actions where applicable

Technical Approach

The primary technical approach to developing a CMP with the highest feasibility for UTM application was to leverage as many existing constructs, data structures, and interfaces as possible. This largely meant abiding by the core NASA UTM Architecture as depicted in Figure 2, and operating within the capacities of UAS Service Suppliers (USS) and Supplemental Data Service Providers (SDSPs). This is not to suggest that the CMP is inherently a USS or singular SDSP, but rather that it utilizes the same data types and interfaces. Specifically, the CMP implemented interfaces compatible with the ASTM DSS/Inter-USS communications specification which was leveraged for the UAS Pilot Program Phase 2 (UPP2) for exchange of operational data, telemetry, and constraints.



Source: FAA UTM CONOPS Version 2

Figure 2: NASA UTM Architecture

Some distinction between the CMP and a USS comes by way of the target end users. While USS are meant to be UAS operator facing platforms, the CMP is firmly intended to be used by supervisory users; referred to as UTM Airspace Supervisors in this document. Organizations which require supervision over a regional AOR are UTM Deployment Authorities working towards operationalization through investment in infrastructure and services to realize the NASA UTM architecture. Examples include FAA UAS Test Sites such as NYUASTS, and State Departments of Transportation such as the Ohio DOT (ODOT). The organizations implementing UTM have a need to not only ensure their foundational infrastructure, components, and services are working properly for their end users, but also that the UAS operators are abiding by the FAA regulatory requirements and additional UTM system participation requirements.

ATM Influences

It is widely accepted that UTM necessitates a different approach than ATM based on nuances in the problem-space and need for greater scalability, yet clarity regarding the exact differences between the two has not yet been achieved. Although the topic is being explored, a consensus has not yet been reached in terms of what functionalities should be common or distinct across both UTM and ATM. Some proponents prefer to view UTM as an independent functional equivalent of ATM for unmanned operations, whereas others view UTM as a complimentary set of services to ATM. In execution however, the emerging UTM systems appear to fall somewhere in-between, and conditionally variable.

The largest uncertainty, particularly if considering UTM as a replication of ATM functionality, is how it can be accomplished with almost no physical infrastructure, as is commonly assumed based on the top-level NASA UTM architecture, when ATM is critically dependent upon distributed, connected physical facilities (See Figure 3). CAL Analytics believes that based on this FAA BAA effort and our participation in developing UTM environments that the answer to the question is straight forward: UTM, at least in the near-term, will be reliant on some regional physical infrastructure.

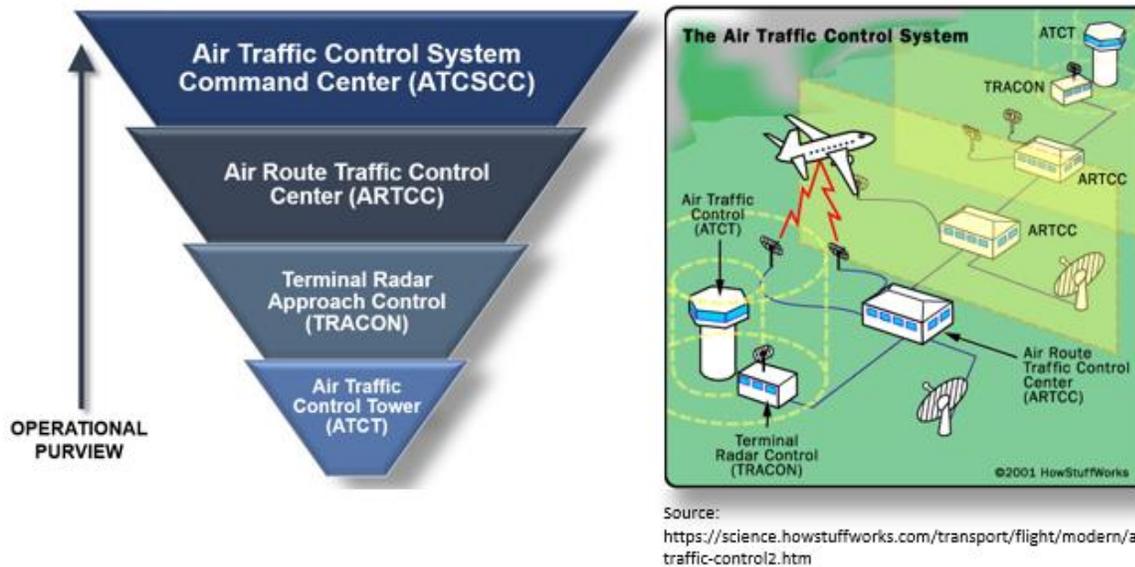


Figure 3: ATM Physical Infrastructure and Operational Oversight

Developing UTM ecosystems have rather consistently evolved around a common construct of a central, physical command center; often referred to as an Operations Center (OPCEN) or Operations Control Center (OCC). This is a physical element that is not included in the base NASA UTM architecture but has been a repeated design pattern throughout disparate UTM systems. Based upon this understanding, our research suggests that the criticality and broad applicability of CMP services to the rest of the UTM ecosystem, would be most suited for initial deployment in existing operations OPCENs or OCCs. As these ecosystems evolve further, it is assumed that the primary functionality of such facilities will shift from supporting individual operations to maintaining UTM system reliability and serviced airspace safety at a more macro-level. These facilities are expected to perform a mix of functions analogous to many currently performed by Air Route Traffic Control Centers (ARTCC), Terminal Radar Approach Control (TRACON), and Air Traffic Control Towers (ATCT).

CMP Overview

Figure 4 depicts the high-level context diagram of the CMP. This diagram is intended to convey the inputs and outputs of the CMP and the associated operational actors / entities. Figure 4 only includes operational CMP actors, i.e., the End User(s) leveraging the CMP display in support of actively monitoring UTM system performance and maintain safety of airspace. It does not include developmental or support actors such as CMP System Administrators who configure the platform or independent service personnel who may facilitate the creation of mitigation messages.

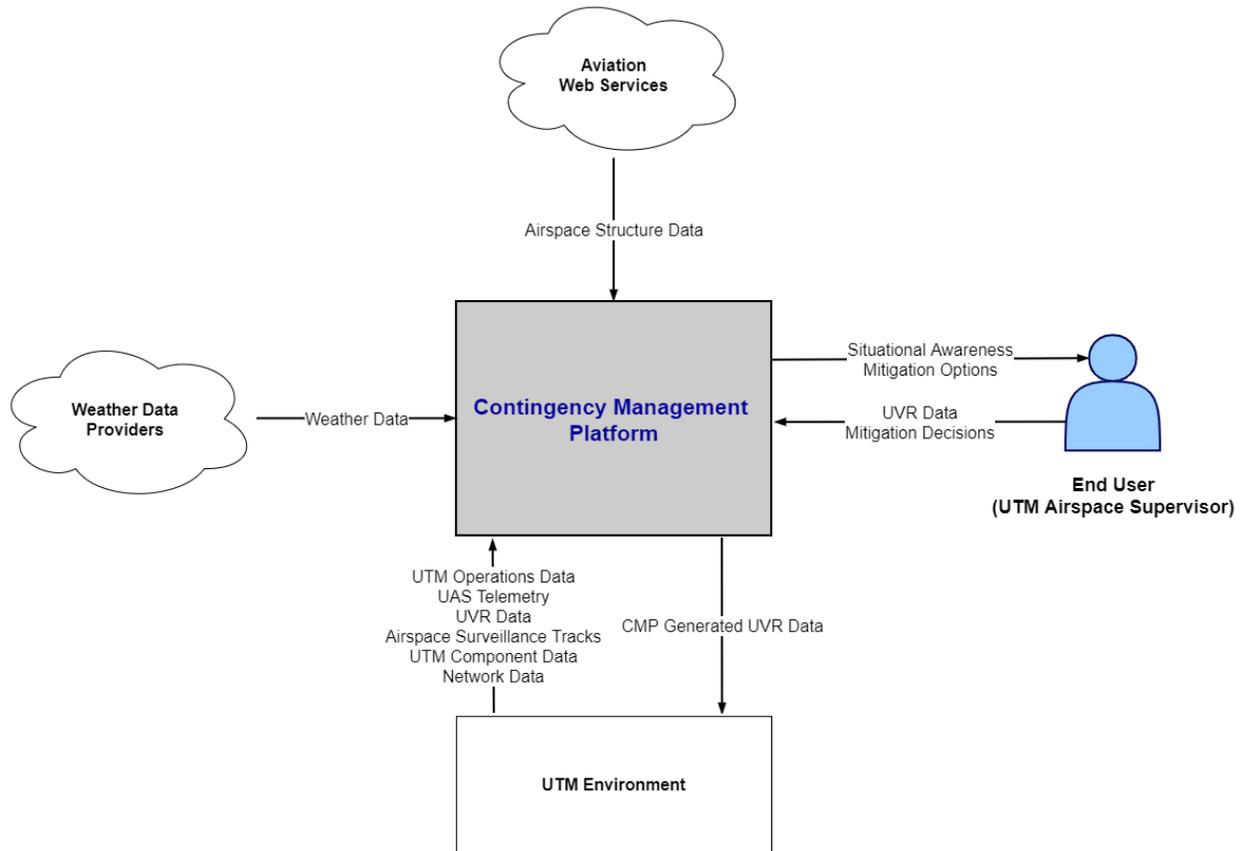


Figure 4: CMP Context Diagram

The CMP resulting from this effort offers its capabilities to supervisory users through a single user interface. This interface provides a common operational airspace picture to UTM Supervisors over a regional AOR. UTM Airspace Supervisors leverage this interface to understand all current airspace conditions, monitor both planned and active UTM operations, evaluate the performance of UTM services and infrastructure, and issue UVRs where applicable to influence operator behaviors and maintain safety.

CMP User Interface

Figure 5 depicts a general view of the CMP display, although it can be configured per operator preferences through use of service provider web-cards and manipulation of map layers. Table 2 describes the features called out via reference numbers in Figure 5. More detailed information on specific features, and additional features that may not be well reflected though the CMP user interface are provided in Appendices A through E.

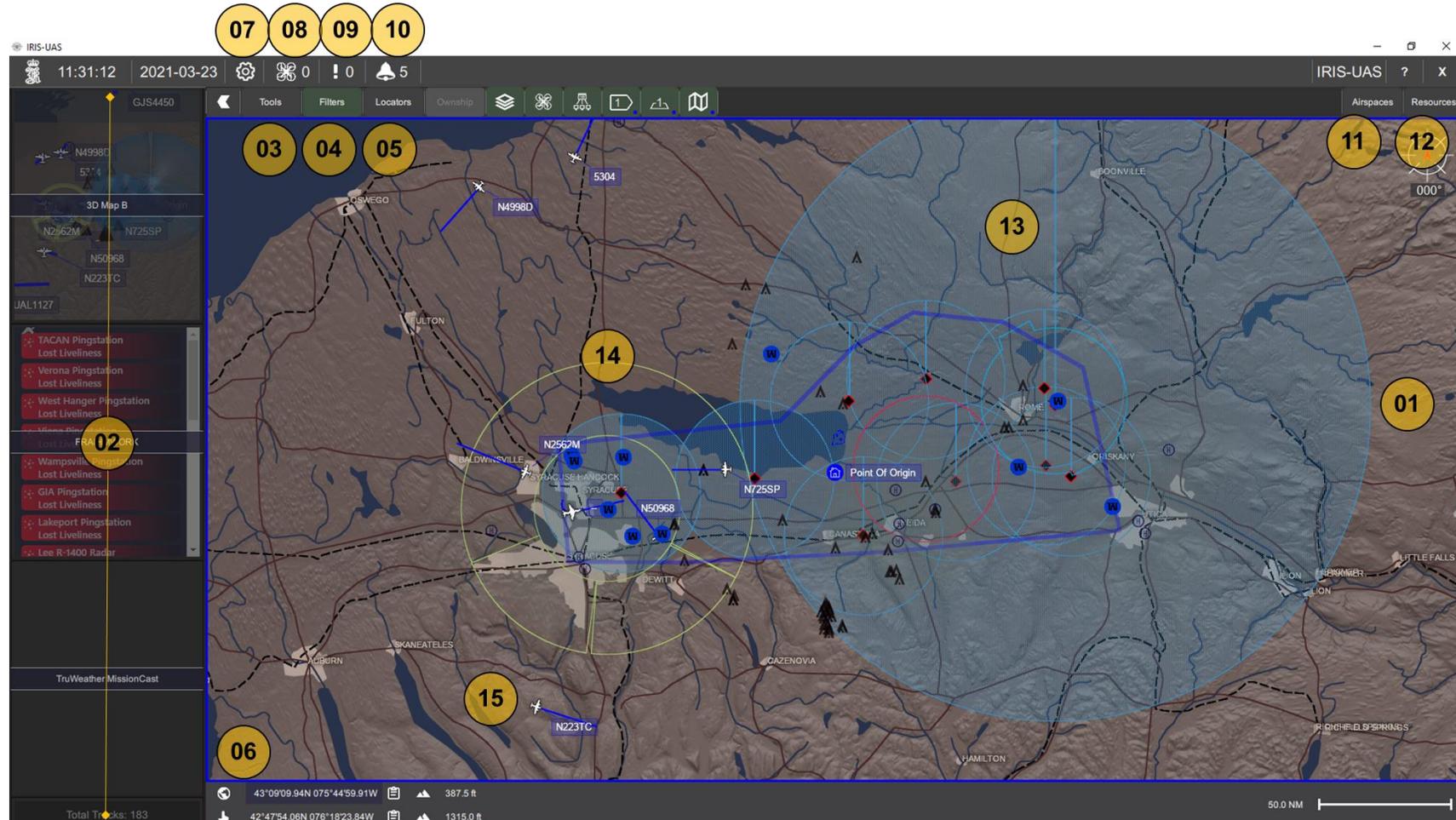
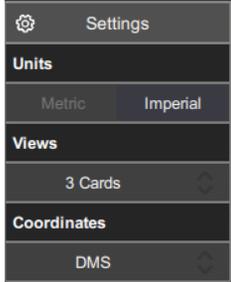
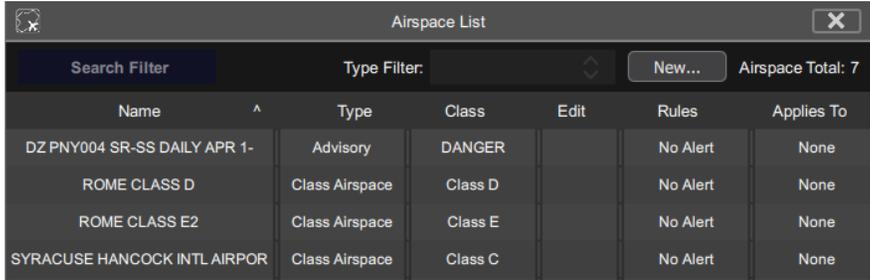


Figure 5: CMP User Interface

Table 2: CMP Feature Descriptions

Ref. Number	Description
01	The CMP provides a geographic map in both 2D and 3D formats. The primary map layer can be toggled between multiple satellite, topographical, and street map views.
02	<p>The CMP window can be reconfigured using service web-cards. Available web cards are displayed in the left-hand web-card tray and are dragged into the main window for use. Currently configured web-cards include:</p> <ul style="list-style-type: none"> • 2D Map • 3D Map • FRAIHMWORK Tiered Maintenance Interface (TMI) Display • TruWeather MissionCast Forecasting Service • TruWeather RouteCast Operation Planning Assistance Service • Track List – Displays details on all current surveillance tracks • Operation List – Provided operational details for all participant UTM operations • FAA NOTAM Search Portal (Any web accessible service can be accessed within the CMP if configured)
03	<p>The Tools button allows users to draw, annotate, and publish airspaces.</p> 
04	<p>The Filters button allows users to manipulate a variety of map layers. This includes configuring the airspaces shown, UTM telemetry layer, surveillance target layers, UTM service footprints, and weather information.</p> 
05	<p>The Locators button provides quick access to points of interest including operational regions within user AOR, bookmarked points, and ‘Home’ locations – more pertinent if UTM Supervisor is acting as a Mission Commander in support of specific operations.</p> 
06	Latitude, Longitude, and elevation for both the current center of the map and the cursor are provided.

Ref. Number	Description
07	<p>The Settings button allows CMP users to configure units, Web Card Panel display, and coordinate format.</p> 
08	<p>The 'Ownship Icon' provides access to a list of UTM participant aircraft flagged as 'Ownship.'</p>
09	<p>The 'Alert Icon' opens the active Alert List, and provides operators the ability to Acknowledge alerts.</p> 
10	<p>The 'Notification Icon' opens the active Notification List.</p>
11	<p>The Airspaces button opens a list of all current airspaces.</p> 



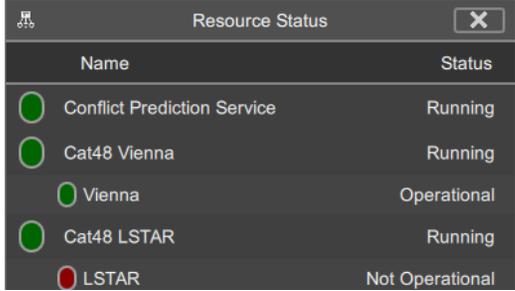
Ref. Number	Description												
12	<p>The Resources button opens the list and status of internal CMP services and external data sources including surveillance sensors.</p>  <table border="1" data-bbox="415 326 930 617"> <thead> <tr> <th data-bbox="422 375 457 391">Name</th> <th data-bbox="856 375 909 391">Status</th> </tr> </thead> <tbody> <tr> <td data-bbox="422 418 688 443">Conflict Prediction Service</td> <td data-bbox="842 418 909 443">Running</td> </tr> <tr> <td data-bbox="422 464 590 488">Cat48 Vienna</td> <td data-bbox="842 464 909 488">Running</td> </tr> <tr> <td data-bbox="422 509 548 534">Vienna</td> <td data-bbox="814 509 909 534">Operational</td> </tr> <tr> <td data-bbox="422 555 590 579">Cat48 LSTAR</td> <td data-bbox="842 555 909 579">Running</td> </tr> <tr> <td data-bbox="422 600 548 625">LSTAR</td> <td data-bbox="779 600 909 625">Not Operational</td> </tr> </tbody> </table>	Name	Status	Conflict Prediction Service	Running	Cat48 Vienna	Running	Vienna	Operational	Cat48 LSTAR	Running	LSTAR	Not Operational
Name	Status												
Conflict Prediction Service	Running												
Cat48 Vienna	Running												
Vienna	Operational												
Cat48 LSTAR	Running												
LSTAR	Not Operational												
13	The CMP includes layers for configurable service footprints. They are currently used to depict radar surveillance coverage regions, but could be used for any geo-localized service or sensor.												
14	The CMP includes layers for classed airspaces which are configurable.												
15	The CMP displays live airspace targets from available surveillance data including ADS-B and radar.												

Figure 6 depicts how CMP web-cards can be used to dynamically reconfigure the display to reference multiple services simultaneously. In this configuration the UTM Airspace Supervisor is viewing the IRIS UAS 2D geographical map, the Operations List web-card, and the FRAIHMWORK health & integrity monitoring display. The CMP user interface can also be extended across multiple physical displays to maximize web-card views.

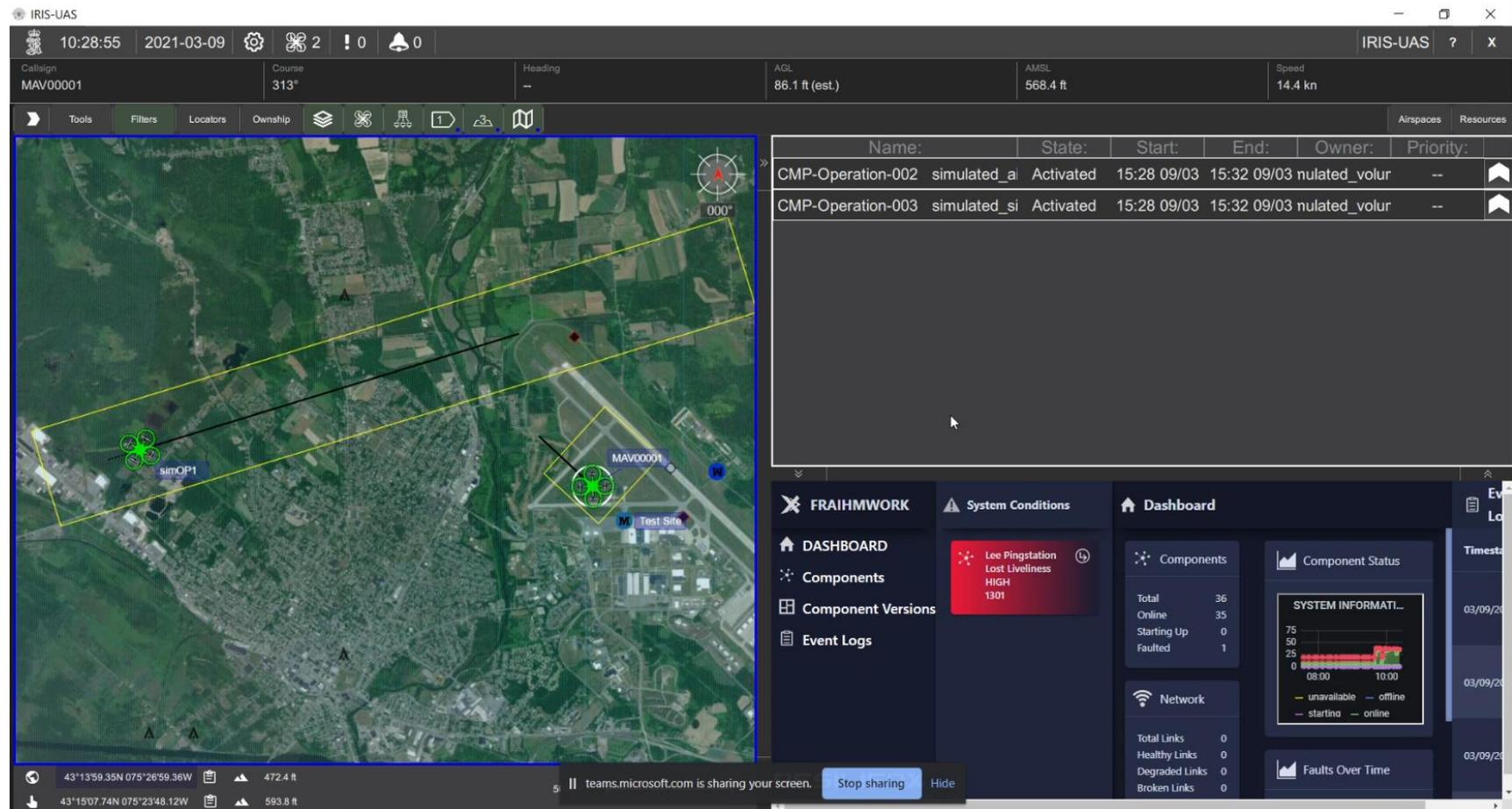


Figure 6: Alternately Configured CMP User Interface

Figure 7 provides a closer look at one of the FRAIHMWORK TMI display views. FRAIHMWORK is used to provide details on the health and integrity of UTM components and supporting services. Faults against registered components are reported via FRAIMWORK. In this example, a cyber security vulnerability is being reported against a connected ground control station by the AIS Metaspense services. More specific details on the FRAIHMWORK TMI display are provided in Appendix C: ResilienX Service Descriptions.

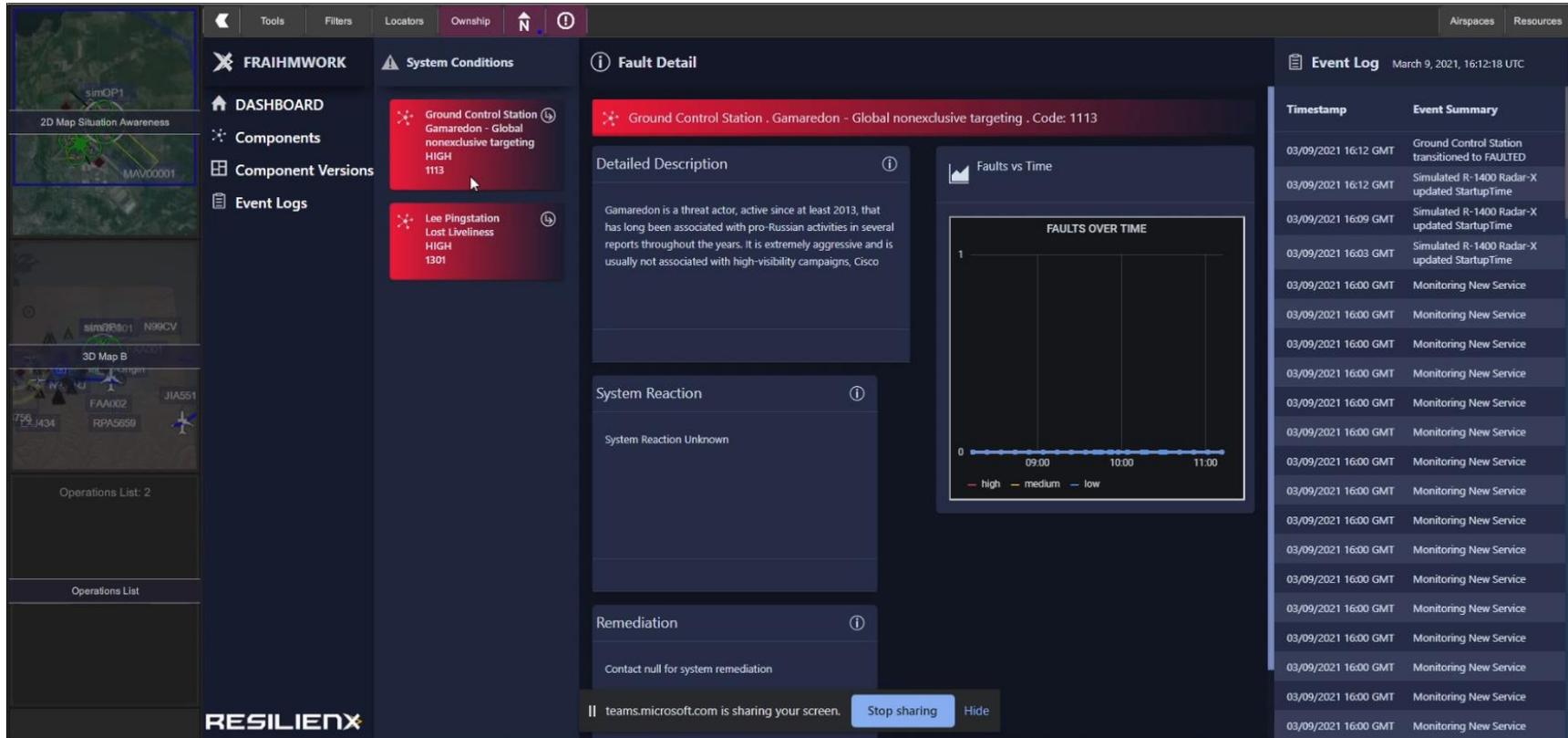


Figure 7: FRAIHMWORK TMI Display

CMP Architecture

This section describes the final architecture of the CMP both in terms of how partner components were integrated and how the CMP was deployed for use in the NYUASTS. Further detailed design information can be found in the CMP System Design Document (SDD) [3] and the CMP Interface Control Document (ICD) [4].

Logical Architecture

Figure 8 expands upon the CMP Context Diagram to convey internal and external data types and how they are exchanged between integrated partner components.

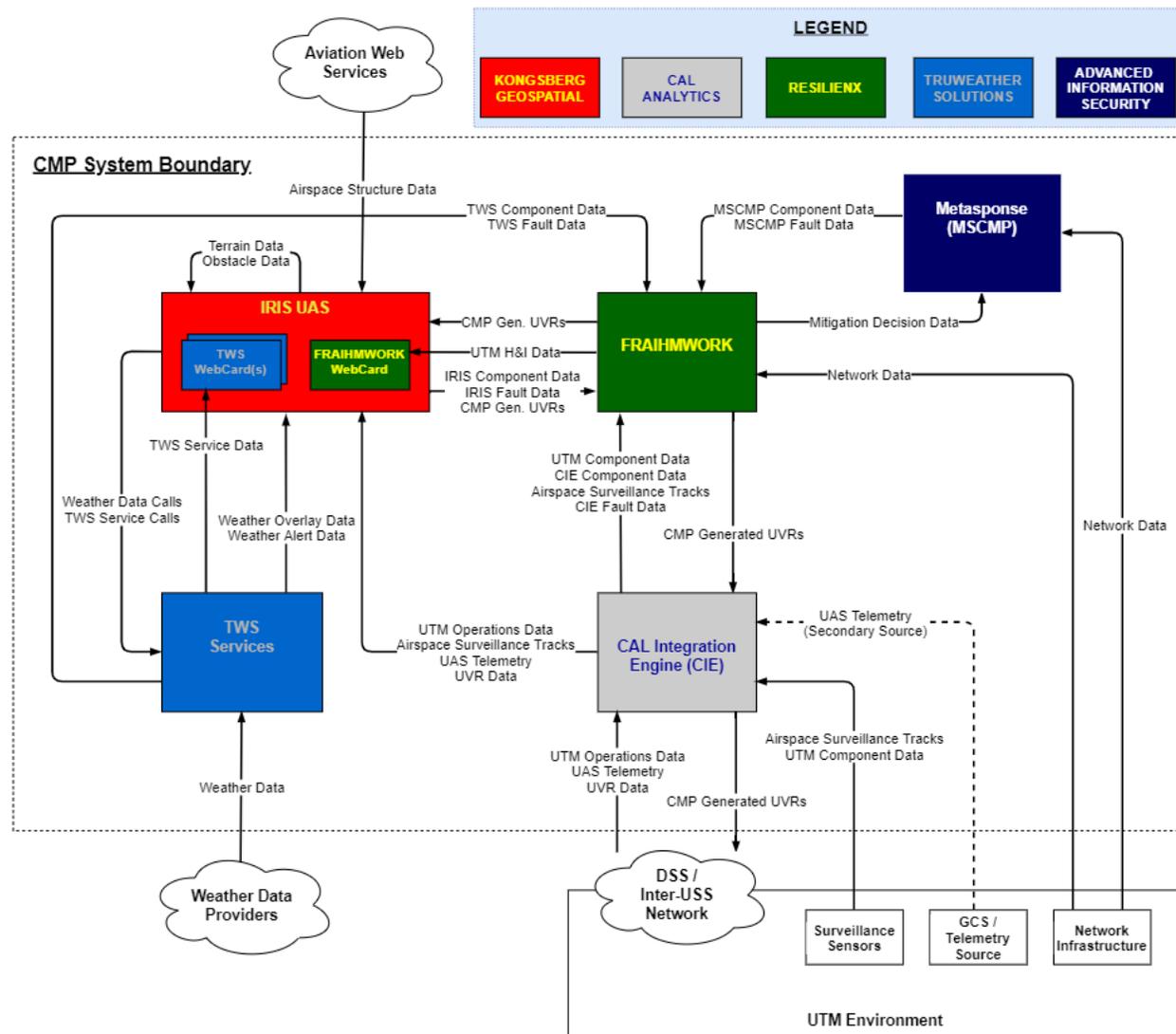


Figure 8: CMP Logical Architecture

Physical Architecture

The CMP offers flexibility in terms of its physical deployment. Some CMP components must be deployed locally, whereas others can be either physically instantiated or cloud based. Given this, the CMP physical footprint can be adapted to best suit the needs and constraints of each deployment environment. In an unconstrained UTM environment the standard CMP deployment configuration is comprised of IRIS, Metaspense, and the CAL Integration Engine operating on a local CMP machine with FRAIHMWORK and TWS Services running in the cloud. This configuration is represented in Figure 9.

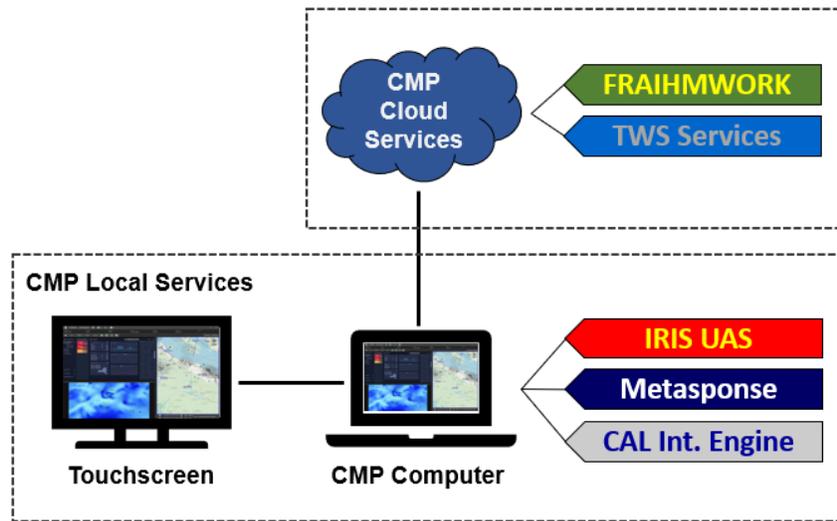


Figure 9: CMP Physical Architecture

Figure 10 illustrates how the CMP product is deployed specifically within the context of the NYUASTS environment. This configuration allows the CMP to receive NYUASTS data directly over the test site Extranet, or via the internet for remote use and testing.

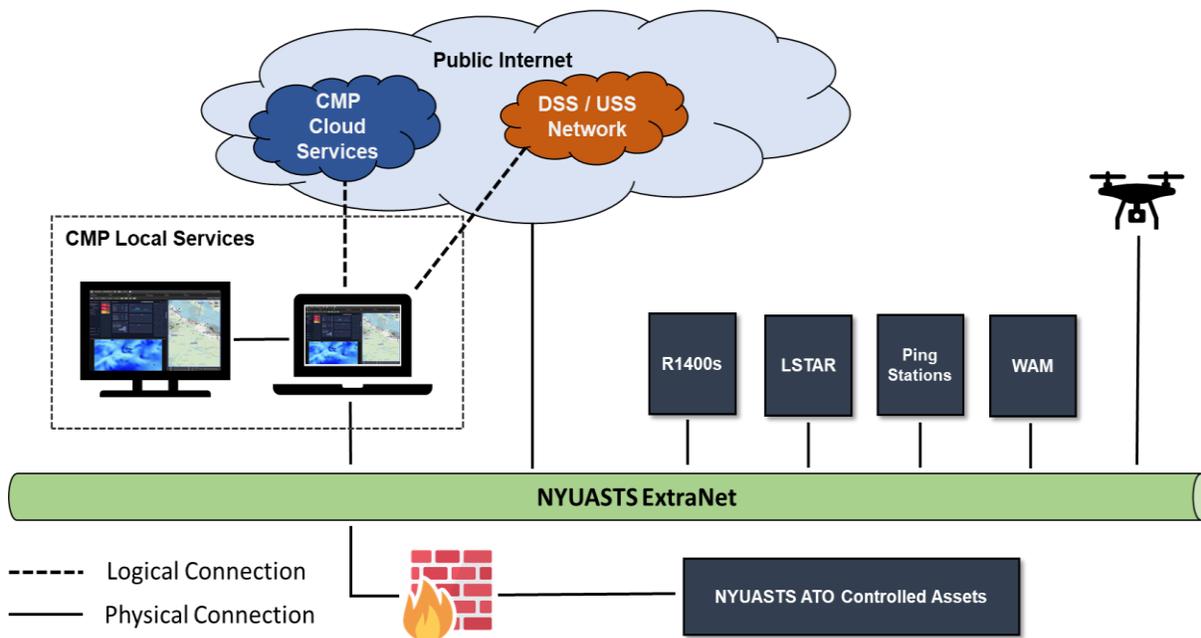


Figure 10: CMP Deployment at NYUASTS



CMP Capabilities

The CMP System Level Requirements [1] established the top-level functional requirements of the platform. These requirements served as the foundation for identification of the user-facing capabilities the CMP is intended to provide. A complete mapping of requirements to capabilities is provided in Appendix F: Capability to Requirements Trace.

Table 3: CMP Top-Level Capabilities

CMP Capability ID	Capability Description
CMP-CAP-001	Accept & display UTM participating ownship telemetry
CMP-CAP-002	Accept & display UTM surveillance sensor tracks
CMP-CAP-003	Display details of selected ownship telemetry
CMP-CAP-004	Display details of selected surveillance target tracks
CMP-CAP-005	Flag and display track as ownship
CMP-CAP-006	Follow ownship on airspace display
CMP-CAP-007	Accept & display airspace structure data - NOTAMS, TFRs, Classes, etc.
CMP-CAP-008	Accept & display UTM operation volume data
CMP-CAP-009	Accept & display UVR volume data
CMP-CAP-010	Accept & display terrain data
CMP-CAP-011	Accept & display obstacle data
CMP-CAP-012	Accept & display current weather conditions and information
CMP-CAP-013	Register UTM system components
CMP-CAP-014	Display UTM component description and condition data
CMP-CAP-015	Create & publish a UVR automatically
CMP-CAP-016	Create & publish a UVR manually
CMP-CAP-017	Monitor & report CMP component description and condition data
CMP-CAP-018	Configure airspace display settings
CMP-CAP-019	Create & display custom airspaces and annotations
CMP-CAP-020	Configure UI display settings (Web Card Panels)
CMP-CAP-021	Detect and display terrain alerts
CMP-CAP-022	Display system alerts (faults) and associated information
CMP-CAP-023	Establish and monitor UTM system configuration baseline
CMP-CAP-024	Detect and display configuration alerts
CMP-CAP-025	Detect and display UAS weather hazard information
CMP-CAP-026	Detect and report loss of component connection
CMP-CAP-027	Monitor and display network & network component health
CMP-CAP-028	Monitor for and display cyber security alerts
CMP-CAP-029	Deploy cyber security threat mitigations
CMP-CAP-030	Maintain and display component blocklist
CMP-CAP-031	User / Laptop Login



Integrated Services

To support the system-level capabilities, CMP requirements were allocated to partners for implementation via integration of existing services and development of additional features. This section provides high-level descriptions of the services and sub-system capabilities provided to the CMP by each partner, respectively.

CAL Analytics Services

CAL Analytics components, namely the CAL Integration Engine (CIE) serve as the primary interface between existing UTM infrastructure and the CMP. The CIE is a collection of software tools and utilities which accept data, translate it where necessary to match internal CMP formats, and disseminate it appropriately to requisite CMP services. This avoids multiple CMP service providers from having redundant interfaces to UTM components and simplifies integration. The CIE also enables simulated data from the CAL Analytics Modeling & Simulation (M&S) environment to be injected into the CMP for test and evaluation purposes. Table 4 identifies the specific services and capabilities CAL contributes to the CMP product, greater detail is offered in Appendix A: CAL Analytics Service Descriptions.

Table 4: CAL CMP Services & Capabilities

Service / Capability	Description
Surveillance Data Collection, Translation, Distribution	The CAL CIE receives live ground-based radar and ADS-B receiver surveillance track data from the NYUASTS forwarded over UPD. The CIE leverages Redis as a message broker to offer surveillance data to CMP services – primarily the IRIS UAS for display.
Telemetry Data Collection, Translation, Distribution	The CAL CIE accepts telemetry from UTM participants either via ASTM UTM format or MAVLINK mirroring directly from GCS. Telemetry data is translated for delivery to IRIS UAS for display.
Health & Integrity Data Translation & Distribution	As no existing NYUASTS UTM components natively transmit Built-In-Test (BIT) or H&I data in the ResilienX FRAIHMWORK API formats, the CAL CIE translates native radar and ADS-B receiver data into FRAIHMWORK formats and reports status on behalf of the components.
DSS Connectivity	The CAL CIE was credentialed and registered to connect to the NYUASTS UPP2 DSS network for data exchange with other connected service providers – primarily USSs. Note: The CIE was granted use of ResilienX DSS credentials based upon ResilienX participation with the NY UPP2 initiative.
Operational Data Collection, & Distribution	The CAL CIE subscribed to operational data through the NYUASTS DSS inter-USS network and provided details to IRIS UAS for display.
Constraint (UVR) Collection, Distribution, & Publishing	The CAL CIE subscribed to UVR data through the NYUASTS DSS inter-USS network. UVR data is shared with IRIS UAS for display, and FRAIHMWORK for condition awareness. When CMP services publish a UVR (manual or automated) the CIE is responsible for communicating it to the external entities.
Data Simulation	The CAL CIE enables ingestion of simulated data into the CMP through translation of CAL M&S environment parameters. CAL leverages the Air Force AFSIM platform to simulate surveillance data, ownership telemetries, operational details including operation volumes, UVRs, UTM component data, and simulated fault conditions against CMP registered components and services.



Kongsberg Geospatial Services

Kongsberg Geospatial’s IRIS UAS is a comprehensive, real-time Airspace Management System, which provides operators with a clear picture of all manned and unmanned air traffic in the operational airspace. The application is intended for use in safely integrating unmanned systems into the airspace, assisting with deconfliction during emergency operations, disaster response, or monitoring system for non-cooperative traffic around critical operations or infrastructure.

This section describes the new IRIS UAS capabilities developed or existing IRIS UAS capabilities which were enhanced during this effort and which were released in the final CMP version delivered to CAL and used in the final NYUASTS/CMP system demonstration on March 9th, 2021. Detailed descriptions of all IRIS capabilities (including those existing prior to CMP participation) can be found in Appendix B: Kongsberg Geospatial Service Descriptions.

Table 5: Kongsberg Geospatial CMP Services & Capabilities

Service / Capability	Description
IRIS UAS and the ResilienX FRAIHMWORK Interfaces	An interface to accept UVR details was developed in the IRIS UAS application to facilitate the communication of geospatial coordinates and properties for later display.
UVR Visualization	The above developed UVR interface was used to supply data to a new IRIS UAS UVR visualization capability developed specifically for the CMP. These UAS Volume Restrictions are able to convey to operators who are impacted and allow for the evaluation of whether safe operation within or near the UVR bounds is possible.
IRIS and TWS Service Interfaces	An interface between TruWeather and their TruLiteUAS product was created to allow for the registration of our system to receive pertinent weather event data for a requested defined location.
Weather Alerting and Visualization	Because UAS platforms are very weather dependent, any uncertainty is a factor in the decision of whether planned flights may take place or must be cancelled. Using the newly refined alerting user interface provided by IRIS UAS, a capability to warn operators in near real-time using the received weather event data from TruWeather was delivered.
Interface/Integration between IRIS and CAL Integration Engine	An interface into the CAL Integration Engine was developed to facilitate the display of real-time telemetry data within the IRIS UAS system from UAS platforms.
NYUASTS Sensor Interfaces	Multiple ground-based sensors were interfaced to for the purpose of displaying PingStation ADS-B receiver for cooperative traffic, Eurocontrol ASTERIX CAT048 RADAR for non-cooperative traffic, weather sensors (via TruWeather), UAS telemetry (via CAL telemetry system).
ResilienX Web Card Interface for TMI Display	With all the capabilities provided by the ResilienX FRAIHMWORK with respect to liveliness and health monitoring, fault registration, network monitoring, etc., the display of this data as well as all flight data in real time and airspace and volume restrictions united within the IRIS UAS application was essential to ensuring operators had the capability to visualize all pertinent information in a single flexible and efficient integrated user interface.



ResilienX Services

ResilienX provided the FRAIHMWORK health & integrity monitoring software to the CMP product. This section describes the ResilienX capabilities developed during this effort and rolled into the final FRAIHMWORK version delivered to CAL and used in the final demonstration at the NY UAS Test Site. Note that some capabilities listed existed prior to the start of this effort but were updated or enhanced and are included for completeness. Detailed descriptions of these capabilities can be found in Appendix C: ResilienX Service Descriptions.

Table 6: ResilienX CMP Services & Capabilities

Service / Capability	Description
Component Management and Registration	Components can be pre-registered or registered through an API with the FRAIHMWORK. Once registered, components are monitored for liveness, can register faults, contribute to event logging, can be added to the blacklist, and are shown on the TMI Display.
Passive Component Health Monitoring	This service listens for self-reported faults reported from a registered component. These faults may be as a result of BIT failures or some other detection mechanism within a system. Passive monitoring issues reported will result in a fault being registered.
Fault Registration	Enables faults to be reported and registered with FRAIHMWORK. Faults are displayed on the TMI along with additional data that may be pre-configured about the fault. Registered faults may cause components to be added to the blacklist and may have mitigations assigned to them.
Data integrity Monitoring	Every message received is checked against a configured schema for validation. Validation checks currently include: <ul style="list-style-type: none"> • Data Completeness • Field Type • Bounds • Message Rate • Data Rate Change
Event Logging	Every event which occurs within FRAIHMWORK is logged. These logs are displayed on the TMI and can be analyzed offline for event reconstruction.
Liveness Monitoring	Registered components are monitored for liveness based on a configurable timeout threshold. If a message is not received within the threshold, a liveness fault is registered
Mitigation Registration	Mitigations can be registered to a specific fault. Registering a mitigation gives the user an option to deploy that mitigation when the associated fault is registered. Mitigations can be registered by 3 rd party systems as well as FRAIHMWORK services/plugins
Blocklisting Faulted Components	The blacklist is a list of systems that FRAIHMWORK has determined are failed, faulted, or are putting out bad idea. While not prescriptive, this list gives other ecosystem components the insight into systems they may want to treat as failed and stop processing data from.
UVR Generation	UVRs can be posted to FRAIHMWORK, which can then be queried or edited by users or by other systems. Once a UVR has been accepted, it can no longer be edited. “Auto-UVRs” can also be posted to FRAIHMWORK, which will create a ‘default’ UVR that will be triggered in response to a specific component reaching a FAULTED state.



Service / Capability	Description
Configuration Baselineing	Registered components report their version numbers to FRAIHMWORK. TMI Users can baseline or take a snapshot of the configuration of the registered ecosystem at any time. If version numbers change after a baseline is snapped, an indication is given so that the user can investigate the change or approve and set a new baseline.
Network Monitoring	Network endpoints can be configured to be periodically pinged by FRAIHMWORK to assess network latency and confirm that a component is available for contact. Currently limited to devices that can be directly reached by a cloud service.
Component Metric Tracking	Uptime, availability, and running time metrics are tracked for each component and displayed on the TMI, including options to reset percentages.
Tiered Maintenance Interface (TMI) Display	The TMI Display provided the visual interface into FRAIHMWORK and includes the following user interfaces: <ul style="list-style-type: none"> - System Health Situational Awareness - Event Log - Individual Component State and Status - Component Version Information - Fault Information - Available Mitigations - Uptime and Availability Metrics - Various Graphs - Liveliness Indication
Plugin Capability	The FRAIHMWORK architecture was re-designed to enable 3 rd party plugins as FRAIHMWORK services.

TWS Services

TruWeather Solutions (TWS) is a micro-weather data and analytics company that translates complex weather data and science into simple insights. TWS is striving to be a benchmark weather Supplemental Data Service Provider (SDSP) in support of NASA and FAA UTM Concept of Operations. TruWeather leads the ASTM F38 Weather SDSP Specifications Working Group to develop weather standards for the Unmanned Aerial System (UAS) industry that align with the overall FAA and NASA direction. TWS provides forecast and real-time weather information to support operational decisions for UAS Traffic Management Service Suppliers (USS), Drones-as-a-Service (DaaS) providers, UAS test ranges, ground control systems, drone manufacturers, dispatchers, and operators to specifically target and address UAS unique weather pain points and hazards. Our platform is agile, and our products reflect the emerging learning about weather impacts and needs to respond quickly with cutting-edge, innovative mission-enabling services.

The weather services that we provide are a ‘force multiplier’ as they enable a host of airspace management and operator workflows. It all starts with Operational Planning using our longer-range threshold-based products, giving the Operator the ability to find the windows of opportunity where they can safely conduct flight. Although the CMP is focused on supervisory actors, these services are integrated into the CMP for Flight Dispatch services for consideration of certification or special authorization if the platform is used to support mission commander roles as well in the near term. Table 7 identifies the specific services and capabilities TWS contributes to the CMP. Greater detail is offered in Appendix D.



Table 7: TWS CMP Services and Capabilities

Service / Capability	Description
Weather Data Tiles	TruWeather provides IRIS UAS with weather visualization tiles to be displayed on top of the IRIS GeoViewer. This includes real-time weather radar data, wind speeds, cloud ceiling data, reflectivity, and visibility data.
MissionCast	TruWeather returns a weather forecast spotlight chart for a specific point determined by the CMP End User. The CMP End User can select the target MissionCast area on the IRIS GeoViewer display, and the resulting chart appears in the TruWeather MissionCast web-card.
TruFlite Alert	The TruFlite Alert service receives observation weather thresholds volumes defined by the CMP End User, monitors the location or area for the requested time period, and returns alert volumes that exceed certain thresholds in that time period. Alert volumes are displayed within the IRIS GeoViewer, and detailed alert information is displayed through the built-in IRIS alerting UI.
RouteCast	RouteCast ingests a planned UAS route, provided by a CMP End User directly through a RouteCast web-card, and returns information regarding efficiency or risk along that route based on wind impacts.
METAR, G-AIRMET, SIGMET Services	TWS provides additional weather layer information for traditional aviation weather reporting formats, including METAR, G-AIRMET, and SIGMET.

AIS Services

AIS brings its Metaspense cyber security product to the CMP in support of monitoring the UTM ecosystem for cybersecurity issues. Metaspense is an incident response and remediation capability deployed widely across the Department of Defense (DoD) to detect and respond to sophisticated cyber-attacks and intrusions. It contains a wide variety of plugins for connecting to network endpoints (transports), gathering data potentially containing artifacts of compromise (collectors), and analysis capabilities (analyzers). In this effort, we tailored Metaspense to the UTM in two ways. First, we added an automation layer to enable Metaspense to regularly scan the UTM for cybersecurity issues or faults. Second, we extended and customized its plugin set to include an active vulnerability scanner component and a passive network intrusion detection component. Table 8 identifies the specific services and capabilities AIS Metaspense contributes to the CMP, greater detail is offered in Appendix E: AIS Service Descriptions.

Table 8: AIS CMP Services and Capabilities

Service / Capability	Description
Cyber Vulnerability Assessment	The Metaspense component of CMP (MSCMP) leverages the OpenVAS open-source vulnerability scanner to scan components of the UTM, including both local and remote systems, for software vulnerabilities that could provide attackers with an opportunity to breach the network or system. All vulnerabilities with an elevated level of criticality are reported to CMP via the FRAIHMWORK API as faults.



Service / Capability	Description
Active Cyber Threat Detection	<p>MSCMP scans the UTM for active cyber threats in two ways. First, it includes a component that wraps the Snort open-source intrusion detection system (IDS) to continuously analyze UTM network traffic for signs of attacks or compromised system. Second, MSCMP deploys collectors to UTM systems reachable on the LAN (e.g., in an operations center) to look for signs of malware in recent domain name system (DNS) lookups, current network connections, and Windows Registry locations often used for malware persistence. All critical findings are reported to the CMP via FRAIHMWORK as faults.</p>
Cyber Security Mitigation Recommendations	<p>MSCMP provides recommendations for mitigating registered cyber faults to the CMP. For vulnerability faults, the recommendation is to update or disable the identified vulnerable software. For active cyber threats, the recommendations provide the requisite data to enable a more thorough investigation and response by network security analysts. Future efforts are expected to enhance this capability to actively perform cyber mitigations whenever possible.</p>



Functional Testing

The CMP system level-requirements and associated capabilities were subject to functional tests and verification procedures to evaluate the platform’s overall effectiveness. Functional test procedures were developed to provide step-by-step instructions for exercising functionalities and identifying expected CMP behaviors. A total of 26 functional test procedure were generated and executed for verification of the 31 identified capabilities (Table 4) and 98 allocated requirements. Test procedure mapping is provided in Appendix F: Capability to Requirements Trace. Complete functional test procedures are captured within the CMP Functional Requirements Verification Procedures Document [7] submitted to KSN as supplemental Operational Data.

Functional test activities were executed iteratively throughout the CMP development phase to incrementally verify requirements as the platform evolved, as well as to aide in the development process. Functional testing was an invaluable tool for identifying and remediating platform integration and component issues. Regression tests were conducted following platform or component updates to validate changes and confirm requisite functionalities. Furthermore, the CMP system configuration was baselined prior to more formal test, evaluation, and demonstration activities to ensure validated capabilities would not be compromised.

Functional Test Results

At the conclusion of CMP functional testing against the developed test procedures, all test cases reached a ‘Pass’ state, with exception of one ‘Deferred’ test case associated to 4 CMP requirements. The Deferred test case was the one pertaining to UTM Ecosystem Network Monitoring. A summary of functional testing results can be seen in Table 9.

Table 9: Functional Test Result Summary

CMP Capability ID	Requirements Allocation	Test Case	Result
CMP-CAP-001	5.1.1, 5.2.22, 5.2.28	CAP-TST-001	PASS
CMP-CAP-002	5.1.3, 5.2.22, 5.2.28	CAP-TST-002	PASS
CMP-CAP-003	5.2.23, 5.2.24, 5.2.26	CAP-TST-001	PASS
CMP-CAP-004	5.2.23, 5.2.24, 5.2.32, 5.2.27	CAP-TST-002	PASS
CMP-CAP-005	5.2.29, 5.2.30, 5.2.31	CAP-TST-003	PASS
CMP-CAP-006	5.2.33	CAP-TST-003	PASS
CMP-CAP-007	5.1.4, 5.2.7, 5.2.8, 5.2.9, 5.2.11, 5.2.14	CAP-TST-004	PASS
CMP-CAP-008	5.1.5, 5.2.10	CAP-TST-005	PASS
CMP-CAP-009	5.1.6, 5.2.6	CAP-TST-006	PASS
CMP-CAP-010	5.1.7, 5.2.2	CAP-TST-007	PASS
CMP-CAP-011	5.1.8	CAP-TST-008	PASS
CMP-CAP-012	5.1.9, 5.2.52, 5.2.55, 5.2.53	CAP-TST-009	PASS
CMP-CAP-013	5.1.10	CAP-TST-010	PASS
CMP-CAP-014	5.1.10, 5.1.11, 5.1.12, 5.2.41 5.2.42, 5.2.43, 5.2.44, 5.2.46, 5.2.47	CAP-TST-011	PASS
CMP-CAP-015	5.1.15, 5.6.2, 5.6.3, 5.6.4	CAP-TST-012	PASS
CMP-CAP-016	5.1.15, 5.6.2, 5.6.3, 5.6.4	CAP-TST-013	PASS
CMP-CAP-017	5.1.17, 5.1.18, 5.1.19	CAP-TST-014	PASS



CMP Capability ID	Requirements Allocation	Test Case	Result
CMP-CAP-018	5.2.1, 5.2.3, 5.2.4, 5.2.5, 5.2.12, 5.2.13 5.2.18, 5.2.25, 5.2.28	CAP-TST-015	PASS
CMP-CAP-019	5.2.15, 5.2.16	CAP-TST-011	PASS
CMP-CAP-020	5.2.19, 5.2.20, 5.2.21	CAP-TST-016	PASS
CMP-CAP-021	5.2.37	CAP-TST-017	PASS
CMP-CAP-022	5.1.13, 5.2.38, 5.2.39, 5.2.40, 5.2.45, 5.3.2, 5.3.3, 5.3.4	CAP-TST-018	PASS
CMP-CAP-023	5.2.48, 5.2.49	CAP-TST-019	PASS
CMP-CAP-024	5.2.51, 5.2.50	CAP-TST-019	PASS
CMP-CAP-025	5.2.54, 5.2.56, 5.2.57, 5.4.1, 5.4.2, 5.4.3, 5.4.4, 5.4.5	CAP-TST-020	PASS
CMP-CAP-026	5.3.1	CAP-TST-021	PASS
CMP-CAP-027	5.1.14, 5.3.5, 5.3.6, 5.3.7	N/A	DEFERED
CMP-CAP-028	5.5.1, 5.5.2, 5.5.3, 5.5.4	CAP-TST-023	PASS
CMP-CAP-029	5.5.5	CAP-TST-024	PASS
CMP-CAP-030	5.6.1	CAP-TST-025	PASS
CMP-CAP-031	5.2.17	CAP-TST-026	PASS

Deferred Requirements

A total of 4 CMP requirements were deferred at the end of our functional test activities. These requirements pertained to UTM Network Monitoring functionalities. Those specific requirements are:

5.1.14 Simple Network Management Protocol (SNMP) Data Input

The CMP shall ingest SNMP data as an input.

5.3.5 Condition Reporting –Degraded Network

The CMP shall report a condition if degraded network performance is detected.

5.3.6 Network Health Monitoring

The CMP shall monitor the performance of the network on which it is running.

5.3.7 Networking Equipment Health Monitoring

The CMP shall monitor the health of available networking equipment.

There were a few reasons for deferring these requirements. Firstly, the NYUASTS UTM networking components were encompassed by the test site’s NASA ATO, therefore we did not want to attempt any integrations that may compromise that environment. Our team had considered ‘agentless’ means to monitor and assess network health but did not feel UTM networking environments are common enough to invest in those capabilities yet. Lastly, our team has not reached consensus as to whether network monitoring functionalities should fall under the purview of Health & Integrity Monitoring or the Cyber Security domain.

Although these requirements were deferred from the FAA BAA iteration of the CMP, they remain valid and will be pursued through further CMP development efforts.



Capabilities Demonstration

As the culmination of the CMP development effort conducted under this FDAA BAA initiative, CAL and our partners coordinated with NUAIR and the NYUASTS to conduct a live flight demonstration. This demonstration included the execution of 4 contingency scenarios to demonstrate the primary features and capabilities of the platform. High-level descriptions of these scenarios are provided in Table 10.

Table 10: CMP Live Flight Demonstration Scenarios

Scenario #	Description
1 – Automated UVR	A radar failure occurs (against a simulated radar component) which triggers FRAIHMWORK to recommend an automated UVR. The UTM Airspace Supervisor accepts the UVR. Conflicting live and simulated UAS operations respond accordingly.
2 – Manual UVR	A weather alert is simulated and displayed on the CMP. The UTM Airspace Supervisor translates the weather alert information into a manually generated UVR. The UVR is published, and conflicting live and simulated UAS operations respond accordingly.
3 – General Features / Cyber Event	Demonstration of several features of the platform interface, including ownship flagging and following, terrain proximity visualizations, surveillance data visualization. At the end of this scenario a simulated Cyber Security vulnerability causes AIS Metasponse to issue a fault against a pilot GCS, thus driving the pilot to land their aircraft.
4 – Non-Conforming Op	A simulated UTM operation exits their approved operational volume becoming ‘Contingent.’ The UTM Airspace Supervisor issues a general area UVR to convey the rogue aircraft to operators, including a live operation. While the live operation proceeds to land, CMP conflict alerts inform the UTM Supervisor or aircraft proximities to one another.

These live flight tests were conducted between 3/8/2021 and 3/9/2021 at the NYUASTS at Griffiss International Airport in Rome NY. All scenarios were streamed via CMP screenshare on Microsoft Teams to an FAA audience. A full mission brief with scenario logistics is provided in Appendix G: Live Flight Mission Brief. Video recordings of all scenarios are also available upon request.



Analyses Conducted

Several research and analysis activities were conducted in support of both CMP development activities and CMP functional, performance, and usability evaluations.

Weather Hazards Analysis

TruWeather Solutions conducted a study to 1) identify the weather observation capabilities within the NYUASTS UTM Corridor boundary, and 2) identify primary weather hazards and risks pertaining to potentially lacking observation capabilities. The results of this analysis are provided in Appendix H: UTM Weather Hazards Analysis

UTM Data Structures Analysis

Considerable effort went into determination of internal and external CMP interfaces and supported data formats. Our team evaluated the current ASTM UTM APIs that were being implemented on UPP2, to determine supportability requirements on behalf of individual CMP requirements, but also to assess their overall suitability towards UTM ecosystem safety and reliability. To the latter effect, CAL Analytics leveraged our experience with NASA Technical Capability Level 4 (TCL4) data structures to identify areas in which the ASTM interfaces were less complete, dynamic, or extensive. ASTM UTM and NASA TCL4 data structure tables are provided in Appendix I: UTM Data Structures Comparison.

UAS Weather Risk Mitigation Analysis

TruWeather Solutions conducted a research activity that focused on identifying weather conditions pertinent to UAS performance and operational safety, and how such information should be conveyed to operators via UTM weather alerts. This study is provided in Appendix J: Weather Risk Mitigation Analysis.

CMP Cognitive Walkthroughs

CMP partners have been participating in the conduct of cognitive walkthrough meetings with UTM industry stakeholders and ATM subject matter experts to aide in evaluation of the current CMP capabilities and identify areas for new or enhanced features. These efforts have been conducted on a cost-shared program funded by the Ohio Federal Research Network (OFRN), focused on operationalizing, and scaling the ODOT UTM corridor in central Ohio. These cognitive walkthroughs aim to place participants in the driver's seat of the CMP to observe and respond to a variety of contingency scenarios. A condensed summary of these scenarios is provided in Appendix K: CMP Cognitive Walkthroughs and was briefed to FAA personnel in February 2021.



Research Findings

Table 11 summarizes the key observations and findings made throughout execution of CMP development, test, and evaluation. These findings primarily address constraints or limitations of current UTM constructs which potentially hinder not only CMP capabilities but other UTM services providers at large. Findings are further elaborated on in this section.

Table 11: CMP Project Observations and Findings

ID	TITLE	DESCRIPTION	SIGNIFICANCE / RECCOMENDATIONS
F-01	UTM Constraint Limitations	The singular system constraint available to influence UTM operator behavior is the UAS Volume Reservation (UVR). This data structure is not dynamic enough to address all hazard conditions per its current definition (ASTM UTM Interfaces).	Although the CMP can detect a variety of hazard conditions, response to each currently relies on the same mechanism – UVRs. UVR definitions need to be expanded to capture their reason for issuance, and detail expectations of compliance. Alternatively, new data structures should be developed to specifically address different hazard types, e.g., weather alerts.
F-02	Operational Detail Limitations	Current data communicated between USSs regarding operational or mission details is not sufficient for supervisory users to evaluate operator compliance against dynamic airspace and system conditions.	Supervisory operators should know the type of aircraft being flown and potentially its performance capabilities to evaluate appropriate response against hazard conditions.
F-03	Telemetry Sharing Limitations	The ASTM UTM Interfaces currently only support telemetry sharing for operations in Non-Conformant or Contingent states. Alternatively, authorized providers may support Remote ID displays, but Remote ID has not been implemented in a standardized form yet.	Operator privacy concerns appear to be superseding safety considerations in the UTM space. CAL suggests telemetry for all UTM participants should be openly shared with authenticated users and service providers. At a minimum, supervisory SA providers such as the CMP should be allowed unrestricted telemetry.
F-04	Lack of Active UTM Networks	Although an ASTM compliant DSS was leveraged at multiple test sites for UPP2, test sites and the FAA are not persistently operating these assets.	UTM Deployment Authorities need to stand up persistent DSS capabilities to ease integration and enable a representative service environment for testing and operationalization. If such DSS will include FIMS Authorization/Authentication services, the FAA should make those available as well to issue and authenticate DSS credentials.



ID	TITLE	DESCRIPTION	SIGNIFICANCE / RECCOMENDATIONS
F-05	UTM Data Access Equality	The current ASTM UTM interfaces assume USSs are the gateway for UTM data for SDSPs, or other non-USS providers such as the CMP. This gives USS a potentially unfair competitive advantage over other industry players and presents a potentially inefficient communication scheme that complicates service provider integration.	All authenticated service providers should be allowed equal access to UTM operational data. If interfaces evolve to include more potentially sensitive data, then service providers should be subject to certification against specific classes with defined data access permissions. SDSPs may still integrate directly with specific USS providers, but based upon a business case not a regulatory requirement.
F-06	Health & Integrity Data Availability	Current UTM components and services are not required to provide anything more than operational data. Additional requirements need to be established to also publish health & integrity related data to assure performance of all ecosystem elements.	FRAIHMWORK Health & Integrity APIs assume that UTM ecosystem participants have a responsibility to provide assurance of their operational capability and configuration in real time. These APIs should be pushed out to industry for evaluation and adoption.

F-01: UTM Constraint Limitations

The only UTM behavior influencing mechanism available within the ASTM DSS/Inter-USS interfaces currently is an Unmanned Volume Reservation (UVR). UVRs support clearing specified airspace of UTM operations for a specific duration of time. This is a useful design pattern for keeping all UAS out of an airspace in scenarios accommodating external emergencies such as medivac operations. However, as defined, the ASTM UVRs do not provide enough contextual information as to why a UVR was published to incite nuanced responses of aircraft and operators performing different missions under different authorizations. Possible UVR enhancements include:

- Issuing UVRs against specific operation priorities (TCL4 construct)
- Issuing UVRs against specific UTM Operations (TCL4 construct)
- Issuing UVRs against specific operating guidelines or COAs
- Including UVR contextual information in definition
 - Rogue Aircraft
 - Weather Alerts
 - UTM Service Degradation

Regarding the last enhancement, a possibly superior alternative to leveraging UVRs to convey information pertaining to various hazard conditions would be to instead develop new UTM airspace definitions for different conditions. That is, UVRs should be used to clear airspace – as currently intended. But new airspaces should be used to convey conditional information which different operators may respond to uniquely. If for example



a weather alert were a defined UTM data structure, it could convey wind alerts at various thresholds. High performance UAS may be able to safely travel through wind alert areas that lower performance aircraft could not.

F-02: Operational Detail Limitations

For UTM Supervisor roles to be conducted effectively, they will require additional details pertaining to each UTM operation in order to assess if operators and aircraft are responding appropriately to the current airspace conditions. Possible enhancements to ASTM UTM Operation definitions include:

- Aircraft Type/Class Identification – May be encompassed in Aircraft Registration and associated ID
 - Fixed-Wing
 - Multi-Rotor
- Operation Mission Criteria - Identifies operational capacity for dynamic rerouting
 - Path Critical (Survey Operations)
 - Point Critical (Delivery Operations)
- Aircraft performance capabilities
- Operating rules / COA identification
- Flight plan geometry sharing

F-03: Telemetry Sharing Limitations

The current ASTM Inter-USS APIs only support telemetry sharing under two conditions, 1) when a UTM operation enters a Non-Conformant or Contingent State or 2) if telemetry is requested by an authorized Remote ID display provider.

Although the CMP likely has the appropriate system CONOPS to pursue being a Remote ID display provider, the process and certification guidelines for doing so currently do not exist. Furthermore, although the FAA has issued a Notice of Proposed Rule Making (NPRM) regarding Remote ID, no compliant implementation has been operationalized to date, i.e., there is no remote ID data to currently subscribe to. Beyond this issue, CAL and our partners feel that open telemetry sharing, void of Personally Identifiable Information (PII) reserved for Remote ID, should be standard across UTM. It is our opinion that the needs of safety should supersede privacy, and that telemetry sharing in and of itself is not an infringement on privacy any more than General Aviation ADS-B data is – ADS-B data can be viewed by anyone with a commercial receiver or through data sharing providers such as FlightRadar24.



F-04: Lack of Active UTM Networks

To date, representative UTM environments have only truly been stood up in small, controlled, experimental conditions. NASA TCL4 and the FAA UPP2 initiatives have allowed a select group of industry members the ability to participate and test in inter-service network environments. It is understood that there are appropriate reasons for exclusivity as foundational architecture and communications protocols are solidified. Our team, however, feels that there is now sufficient clarity around enough elements of UTM – largely due to the ASTM inter-USS specifications – that industry members at large should be able to operate and test in representative environments. This means establishment of persistent DSS and service networks, presumably hosted by FAA designated test sites, to allow for more realistic test environments and maturation of UTM products.

Our team had hoped to leverage the NYUASTS UPP2 DSS and inter-USS network as part of our live flight test demonstrations. Although we did conduct integration testing on this network, ingesting operational data from live USSs, the environment was no longer available to support live testing under this FAA BAA effort. To work around this, we simulated operation details and operational volumes that would have otherwise come from USS providers. We also mirrored telemetry to our platform from a live ground control station as opposed subscribing to associated USSs.

F-05: UTM Data Access Equality

Although the CMP may share some functional similarities with USSs, it is also significantly different. The CMP does not support flight plan creation or submission, nor is it intended in its current iteration to be a pilot facing platform. The CMP does however require access to almost all the same UTM data that USSs do. Access to this data within the current NASA UTM architecture and per FAA regulated DSSs such as those exercised in UPP2 is currently questionable. Per the NASA UTM architecture operational data can only be accessed by non-USS service providers (currently overly categorized as SDSPs), through USS integration. Furthermore, the DSS and FIMS authorization server leveraged for UPP2 assumed USS specific capabilities for certification. Although our team was able to circumvent the latter through coordination with the UPP2 program office, both conditions set a potentially limiting precedent for non-USS UTM technology and solution providers.

F-06: Health & Integrity Data Availability

While some UTM components such as surveillance sensors do report health & integrity relevant information as part of their native outputs, software-based services operating in UTM offer no such details. To exercise CMP capabilities, surveillance sensor data was translated to comply with FRAIHMWORK health & integrity APIs. ASTERIX data does provide some relevant data to this effect although limited. Complete component state, status, mode, configuration details are not all present. Furthermore, USS and SDSPs have no requirements to publish this information to the UTM environment, although they may be functionally vetted prior to certification. If UTM is going to be fully self-regulated in the future, real-time health and integrity data needed to be communicated throughout the UTM environment to at least a delegated authority such as the CMP, if not openly to all service provider peers.

Lessons Learned

This section identifies lessons learned specific to the execution of this project and development of the CMP, as opposed to broad UTM concepts reflected in our findings.

Kanban Board

Our distributed team found the use of a Kanban board to be very useful in the identification, resolution, and tracking of integration and test issues and platform enhancements. We utilized Trello, a web-based Kanban boards which allowed us to configure it for our project specific needs. CAL refined our problem tracking process over time by implementing a standard workflow to include steps for assigning problems to team members, and a status area to ensure validation prior to problem ticket closure. Problems were reviewed for updated status at every bi-weekly IPT meeting.

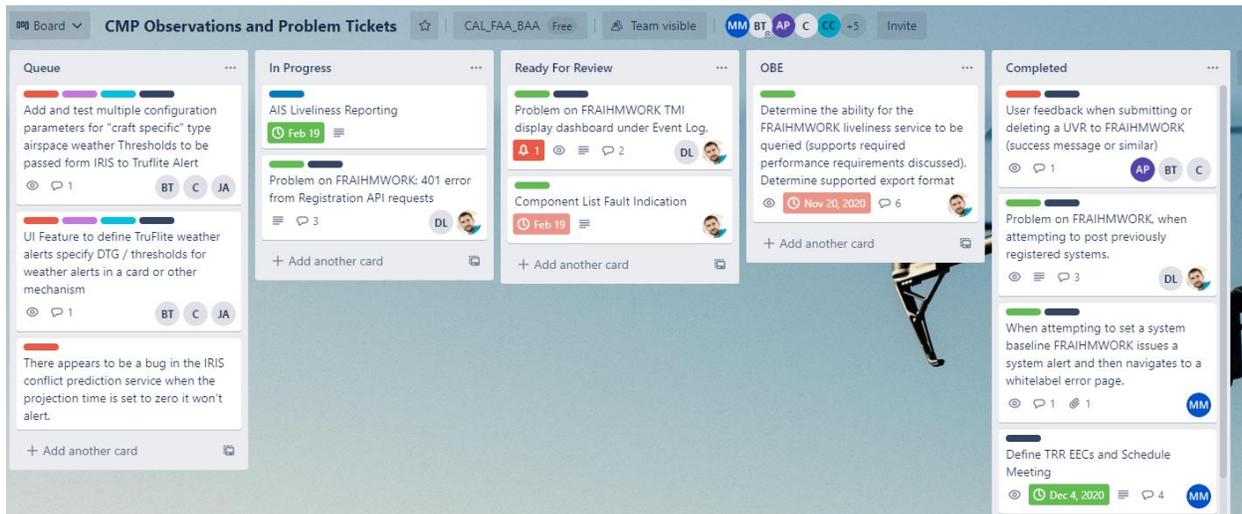


Figure 11: CMP FAA BAA Kanban Board

Multiple Instances on Same Network

One of the most significant technical lessons learned encountered by the team did not come until our live flight testing dry-run activity. Prior to this even all partners had been running independent instances of the CMP on their local machines and networks for various test purposes. Upon preparing for operations at the NYUASTS, multiple instances of our platform ended up running on the same network. This caused issues due to echoing duplicate information across the IRIS UAS DSS and unexpected information due to different configurations of specific instances. This issue was quickly troubleshot by Kongsberg Geospatial, and we only ran one instance of the platform for the remainder of testing. In an operational setting it is assumed only one instance of the CMP would be required per regional environment and thus this issue should not be a factor in the future. Ideally the CMP will also implement user profiles and permissions to allow multiple users to interact with a single instance.



UTM Recommendations

This section provides CMP team recommendations to support the furtherment of UTM operationalization, of which can be both enable by and a benefit to the developed CMP. These recommendations are pursuant with our research findings.

Expanding UTM Airspace Definitions

Our research suggests that current UTM airspace data structures, namely UVRs and Operational Volumes, are insufficient to address nuanced mitigation needs in a scaled environment. UVR definitions should be expanded to be more dynamic, incorporating the reason for issuance and permitting of specific operation or aircraft use. Operational Volumes and associate operational details should be expanded to capture aircraft and operation classes for alignment with suggested UVR updates. Lastly, new data structures are suggested to convey advisory type information to UTM operators. UVRs should be used for blanket system airspace restrictions, but a UTM Advisory class airspace should be created to allow for pilot interpretation on an operation-by-operation basis, e.g., weather advisories.

Open Telemetry Sharing

UTM telemetry should be openly shared across UTM participants. Restricting operational visibility to general operational volumes inherently limits UTM Supervisor abilities to predict potential issues or conflicts. This is further compounded by the current disparity among USSs regarding how operational volumes are defined, what margins are used, and how Non-Conformant state changes are executed. Until the reliability of USSs to effectively and uniformly implement strategic deconfliction, conformance monitoring, and dynamic rerouting is thoroughly proven, UTM Deployment Authorities will have a need for human in the loop oversight of the conduct of operations.

The obvious counter argument to this recommendation is for the protection of privacy of operators. Although our team does not feel this need should supersede safety considerations, privacy can still be protected through implementation of certain controls. UTM participants should be registered or onboarded with UTM environments to allow them to operate and leverage associated services including telemetry sharing. And of course, PII information can be obfuscated from telemetry data – UTM participants do not need to know what specific aircraft are operating nearby, or who is operating them, only that there are other active operations presenting potential for conflict.

Persistent Test Environments

Although the FAA is certainly working on UPP2 follow on activities to further the lessons learned from those activities, our team suggests that resultant UPP2 test assets be made available for broader industry test and evaluation. In particular, this would mean the prototype FIMS Authorization Server, and associated DSS/Inter-USS networks the FIMS credentials service providers to connect with. It would make sense to have these assets accessible at some or all the FAA designated USS test sites, including the NYUASTS. Operating these sandbox environments would require very little FAA oversight, with the primary need simply being issuing of new credentials for service providers. Interested parties who leverage the test assets would be able to provide the FAA with insights and recommendations for improvements or enhancements.



UTM Architecture Considerations

CAL Analytics believes that USS have potentially absorbed too many functional responsibilities and present a possible bottle neck in the current NASA UTM architecture. Although the first responsibility of a USS per the FAA UTM CONOPS is "...[to act] as a communications bridge between federated UTM actors to support Operators' abilities to meet the regulatory and operational requirements for UAS operations..." not all USS support the data types that all current and developing SDSPs want to provide. Although SDSPs can and have integrated with specific USS to use them as a vehicle to provide their services to users, it comes at a cost and necessitates an agreeable business case between the two parties. USS may be communication bridges but there is a toll.

The UTM industry should focus more on a service-based, data-driven architecture wherein the whole ecosystem supports publication of and subscription to well defined data types. A weather service for example should not have to choose a USS platform to integrate with, but rather be able to publish weather data to the UTM environment in a common format for any USS to subscribe to, driven by request of an operator. Ultimately, our recommendation is to allow SDSP or non-USS service providers greater ability to openly provide and ingest UTM operational data. This can be accomplished by opening up DSS access to additional service providers beyond USS. "Inter-USS" networks should become "Inter-Service" networks.

Reliability Assurance Data

Regarding UTM component Health & Integrity (H&I), as well as cyber security posture, the CMP is currently acting as a compliance mechanism. Through this effort our team has established what H&I data we would like UTM components to report and have translated or adapted native component data to comply with those interfaces to the extent possible. Similarly, we have implemented specific cyber security scans to execute on accessible networked equipment, and we execute those scans through the CMP. However, these implementations have issues at scale:

- OEM infrastructure components and developing UTM services likely do not report all requisite H&I information expected by our APIs
- It is not likely that a centralized cyber security monitoring element will be allowed sufficient access to conduct scans across all federated UTM elements

Based on these considerations, we suggest that the UTM industry focus more on H&I and Cyber Security assurance as opposed to compliance. This means that the CMP can still be the aggregator of such information, but not the sole source. All connected UTM components and services should comply with published H&I data outputs and report result of self-conducted cyber security scans, meeting industry wide guidelines.



Standards Support

To forward our team’s perspectives regarding UTM industry recommendations, CAL Analytics directly supports the following standards developing committees related to UTM:

- ASTM F38.02, UAS Traffic Management (UTM) UAS Service Supplier (USS) Interoperability (WK63418)
- ASTM F38.01, Surveillance UTM Supplemental Data Service Provider (SDSP) Performance (WK69690)
- RTCA SC-228, Minimum Performance Standards for Unmanned Aircraft Systems

CAL Analytics also monitors the activities of the following organizations for outputs pertinent to UTM:

- FAA
- NASA
- Global UTM Association (GUTMA)
- International Civil Aviation Organization (ICAO)
- Single European Sky ATM Research (SESAR)
- Concept of Operations for European Unmanned Traffic Management Systems (CORUS)
- Joint Authorities for Rulemaking on Unmanned Systems (JARUS)
- European Organization for Civil Aviation Equipment (EUROCAE)



Research Gaps for Future Efforts

There is ample room for improvement of the CMP and of the environment our team intends it to operate in. This section identifies areas in which future effort should be expended to help refine UTM ecosystem definitions and constructs as well as enhance the CMP platform.

Weather Condition to Aircraft Class Mapping

During the capabilities demonstration, our team notionally issued a “Category X Wind Advisory” under the premise that UAS of different performance capabilities would respond to weather alerts of various thresholds differently. Although this concept is not novel to UTM, it has not received sufficient attention for standardized implementation. Firstly, the UTM industry needs to assign weather-related performance capabilities to UAS in a classed structure. Secondly, weather thresholds for various conditions such as wind speed, temperature, and precipitation need to be categorized for mapping to UTM aircraft classes.

UTM Supervisor Human Factors Analyses

The CMP is a product which has been designed for a user, the UTM Airspace Supervisor, that does not currently exist in a persistent capacity. Given this there is some difficulty in identifying and prioritizing the CMP features which would be of most use to this actor. To date, the CMP team has relied on traditional ATM SMEs and ex-air traffic controllers assuming there will be significant correlations between the roles. Although this assumption is likely valid, there will undoubtedly be functional and operational differences between ATM and an operationalized UTM. Considerable research should be conducted to better define how UTM OPCENs – whether physical or virtual – will be managed and utilized by respective actors such as the proposed UTM Airspace Supervisors.

New CMP Services & Features

As all contributing CMP partner make enhancements to their products for incorporation of new services and features, there will be opportunities for rolling those updates into the platform. Identified potential updates include:

- CMP user profiles and login (Kongsberg)
- Emergency Operation Support Features (Kongsberg)
 - See Appendix B: Kongsberg Geospatial Service Descriptions for more information
- Automated Messaging of Contingency Alerts to CMP users and/or UTM operations (ResilienX)
- Risk Assessment Service Integration (ResilienX)
 - See Appendix C: ResilienX Service Descriptions for more information
- C2 Monitoring and Assessment Services (ResilienX)
 - See Appendix C: ResilienX Service Descriptions for more information
- UI Accessible Weather Alert Threshold Configurations (Kongsberg / TWS)
- DAA as a Service Integration – ACAS-sXu based (CAL)
- System Impact Service – Maps contingency conditions to functional impacts (CAL)
- Operational impact Service – Maps functional degradation to operational impacts (CAL)
- Standardized Cyber Security Assurance Interfaces (AIS)
- New cyber security scan capabilities (AIS)



References

Raju, Rios, Jordan (April 2018.) UTM – A Complimentary Set of Services to ATM. Retrieved from National Aeronautics and Space Administration: <https://utm.arc.nasa.gov/docs/2018-Raju-ICNS-Apr.pdf>

Whitley (2020). UTM Concept of Operations v2.0. Federal Aviation Administration.

ASTM UTM APIs, Version 0.3.11

<https://redocly.github.io/redoc/?url=https://raw.githubusercontent.com/astm-utm/Protocol/master/utm.yaml>



Appendix A: CAL Analytics Service Descriptions

Appendix Prepared by
CAL Analytics



CAL Analytics’ primary technology contribution to the CMP is a suite of tools and services collectively referred to as the CAL Integration Engine (CIE) – although moving forward CAL will be rebranding this package as the CAL Universal Information Exchange (UIE). This software package supports the collection, translation, and distribution of requisite data across CMP partner services.

Surveillance Data

Live radar and ADS-B receiver data is forwarded to CAL from the NUYASTS (we also have common integrations with the ODOT UTM environment). This data is then made available for CMP services to subscribe to over a UDP Redis message broker channel.

AWS Server IP:Port	Surveillance Type/Name/Loc	Redis Channel
faabaa.calanalytics.com:16720	Gryphon - Cicero	udp.repeater:16720
faabaa.calanalytics.com:16721	Gryphon - GIA	udp.repeater:16721
faabaa.calanalytics.com:16722	Gryphon - Lakeport	udp.repeater:16722
faabaa.calanalytics.com:16723	Gryphon - Lee	udp.repeater:16723
faabaa.calanalytics.com:16724	Gryphon - Liverpool	udp.repeater:16724
faabaa.calanalytics.com:16725	Gryphon - Oriskany	udp.repeater:16725
faabaa.calanalytics.com:16726	Gryphon - Verona	udp.repeater:16726
faabaa.calanalytics.com:16727	Gryphon - Viena	udp.repeater:16727
faabaa.calanalytics.com:16728	Gryphon - Wampsville	udp.repeater:16728
faabaa.calanalytics.com:16729	SAAB MLAT	udp.repeater:16729
faabaa.calanalytics.com:16732	SRC LSTAR	udp.repeater:16732
faabaa.calanalytics.com:16733	PingStation - Cicero	udp.repeater:16733
faabaa.calanalytics.com:16734	PingStation - GIA	udp.repeater:16734
faabaa.calanalytics.com:16735	PingStation - Lakeport	udp.repeater:16735
faabaa.calanalytics.com:16736	PingStation - Lee	udp.repeater:16736
faabaa.calanalytics.com:16737	PingStation - Liverpool	udp.repeater:16737
faabaa.calanalytics.com:16738	PingStation - MOC	udp.repeater:16738
faabaa.calanalytics.com:16739	PingStation - Oriskany	udp.repeater:16739
faabaa.calanalytics.com:16740	PingStation - TACAN	udp.repeater:16740
faabaa.calanalytics.com:16741	PingStation - Verona	udp.repeater:16741
faabaa.calanalytics.com:16742	PingStation - Viena	udp.repeater:16742
faabaa.calanalytics.com:16743	PingStation - Wampsville	udp.repeater:16743
faabaa.calanalytics.com:16744	PingStation - West Hanger Roof	udp.repeater:16744

Figure A-1: CAL Surveillance Data Redis Channels



Telemetry Data

UTM participant telemetry data is collected by the CIE in two methods. If a DSS is being utilized standard ASTM API calls are used:

```
GET /uss/v1/operations/{entityid}/telemetry
```

If no DSS is used, then MAVLINK formatted telemetry can be mirrored directly from a GCS to a CIE port:

- Hostname/ip: `faabaa.calanalytics.com`
- Port: `16770`

Under both conditions, telemetry is then translated into a native IRIS format for display. IRIS can support MAVLINK data natively, but not in the build leveraged in the current iteration of the CMP.

Health & Integrity Data Translation

The CAL CIE maps native surveillance sensor target report fields to relevant FRAIMWORK APIs for status and display. This currently includes parsing ASTERIX CAT 048 data for radars and JSON data from ADS-B receivers.

DSS Connectivity

The CAL CIE was granted use of UPP2 DSS credentials to access UTM operational data. Only one service of the CMP was granted access as to minimize integration complexities and redundancy. This interface complied with the ASTM DSS APIs.

<https://redocly.github.io/redoc/?url=https://raw.githubusercontent.com/astm-utm/Protocol/master/utm.yaml>

UTM Operational Data

Operational data is source from DSS when connected, leveraging standard ASTM API calls:

```
GET /dss/v1/operation_references/{entityid} Retrieve the specified Operation reference from the DSS.
```

```
GET /uss/v1/operations/{entityid} Retrieve the specified Operation details from a USS.
```

UTM operational data including operational details and volumes can also be simulated by CAL.



UTM Constraint (UVR) Data

UVR constraint information is both collected from and published to a DSS when connected using standard ASTM API calls:

POST	<code>/dss/v1/constraint_references/query</code>	Retrieve all Constraints references in the specified area/volume from the DSS.
GET	<code>/dss/v1/constraint_references/{entityid}</code>	Retrieve the specified Constraint reference from the DSS.
PUT	<code>/dss/v1/constraint_references/{entityid}</code>	Create the specified Constraint reference in the DSS.

Modeling & Simulation

CAL Analytics can model and simulate many UTM elements for testing through use of AFSIM. In this environment CAL can simulate:

- UTM Operational Details
- Operational Volumes
- Aircraft Telemetry
- Radar Targets
- ADS-B Targets
- Simulated UTM Components
- UTM Component Failures

All simulated elements are formatted to CMP internal data formats for seamless integration. Since the CIE is the gateway for CMP services to access this data regardless, other CMP services process real and simulated elements in the same manner.

Appendix B: Kongsberg Geospatial Service Descriptions

Appendix Prepared by
Kongsberg Geospatial



KONGSBERG

IRIS UAS Description

IRIS UAS is a comprehensive, real-time Airspace Management System, which provides operators with a clear picture of all manned and unmanned air traffic in the operational airspace. The application is intended for use safely integrating unmanned systems into the airspace during emergency operations and disaster response, or as an airspace monitoring system for counter-UAS operations around critical infrastructure.

The IRIS UAS product can also be used for control and guidance, providing Unmanned Systems (UAS, UUV, USV) operators, with the necessary situational awareness to safely operate Beyond Visual Line-of-Sight (BVLOS). The platform presents users with 2D and 3D map and terrain data, aeronautical information such as aerodrome locations, obstacles and airspace, and real-time data from data feeds, sensors, cameras, and weather sources - all integrated within a single, common operating picture display that's easy to use, and customizable on a per-mission basis.

IRIS is a combination of software and sensor technology that gives operators a precise real-time picture of their operational airspace when piloting one or more unmanned vehicles beyond visual line-of-sight (BVLOS).

The IRIS UAS system functions as full-featured Fleet Control Station, providing operators with a real time, comprehensive picture of their mission airspace, as well as the capacity to directly control multiple UAS with an integrated autopilot of your choice.

The IRIS UAS system greatly enhances the situational awareness of UAS operators in BVLOS operations by presenting a single situational awareness display that aggregates a broad array of external and ownship information sources that are not normally available or presented to a UAS operator by typical Ground Control Station (GCS) displays. The IRIS display is ideal for fleet operations, since it makes it easy to track and control multiple ownship UAS.

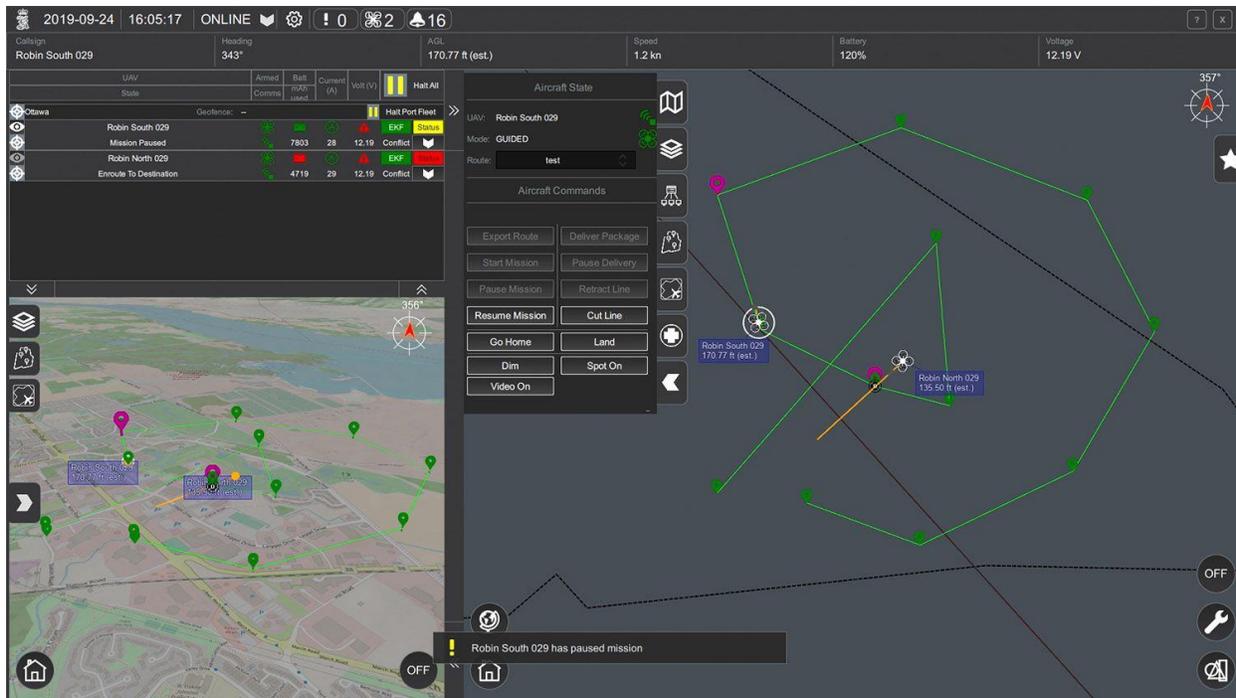


Figure B-1: IRIS UAS Interface

[In addition to providing a clear picture of the airspace, IRIS UAS is optimized for managing multiple semi-autonomous UAS.](#)

A Common Operating Picture for BVLOS Operations

IRIS UAS also provides airspace visualization which equips Unmanned Systems (UAS) operators with real-time situational awareness for BVLOS operations in an integrated UTM (Unmanned Traffic Management) airspace.

The system is also integrated with near-time ATM / UTM data sources including the Harris® National ATM feed and LATAS®.

As the Commercial UAS sector matures, the prospect of conducting BVLOS in an integrated UTM airspace is becoming more immediate.

Some commercial enterprises in North America are already conducting BVLOS operations under FAA waivers. The need to effectively visualize all air traffic and navigations in an operational airspace is becoming increasingly acute, and will continue to do so as the volume of unmanned traffic increases.

IRIS UAS is optimized as an edge monitoring display for restricted airspaces – fusing near-time ATM / UTM traffic data with real-time RADAR, ADS-B, and telemetry data. The IRIS UAS system is also fully integrated with a wide range of autopilots, allowing direct control of a wide range of fixed-wing and rotary wing UAS directly from the IRIS console. The IRIS UAS airspace awareness is built around an innovative, customizable touch-driven user interface that allows operators to easily visualize and manage multiple data feeds.

How IRIS UAS Works

The IRIS UAS system comprises a software engine connected to a Data Distribution Service (DDS) bus. The software engine accepts real-time updates from a variety of sensor inputs and performs target fusion between multiple dissimilar sensor types. The resulting airspace picture is layered over the terrain and environment and displayed in real-time, using Kongsberg Geospatial’s TerraLens® geospatial engine.

IRIS UAS supports integration with a variety of sensor types and data feeds out of the box, including RADAR, ADS-B, and GPS receivers. Additional sensor support can readily be added via the DDS bus.

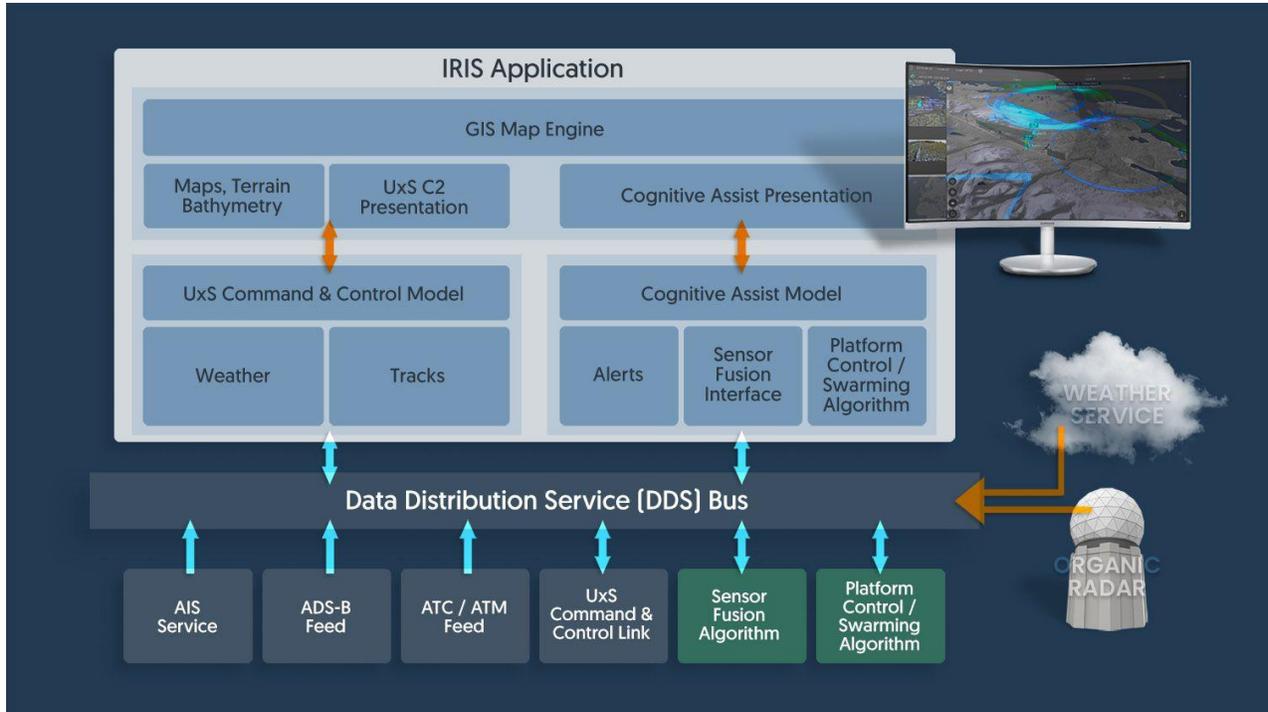


Figure B-2: IRIS UAS DDS Architecture

[IRIS UAS supports integration with a variety of sensor types and data feeds out of the box. Additional sensors can be added via the DDS bus.](#)

Multi-Domain Capabilities

While IRIS UAS is most frequently used for managing Airspaces, or specific UAS missions, it is a multi-domain-capable system, and can be used to pilot any combination of aerial, surface, and underwater vehicles. The system can also present operators with a picture displaying marine navigational data, or a bathymetric picture of the underwater environment.

A specialized version of IRIS UAS called [MEDUSA](#) has been developed for naval, military, and homeland security missions, and IRIS UAS can be adapted to particular mission needs and domain environment.



Critical Infrastructure and Emergency Airspace Management

IRIS UAS serves as a comprehensive, real-time Airspace Management System, which provides operators with a clear picture of all manned and unmanned air traffic in the operational airspace and can help safely integrating unmanned systems into the airspaces, especially during emergency operations and disaster response.

For example, IRIS UAS is deployed by first responders and security organizations for integrated emergency operations that require the safe operation of UAS in the same airspace as manned aircraft, and by security organizations that need to manage the airspace and prevent intrusions by non-cooperative or even hostile UAS around critical infrastructure, including prisons, airports, and sports stadiums.

IRIS UAS has even been used for combined emergency response and search-and-rescue operations - tracking ground vehicles, and dismounted searchers (tracked via cell phones) in addition to UAS and nearby aircraft.

Utilizing real-time data sources including RADAR, telemetry and ADS-B, IRIS UAS calculates the airspace separation between all contacts in the operational space, and between each ownship and the terrain. The system computes the projected flight path of every detected aircraft forward through time, and displays warnings, alerts and cues to the operator if there is a danger of a developing airspace conflict, or an intrusion by unauthorized UAS.

This helps first responders and security organizations effectively operate unmanned systems in an emergency airspace without putting other emergency aircraft operating at low altitude, including water bombers, air ambulances, or police helicopters at risk. With IRIS AM, pilots can confidently and effectively operate UAS in close proximity and chaotic situations without posing a risk to manned aircraft.

IRIS UAS is an ideal airspace management tool for protecting airspace, and when integrated with the right combination of sensors, has proven effective in detecting small, commercially available drones, including the [DJI Mavic](#), and in triangulating the likely location of the drone operator.

The system has proven effective at ranges of up to 4.3 nautical miles away, and has been used successfully to locate hostile drone operators in repeated policing and security exercises.

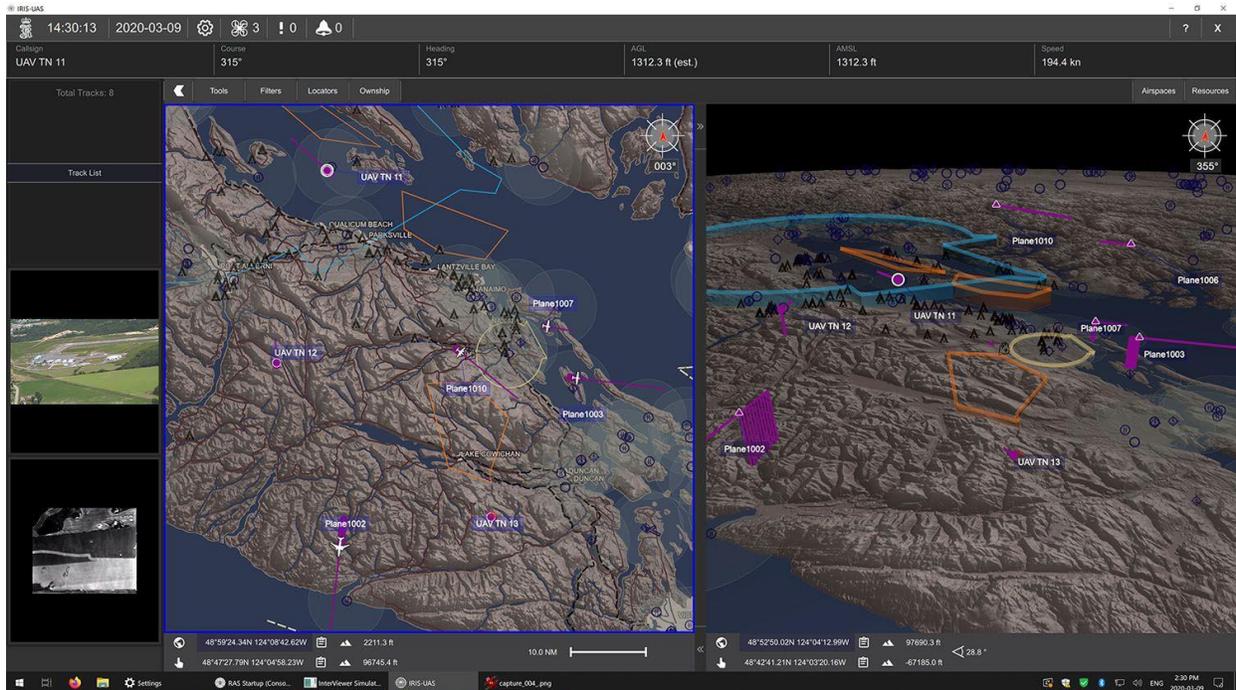


Figure B-3: IRIS UAS 2D and 3D Viewports

[IRIS UAS displays 2D and 3D real-time viewports, as well as live video and sensor feeds.](#)

IRIS System Architecture

IRIS is comprised of a number of different components. The IRIS Display is the main component and allows the operators to interact with the IRIS System. A high-level understanding of the IRIS System Architecture is beneficial to understand some of the information provided to the user, particularly System status information.

The main components of an IRIS System are:

- One or more IRIS Displays (the subject of this User Guide)
- Sensors, such as ADS-B receivers, weather stations, radars, aircraft telemetry, etc.
- IRIS Services which interface with the Sensors and provide the IRIS Displays with dynamic data to display. Some services also compute or derive data used by all IRIS Displays
- IRIS Resource Agent Service (RAS) used to start, stop, and monitor all IRIS related applications and services

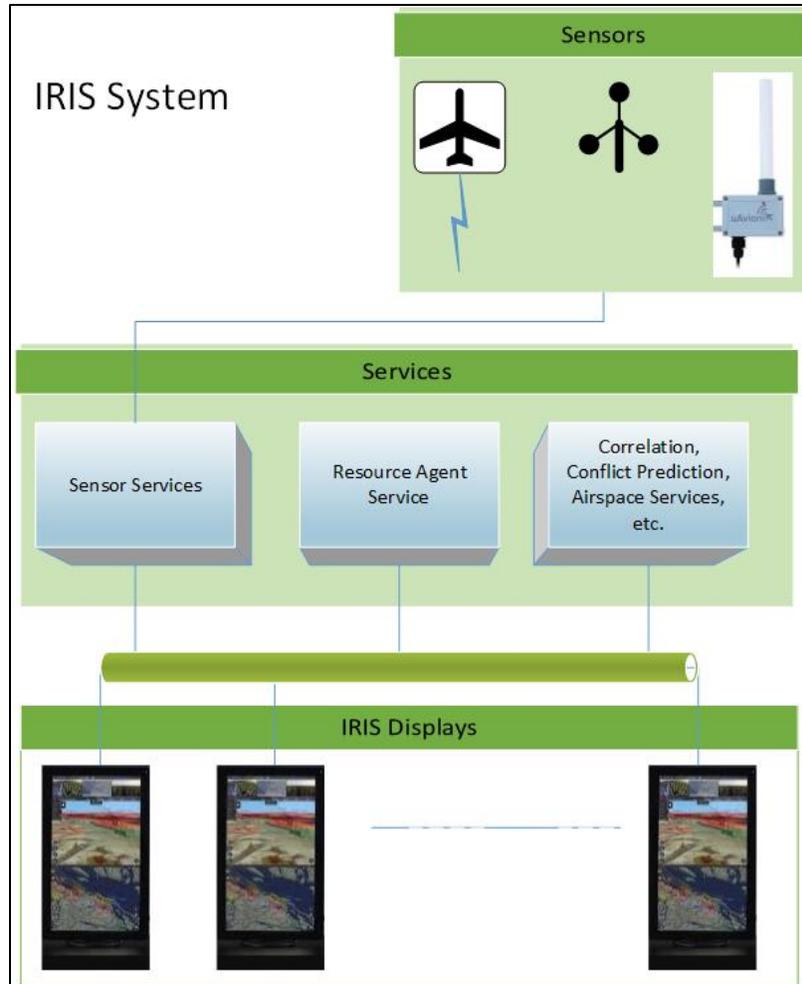


Figure B-4: IRIS UAS System Architecture

IRIS UAS Features

- Displays ownship UAS feeds, including telemetry and video
- Live track data from **ADS-B**, **Harris NEXTGEN™** and **PrecisionHawk LATAS™**
- Live ADS-B data integration with **uAvionix PingStation™**
- Integrated with **Cloud Cap Piccolo**, **ArduPilot**, **PixHawk**, **Cube** and **Micropilot** autopilots
- High-performance plotting of up to 10,000 simultaneous tracks
- High-performance 3D map and terrain engine powered by **TerraLens® 9.1**
- Deployable to multiple form factors, from mobile devices to 4K touch displays
- Pilot-configurable UI, map styling, and data layers
- Integrates feeds from cameras, sensors, and web sources
- Supports multiple map data formats and coordinate systems

Overview of the Display

The IRIS Display is designed to combine and aggregate a variety of data sources and present the important information to the operator in a clear and unambiguous manner. This section provides an overview of the main areas of the display including general use and interactions.

You can interact with the display using multi-touch actions (when a multi-touch compatible monitor is connected) as well as via mouse / trackball devices.

The IRIS Display can be used in either “Portrait” or “Landscape” mode. To change modes, select the desired monitor orientation via the operating system before starting IRIS. By default, the IRIS Display is configured to start as a full-screen application on the main monitor.

The majority of features and functions described in this guide assume you are using the application in the “Portrait” mode. When in “Landscape” mode, a few functions and features will be in different locations, primarily the **Card Tray**. Figure B-5 shows examples of IRIS in “Portrait” and “Landscape” modes.

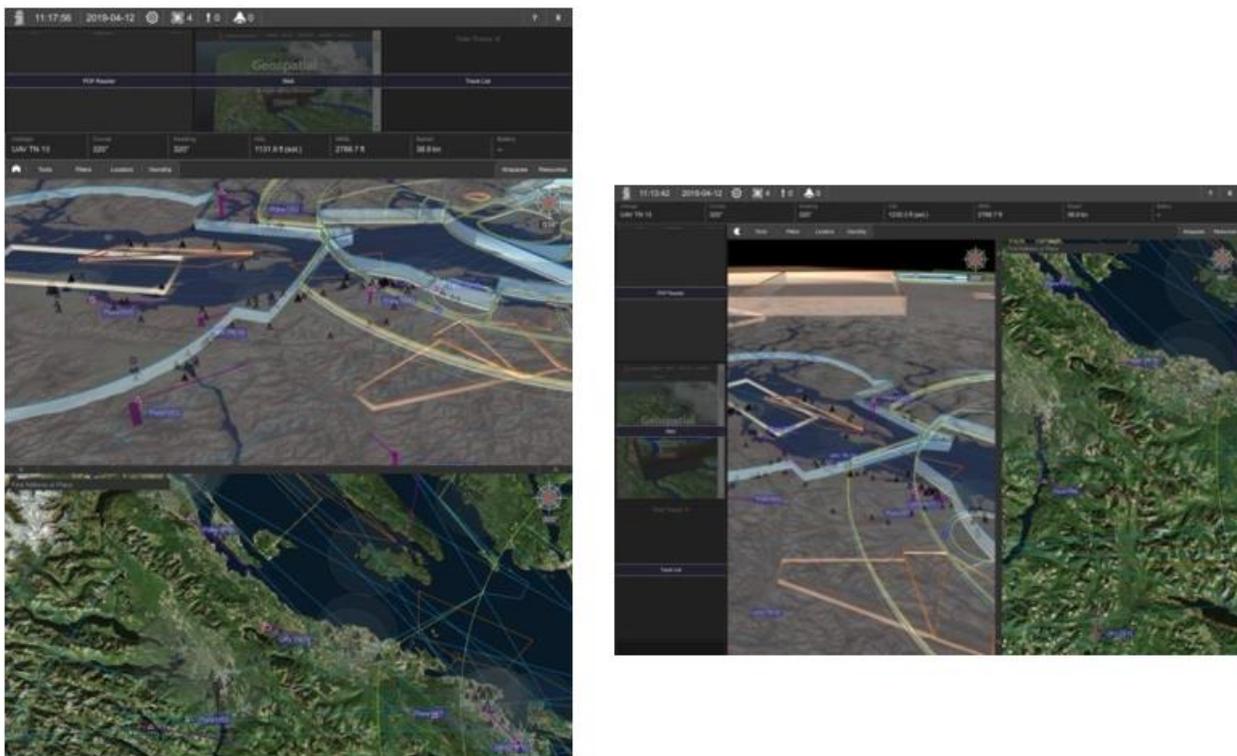


Figure B-5: Portrait & Landscape Screen Orientation

Map Views and the Tool Bar

IRIS is typically configured with two Map Views: one 2D Situational Awareness View and one 3D Situational Awareness View, although the number and types of Map Views may vary.

The Tool Bar (see Figure B-6) provides a number of features which can be used with the Map Views to control such things as filtering of map layers and sensor display layers. Some controls only apply to the selected view, some only apply to 2D or 3D views, and some apply to all views.

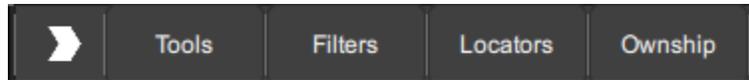


Figure B-6: Tool Bar

In Figure B- 7 two Map Views are shown, and the selected view is identified by the blue highlighted border. The tool bar has the Filters options selected with three options shown with the Map View specific indicator (blue dot in the lower right) meaning that changes made using that option only apply to the selected Map View. Changes made using any of the other options shown are applied to all Map Views, not just the selected view.

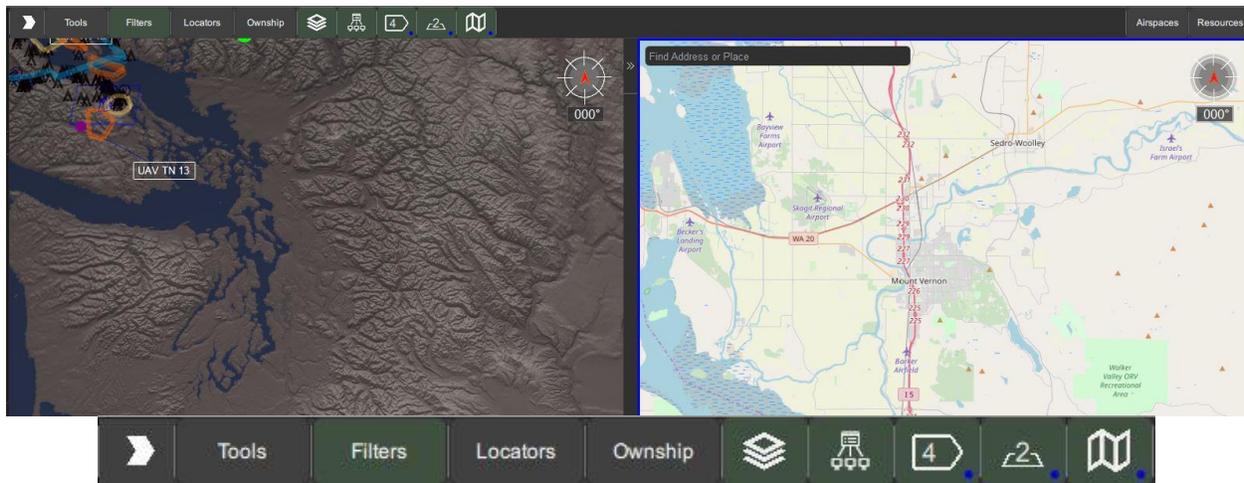


Figure B- 7: Tool Bar Options 2D View

2D Situational Awareness View

The primary view used to provide situational awareness is the 2D View which is capable of displaying a wide variety of dynamic and static data including:

- Tracks received from various sensor feeds
- Maps
- Airspace Objects
- Imagery

A secondary situational awareness view is available in 3D as described in the following section.

3D View Pane Features

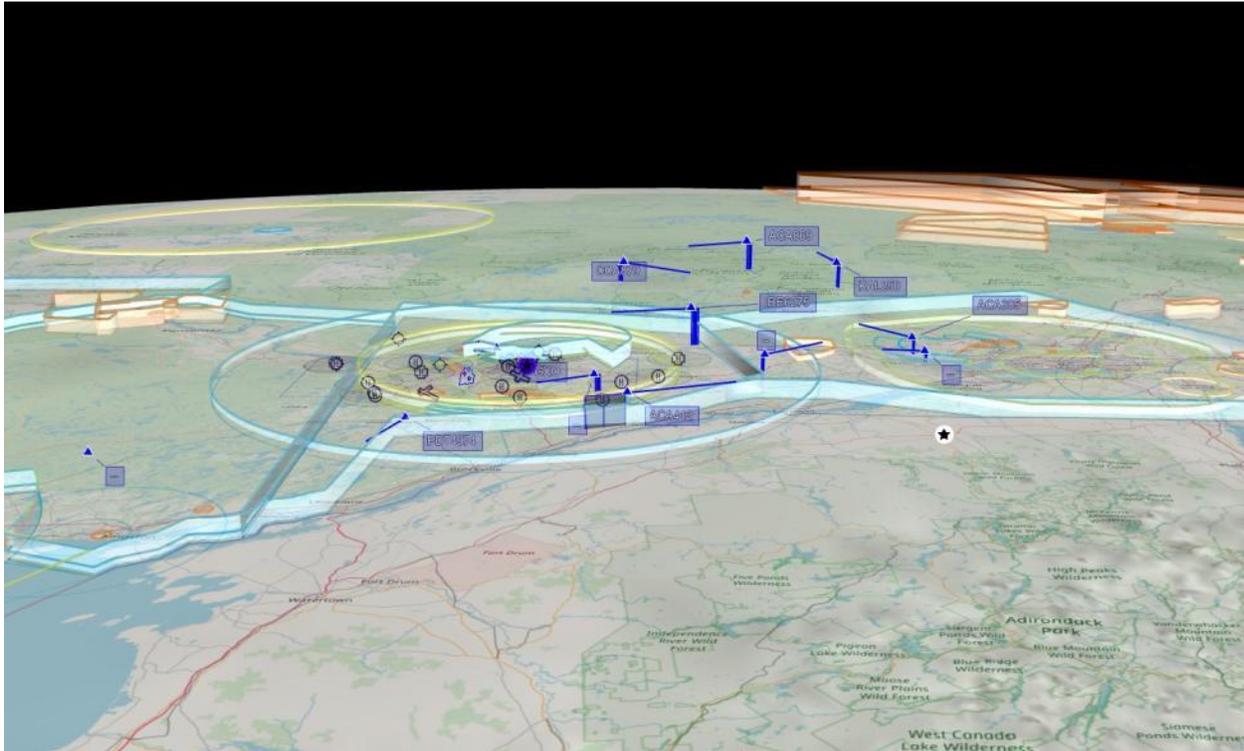


Figure B-8: 3D View Pane Features

The following subsections detail the various features and tools associated with the **3D View Pane**. In addition, you can control the general view of the **3D View Pane** by using touch controls such as “touching and dragging”, “pinching”, and “sliding”. Some of these controls are dependent on whether the *Follow* function is active.

Viewpoint Adjustment

The viewpoint can be manipulated using either a mouse or touch controls. The controls are the same as for the 2D View except that additional Tilt controls are available in the 3D View:

Pan: Click or touch the screen, then drag.

Zoom: Scroll up/down or expand/pinch to zoom in/out. Alternatively, double-tap one finger or double left click to zoom in and with two fingers double-tap or double right click to zoom out.

Rotate: Right mouse button with a horizontal drag or touch with two fingers and rotate.

Tilt: Right click or touch the screen with two fingers, then drag vertically.

Track Display Features

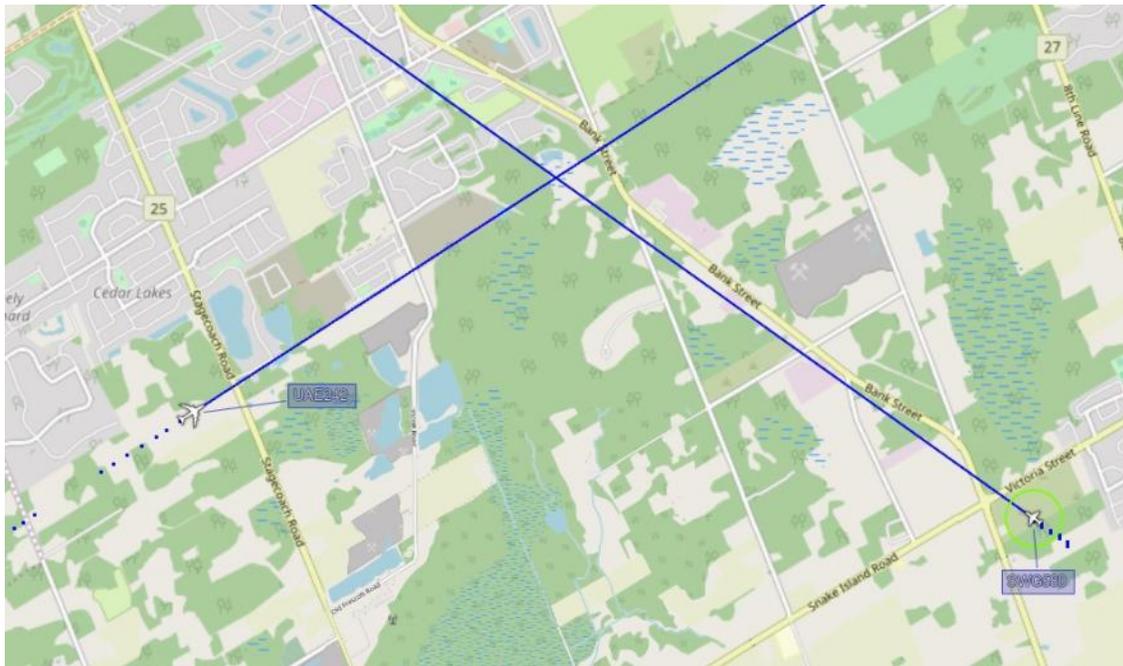


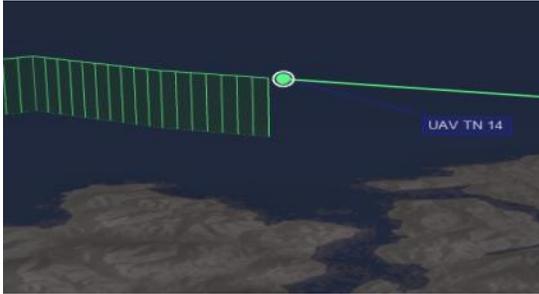
Figure B-9: Track Display Features for ADS-B Contacts

IRIS provides a set of visual attributes of a given track. The display attributes may vary depending on the installed configuration, but a track will typically be presented (in 2D and 3D map views) depicting the characteristics shown in Table B-1.

Table B-1: Track Display Features

Display Feature	Description
<p>Symbol</p> <p>A visual object representing the last reported geo location of the track.</p>	<p>IRIS displays tracks as instructed by the service which generated the track data. Tracks may be represented as an image symbol (e.g., an airplane) or by a geometric shape (triangle, circle, diamond, or square with an associated color). The color assignment is associated to the sensor generating the tracks (e.g., tracks generated by the ADS-B sensor service will have a color assignment of blue as depicted in Figure B-9). The default sensor color can be overridden by selecting the appropriate sensor in the sensor list.</p> <p>When a user selects a track on the 2D or 3D view, a green selection ring is shown around the symbol.</p>  <p>When a user selects an ownership to be in Focus, a white inner ring is overlaid around the symbol.</p>  <p>When a track becomes in conflict (either with another track or from violating an airspace rule) the track symbol will become enlarged and with red outer ring surrounding the symbol. The symbol will return to its normal visualization once the track is not in conflict.</p> 
<p>Data block</p> <p>A textual block of information attached to a track depicting a subset of telemetry data on the 2D and 3D views.</p>	<p>IRIS supports the display of a textual data block. Depending on the installed configuration, the data block may display one or more track attributes including: callsign, position, altitude (AMSL and AGL), speed over ground, course over ground, and sensor source. A typical IRIS configuration will display the track callsign and AMSL altitude in the configured units.</p>

Display Feature	Description
	 <p>If an attribute is not available the data block will display the value as [***].</p> <p>Depending on the installed IRIS configuration, data blocks may be shown only for tracks involved in an alert.</p> <p>When tracks are in close proximity in the view, IRIS will attempt to rearrange the data blocks so that they do not overlap for improved readability.</p>
<p>Vector Line</p> <p>A line stretching from the front of the track symbol representing track direction and estimated future position.</p>	<p>IRIS renders a vector line in both 2D and 3D views representing the direction and speed at which the track is travelling. IRIS will use the track’s reported course over ground and speed over ground. If course over ground is not available then heading will be used.</p>  <p>The length of the vector line represents the predicted location where the aircraft will be in two minutes from its current position (or other time duration as otherwise configured for the IRIS installation).</p> <p>The color of the vector line is associated to the color attribute associated to the sensor. This can be overridden by changing the sensor color via the sensor list function.</p> <p>Depending on the installed IRIS configuration, the display of vector lines may be disabled.</p>
<p>History Trail</p> <p>A series of dots behind the track symbol representing a</p>	<p>IRIS can be configured to display history trails for all contacts in both 2D and 3D views.</p>

Display Feature	Description
<p>trail of historical track positions.</p>	<p>In the 2D view, the history trail line grows as new track position updates are received. The oldest point is removed from the trail once the maximum history trail length has been reached.</p>  <p>In the 3D view, the history trail line is visualized as a curtain illustrating historical track altitude above ground. The operation of the history trail in 3D is identical to that of the 2D view.</p>  <p>The display of history trails may vary according to the installed configuration including:</p> <ul style="list-style-type: none"> • The length of the history trail in either time or number of previous position reports. • Set to display history trails only for ownships, all track, only for tracks involved in an alert, or never display history trails. <p>You can override the default history trail length via the track Amplified Data Panel.</p>

Tools

The Tools options allow various annotations to be made to the 2D Map View:

- Creation of shapes: circles, polygons, line strings, and rectangles
- Range Rings
- Range Bearing Lines
- Bookmarks

Filters

There are five filtering options that are used to selectively show or hide certain features, controlling what will be shown on the map:

- Map Symbol Filtering
- Track Filtering
- Sensor Layer Filtering
- Label Style
- Map Option Selection
- Map Layers Filtering

Terrain Warnings

The Terrain Warning option compares the current ownship altitude with the nearby terrain elevation to generate a graphical overlay on the terrain. There are two thresholds used for the overlay. Yellow areas indicate nearby terrain that falls within the configured “warning” distance to the aircraft altitude, while red areas indicate terrain that is within the “danger” distance threshold (see example in Figure B-10).

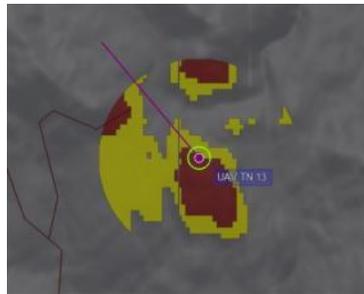


Figure B-10: Terrain Warning Graphical Display

The *Terrain Warning* option button displays the dialog shown in Figure B-11. Turning the Overlay on will enable the display for all ownships. The various thresholds used are preconfigured for the IRIS Display installation and are shown in the dialog. In the example shown in Figure B-11:

- “Nearby” terrain is set to a default radius of approximately 1 mile (1600 meters) around the current location of the aircraft.
- “Warning” areas are shown where the terrain elevation is within 100 feet of the current aircraft altitude.
- “Danger” areas are shown where the terrain elevation is within 50 feet of the current aircraft altitude.

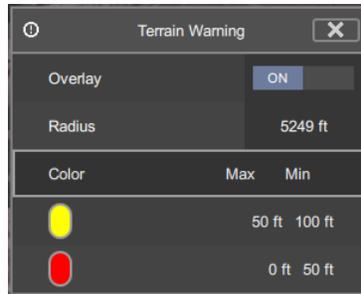
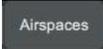


Figure B-11: Terrain Warning Dialog

Please note the following:

- This feature requires terrain elevation data to be installed specifically for this feature. The display of 3D terrain data in the 3D View is not an indication that the Terrain Warning feature is available.
- Where an aircraft is outside of the area where terrain elevation data is available, no warnings will be shown.
- Terrain elevation data typically does not account for such obstacles as trees and man-made structures. In addition, the accuracy of the warnings is dependent on the accuracy of the altitude reported by the aircraft as well as the accuracy of the terrain data. Both of these measures may be significantly off and as such this Terrain Warning feature must not be used to ensure safe height above terrain or other obstacles.

Airspaces

After pressing the Airspace button , the Airspace List Dialog displays as shown in Figure B-12.

The Airspace List shows a list of all airspaces currently loaded in the IRIS Display. IRIS can display airspaces from the following sources:

- Locally stored non-editable airspaces which are loaded when the IRIS Display is started.
- User created airspaces which can be created, edited, and deleted dynamically by the user. These airspaces are persisted locally and are loaded when the IRIS Display is started.
- External sources including internet-based services.

Airspaces can also have alerts associated with them.

Selecting an airspace from the list will show the details of the airspace in the Amplified Data Panel. Press and holding on the airspace name will center the 2D view on the corresponding airspace.



Figure B-12: Airspace Dialog List

User Created Airspaces

To create an airspace from the Airspace List Dialog:

- Press the *New* button.
- The display automatically changes from showing the User Created Airspace List to showing the Airspace Point List (See Figure B-13).
- To create an airspace point, press a location on the **2D View Pane**:
 - An airspace point symbol is added to the display which can then be “touched and dragged” to the desired location.
 - The point is added to the bottom of the point list.
 - The airspace line is drawn from the last point in the list to the newly added point.
- The *Save and Exit* button ✓ is used to finish the airspace point creation and returns to the Airspace List. The *Cancel and Exit* button ✕ cancels the airspace creation and returns to the Airspace List. The orange frame around the **2D View Pane** is removed.

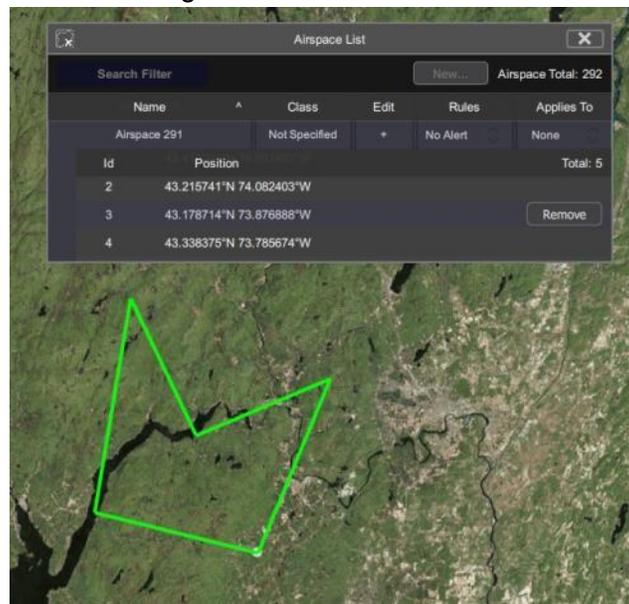


Figure B-13: Airspace Points List

To edit the class, name, and other airspace details, select the airspace from the User Created Airspace List and use the **Amplified Data Panel** to edit the values.

To edit the points of a previously user created airspace, double click on the desired airspace in the Airspace List. Points can be moved by selecting the point from the airspace list and dragging

it in the 2D view, or by editing the lat/long position displayed in the list. A point can be removed by selecting the desired point and pressing the Remove button in the Airspace List.

You can delete User Created Airspaces by selecting the airspace in the **2D View Pane** and then right clicking and selecting Delete. Alternatively, user created airspaces can also be removed using the Airspace List by selecting an editable airspace and swiping left to reveal an option to remove.

Notifications

Pressing the Notifications button displays a list of previously received notifications in a dialog. The most recent notifications are shown at the top of the list. Notifications can be filtered by text, priority or by category. In addition to being displayed in the notification list, new notifications are also briefly displayed as a popup message at the bottom of the screen. Notifications can be cleared from the list by a press and hold action on the “Clear All” button. Note that older notifications may be automatically cleared from the list, depending on the installed configuration.

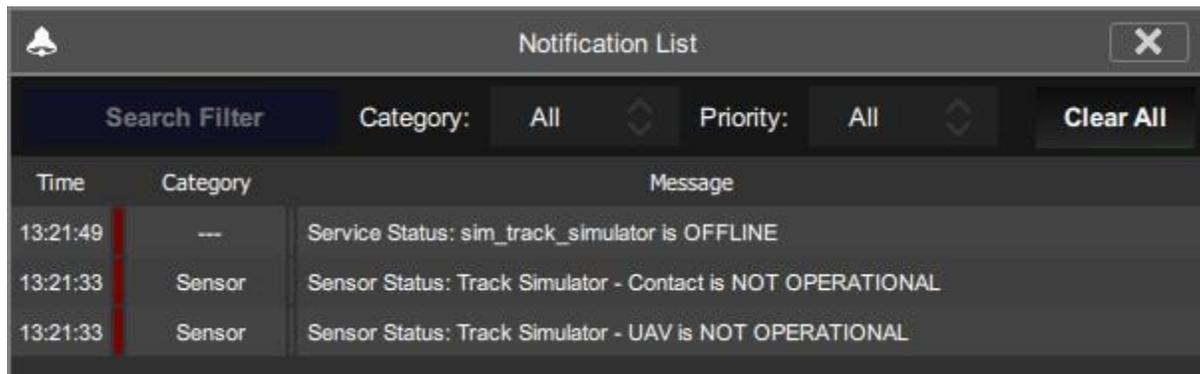
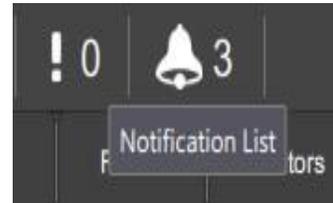


Figure B-14: Notification List



Figure B-15: Notification Popup

Alerts

The Alerts Icon in the Header Bar shows the total number of alerts and also turns red when one or more alerts are present. Pressing on the Alerts Icon displays the Alert List.

There are two types of alerts: Predicted Loss of Separation Alert and Airspace Alert.

When an Alert occurs, an audible warning tone sounds along with a graphical depiction of the alert on the 2D and 3D Views. All aircraft involved in an Alert will be displayed in the 2D and 3D

Views with enlarged icons and a red circle around them. Pressing the Acknowledge (“Ack”) button will silence the audible tone for a specific alert. This action can be reversed by pressing the Unacknowledge (“UnAck”) button.

For installations with multiple IRIS displays, acknowledging a separation alert will silence the audible tone for all IRIS stations. The Alert List will also indicate which IRIS station has acknowledged a particular separation alert. Note that airspace alerts are local each IRIS station and are acknowledged independently. For example, Figure B-16 shows:

- The separation alert between ETH502 and EVA670 has been acknowledged by this IRIS station (eyeball icon). The audible tone for this alert has been silenced on all IRIS stations. Only this IRIS station can unacknowledge the alert.
- The separation alert between GRN491 and SRD247 has been acknowledged by a different IRIS station (person icon). Hovering over the person icon shows the name of the IRIS station which acknowledged the alert.
- The airspace alert between RFS994 and Airspace 41 has not been acknowledged by this IRIS station and the audible tone is active. If other IRIS stations have the same airspace alert configured, they will independently acknowledge the alert.

Selecting an alert from the Alert List will display the **Amplified Data Panel**. This provides the details of either the Contact that is in conflict with the ownship, or the Track that has triggered an airspace alert. Additionally, the 2D and 3D Views will center to the location of the alert.

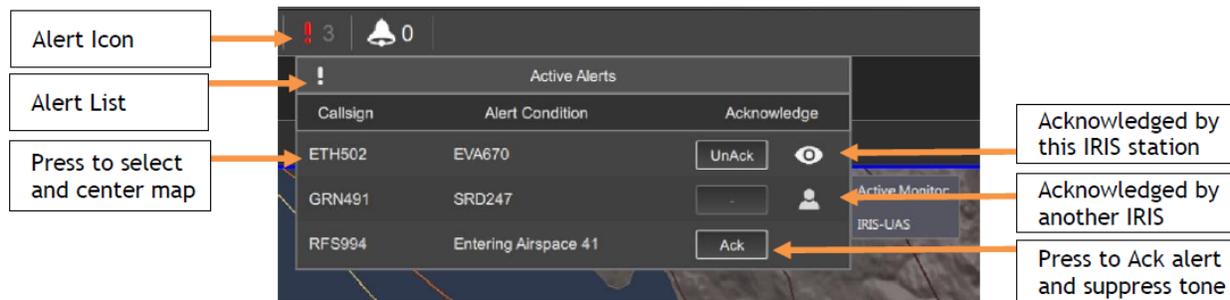


Figure B-16: Alert Icon & Alert List



Kongsberg Geospatial Future Developments

Kongsberg Geospatial is constantly working to improve our IRIS UAS product through support and maintenance and is continually adding new functionality through new partner integrations as well as the introduction of new features made specifically to address client needs.

Kongsberg is an ongoing participant in the furtherance of the CMP through the OFRN sponsored CMP effort and will continue to expand our product offering based on the feedback generated from these demonstrations in cooperation with our partners and the FAA.

Kongsberg Geospatial has previously delivered an IRIS UAS based Emergency Operations Airspace Management System to Defense Research and Development Canada's Centre for Security Science. In cooperation with the Royal Canadian Mounted Police, multiple RADAR vendors, RF Spectrum analysis specialists and NAVCANADA, the IRIS UAS system was deployed and tested in multiple scenarios from Search and Rescue to VIP protection, and even wildfire airspace management. Kongsberg is currently planning the next phase of this deliverable, where we will deploy this system at an operational airport in cooperation with public safety and security organizations to assist in the development and rehearsal of procedures for management of uncooperative UAS or other aircraft.

Kongsberg has delivered our IRIS UAS application as the common operational picture and situational awareness solution to the Canadian Area X.O Autonomous Vehicle Test Site, a state-of-the-art facility which offers a safe and secure environment to create, test and demonstrate future mobility, autonomy, and connected technologies, including UAS platforms. With close proximity to an international airport this facility requires unique cooperation between the local operators and Air Traffic Controllers at NAVCANADA. Our continued involvement and engagement supporting this facility and working within their living laboratory methodology exemplifies our commitment to lasting cooperation with all participating companies and agencies to ensure a safe, and robust UAS airspace management blueprint which can be replicated and adapted for use in any environment. As an addition to this venue, a mobile command center van was also created, allowing for the technologies available at the fixed site to be deployed outside the facility, even to rural environments for testing of new innovations as well as for disaster management, search and rescue, and more. This van is equipped with the IRIS UAS common operating picture, as well as its own 4G and 5G cells granting it the capability to deploy communications devices and perform monitoring and control of telecom connected drones and other equipment in remote locations.

Kongsberg is also in the process of pursuing additional opportunities to install our system in other UAS test and training facilities in Canada and the United States.

Through the continued efforts of the tasks above and with the help of our team partners, we are dedicated to the continuance of the CMP product future.

Appendix C: ResilienX Service Descriptions

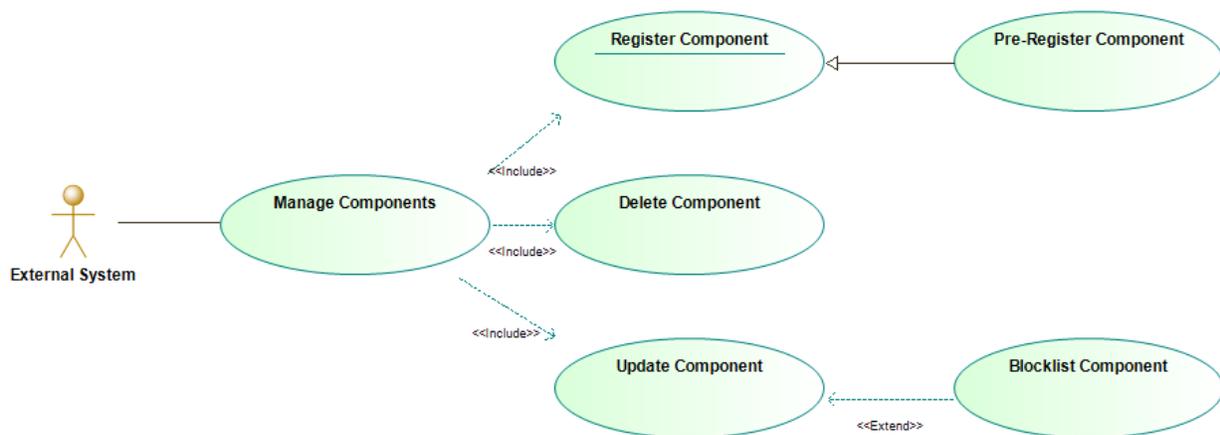
Appendix Prepared by
ResilienX



Components

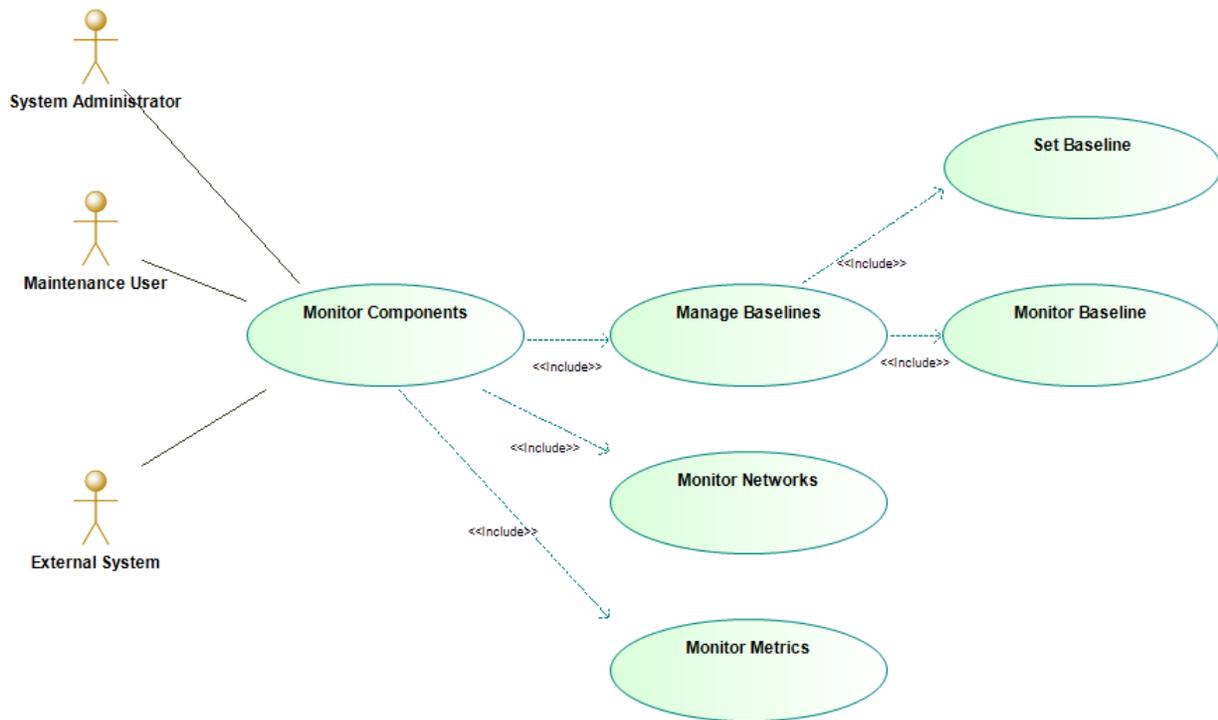
A component can be software, network device, or anything else that can be monitored. The FRAIHMWORK system monitors a component’s state and attributes.

Component Registration and Management



- A set of known components that are expected to be reported are pre-registered by a user with FRAIHMWORK and made available to them. The component pre-registration details include:
 - Component image
 - Component information: name, description, manufacturer, model
- An external system can register its components.
 - The external system can make use of pre-registered components.
 - If a new component has to be registered, the user can pre-configure the component image.
- Registered components can be updated/deleted.
- Details of registered components will be available to the external systems and users.

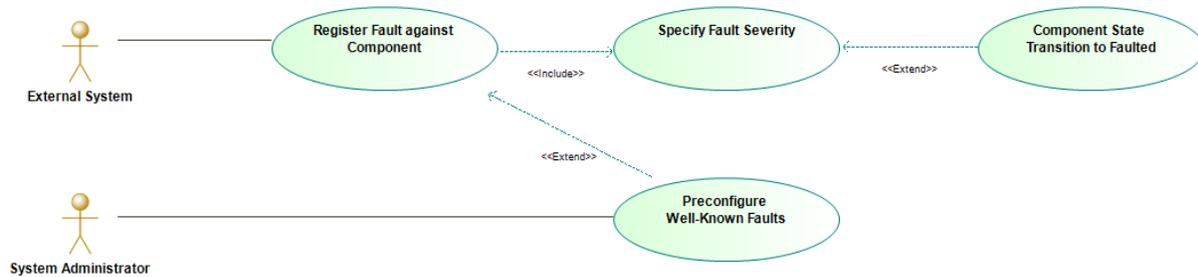
Component Monitoring



- **Component version baselining:** *Baselines can be set to easily visualize changes to version details.*
 - A baseline for version details (hardware, software, firmware, configurations) of all monitored components can be set.
 - On registering/updating a component whose version details are different from the set baseline, the user can easily visualize the values that have changed.
 - A set baseline can also be cleared by the user.
- **Network device monitoring:** FRAIHMWORK monitors the status of network devices by performing network tests and extracting information from them.
- **Component details tracking:** The user can visualize component details such as name, description, state, associated faults, etc.
- **Uptime and Availability Metrics Tracking:** The user can visualize the uptime and availability details of a component.

Faults

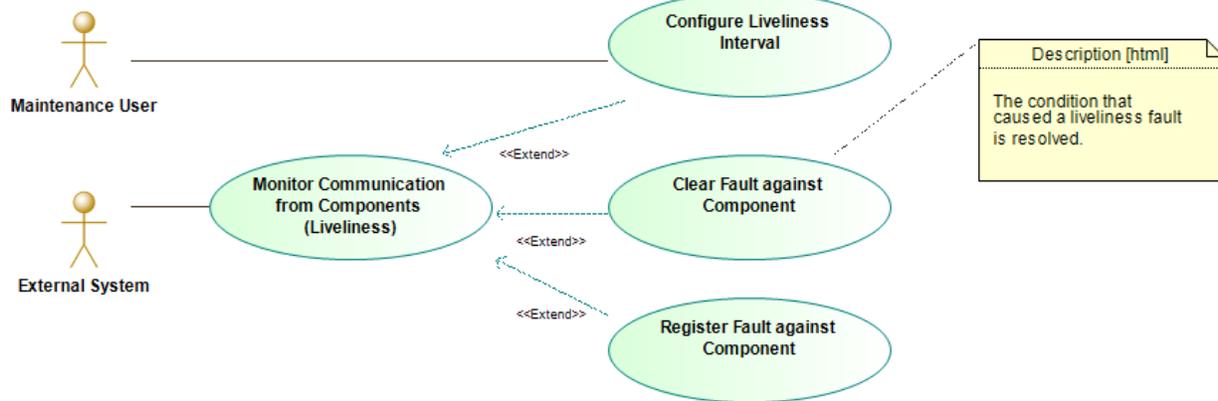
A fault describes a specific condition that is adversely affecting a monitored component.



- **Fault Registration and Management**
 - Faults can be registered against a component exhibiting undesirable behavior.
 - Registered faults can be updated/cleared.
 - Details of registered faults will be available to external systems or users.
- **Pre-configuration of well-known faults:** The user has specialized knowledge about specific faults related to a component that could occur. FRAIHMWORK allows that information to be stored to provide additional context when the faults are reported to FRAIHMWORK. This information can include:
 - **Additional Details:** Provides a more detailed description about the fault.
 - **System Reaction:** Describes the actions that will automatically be taken to resolve the fault.
 - **Remediation:** Defines a list of steps the user can take towards resolving a fault.
- **Fault monitoring**
 - Users can monitor faults which include details such as name, code, source, description, etc.
 - Users can visualize historical fault information.

Liveliness Monitoring

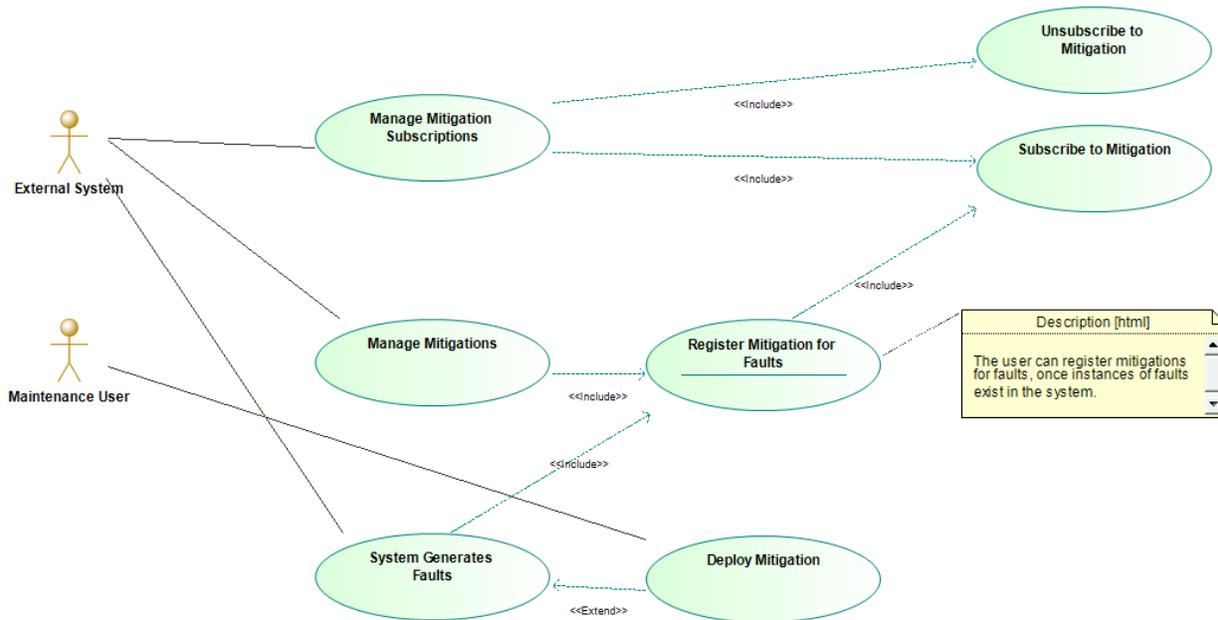
Monitors if a component is “alive”, i.e. actively communicating with the rest of the ecosystem.



- Component updates must be sent at regular intervals as defined by a configurable timeout value. If the time since the last received update elapses, then the component is considered faulted and a ‘lost liveliness’ fault is registered against it.
- Fault updates must be sent at regular intervals as defined by a configurable fault timeout value. If the timeout time passes, since the last received data, then the fault is considered to be resolved and will be cleared.

Mitigations

A list of actions that an external system can take to reduce the effect of or clear an active fault in the ecosystem.



- **Registration and Management**

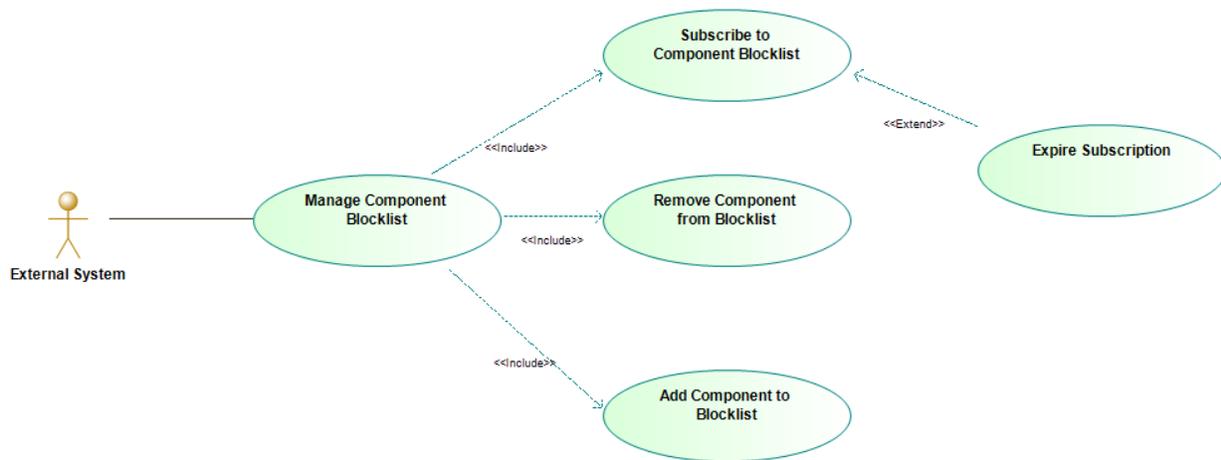
- Monitored components can register mitigations which may be associated to one or more faults.
- Mitigations can be accepted/rejected by the user.
- Accepted mitigations are deployed by the component associated with it.
- Details of available and deployed mitigations will be visible to the user.

- **Subscriptions**

- An external system can subscribe to updates from one or more mitigations.
- Subscribers have access to the latest mitigation subscription details.
- Subscribers can unsubscribe from mitigations.
- Subscribers can update/delete mitigation subscriptions.

Blocklist

A list of monitored components that have been indicted by FRAIHMWORK or other external systems to be putting out bad data. The blocklist is made available so that other components can elect to stop listening or processing data from them.



- **Component blocklisting**

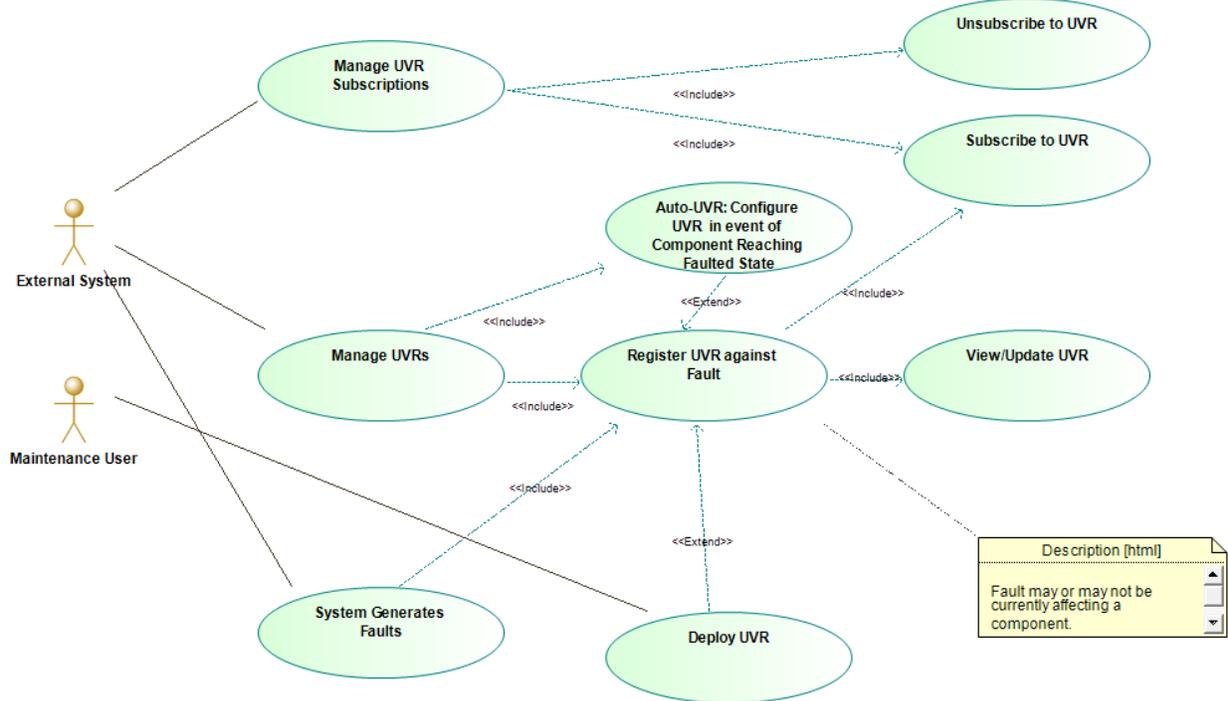
- Components putting out bad data can be blocklisted.
- Details of blocklisted components will be available to external systems.

- **Blocklist subscriptions**

- An external system can subscribe to the blocklist.
- Subscribers have access to the latest blocklist details.
- Subscribers can unsubscribe from the blocklist.
- Subscribers can update/delete blocklist subscriptions.
- **Configurations:** subscription expiration time

UAS Volume Restriction (UVR)

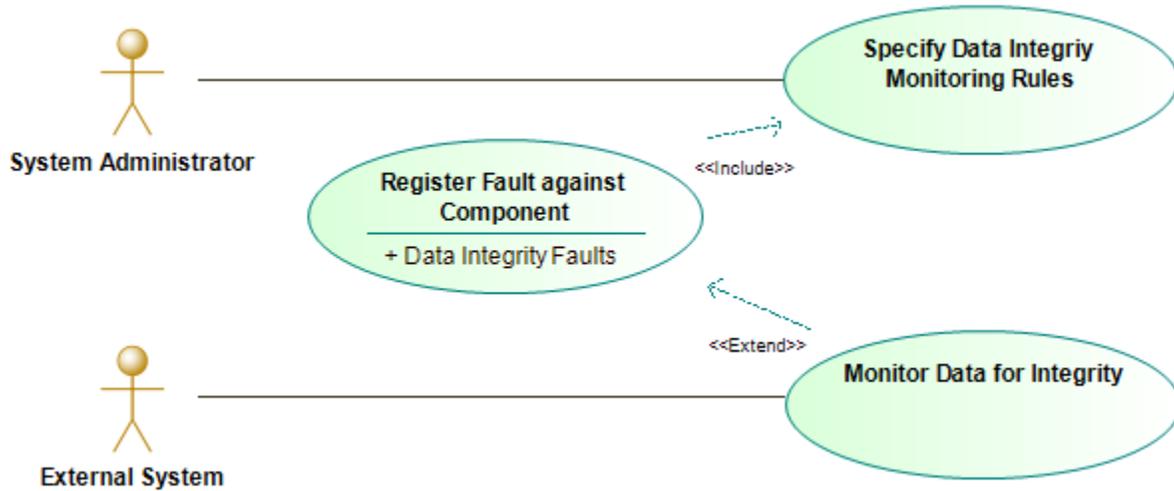
UVR is a type of mitigation related to faults that have a 3D volume-dependent condition.



- **Registrations**
 - Registered components can register UVRs which may be associated to one or more faults
 - UVRs can be accepted/rejected by the user.
 - **Auto-UVR:** A user/external system can configure a UVR to be registered in the event of a specific component reaching a faulted state.
 - Details of UVRs will be available to the user and external system.
- **Subscriptions**
 - An external system can subscribe to updates from one or more UVRs.
 - Subscribers will have access to the latest UVR subscription details.
 - Subscribers can unsubscribe from UVRs.
 - Subscribers can update/delete UVR subscriptions.

Data Integrity Monitoring

Assesses integrity of the data before being passed on to other services.



- All messages sent by external systems will undergo basic validations against pre-defined schemas. If the validation fails, a fault will be registered against the source. Otherwise, the message is passed on to other services.
- The basic checks that can be performed are as follows:
 - **Data Completeness:** Validate if a required field is present in the message.
 - **Field Type:** To validate if a field belongs to a particular type.
 - **Bounds:** To validate if a field value lies within the limits set for the field.
 - **Message Rate:** To validate if number of messages of each type received, lies within the limits specified.
 - **Data Rate Change:** To validate if the change in a field value over a period does not exceed the threshold.
- **Configurations:** Users can register a schema and ruleset (JSON format) for each message structure and source (sender).

Event Logging

Every event performed by FRAIHMWORK can be viewed along with the time it was performed.

- Types of events a user can track:
 - New components registered
 - New faults registered
 - Components being unregistered
 - Faults being cleared
 - Component detail updates
 - Fault detail updates

ResilienX Future Developments

Risk Assessment Framework

Our Risk Assessment Framework concept, illustrated in Figure 4, will create and maintain data sets that contain both modelled predictions and measurements of the airspace environment (e.g. nav, comms, surveillance, weather). We intend to identify or develop open interfaces, with the intent of standardization, around populating these data sets and retrieving data from them for analysis. Our goal will be to design a generic framework which can then be configured for each new airspace risk identified. We will focus this effort on the risks associated with communications. A future goal is to enable precursor, anomaly, and trend (PAT) analysis and detection in time to affect the safety of an operation should an off nominal or adverse event occur.

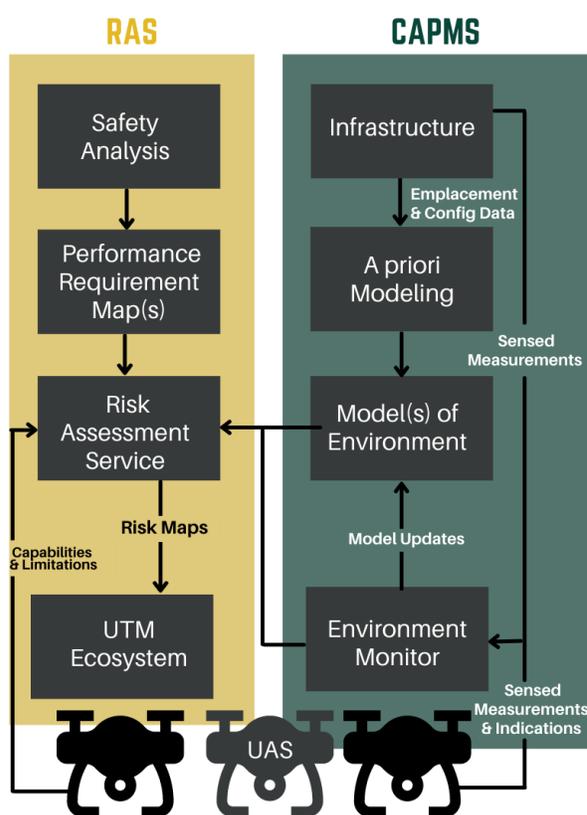


Figure C-1: Risk Assessment Framework

The RAS will assess the realized, in-time performance of the various services with respect to requirements specified in the performance requirements mapping, which will be developed as part of the safety analysis or safety case. For example, if the safety case and performance requirements required a latency of 1 second be maintained over the command and control (C2) link in a certain operational area, the Risk Assessment Service validates that this performance is actively being met. This validation is done by crowd sourcing measurements from UAS, which may report sensed measurements or non-compliance events, as well as from fixed infrastructure sensors.

Our vision is to enable this crowd sourcing via reporting requirements to all airspace actors which will greatly enhance the ability to monitor the overall health of the system with the capability to isolate areas (based on the geo-tagged reports) and provide precise mitigation services. We plan to explore using distributed sensors such as the Unify BLIP for monitoring

4G/LTE connectivity. By logging the signal strength (or loss) of many airborne devices and linking the signal data to their position, we could build a dynamic coverage map that can be leveraged for risk assessment and mitigation by all operators flying in the area (more details in the CAPMS design section below).

The output of the Risk Assessment Service (described in greater detail in the ecosystem integration approach section below) will be gridded or 3-D cubed areas where the performance or safety margins have been assessed to be less than required, or off-nominal. These areas can be used by the UTM



ecosystem to plan and reroute operations. Our research into this output will include looking at the utility of breaking up this risk map along lines such as risk factors or operations, or if a single, aggregate picture of risk is desired.

Our priority is to develop an approach for near real-time analysis, but we also want to lay out the architecture for off-line data analysis to look at PATs that can only be seen over time, as we collect more data and in different environments. We believe the future power of our approach will be to look across multiple environmental safety factors to determine if events on one environmental factor affects the performance of another. An example that we have observed at UTM test events, but never analyzed or quantified, is the effect rain has on surveillance. Even rain that is much too far away to affect a localized operation can still have a debilitating effect on surveillance performance of some sensors. By looking across the environmental factors of both weather and surveillance, a future mitigation may involve telling a radar to filter out detections past a certain range in the direction of a weather cell. This type of mitigation could preserve surveillance performance during an adverse situation where safety could otherwise be affected. As we collect and process data, we anticipate future efforts around correlating events between different risk factors.

Risk Assessment Service Ecosystem Integration Approach

We believe that for risk and safety margins to be adopted and usable by industry, they must be communicated in a means that is easily understood. We have identified Low Altitude Authorization and Notification Capability (LAANC) as laying out a roadmap for what this communication might look like. LAANC lays out a grid over an area and identified a risk threshold, which is then used to automatically approve operation plans. LAANC does this for air risk, using elevation as the main factor considered, with an a priori risk assessment of the air traffic within an airspace. Airservices Australia and Queensland University of Technology have expanded this concept by researching how to adjust the grid based on environmental changes such as which runways are currently active.

We intend to expand and scale this concept, with the goal of enabling a performance authorization paradigm. With many ISSA services and capabilities in use, we envision producing aggregate maps of safety margins, operational performance requirements and risks across a gridded (or in some cases 3 dimensionally cubed) airspace. These maps will be accessible via standardized APIs with the underlying performance requirement and safety margin data likely to be open sourced, much like a LAANC facility map.

The power of our RAS concept will be allowing adjustments to this map when events have occurred which change the safety margins or increase a risk factor, thus greatly expanding our capability beyond the use of UAS Volume Restrictions (UVRs). Much like an adaptable Facilities Map may change the altitude a drone can fly around an airport based on what runway is open, our map may limit what operations may occur based on the operational environment. For example, an IASMS may detect that surveillance is not available in a region (based on its surveillance monitor and assessment functions) which would then be communicated as a grid which can no longer be operated in without visual line of sight or on onboard DAA solution. These grid-based constraints would be based on UAS's capability and performance, enabling a much finer grained, risk-based constraint mechanism than currently exists within UTM environments.

Additionally, this capability can then be leveraged during mission planning by checking UAS capabilities and limitations, which include payload packages, against environmental risk maps in a binary manner. This



would form access areas of where the UAS can operate. In the future, a specific flight plan may be input into the IAMS which will return the requisite performance of the UAS to perform that operation. This approach can be used within the UTM ecosystem to identify and eliminate known and predicted risks prior to the take-off. It will be layered in with pre-flight services such as flight plan validation (against the regulations and temporary/permanent flight restrictions), strategic deconfliction, weather forecast, etc.

Communication Availability and Performance Monitoring Service (CAPMS)

Our goal is to develop a capability to automate the assessment of the communications environment and relate that assessment to risk within an airspace, on an operation-by-operation basis, based on craft onboard communications capability and performance. Risk here will be determined based on safety margins and performance requirements dictated in a safety case or performance authorization.

To achieve this goal, we will utilize the RAS architecture (Figure C-1) and develop monitoring capability around the communications link with the UA. Our Communications Availability and Performance Monitoring Service (CAPMS) will start simple, with a goal of expanded complexity as we learn and collect data within UTM environments. In Figure C-1, the CAPMS represents Model of Environment box and the Environment Monitor box for the communications environment. The CAPMS capability would feed RAS, with the idea that there may be multiple, similar services for additional environments all feeding the RAS, which would aggregate the data and relay it to the ecosystem.

Our envisioned CAPMS will analyze the model or map of the communications environment with respect to a performance characteristic (e.g. SNR) or safety related performance requirement (e.g. latency) and verify that the model of the airspace could support the performance needed, determined by a safety analysis or safety case. For example, if the safety case required a latency of 1 second be maintained over the C2 link, various communications modalities, such as LTE and satcom, may be modeled over the operational area. These models would be compared against the performance requirement to determine the geographic regions where the performance is supported.

Introducing a set of UAS capabilities to the mix will allow the CAPMS to aggregate these regions based on the performance and payloads of the UAS. For instance, a UAS with only LTE communications may have more geographical limitations for operations than a UAS with LTE and a backup satcom system. Additional functionality of the CAPMS, combined with the RAS, is to translate changes detected within the environment to effects on available operational environments, as these changes may reduce the performance below the risk or safety threshold defined in the safety case. For example, an antenna failure or degradation, which may be detected by FRAIHMWORK may affect the availability of communications in an area, which would be assessed, translated, and relayed through the CAPMS and RAS.

In the future, we intend to work with MNOs and UAS/UTM C2 providers to model their communications networks. There are many challenges with this approach, including proprietary data issues and complexity of some of these networks. To reduce complexity, we intend to develop an initial prototype which focus on monitoring the current state of the communications networks by crowdsourcing network performance from active UAS operations. This will put the entire data chain within our control, allowing us to expand and iterate on this capability as we gain access to additional data and form relationships with C2 providers (which we are working on).

Our goal will be to bring our findings and lessons learned to NASA, the FAA, and standards committees with an intention of standardizing ISSA-related interfaces within the ecosystem. As data about the



communications performance becomes more widely available, we anticipate receiving this data directly from GCSs or USSs (which receive it from a UAS/GCS).

Appendix D: TruWeather Solutions Service Descriptions

Appendix Prepared by
TruWeather Solutions



TruFlite Alert

TruFlite Alert is a powerful real-time weather alerting engine designed to provide ground point and airspace weather alerts customized to user-defined thresholds and distances for specific missions and operations. The alerting system is the featured weather product for the CMP and has been designed in conjunction with this project.

TWS uses the most up-to-date weather data to create an alert polygon based on the user's thresholds. Whenever a threshold is met, an alert is sent to the CMP, where it is then displayed graphically. Alert details are then found by clicking on the polygon or selecting the alert dropdown at the top of IRIS.

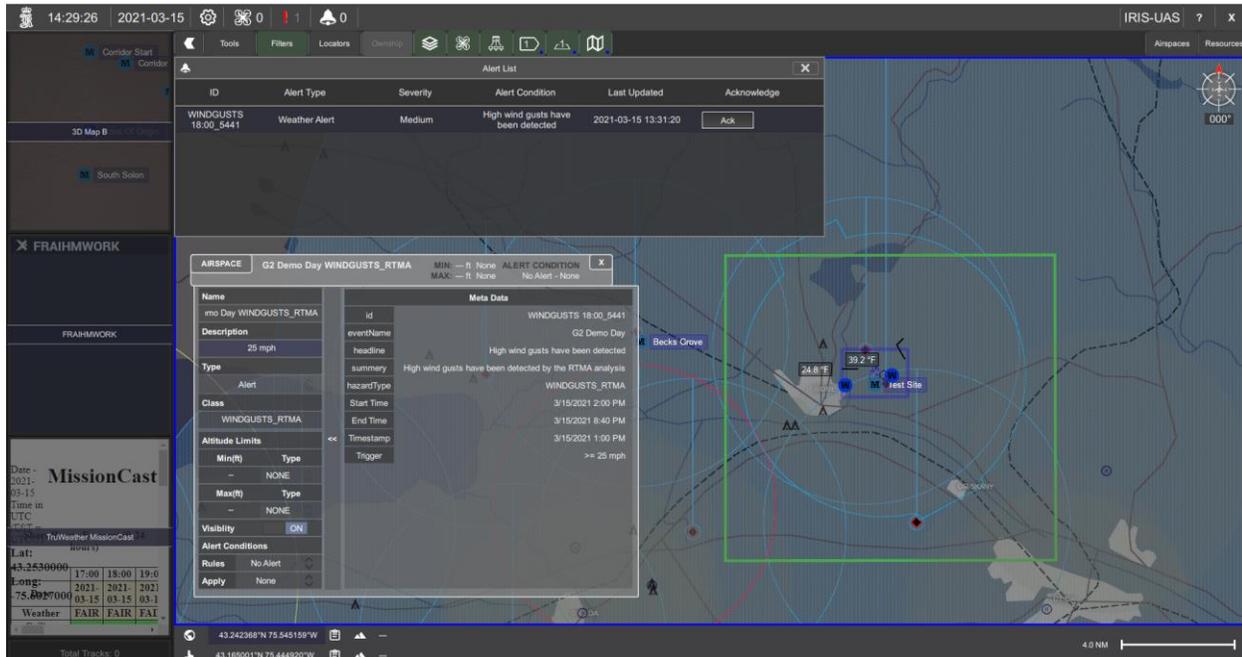


Figure D-1: Weather Alert over Griffiss (Green Polygon Alert Area)

Threshold Setup

The alerting requirements did not include developing a User Interface (UI) within the IRIS system. Therefore, the current version of the CMP requires the user to set their thresholds by changing settings within the system configuration files. The system will only display alerts that correspond with an Operational Area. Therefore, the first step is to make sure an operational area is set. Currently, this is accomplished at the following location:

C:\Program Files\IRIS-UAS\IRIS-UAS\Release-x64\data\OperationalAreas

```
{
  "type": "FeatureCollection",
  "features":
  [
    {
      "type": "Feature",
      "geometry":
      {
        "type": "Polygon",
        "coordinates":
        [
          [
            [-75.4407085509, 43.2208793061],
            [-75.3874538273, 43.2208793061],
            [-75.3874538273, 43.2489223868],
            [-75.4407085509, 43.2489223868],
            [-75.4407085509, 43.2208793061]
          ]
        ]
      },
      "style":
      {
        "stroke-width": "5",
        "stroke": "#0000FF",
        "fill-color": "#0000FF",
        "fill-style": "None"
      },
      "properties":
      {
        "name": "G2 Demo Day",
        "description": "G2 Demo Day"
      }
    }
  ]
}
```

Figure D- 2: Configurable Operational Area Definition for Alerting

The next step is to set the thresholds using the 'postDataRequest' file located here:

```
C:\Program Files\IRIS-UAS\services\svc_truweather\Release\settings\twsAlertPostData
```

In this file, the user can set the coordinates. These coordinates set the area that is monitored for an alert and should coincide with an Operational Area. The 'eventName' should be unique to the user. The 'endTime' sets the time at which alerting will end.

```
{
  "msg_type": "Generate",
  "message": {
    "geometry": {
      "coordinates": [
        [
          [-75.4407085509, 43.2208793061],
          [-75.3874538273, 43.2208793061],
          [-75.3874538273, 43.2489223868],
          [-75.4407085509, 43.2489223868],
          [-75.4407085509, 43.2208793061]
        ]
      ]
    },
    "type": "MultiPolygon"
  },
  "type": "Feature",
  "properties": {
    "eventName": "G2 Demo Day",
    "startTime": "2020-08-27T14:00:01Z",
    "endTime": "2021-03-15T21:20:01Z",
    "notifiables": [
```

Figure D-3: Alerting Area Definition Corresponding to Operational Area

Within the JSON body, there are several weather parameters that a user can set to alert on a certain threshold. If a user does not wish to be alerted on a threshold, they can delete that parameter or choose a threshold that is difficult to reach, such as 100 for wind speed. The 'comparison' allows the user to select whether they want to be alerted above or below a chosen threshold. The 'distance' is how far from the polygon set by the coordinates at the top that an alert will be triggered by. The 'threshold' is the value at which the user chooses to be alerted. Each of the JSON files needs to be saved as a JSON.

```
"products": [
  {
    "hazard": "MRMS_PRECIP",
    "parameters": [
      {
        "thresholdUnits": "dBZ",
        "comparison": ">=",
        "distance": 5,
        "distanceUnits": "miles",
        "threshold": 30
      }
    ]
  },
  {
    "hazard": "WINDS_RTMA",
    "parameters": [
      {
        "thresholdUnits": "mph",
        "comparison": ">=",
        "distance": 10,
        "distanceUnits": "miles",
        "threshold": 5,
        "valueField": "mag"
      }
    ]
  }
]
```

Figure D-4: Alert Threshold Settings

API Products and GUIs

TruFlite smartly and automatically selects the best weather data from various weather data sets to provide the most precise winds (surface and aloft) and weather, explicitly customized for UAS operations. TruFlite offers both observational (actual measured data when available, or a best estimate automated analysis or observation) and predictive products to help make actionable decisions for weather-sensitive operations.

1. **MissionCAST** delivers a Go/No Go mission-specific stoplight chart for a designated takeoff and landing location, reflecting custom thresholds for the specific airframe and mission, as selected by the user. When planning a task, the MissionCast product is an excellent first look at the weather conditions for many surface and aloft parameters. MissionCast is available on the left-hand menu in IRIS and can be pulled up from any 'Mission Point' on the map.

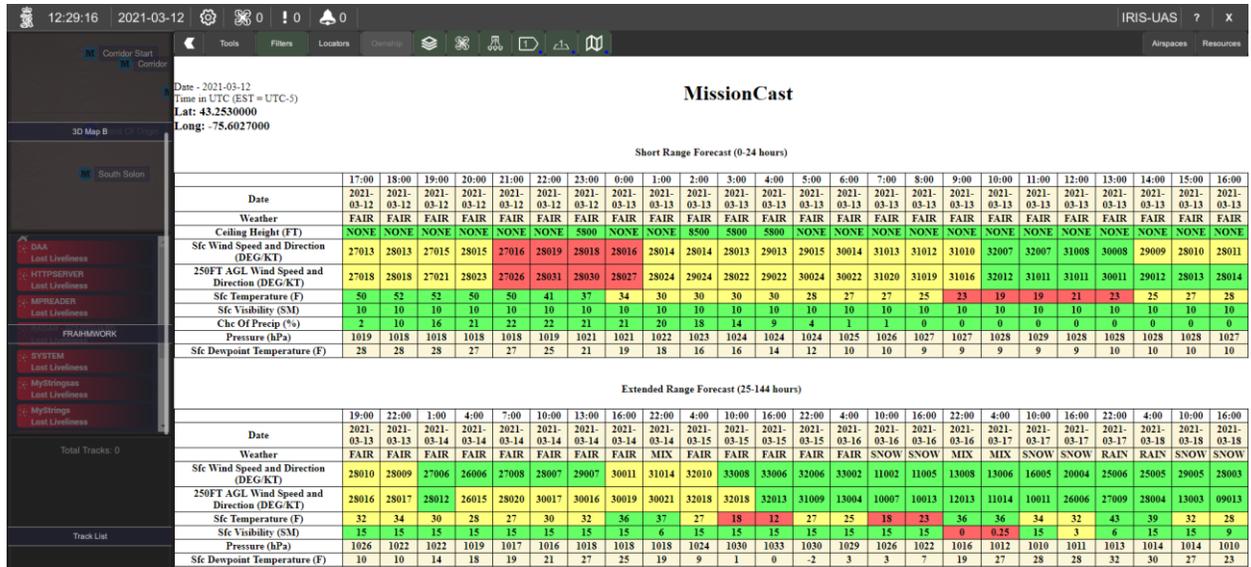


Figure D-5: MissionCast Forecast over Central NY

MissionPoints are set up via a configuration file located here: C:\Program Files\IRIS-UAS\IRIS-UAS\Release-x64\data\missionPoints

```
{
  "features": [
    {
      "geometry": {
        "coordinates": [
          -75.602682,
          43.253025
        ],
        "type": "Point"
      },
      "properties": {
        "comment": "",
        "fill-color": "#00ff00",
        "name": "Becks Grove",
        "uuid": "18d43673-7927-47cc-bafb-9d5fe7c5b995"
      },
      "type": "Feature"
    }
  ],
  "type": "FeatureCollection"
}
```

Figure D-6: MissionCast / MissionPoint Configuration

Open one of the files, change the coordinates to the desired location, then save it as a unique name.

2. **RouteCAST** is a route evaluation tool. A user provides route waypoints and wind thresholds that impact safety and mission accomplishment and receive custom route data based on end-user defined thresholds with a color-coded risk indicator based on the predicted winds. RouteCast is also accessed on the left-hand menu in IRIS that is linked to the RouteCast GUI. While MissionCast is excellent for point forecasts, RouteCast is recommended for evaluating a route.

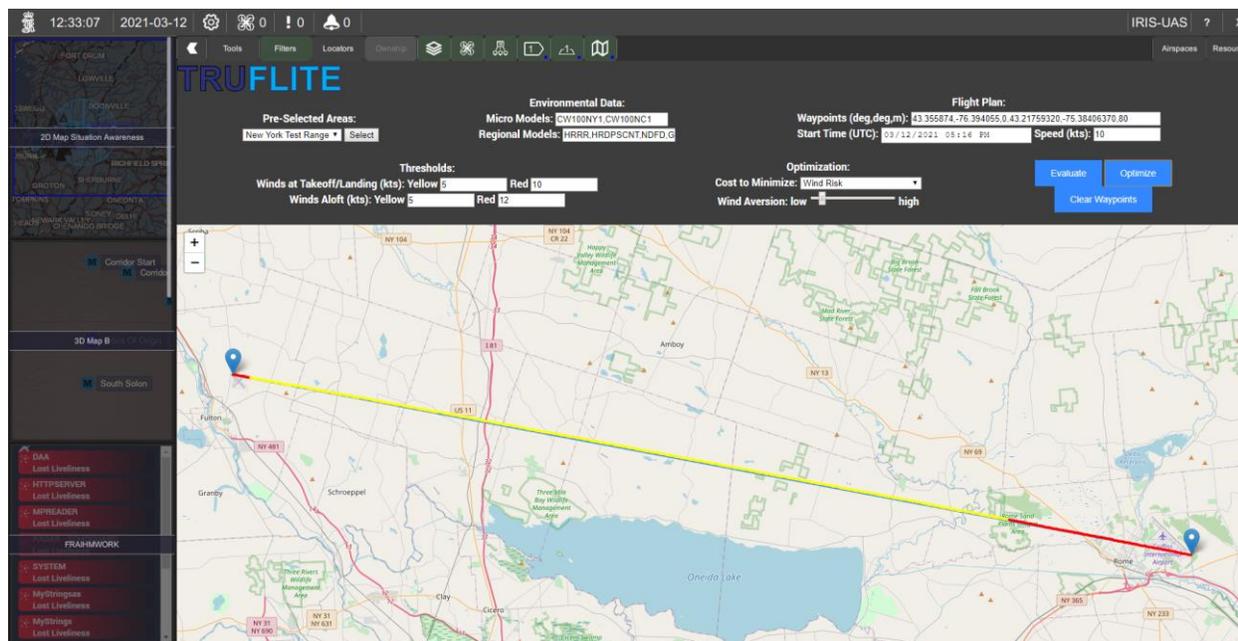


Figure D-7: RouteCast Screenshot in CMP

Specific Weather Models – in the form of web-tile overlays

TWS’s backend database of weather data and models populates the above observational and forecast products. TruWeather meteorologists use the best available weather data and models for the application, time, and place the mission will occur to determine what data populates each of the above products.

1. Weather Models with available vector data:
 - a. **Current Weather Analysis or RURTMA** – RURTMA is the Real-Time Gridded Weather Observations: Rapidly Updating Real-Time Mesoscale Analysis and is a real-time analysis of weather conditions at the surface or just above. This analysis is not ground truth but the best estimate of weather conditions at a location with a 2,500-meter resolution. It is useful for estimating near-real-time weather conditions for awareness and nowcasting purposes. TruWeather encourages operators also to review weather observation reports and MyRadar to improve situational awareness. It is also an excellent product to verify the forecasts from MissionCast. It is found in the 'Map Symbol Filtering' dropdown. The following weather tiles are currently integrated into IRIS:
 - Temperature
 - Wind (Surface)
 - Visibility
 - Ceiling

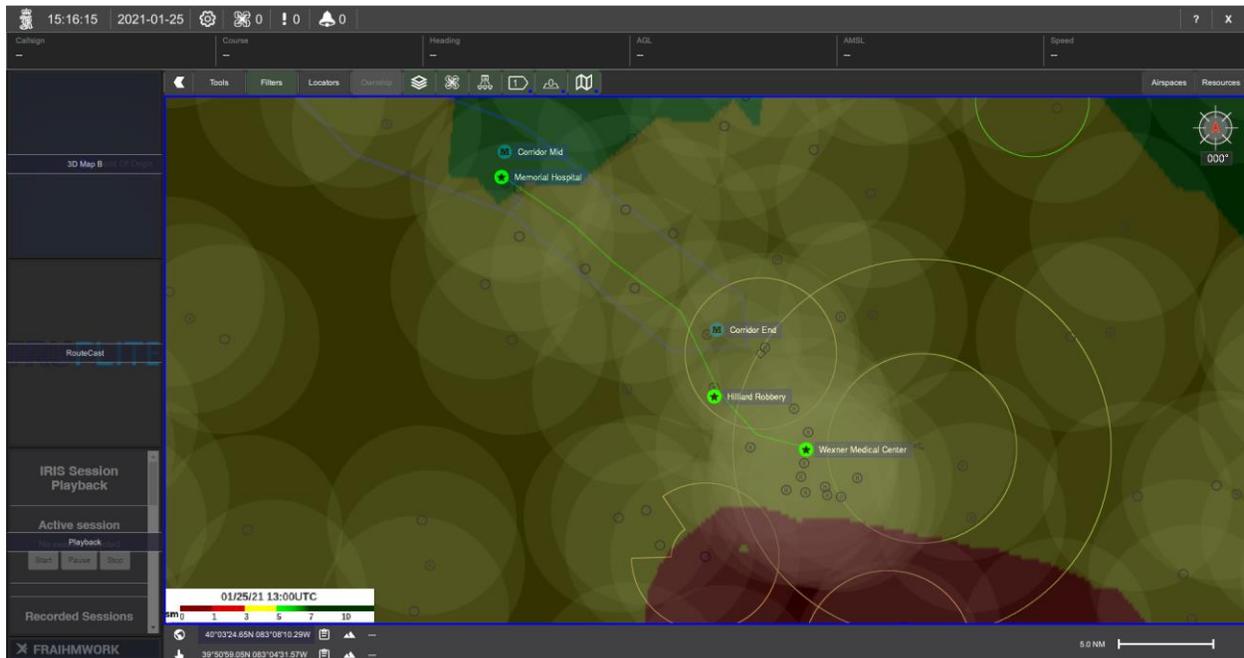


Figure D-8: Visibility Weather Tile Overlay on CMP Display

- b. **Precipitation Reflectivity Visualization** – Also known as MRMS (Multi-Radar/Multi-Sensor System). This is an advanced, real-time precipitation system. MRMS intelligently integrates various weather radar data streams with lightning, surface observations, upper-air observations, and satellites. This product is used to find areas and intensity of precipitation. It is located in the 'Map Symbol Filtering' dropdown menu.

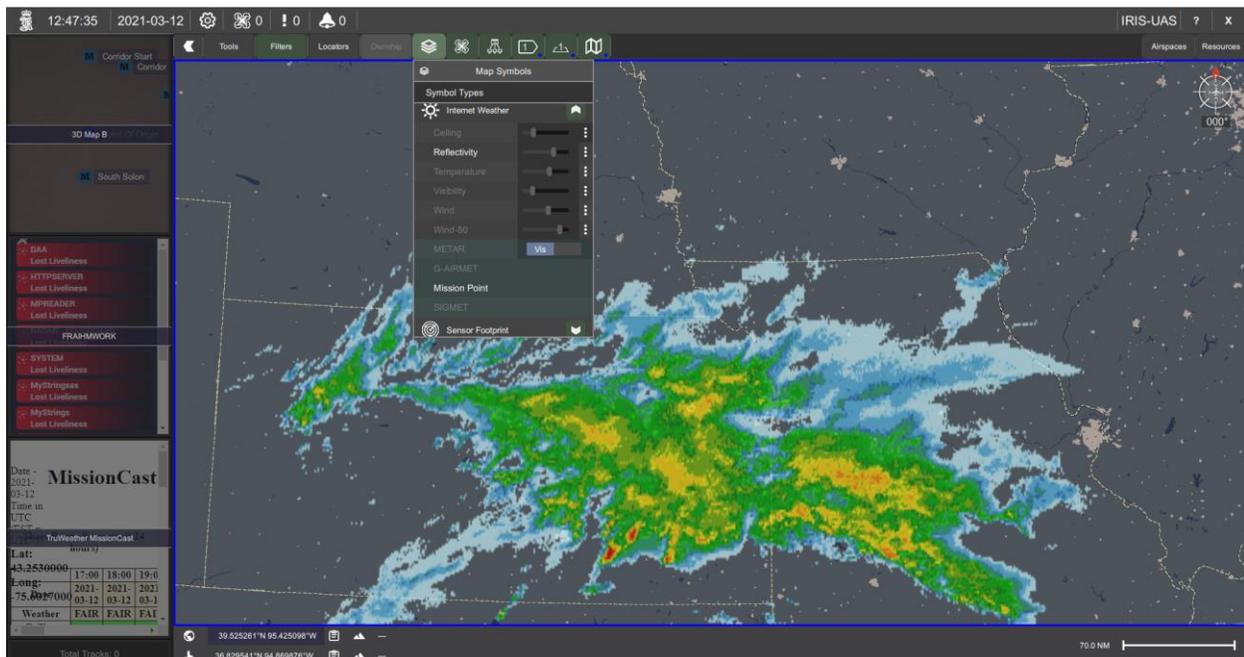
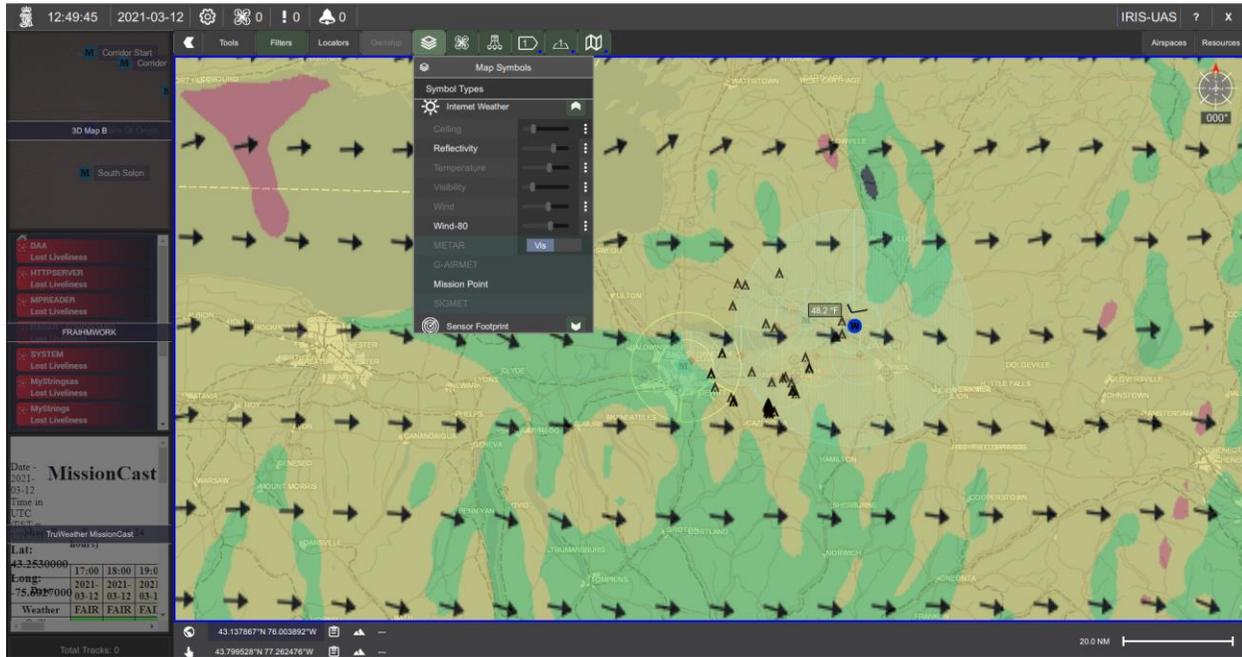


Figure D-9: MRMS Reflectivity Weather Tiles on CMP Display

Figure 12 Screenshot of the MRMS radar tiles in IRIS.

- a. **High-Resolution Prediction Model or HRRR** – The HRRR is the High-Resolution Rapid Refresh Model. This model provides forecast data for Temperature, Wind, Wind Speed, Pressure, Visibility, Ceiling, Radar, and Total Precipitation at various vertical levels. This dataset updates every hour and provides a forecast out to 36 hours into the future in one-hour timesteps. The parameter 'Wind-80' is for 80m wind speeds above ground level from the HRRR and can be found under the 'Map Symbol Filtering' dropdown menu.



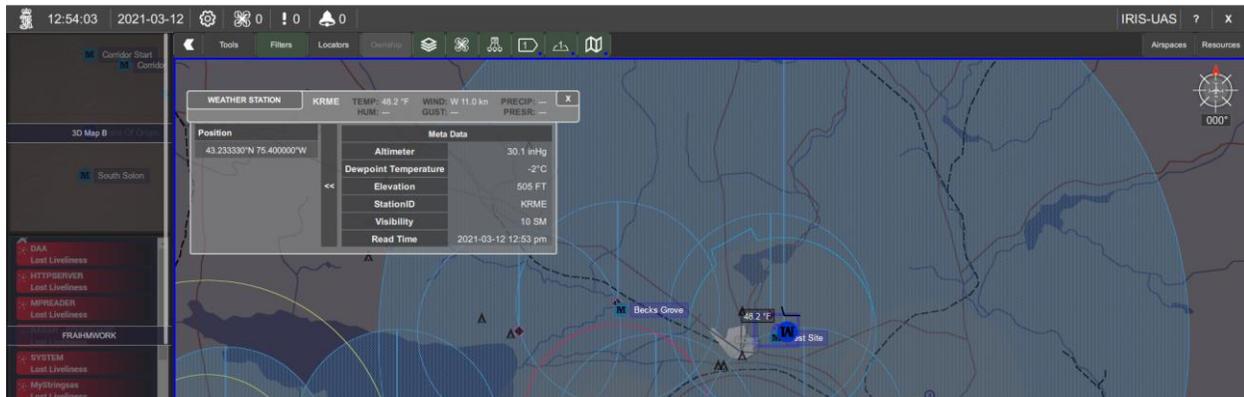


Figure D-11: METAR Data Displayed in CMP

2. **Aviation Weather Advisory or G-AIRMET** – from the Aviation Weather Center: A G-AIRMET is a graphical advisory of weather that may be hazardous to aircraft. They are graphical areas depicting the locations and attributes of AIRMET hazards. They will report such things as turbulence, icing, fog, and wind shear, etc. Future integration will include the height and valid time of the phenomena.

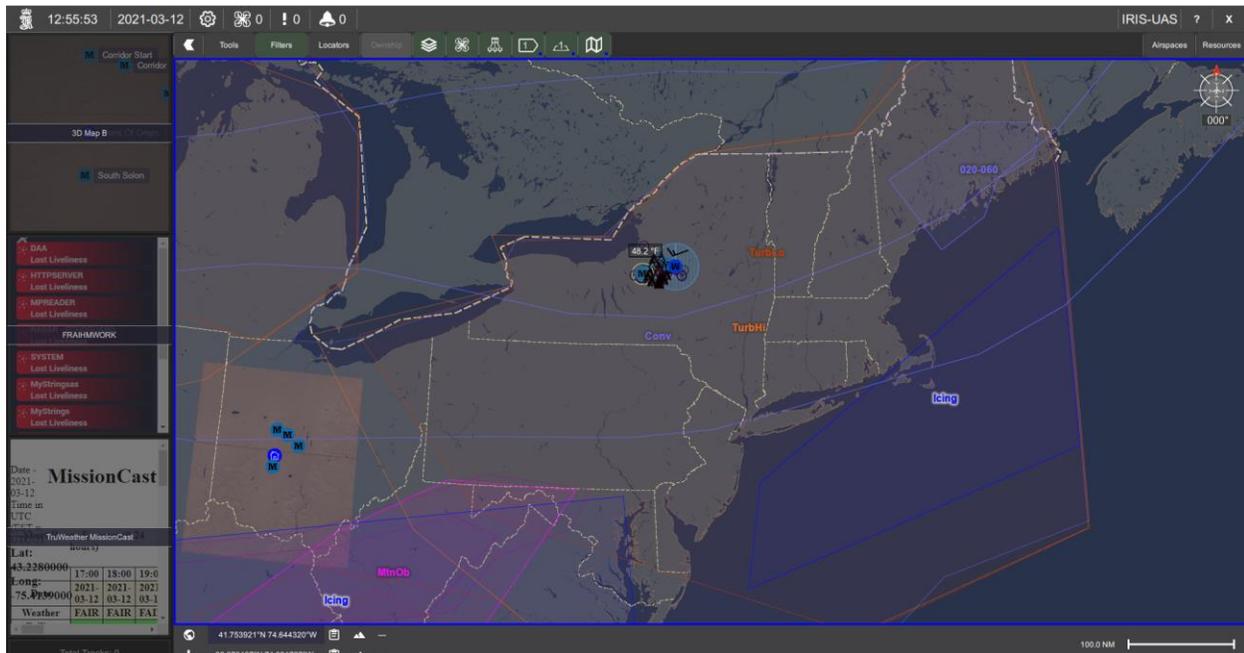


Figure D-12: AIRMET and SIGMET Data in CMP Display

3. **Significant Weather Advisory or SIGMET** – from the Aviation Weather Center: A SIGMET advises on weather, other than convective activity, that is potentially hazardous to all aircraft. This will alert on volcanic ash, severe turbulence, severe icing, and dust/sandstorms resulting in reduced visibilities.

Appendix E: AIS Service Descriptions

Appendix Prepared by
Assured Information Security



Background

Modern systems, spanning from simplistic to extremely complex ones and including the UTM, often contain components subject to cyber effects. The reason modern systems are susceptible to attack is because they leverage software which has proven, over time, to be very difficult to produce without a predictable rate of flaws and vulnerabilities, many of which can be exploited by attackers. In addition, nearly all software projects incorporate open source or third-party software packages that further increase the likelihood of weaknesses that create vulnerability to attack.

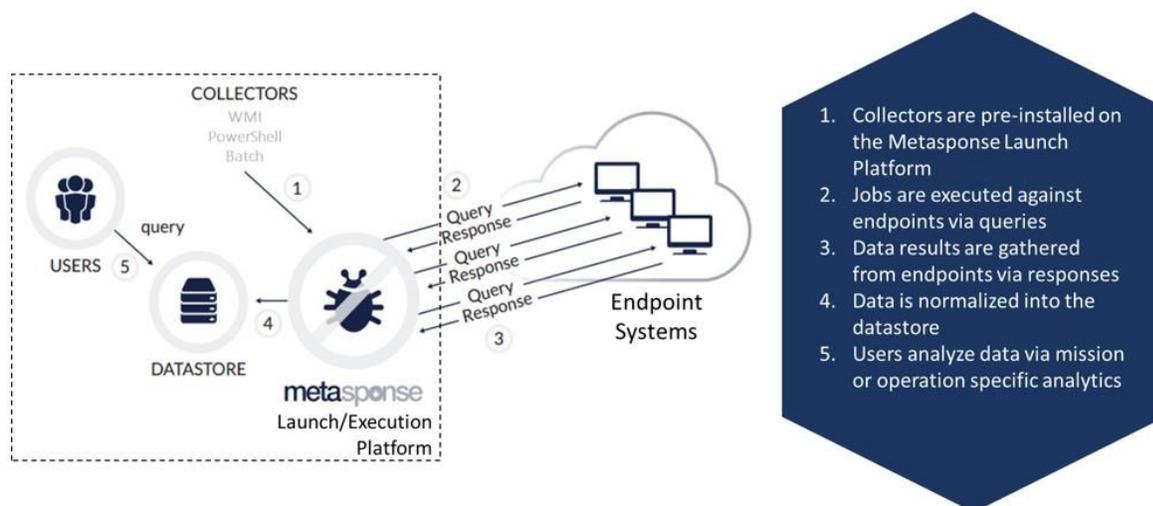
The UTM is a prime example of a system with several cybersecurity-relevant elements. For example, one of several cyber components input to the UTM is a weather feed situated in the cloud, meaning it has internet-facing attack-surfaces subject to a variety of cyber consequences including denial-of-service (DoS), misconfigurations, and exploitable vulnerabilities. Additionally, UTM operators leverage commodity workstations and servers for which cybersecurity is a notable risk. Similar cyber exposure concerns exist for technology in use by an array of Supplemental Data Service Providers (SDSP) that are expected to deliver the reliable and predictable data on which UTM operations depend.

The UTM is also a Cyber Physical System (CPS) in which the physical safety of those in proximity to airborne assets is paramount. While this aspect of human safety differentiates CPSs from more traditional networks, experience has shown that attackers can attack and exploit these networks in the same or very similar ways as they do those traditional networks.

It is in that spirit that AIS contributed to the CMP by designing and developing a component to monitor and assess the cybersecurity of the UTM during operation. This component provides UTM and CMP operators with cyber situational awareness and aids in the mitigation of discovered issues.

Metaspense

AIS brings Metaspense to the challenge of building a comprehensive UTM health monitoring system. Metaspense is an incident response and remediation capability deployed widely across the Department of Defense (DoD) to detect and respond to sophisticated cyber-attacks and intrusions. It contains a wide variety of plugins for connecting to network endpoints (transports), gathering data potentially containing artifacts of compromise (collectors), and analysis capabilities (analyzers). These plugins are extensible for different or custom environments and are tailored for scalability, reliability, and compatibility with existing networks. **Error! Reference source not found.** shows a dataflow for Metaspense as it is traditionally used in incident response.



1. Collectors are pre-installed on the Metaspense Launch Platform
2. Jobs are executed against endpoints via queries
3. Data results are gathered from endpoints via responses
4. Data is normalized into the datastore
5. Users analyze data via mission or operation specific analytics

Figure E-1: AIS Metaspense Data Flow

UTM Cybersecurity Monitoring

We identified two primary aspects of cybersecurity monitoring in the UTM that facilitate effective situational awareness for CMP and UTM operators. First and perhaps foremost, operators need to know when UTM components are under attack and/or compromised by malicious actors. Second, operators benefit from knowing when UTM components present a weak or diminished cybersecurity posture – even when an attack is not underway – because doing so leaves the door open to those attacks by exposing vulnerability.

Knowing when system components are under cyberattack or compromised is important because both can lead to degradation of UTM performance and ultimately affect the safety of people. Simply being under attack can cause targeted components from operating as expected and from providing service to the rest of the system. System compromise is often, in the cybersecurity field, considered synonymous with an attacker having full control over the system with ability to conduct the same set of actions available to authorized users, including supplying radar data, giving go/no-go directives, re-routing traffic in the air, etc.

The UTM’s cybersecurity posture is important because a poor posture leaves the system open to attacks and effects from malicious actors. Cybersecurity posture is a very broad topic with many aspects, some of which are codified in various standards and others that are generally considered “best practices” but perhaps not as well codified. For this effort, we scoped monitoring cybersecurity posture to that of ensuring that the UTM attack surface does not show any well-known software vulnerabilities.

Metaspense for UTM

Our team developed the Metaspense-for-CMP (MSCMP) component of CMP to perform cybersecurity monitoring and mitigation in the UTM.

MSCMP builds upon the Metaspense incident response capability previously described and makes use of its extensibility in order to address the feature gaps needed for effective application in the UTM. Specifically, we developed MSCMP to meet the following objectives:

- Monitor for cyber-attacks
- Monitor for cyber breaches
- Detect poor security posture by scanning for exposed software vulnerabilities
- Report discovered issues as faults to CMP
- Perform these actions without human input

MSCMP monitors for cyber-attacks by subjecting all UTM network traffic to scanning by an intrusion detection system (IDS). For this effort, we chose the Snort IDS due to its maturity, simplicity of operation, and availability of curated signature updates. Leveraging this feature requires a spanning port on the target network which mirrors UTM network traffic to Snort for scanning.

MSCMP monitors for cyber breaches by deploying Metaspense collectors to target UTM components via its transport plugin collection. These collectors search for and retrieve data which may contain indicators of compromise. The three Metaspense collectors integrated into MSCMP during this effort are DNSCache, AutoRuns, and Netstat. The DNSCache collector compares recently queried domain name system (DNS) entries against a blocklist of names associated with malicious activity. The AutoRuns collector checks for persistent applications similarly present on regularly curated blocklists. The Netstat collector checks for existing connections to malicious IP addresses or domains by similarly checking against blocklists. The blocklists are acquired from the publicly available AlienVault threat indicator feed.

MSCMP detects poor security posture by using an open source vulnerability scanner, OpenVAS, to scan UTM systems for well-known software vulnerabilities exposed to the network. This scan also identifies software misconfigurations which can lead to compromise.

Metaspense, which monitors for indicators of compromise and cyber breaches, runs on Windows. OpenVAS and Snort are Linux applications. Due to this misalignment, our architecture includes two primary MSCMP components. First is the MSCMP application itself, running on Windows, which deploys Metaspense-based collectors. Second is a Linux virtual machine (VM) running OpenVAS and Snort that we call the “Appliance VM”. The Appliance VM receives directives to scan the network from the MSCMP application.

MSCMP reports issues it discovers in scans to CMP via the FRAIHWORMORK API. CMP then displays faults to operators, providing the desired situational awareness and giving them an opportunity to acknowledge the fault.

An architecture diagram for MSCMP is shown below.

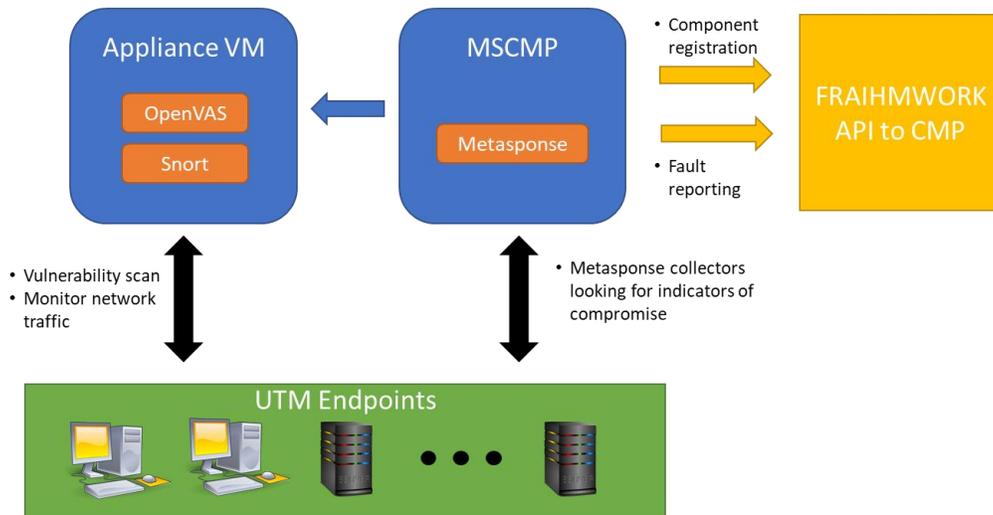


Figure 13: MSCMP Architecture

MSCMP obtains information about targets (UTM components) in two ways. First, targets for vulnerability and IDS scans are obtained via the FRAIHMWORK API. Second, targets for the MSCMP application (i.e. Metaspense) are obtained via a configuration file loaded upon startup. The primary reason for this arrangement is that Metaspense requires administrator credentials to authenticate to target systems prior to pushing and executing collectors while FRAIHMWORK is not currently architected to pass credentials over the network. Thus, we employ the temporary stopgap of using two methods to specify targets.

MSCMP operates by periodically running its various scans, including OpenVAS scans and Metaspense collector scans. The IDS component is always monitoring traffic. The frequency with which MSCMP scans the UTM for cybersecurity issues is controlled by a configuration item in the file consumed by MSCMP upon startup. MSCMP is designed to be started by operators and then to operate in an “always-up” fashion, continuously scanning and reporting faults as they are encountered.

Metaspense Configuration

```
1 # MSCMP
2
3 UTM Cybersecurity health monitoring system.
4
5
6 ## Installation
7
8 1. Download all three items to the system that will run MSCMP app and has
9 Hyper-V for running the Appliance and Test VMs.
10
11 2. Extract appliance.7z, test.7z, and installer.zip
12
13 3. Import the appliance and test VMs by doing the following:
14     - launch Hyper-V
15
16     - Select "Import Virtual Machine"
17
18     - In the wizard to import the VM, when it asks you to specify a folder,
19       specify the folder that has the following three folders within it:
20       "Virtual Machine Hard disks", "Virtual Machine configs", "Snapshots".
21
22     - launch both the Appliance and Test VMs.
23
24 4. Open an Administrator PowerShell console on the MSCMP system.
25
26 5. Execute `Set-ExecutionPolicy Unrestricted` to allow custom PowerShell
27 scripts to execute.
28
29 6. Execute `.\install.ps1`
30
31 ### Configuring MSCMP
32
33 The main configuration for MSCMP is located in the `cmp\config.json` file.
34
35 A brief description of the configuration fields are as follows:
36
37 * uuid - The UUID of this machine.
38 * fraihtwork_url - Options for connecting to FRAIHTWORK
39 * client_id - FRAIHTWORK client username
40 * client_secret - FRAIHTWORK client password
41 * frequency - The frequency in seconds to perform all scans again.
42 * scans -
43     * name - The name of the scan.
44     * hosts - Comma separated list of IPs to target.
45     * scan_options - Scan specific options that will be applied to this
46       scan only.
47     * plugins - A list of Metaspense plugins to use for this scan. Each
48       scan can take plugin specific options as well.
```



```
44
45 The network address of the Appliance VM must be updated in the configuration
    in order for MSCMP to utilize OpenVAS and Snort based detections. Furthermore
    targets for traditional scans must be provided here which includes SSH
    credentials, and the IP address or subnet targeted.
46
47
48 ##### Appliance VM
49
50 For configuring the Appliance VM, the IP address is required. Users must
    ensure the IP address in `cmp\config.conf`, under the Appliance Scan section,
    matches the current Appliance VM IP. The username and password for the
    Appliance VM are already set to the default. If users wish to change the
    default password they can use the `passwd` command in the Appliance VM
    terminal.
51
52
53 ##### Target VM
54
55 Similar to the Appliance VM, the IP address for the Windows target system
    must match the IP address under the scan section of the `cmp\config.conf`.
56
57
58 ##### AlienVault API key
59
60 For IoC detections, users must have an AlienVault account. After registering
    an account at otx.alienvault.com, users can get their OTX API key
    https://otx.alienvault.com/settings page. This key should then replace the
    placeholder in the `cmp\config.json` file. The IoC's will sync with the
    local MSCMP install per the pulses that users are subscribed to. Test
    detection utilize the IoC's compiled by the AlienVault Pulse found at `
    https://otx.alienvault.com/user/AlienVault/pulses` .
61
62 ### Component Registration
63
64 Systems must be registered in FRAIHMWORK in order to report faults. The
    MSCMP components/systems may be registered using the `register_components.py`
    script. IP address, location, descriptions, and names may be modified in the
    script and then executed. The script will clean up any existing AIS systems
    with the description "AIS Test System", "AIS Artemis System", or "AIS Artemis
    Appliance System" and the physical location of Rome. *WARNING* this script
    will remove systems found to match which may result in a loss of data. To use
    the script, modify the values as desired found at the top of the script. Use
    `python .\register_components.py` to execute the script. Once the components
    are registered, replace the UUID in the `cmp\config.json` file with the UUID
    registered for the AIS Artemis System.
65
```



```
66
67   ### First Run
68
69   The first run will require that the Raziel license be registered and the
70   AlienVault signatures be synced.
71
72   1. Execute `. \metaspense-for-utm.bat`
73
74   2. When prompted, provide the full path to the license file. i.e.:
75   `C:\Users\john\Desktop\Artemis\license.txt`
76
77   3. Enter the license password provided when prompted.
78
79   4. The license should register without any errors and the first scan will
80   begin. The first scan will sync the AlienVault IoC's and may take a little
81   while. No signatures are expected to be identified on the initial run due to
82   the initial sync of the AlienVault IoC's.
83
84   ### Fault/Mitigation Registration and Output
85
86   Faults may be observed in the MSCMP debug output as well as in the Fraihmwork
87   Dashboard. Faults must be associated with a registered component or system.
88   If the faulting system is not registered, no fault will be registered in
89   FRAIHMWORK.
90
91   Output from the MSCMP system can be observed in two locations. First, the
92   Powershell console from which metaspense-for-utm.bat is executed in will
93   output debug output. This debug output consists of Metaspense job results,
94   and fault/mitigation registration information. The second method for viewing
95   results is to watch the FRAIHMWORK dashboard found at `
96   https://dev.fraihmwork.resilienx.com/`.
97
98   ## Usage
99
100  Following the first run, consecutive uses of MSCMP no longer require license
101  registration.
102
103  To execute 'Metaspense For UTM'; in an elevated privilege terminal execute:
104  `>. \metaspense-for-utm.bat`
105
106  To execute a log watch for Metaspense for debugging purposes:
107  `>python .\raziel.zip --product=MsCMP:1.0 -m metaspense.scripts.watch`
```



```
96
97  ## Example Detections
98
99
100  ### Setup
101
102  All target systems must be registered prior to usage. If the target
103  systems/components are not, faults will not be reported.
104
105  ### XMAS Scan (Snort Appliance Collector)
106
107  This uses the Snort collector and CMP Appliance Snort sub analyzer to detect
108  a potential threat.
109
110  1. From the Appliance VM, we may execute hping3 against the target VM
111  with the command `sudo hping3 172.17.109.132 --destport 21 -c 1 --syn --ack
112  --fin --rst --push --urg --xmas --ymas`. This will trigger Snort to log a
113  warning for an "Attempted Information Leak". This is a priority 2 Snort log.
114  A priority of 1 (high) is the most severe and 4 (very low) is the least
115  severe. By default, priority of 3-1 are reported per MSCMP.
116
117  2. Execute the MSCMP application. Once the initial scan is complete the
118  fault should be generated and reported against the test component/system.
119
120  ### Malicious Domain (DNSCache Collector/AlienVault Analyzer)
121
122  We have added the malicious domain, libre-office.site, to the Windows target
123  host file and redirected the IP to localhost.
124
125  1. Modify the configuration scan to target the test VM.
126
127  2. Execute a scan and watch for the fault Identified by the
128  libre-office.site IoC.
129
130  ### Windows 10 CVEs (OpenVAS Appliance Collector)
131
132  This fault will identify multiple CVEs for the Windows 10 Target VM.
133  The following CVEs should be identified: CVE-2018-15919, CVE-2018-15473
134
135  1. Similar to previous examples, the Appliance and Target VMs must be
136  running along with having updated the configuration file for the associated
137  IPs.
138
139  2. Again execute a scan and the faults should be displayed in the log
140  output by the CMP analyzer.
```



Appendix F: Capability to Requirements Trace

CMP Capability ID	Capability Description	Requirements Allocation	Test Case Allocation
CMP-CAP-001	Accept & display UTM participating ownship telemetry.	5.1.1, 5.2.22, 5.2.28	CAP-TST-001
CMP-CAP-002	Accept & display UTM surveillance sensor tracks.	5.1.3, 5.2.22, 5.2.28	CAP-TST-002
CMP-CAP-003	Display details of selected ownship telemetry.	5.2.23, 5.2.24, 5.2.26	CAP-TST-001
CMP-CAP-004	Display details of selected surveillance target tracks.	5.2.23, 5.2.24, 5.2.32, 5.2.27	CAP-TST-002
CMP-CAP-005	Flag and display track as ownship.	5.2.29, 5.2.30, 5.2.31	CAP-TST-003
CMP-CAP-006	Follow ownship on airspace display.	5.2.33	CAP-TST-003
CMP-CAP-007	Accept & display airspace structure data - NOTAMS, TFRs, Classes, etc.	5.1.4, 5.2.7, 5.2.8, 5.2.9, 5.2.11, 5.2.14	CAP-TST-004
CMP-CAP-008	Accept & display UTM operation volume data.	5.1.5, 5.2.10	CAP-TST-005
CMP-CAP-009	Accept & display UVR volume data.	5.1.6, 5.2.6	CAP-TST-006
CMP-CAP-010	Accept & display terrain data.	5.1.7, 5.2.2	CAP-TST-007
CMP-CAP-011	Accept & display obstacle data.	5.1.8	CAP-TST-008
CMP-CAP-012	Accept & display current weather conditions and information.	5.1.9, 5.2.52, 5.2.55, 5.2.53	CAP-TST-009



CMP Capability ID	Capability Description	Requirements Allocation	Test Case Allocation
CMP-CAP-013	Register UTM system components.	5.1.10	CAP-TST-010
CMP-CAP-014	Display UTM component description and condition data.	5.1.10, 5.1.11, 5.1.12, 5.2.41 5.2.42, 5.2.43, 5.2.44, 5.2.46, 5.2.47	CAP-TST-011
CMP-CAP-015	Create & publish a UVR automatically.	5.1.15, 5.6.2, 5.6.3, 5.6.4	CAP-TST-012
CMP-CAP-016	Create & publish a UVR manually.	5.1.15, 5.6.2, 5.6.3, 5.6.4	CAP-TST-013
CMP-CAP-017	Monitor & report CMP component description and condition data.	5.1.17, 5.1.18, 5.1.19	CAP-TST-014
CMP-CAP-018	Configure airspace display settings.	5.2.1, 5.2.3, 5.2.4, 5.2.5, 5.2.12, 5.2.13 5.2.18, 5.2.25, 5.2.28	CAP-TST-015
CMP-CAP-019	Create & display custom airspaces and annotations.	5.2.15, 5.2.16	CAP-TST-011
CMP-CAP-020	Configure UI display settings (Web Card Panels).	5.2.19, 5.2.20, 5.2.21	CAP-TST-016
CMP-CAP-021	Detect and display terrain alerts.	5.2.37	CAP-TST-017
CMP-CAP-022	Display system alerts (faults) and associated information.	5.1.13, 5.2.38, 5.2.39, 5.2.40, 5.2.45, 5.3.2, 5.3.3, 5.3.4	CAP-TST-018
CMP-CAP-023	Establish and monitor UTM system configuration baseline.	5.2.48, 5.2.49	CAP-TST-019
CMP-CAP-024	Detect and display configuration alerts.	5.2.51, 5.2.50	CAP-TST-019
CMP-CAP-025	Detect and display UAS weather hazard information.	5.2.54, 5.2.56, 5.2.57, 5.4.1, 5.4.2, 5.4.3, 5.4.4, 5.4.5	CAP-TST-020



CMP Capability ID	Capability Description	Requirements Allocation	Test Case Allocation
CMP-CAP-026	Detect and report loss of component connection	5.3.1	CAP-TST-021
CMP-CAP-027	Monitor and display network & network component health.	5.1.14, 5.3.5, 5.3.6, 5.3.7	N/A
CMP-CAP-028	Monitor for and display cyber security alerts.	5.5.1, 5.5.2, 5.5.3, 5.5.4	CAP-TST-023
CMP-CAP-029	Deploy cyber security threat mitigations.	5.5.5	CAP-TST-024
CMP-CAP-030	Maintain and display component blocklist.	5.6.1	CAP-TST-025
CMP-CAP-031	User / Laptop Login	5.2.17	CAP-TST-026



Appendix G: Live Flight Mission Brief

The slide features a large blue arrow pointing right, containing logos for KONGSBERG, RESILIENX, ais, and TruWeather SOLUTIONS. To the right of the arrow, the FAA logo is at the top, followed by the text 'FAA BAA Program', 'Live Flight Testing Mission Brief', and '09 March 2021'. At the bottom right are logos for NUAIR and GRIFFISS INTERNATIONAL AIRPORT.

Test Objectives



- Demonstrate capabilities of the developed Contingency Management Platform (CMP) for application in Unmanned Traffic Management (UTM) environments.
- Key Capabilities:
 - Aggregated Airspace Situational Awareness - Supervisory
 - UTM Ecosystem Health & Integrity Monitoring
 - Creation and Issuance of UAS Volume Reservations (UVRs)
 - Weather Data Display, Forecasting, & Alerting
 - UTM Component Cyber Security Monitoring & Alerting



Test Scenarios



- Four (4) scenarios will be executed during live flight -testing activities.
- Test scenarios will leverage a combination of live and simulated elements.

Scenario #	Description
1 – Automated UVR	Demonstrates capability of CMP to automatically generate and issue a UVR based on component failure. Will simulate radar failure, issue UVR, and direct operations to land due to conflict.
2 – Manual UVR	Demonstrates capability of CMP to allow operator to draw, define, and publish custom UVRs. simulate a weatherrelated hazard as the catalyst for operator to take these actions.
3 – General Features / Cyber Event	Demonstrates several features of the platform interface, including ownership flagging and follow terrain proximity visualizations, surveillance data visualization.
4 – Non-Conforming Op	Demonstrate visualizations for nonconforming operations and possibly DAA alerting.

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Scenario 1 – Automated UVR



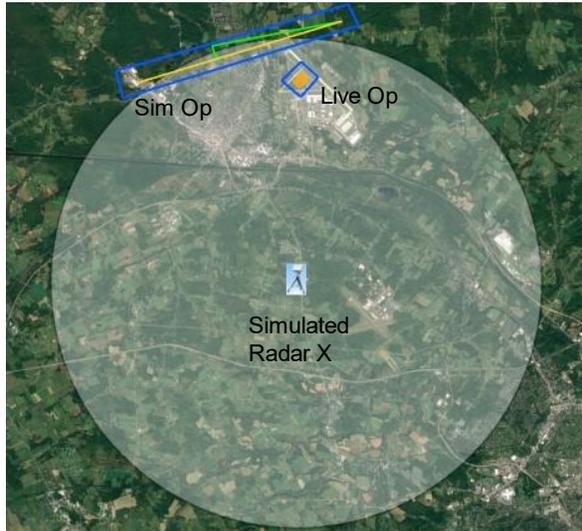
Narrative

UAS A (Live Op) launches and begins a survey operation, executing a grid pattern. Simultaneously UAS B (Simulated Op) launched from a distribution center and begins executing a package delivery mission. Shortly after launch of both operations, a radar failure is encountered and reported on the CMP. The CMP proposes an automated UVR covering the surveillance region of the faulted radar. The CMP user accepts this UVR for publication to the UTM ecosystem. The UVR conflicts with both UAS A and UAS B operations. UAS A (Live Op) is forced to land as the entirety of their operational volume is encompassed by the UVR. UAS B (Simulated Op) changes their trajectory to exit the UVR airspace, and still complete their mission, as their operational volume straddles the faulted radar surveillance region.

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Scenario 1 – Automated UVR



Simulated Radar X Details:

- Location

LAT	LONG
43.159942°	-75.419761°

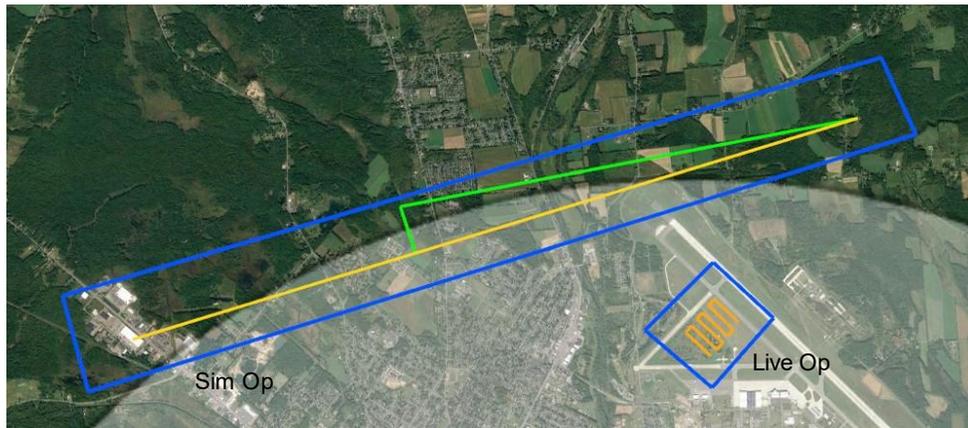
- Surveillance / UVR Range:
 - 10km

Operation Parameters:

Operation	Altitude (ft / m AGL)	Speed (m/s / knots)
Simulated Operation	2000 / 600	40 / 78
Live Operation	300 / 90	10/20

Scenario 1 – Automated UVR

— Notional Simulated Path (Won't be visualized)
 — Actual Simulated Trajectory



Scenario 2 – Manual UVR

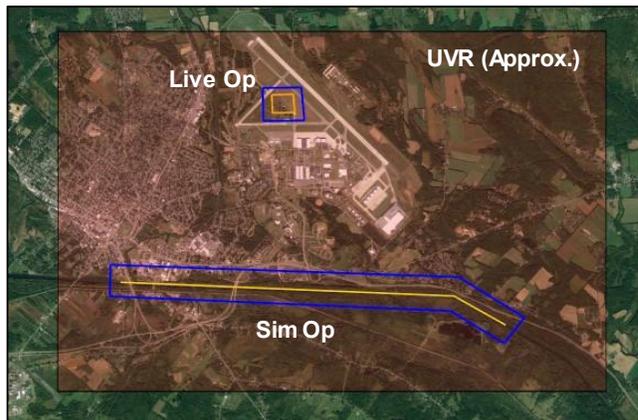
Narrative

UAS A (Live Op) launches and begins a vertical infrastructure inspection operation, executing a rectangular pattern. Simultaneously UAS B (Simulated Op) launches and begins executing a linear inspection operation over the nearby Erie Canal. Shortly after launch of both operations, a regional Weather Alert is received due to potentially hazardous wind conditions. The Airspace Supervisor (CMP Operator) manually defines and publishes a UVR in response to the weather alert. UAS A (Live Op) lands due to the UVR applicability to their class of aircraft. UAS B (Sim Op) however, continues executing their operation as this aircraft has a higher wind tolerance and thus is not affected by the specific Wind Advisory.

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Scenario 2 – Manual UVR – UVR



UVR Details:

- UVR will be drawn manually so exact vertices are not provided
- It does not need to be square, it just needs to cover both operational volumes.
- TWS investigating canning of a weather alert to support demonstration

Operation Parameters:

Operation	Altitude (ft / m AGL)	Speed (m/s / knots)
Simulated Operation	200 / 60	25 / 48
Live Operation	300 / 90	10/20

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Scenario 3 – Gen. Functionalities



Narrative

UAS A (Live Op) launches to begin an operation. During operation of UAS A, ownship flagging and following capabilities are demonstrated using IRIS controls. The terrain alerting feature is turned on and terrain proximity ring around UAS A shown. UAS B (Sim Op) is launched. Changing ownship designation capability is demonstrated, switching from UAS A to UAS B. ADS -B surveillance layer is toggled on in IRIS display. Real Targets of Opportunity indicated if present. Simulated ADS -B tracks in in relative vicinity of UAS operations are also shown.

A cyber security threat against the Live Operation Ground Control Station is registered (simulated). The Live operation is directed to land.

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Scenario 3 – Gen. Functionalities



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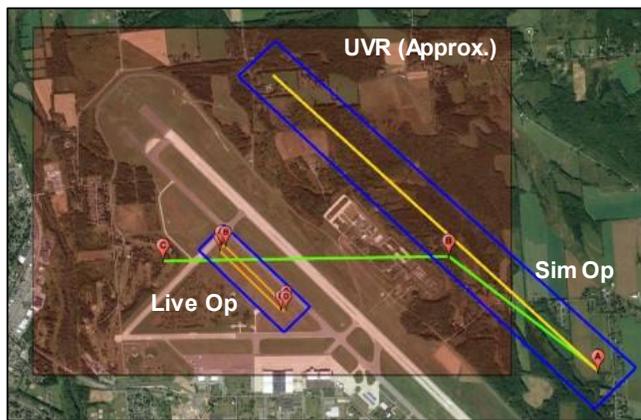
Scenario 4 – Rogue Operation



Narrative

UAS A (Live Op) launches to begin a linear inspection operation. UAS B (Sim Op) launches to conduct a BVLOS operation. Midway through UAS B (Sim Op) operation, it veers off course and exits its defined operational volume and enters a 'Contingent' state. UAS B (Sim Op) is headed in the direction of UAS A (Live Op). The CMP operator issues a UVR around the Contingent operation. A conflict alert is registered between the two aircraft. UAS A (Live Op) lands in response to conflicting with the issued UVR.

Scenario 4 – Rogue Operation



- Notional Simulated Path (Won't be visualized)
- Actual Simulated Trajectory

Operation Parameters:

Operation	Altitude (ft / m AGL)	Speed (m/s / knots)
Simulated Operation	200 / 60	18 / 35
Live Operation	300 / 90	10/20

Appendix H: UTM Weather Hazards Analysis

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Assessment of New York State UAS Test Range Weather Observation Coverage and Gaps

Gary Graeff

Gary.Graeff@TruWeatherSolutions.com



TruWeather Solutions, 10 August 2020

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Assessment of Weather Observation Coverage and Gaps

The purpose of this assessment is to identify weather measurement gaps and primary weather risks to the operational safety of Unmanned Aerial Systems (UAS) flying within the New York UAS Test Site (NYUASTS) at Griffiss International Airport, and the 50 mile NY UAS Traffic Management (UTM) corridor. The corridor stretches from just east of the NYUASTS, westward to include Syracuse Hancock International Airport and surrounding areas. This assessment will evaluate weather sensing capabilities within and surrounding the areas mentioned, which includes the cities of Rome, Utica, and Syracuse, as well as the NYS Preparedness Center (SPTC) in Oriskany, NY. Refer to **Figure 1** for an estimated corridor outline.

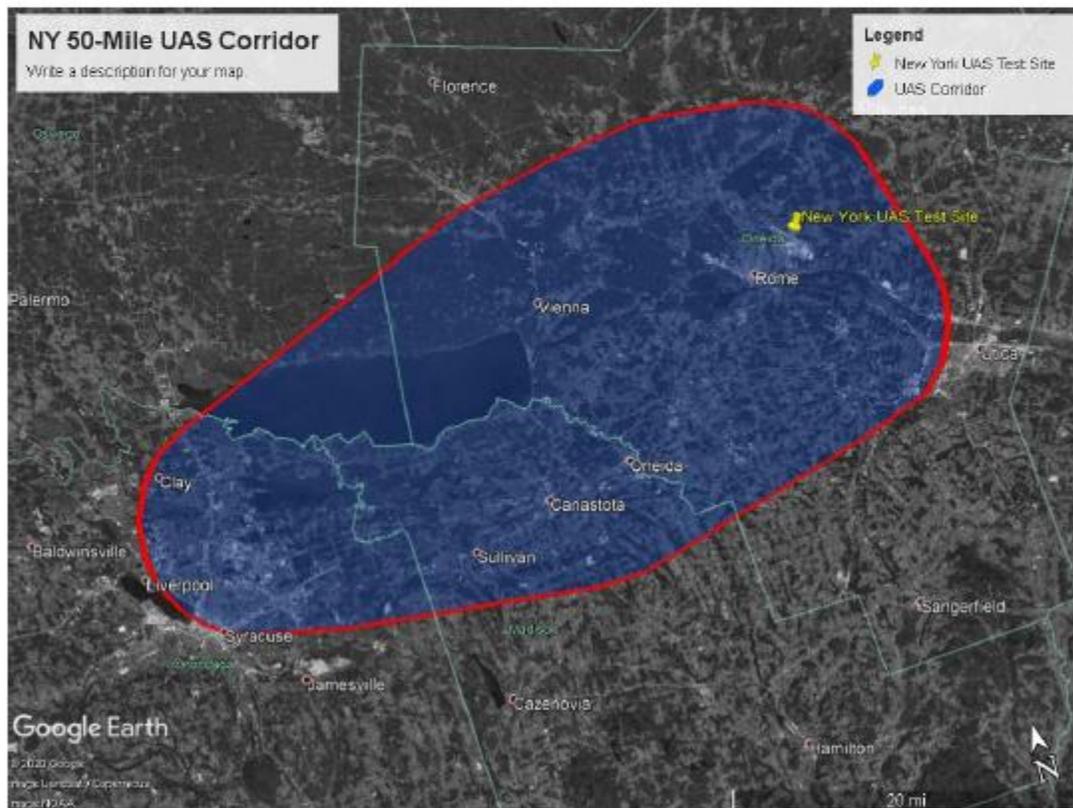


FIGURE 1: ESTIMATED OUTLINE OF THE NY 50-MILE UAS TRAFFIC MANAGEMENT CORRIDOR.

A strategy to mitigate the gaps in these areas is presented. In particular, the risks due to unknown existing upper-level winds, turbulence, icing, and thermals below 3,000 feet Above Ground Level (AGL) due to a lack of weather sensing equipment within the

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areas depicted. These parameters are a focal point, not because they are more dangerous than convection, ceiling, low visibility, and precipitation to UAS; however, they are the hardest to identify by meteorologists and operators. Local wind fields present “invisible threats” that generally require meteorologists to identify through “inference” based on knowledge of how the atmosphere works and skilled interpretation of numerical weather models that have deficiencies in forecasting these events. This weather risk assessment will layout the current weather sensing network within proximity to the test site and UAS corridor. Some sensing solutions are presented to close the gaps and mitigate risks, where possible, to reduce uncertainty, which will enable safe mission planning and better mission effectiveness rates to UAS operations when weather is a factor. This report is part of the FAA BAA UAS Contingency Management Platform project.

Risks to UASs

Due to their small size, lightweight, and lack of human weather situational awareness in the “cockpit,” UASs are more susceptible to weather conditions than larger, better instrumented, and heavier human-crewed aircraft. Changes in wind speed with horizontal and vertical extent, as well as, the timing of changes, could drastically affect flight and flight control. Although thunderstorm hazards may be more visually obvious and avoidable during Visual Line of Sight (VLOS) operations, gust fronts and outflows from convection can often go undetected tens of miles or more from the storm depending on the terrain and land surface characteristics. The test areas lie mostly within western portions of the Mohawk Valley and the southern regions of the Lake Ontario Lowlands. This area is sandwiched between the Adirondack Mountains and Tug Hill Plateau to the north and the Alleghany Plateau and Catskill Mountains to the south. This layout has a localized effect on wind patterns within the Mohawk Valley that are often unresolved by Numerical Weather Prediction (NWP) or “weather models.” The valley can often experience localized fog, especially during the cooler months. Speaking of cooler months, the entire test area is vulnerable to heavy snow from lake effect snow bands. These weather phenomena, which are difficult to predict through standard weather products, will pose a risk to BVLOS missions seeking to practice and meet Beyond Visual Line of Sight (BVLOS) requirements.

The Mohawk Valley has a unique effect on prevailing wind flow. When the large-scale wind flow is from the south, there is a terrain effect that funnels wind through the valley from the east. This easterly flow in the near-surface levels is often slower than the southerly winds a few hundred feet off the surface, creating turbulent effects including wind shear that can send a UAV off track or even lead to a hard landing. Low-level wind shear and turbulence associated with nocturnal inversions and summertime low-level jets are also a threat. All these wind characteristics have a direct effect on battery

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life, efficiency of flight, and may result in a sudden loss of control leading to downed aircraft.

Central New York has its share of convective weather, including lake effect snow. Many of the UASs on the market today have a wind threshold of 20-25 mph. Outflow boundaries from even garden variety thunderstorms can easily reach this threshold and often go undetected by radar miles away from the storm center. Although tornadic activity is much rarer than other parts of the country, they do occur in NYS, and TruWeather Solutions' research shows that the Mohawk Valley can enhance the risk of these storms in certain atmospheric situations. Lake effect snow and snow squalls are about as hard to predict as thunderstorms and can be equally as dangerous. Weather conditions can change from favorable to near-zero visibility and high winds in a matter of minutes. Any of these phenomena can form rapidly and have a significant impact on operations and foremost to safety.

A Lincoln Labs survey asked operators to "Provide the significance of each weather condition to the feasibility of your operation." Refer to **Figure 2**, which shows that convective weather and precipitation were ranked very high. The survey separated winds into "surface wind, surface wind gust, winds aloft, and surface wind direction" (Campbell, Clark & Evans, 2017). Combining these categories while including turbulence and the hazardous wind effects from convection lead to wind conditions as the most significant weather phenomena affecting flight.

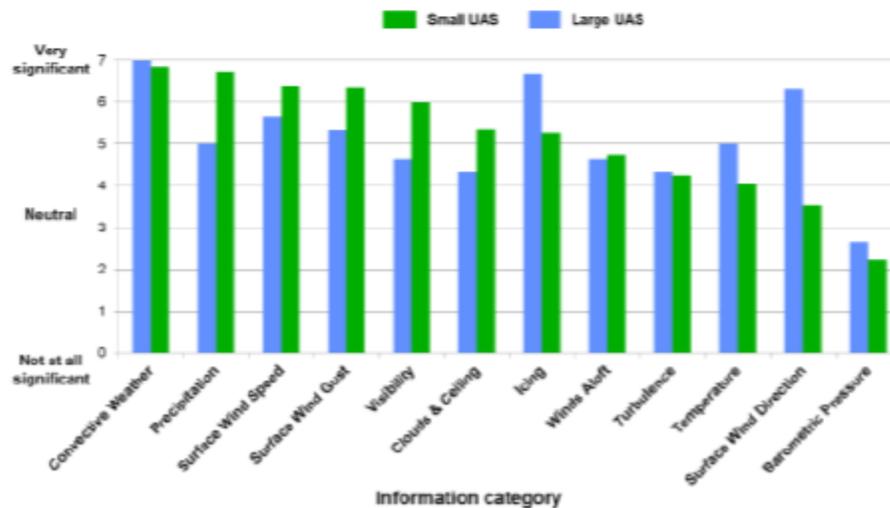


FIGURE 2: WEATHER CONDITION SIGNIFICANCE AS DETERMINED BY UAS SURVEY FEEDBACK

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Although wind, turbulence, and thermals will likely become the most common weather risks to flight safety, effectiveness, and productivity, other weather parameters, such as icing, have detrimental effects on flight as well. Attention to drizzle or rain with near-freezing temperatures at the surface needs to occur to prevent ice buildup that could lead to loss of control.

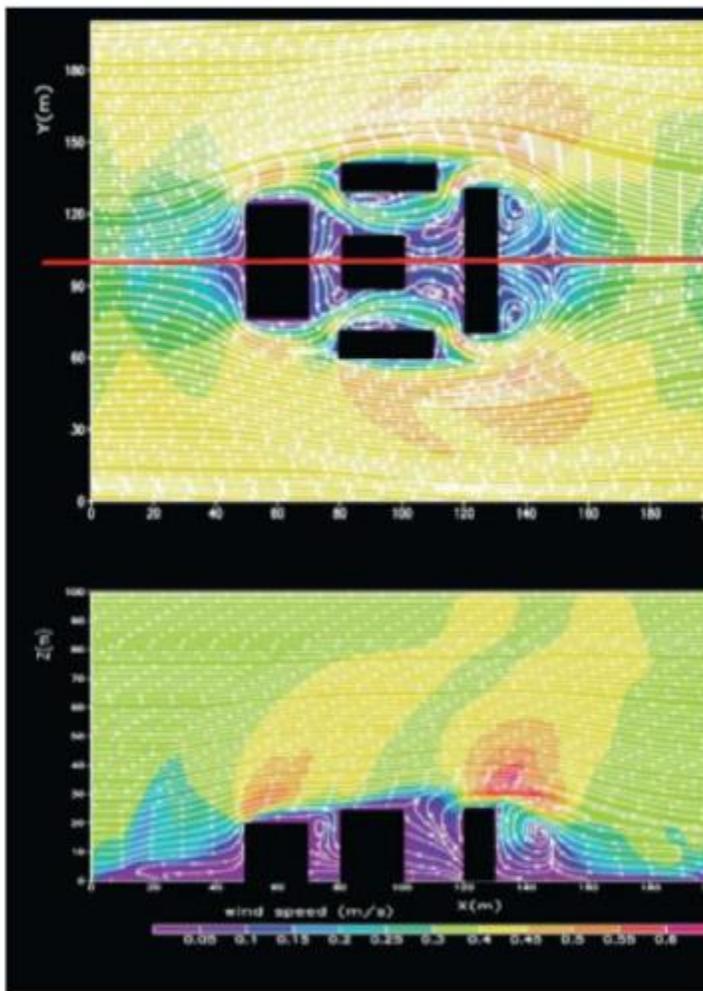


FIGURE 3: WIND PATTERNS COMPUTED USING ARMY RESEARCH LABORATORY (ARL) MICROSCALE ATMOSPHERIC BOUNDARY LAYER EXPERIMENT (ABLE) NUMERICAL MODEL (DAVE KNAPP PRESENTATION AT UAS-WX WORKSHOP NASA AMES. JULY 2016.)

Cloud ceilings and visibility thresholds need to meet FAA Part 107 requirements for VLOS systems and IFR conditions for BVLOS. Cloud and ceiling conditions have highly localized characteristics due to topography or rapidly changing weather conditions. Rapid changes in visibility or cloud ceilings may result in encounters with tall objects such as towers and buildings. Hard landings are possible if the ground becomes obscured. All these conditions may occur within the NYS UTM corridor.

Finally, wind, turbulence, and thermal risks increase in urban environments where buildings and other structures impact wind flow where winds may significantly accelerate or decelerate due to the wind being funneled into narrow streets due to obstructions.

Figure 3 shows the effect a simple building configuration has on local winds. Additionally, the risk of unanticipated turbulent eddies and vortices occur that are not captured with traditional weather forecast models. Wind speeds are sped up or slowed down 50% to as much as 90% of

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the mean wind. Turbulent eddies are created as the wind swirls around obstructions. These effects can be felt within smaller cityscapes such as downtown Rome and occur very often in downtown Syracuse, especially during windy days.

Current Weather Sensor Layout

There are different methods to observe or remotely sense weather conditions today with varying accuracy in the near-Earth environment (0-3,000 feet AGL) within and surrounding the NYUASTS and 50-mile corridor. These include Automated Surface Observing Systems (ASOS), various mesonet systems, Personal Weather Stations (PWS), weather radar, radiosondes, traffic cameras, and satellite data. Refer to **Figures 4** for the current surface observation layout.

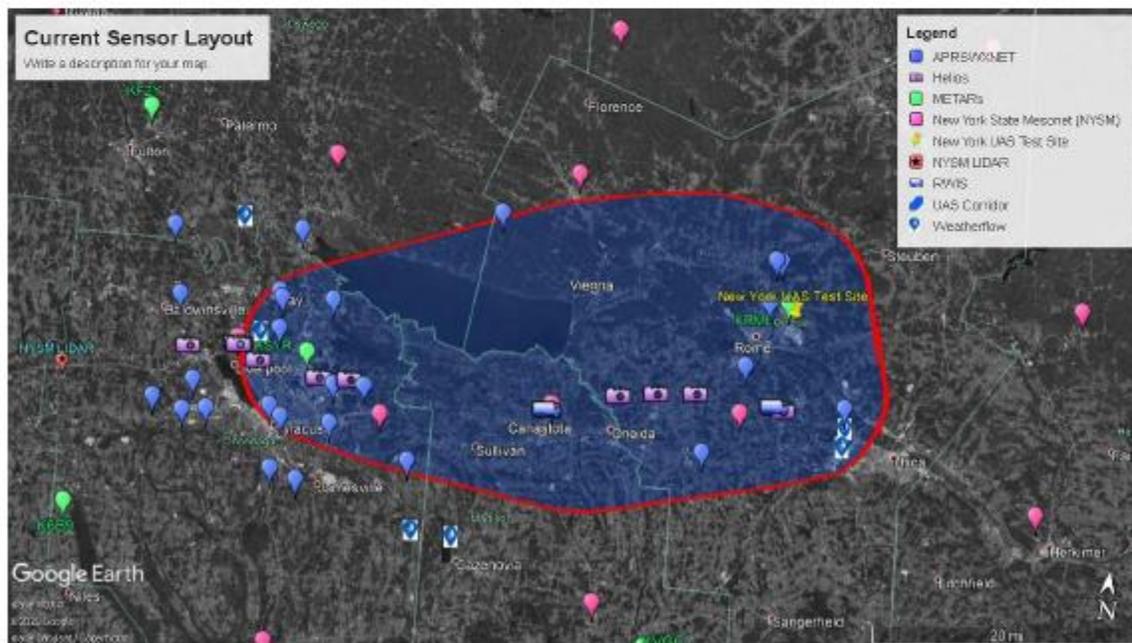


FIGURE 4: LOCATIONS OF SURFACE WEATHER SENSORS WITHIN AND NEAR THE 50-MILE UTM CORRIDOR.

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Primary Weather Observation Capabilities within the test areas today

1. Automated Surface Observing Systems (ASOS) and Automated Weather

Observation Systems (AWOS): The ASOS/AWOS network is one of the most reliable weather networks available today. Refer to **Figure 5** for a typical ASOS configuration. These systems are sited to a standard and undergo routine maintenance and calibration, making them very reliable. However, coverage is limited to locations at airports, and the measurements are only valid within a 5NM radius of the aerodrome



FIGURE 5: AUTOMATED SURFACE OBSERVATION SYSTEM (ASOS)

center point. There are five such sensors within a respectable distance of the test corridor. There are two ASOS sensors within the corridor. One is at the NYUASTS on Griffiss International Airport (KRME), and the other is at Syracuse Hancock International Airport (KSYR). The other three lie outside, but within 20 miles of the estimated corridor boundaries. One AWOS site is 12 miles to the south at Hamilton Municipal Airport (KVGK), another AWOS site is about 17 miles southwest of Syracuse at the Skaneateles Aero Drome (K6B9). The third sensor is an ASOS system located at Oswego County Airport (KFZY).

Wind measurements are taken at a standard height of 10 meters (33 feet) above ground. Although these sensors are accurate, they do have some biases due to all of them being located very near an open runway. This environment is dissimilar from where small UAS will likely take-off and land from near forest edges, buildings, and other landscapes that cause unstable wind flow. Having only two stations within the test areas, valid for 5NM miles from aerodrome center point, leaves large gaps along the route for ASOS/AWOS-quality observations. These sensors **do not** measure wind and temperatures at UAS flight levels above ground level, leaving another significant gap in coverage. In areas where small UAS fly, the wind differences in areas with inhibited surface wind flow and rising to an altitude above tree levels could be mission impacting, yet undetectable from the ground.

The official METAR reports generated from these networks is low latency and updates too infrequently for meeting UAS requirements. A METAR is transmitted every hour with sub-hourly reports generated under specified changes in weather. These changes include the beginning and end of precipitation or thunderstorms, changes in cloud height above or below specified levels, or visibility changes above or below specified thresholds. Those thresholds have been set based on the impact to human

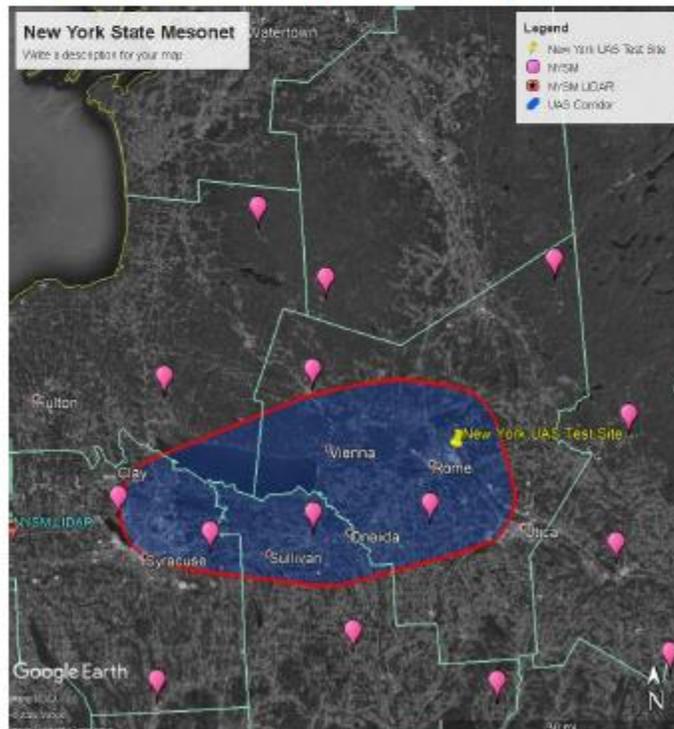
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crewed aviation. There are wind thresholds that trigger sub-hourly observations; however, they are only for significant changes in direction or speed. The system continually takes observations with data every 5 minutes available for some airports with a 5-15-minute lag time. The sensor locations within the corridors with this capability include KRME, KSYR, and KFZY. The AWOS at KVGC can report an observation at this interval, as well as, send the observation out as a METAR every five minutes. The K6B9 sensor sends a report every 20 minutes despite changes in weather.

2. New York State Mesonet (Mesoscale Network): The NYS Mesonet is an extensive weather sensing network with many weather parameters available at each location. These include wind, temperature, and precipitation measurements. Ceiling and visibility are not reported; however, visibility may be derived to some extent from cameras that upload pictures at 5-minute intervals. There are four NYS Mesonet locations within the estimated corridor. From west to east, they include one in Liverpool, Fayetteville, Canastota, and Westmoreland. Refer to **Figure 6** for the NYSM layout. These measurements are taken to the same standard heights as the ASOS at 10 meters for wind and 2 meters for temperature, dewpoint, and humidity, etc.



There is one site to the southwest of the corridor near Jordan, NY that features a LiDAR (Light Detection and Ranging) sensor. This is the only readily available sensor data that can measure winds between the surface and 3000 feet above ground level within close proximity to the Syracuse to Rome corridor every 5 minutes with reasonable accuracy.

FIGURE 6: NEW YORK STATE MESONET LAYOUT.

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3. Road Weather Information System (RWIS): There are three RWIS sensors along the Interstate 90 thruway which run through the corridor. Each of these sites has a camera and are within very close proximity to a Helios traffic camera (described later)



FIGURE 7: EXAMPLE OF AN RWIS SENSOR.

The locations are near Liverpool to the west, Canastota in the middle, and Oneida to the East. These locations report temperature, relative humidity, and wind speed and direction. Refer to **Figure 7**.

4. County and local government and Commercial off the shelf Personal Weather Stations (PWSs): There are other weather stations within local and county government, along with PWSs that are crowd-sourced and offered through the US National Mesonet Program. These data are resold and quality controlled through a broker to TruWeather Solutions and other weather providers. The integration of this data into the previously mentioned networks provide a much denser network of surface observations. Refer to **Figure 8** for the current layout.

The data from this equipment is not generally of the same specifications as official government systems; however, the specs are usually adequate for sUAS operational decision making. The risk in using these observations there is no standard to which they are employed. There is often no way to verify the height of the sensors or their location in relation to buildings or trees. For example, an instrument mounted at 6 feet above the

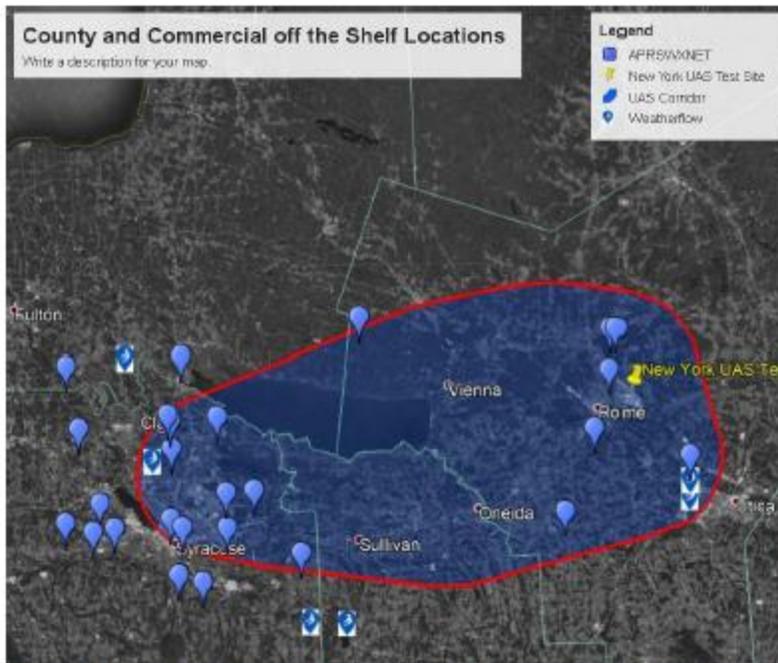


FIGURE 8: LOCAL GOVERNMENT AND PERSONAL WEATHER STATION LAYOUT.

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ground and 20 feet from a building, is vulnerable to errors in wind speed and direction due to the obstruction caused by the building. The PWS locations provided through the broker have a quality control method that will eliminate suspect observations when siting is affecting the quality of the observation when compared to surrounding weather data. These wind data sets are useful for planning and providing a measure of situational awareness that would otherwise not be available. A trained meteorologist is then able to infer the likely conditions at a location and create usable Go vs. No Go decision level data.

There are 32 additional weather sensors of this category within and surrounding the corridor. Most of which are clustered around the greater Syracuse area.

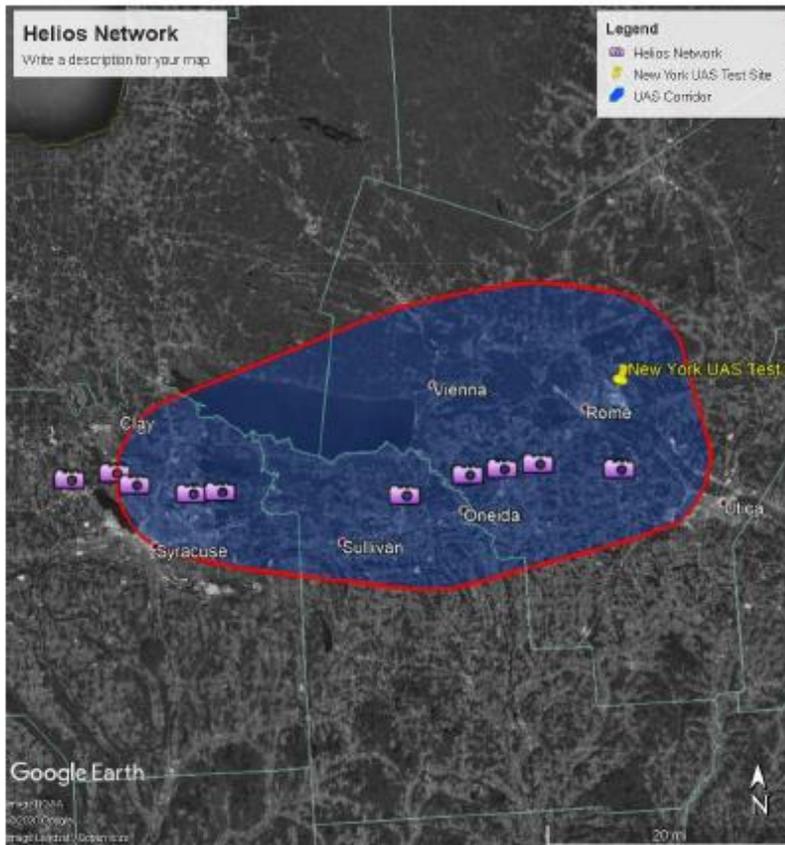


FIGURE 9: HELIOS TRAFFIC CAMERA LAYOUT.

5. Traffic Camera Analytics (Helios): In addition to cameras on the three RWIS sensors mentioned earlier, there are several traffic cameras along the Interstate 90 Thruway. These cameras not only give a visual look at the current conditions, they also provide analyzed weather data. The Helios network within the TruWeather Solutions system can return the rate of precipitation and visibility data, delineating visibility less than 0.6 miles. Refer to **Figure 9** for the Helios traffic camera layout.

6. Weather Radar: The 50-mile UTM corridor sits roughly in the middle of the National Weather Service Weather radars located in Binghamton and Montague, NY. These radars are often placed on top of an elevated area, such as

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the Tug Hill Plateau. The radar beam is tilted at different angles to sense different elevations of the atmosphere. The lowest tilt is 0.5 degrees. This tilt along with the curvature of the Earth results in a radar beam that exponentially rises above the surface with distance from the radar site. Therefore, the surface of the main test corridor is thousands of feet below the lowest radar beam, meaning the beam is overshooting the ground over Griffiss International at 7600' and 4347' above ground level from the Binghamton and Montague radars respectively. This renders their wind sensing abilities almost useless when it comes to UAS flight in the lowest levels. Low cloud top precipitation and drizzle are often missed by these radars.



FIGURE 10: WEATHER BALLOON (RADIOSONDE)

7. Weather Balloons (Radiosondes):

Whenever one hears about a weather balloon, they are referring to a radiosonde. Radiosondes are attached to a balloon and report temperature, dewpoint, wind data, and location back to a ground station. Refer to **Figure 10**.

The National Weather Service launches these radiosondes twice per day at precisely 00Z and 12Z. The observations return much needed upper air data; however, two times per day is hardly enough observed data. The other issue is how far apart these observations are. The closest radiosonde launch location is at the National Weather Service offices 87 miles to the east in Albany, and 169 miles to the West in Buffalo, NY.

8. Weather Satellites: Satellites can remotely sense weather, including the detection of clouds, cloud top heights, convection, and fog detection, among other things. They can infer wind speed by cloud-top movement. The limitation is as the Infrared satellite sensor passes through the atmosphere, it degrades due to clouds and particulates and generates sub-quality measurements for winds in the lowest levels. Additionally, using visual imagery, very low-level stratus clouds, and ground fog are very difficult to measure the speed of movement due to their smooth nature. This makes it challenging for humans or computers to track the movement of cloud elements.

Gaps in Weather Sensing Coverage

Lincoln Labs conducted a Gap Analysis across the National Airspace. It identified which weather conditions are the most significant to UAS operations. In addition, it identified the deficiencies in observing and forecasting those elements within the current weather infrastructure. Refer to **Figure 11** for the results of the analysis,

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Ranking of Weather Condition by Information Gap Score and Product Availability

Rank	Weather Condition	Gap Score (Significance/Product/Total)	Information Gap Description Assuming Access to Currently Available Weather Products	Opportunity to Leverage FAA-current and near term Weather Products
1a	Convective Weather	21/13 34	Tactical products lack short-term storm forecasts and are susceptible to latencies. Strategic products lack precision at long forecast horizons and need better uncertainty information to support decision making.	FAA products (CIWS, CoSPA, NWP) would reduce the weather gap.
1b	Winds Aloft	21/11 32	Current wind aloft forecasts lack precision and winds aloft observations are lacking in the low-altitude and super high-altitude regions.	FAA ITWS and ASR-9 WSP products provide significant improvements in wind aloft and wind shift information for major metropolitan areas.
2a	Visibility	14/11 25	Sparse off-airport observation field. Models are often inadequate, especially where there is a large variation in terrain and soil moisture	N/A
2b	Clouds and Ceiling	14/11 25	Sparse off-airport observation field. Models need evaluation in off-airport areas, especially where there is a large variation in terrain. Also, cloud layers are not resolved well, especially away from airports.	N/A
2c	Surface Winds	14/10 24	Sparse off-airport observation field. Rapid changes in surface winds (e.g., due to microburst outflows, gust fronts and sharp synoptic fronts) are not alerted. Urban wind effects are uncertain.	FAA ITWS and ASR-9 WSP products provide significant improvements in wind shift information for major metropolitan areas.
3a	Turbulence	10/12 22	turbulence information. Models not calibrated for small UAS. Forecasts lack uncertainty element	N/A
3b	Icing	11/11 22	Ice will build up faster on a small airframe. Models not calibrated for small UAS. Models do not account for 'cold soak'. Forecasts lack uncertainty element.	N/A
3c	Precipitation	11/7 18	Only significant for small UAS.	FAA products (CIWS, CoSPA, NWP) would reduce the weather gap.
4a	Temperature	7/5 12	No significant gaps identified.	N/A
4b	Barometric Pressure	6/4 10	No significant gaps identified.	N/A

FIGURE 11: WEATHER INFORMATION GAP SCORE (CAMPBELL, CLARK, AND EVANS, 2017)

with the most significant phenomena being convective weather and winds aloft due to the deficiencies in observing and forecasting those elements. For example, the study recognizes that there is a lack of precision in the forecasting and observation of winds aloft.

As can be inferred from the sensing layout from the previous sections, there are some significant data gaps within the test corridor, especially above ground level, just as there is across the entire National Airspace. The distance between reliable surface observations, such as ASOS stations, can be tens of miles apart. One study shows that a distance of four miles from measured wind data produces less than a 50% correlation in certain weather conditions. A distance of 13 miles from a point can be completely uncorrelated. For example, a measurement from an ASOS from KRME **may not be**

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representative of the winds just 13 miles away. Local effects due to large bodies of water, such as Oneida Lake, and topography can often go undetected.

Even more glaring is the complete lack of sensing of the atmosphere between 33 feet and the lowest weather radar beam. There are no measurements within the corridor between the surface and the lowest radar beam, which is about 3,700 feet above ground. This is particularly concerning considering the difference in wind speeds from the ground to 400 feet can reach 25 knots or more in some situations. Similar weather situations can lead to a spread of 50 or even 60 knots from the surface to 3,000 feet. Flyable conditions at the surface have lulled operators into launching only to find that speeds just off the surface were above thresholds resulting in loss of control and sometimes leading to catastrophic landing. These strong winds can significantly reduce flight time due to battery drain.

The sensing systems discussed are those that are considered “readily available” to users. In addition to these systems, there are other private and proprietary data sets available. These data sets are becoming available through weather providers and can add considerable precision and accuracy to the current dataset.

Forecast Conditions

Most weather forecasts are based on data derived by Numerical Weather Prediction (NWP) models or more commonly referred to as “weather models.” These models ingest current conditions from many sources, including surface observations, weather balloons, satellite data, and aircraft data, among others. The resolution or the ability of the model to resolve small scale effects is dependent on two key capabilities: The resolution and accuracy of the data ingested and computing resources that constrain the resolution of the output. Higher-resolution models require an exponential amount of computing power. The resolution of government modeling is insufficient for UAS flight. Proprietary methods to increase the resolution of the data, as well as the model output, are currently being employed by some weather companies. These capabilities will allow modeling to resolve more localized features such as lake breezes and micro-scale terrain effects. We will be able to model differences in wind speeds between low and high points on either side of the Mohawk Valley. The employment of more low-level observations is still fundamental to improve knowledge of current conditions and to validate how well the computer models are simulating the wind field. The more quality data into the system results in more reliable data out. This, coupled with new machine learning technologies, will lead to an increase in forecast accuracy at the micro-level.

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Future Additions to Sensing Network

An increase in the density of observations can reduce the risk and uncertainty of weather conditions that impact UASs operating in the test corridor. They can improve high-resolution weather models. There are three types of sensors proposed for the test area:

- **PA-XS SODAR Wind Profiler from Remtech:** This is a wind profiler that can sense the winds aloft from a ground sensor in real-time. Estimated cost: \$67,800 ea.
- **Micro-Weather Sensor (MWS):** These sense temperature, dewpoint, pressure, wind, precipitation, etc. as well as visibility with a 360-degree camera function. Estimated cost: \$23,700 ea.
- **Mobile Vehicle Sensors:** Mobile vehicle sensors sense numerous weather parameters and can be used to fill in the remaining gaps along the route. This will allow sensing in the precise areas needed during questionable weather situations where missions are expected to take place. Estimated cost: \$6,250 ea.

For the 50-mile UTM corridor, we prioritize the needs as follows:

- Better wind, turbulence, and thermal measurements above ground level and granular predictive modeling.
- Better surface observations to detect localized surface winds, fog, and low visibility, and improve predictions.
- Better detection and measurements of cloud icing—this will increase in priority when UASs fly higher and in-cloud.
- Urban measurements of street level and building canyon winds. Also, turbulent eddies, and urban canyon scale predictive capabilities, especially in and around the city of Syracuse.

Potential Short-Term Solutions at reasonable costs:

- Micro-Weather Sensors (MWS) in properly sited locations within the test area. Two MWSs are proposed to fill in the surface observation gaps. One near Sylvan Beach on the east shore of Oneida Lake, and the other near the town of Lee to the northwest of Rome. Refer to **Figure 12**.
- Multiple mobile vehicle sensors that can be deployed anywhere along a route within the corridor. This method will be especially helpful for BVLOS missions.

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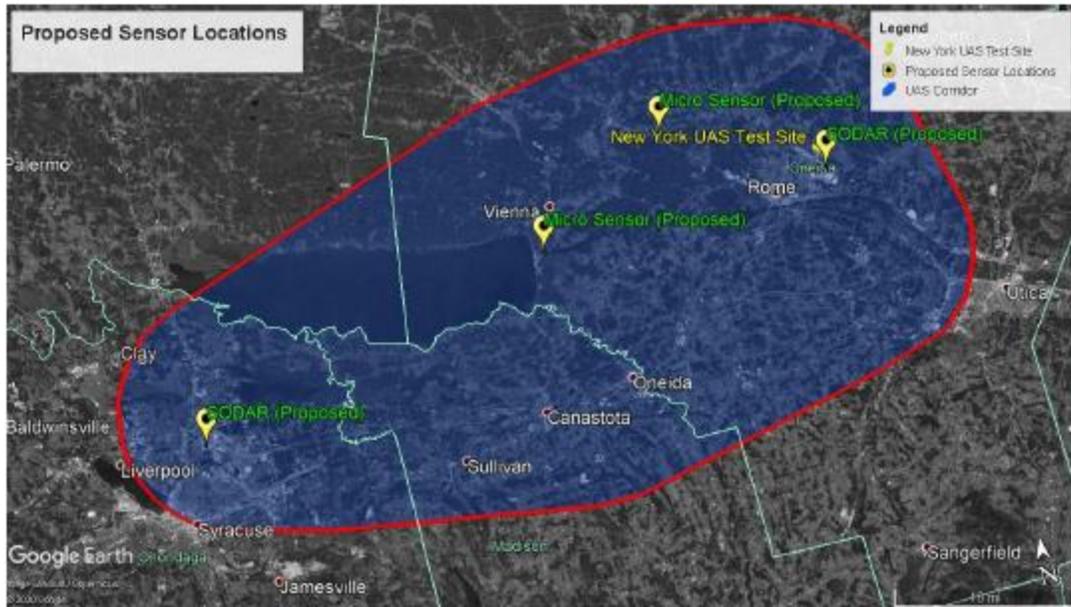


FIGURE 12: PROPOSED MICROSENSOR AND SODAR LOCATIONS ALONG THE 50-MILE UTM CORRIDOR.

Mid-Term Solutions:

- Employment of multiple LiDAR's or SODARs at Griffiss International Airport (KRME) and Syracuse Hancock International (KSYR) to improve above ground wind measurements. One recommended SODAR system costs \$67,738 for the installation, training, the SODAR itself, communications equipment, antenna heater, shipping, and software.
- Acquire X-Band detect and avoid data feed and strip off weather information.
- Procure a weather scout drone with a suite of weather sensors to fly as needed to check wind, thermal, turbulence, and icing conditions aloft in high traffic areas.
- Acquire data from drones that can derive wind speed and direction. Anemoment Drone Sensors are a lightweight sensor that attaches to the drone fuselage and measures several weather parameters, up to 32 times per minute.

Longer-Term Solutions:

- Collect data from drones and develop advanced Machine Learning models to improve micro-climate predictions of wind and other mission limiting parameters.

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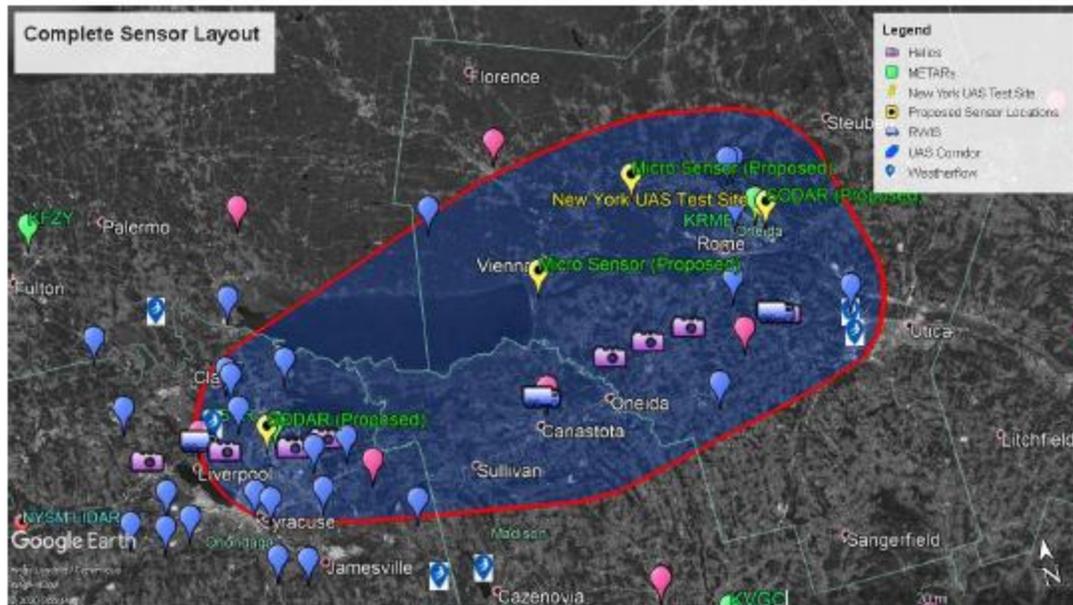


FIGURE 13: 50-MILE CURRENT AND PROPOSED SENSOR LAYOUT.

Conclusion

The current aviation weather construct has been built for the needs of human-crewed aviation. A denser sensing and modeling network will reduce weather risk for flight operations. Using the 50-mile UTM corridor as a guide, the MIT paper indicates there are weather observation gaps within the low levels of the atmosphere. Refer to **Figure 13** for the current sensor layout and proposed additions.

The uncertainty of wind and thermal conditions presents a threat risk to flight on days where weather may be a factor, especially if UAV operators are unaware of weather conditions that exceed airframe airworthiness standards or impact battery power. Wind changes at the surface and aloft will go undetected with the current sensing network. Low-level clouds, fog, and precipitation will go undetected within these gaps. Hazardous conditions from thunderstorm gust fronts, low-level inversions, and thermals, which include downdrafts from virga, are better observed and potentially predicted with a denser sensing network. This network will reduce weather uncertainty and risk to UAV flight and increase productive flight time when weather is a factor.



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References

Campbell, S.E., D.A. Clark and J.E. Evans. "Weather Information Gap Analysis for UAS Operations." (2017). Document.



Appendix I: UTM Data Structures Comparison

ASTM UTM DSS/Inter-USS Interfaces

CMP Data Type Nomenclature	Data Category	Source	API Data Type Nomenclature	API Format
UTM Operation ID	UTM Operations Data	DSS	Operation_References [id]	UUIDv4 (String)
		USS	Operation > Reference [id]	
UTM Operation Publisher (USS)	UTM Operations Data	DSS	Operation_References [owner]	String
		USS	Operation > Reference [owner]	
UTM Operation Publisher (USS) Base URL	UTM Operations Data	DSS	Operation_References [uss_base_url]	String
		USS	Operation > Reference [uss_base_url]	
UTM Operation Start Time	UTM Operations Data	DSS	Operation_References > Time_Start [value]	String <date-time> (RFC3339 formatted, Time Zone == Z)
		USS	Operation > Reference > Time_Start [value]	
UTM Operation Start Time Format	UTM Operations Data	DSS	Operation_References > Time_Start [format]	String (format == RFC3339)
		USS	Operation > Reference > Time_Start [format]	
UTM Operation End Time	UTM Operations Data	DSS	Operation_References > Time_End [value]	String <date-time> (RFC3339 formatted, Time Zone == Z)
		USS	Operation > Reference > Time_End [value]	
UTM Operation End Time Format	UTM Operations Data	DSS	Operation_References > Time_End [format]	String (format == RFC3339)
		USS	Operation > Reference > Time_End [format]	
N/A	N/A	DSS	Operation_References [ovn]	EntityOVN (String)
		USS	Operation > Reference [ovn]	
N/A	N/A	DSS	Operation_References [subscription_id]	UUIDv4 (String)
		USS	Operation > Reference [subscription_id]	
UTM Operation Volume Outline	UTM Operations Data	USS	Operation > Details > Volumes > Volume [outline_circle]	Circle (Object)
			Operation > Details > Volumes > Volume [outline_polygon]	Polygon (Object)
UTM Operation Volume Upper Alt Value	UTM Operations Data	USS	Operation > Details > Volumes > Volume > Altitude_Upper [value]	Number <double> [-8000..10000]
UTM Operation Volume Upper Alt ReferenceA2	UTM Operations Data	USS	Operation > Details > Volumes > Volume > Altitude_Upper [reference]	String (reference == W84)
UTM Operation Volume Upper Alt Units	UTM Operations Data	USS	Operation > Details > Volumes > Volume > Altitude_Upper [units]	String (units == M)
UTM Operation Volume Lower Alt Value	UTM Operations Data	USS	Operation > Details > Volumes > Volume > Altitude_Lower [value]	Number <double> [-8000..10000]
UTM Operation Volume Lower Alt Reference	UTM Operations Data	USS	Operation > Details > Volumes > Volume > Altitude_Lower [reference]	String (reference == W84)



CMP Data Type Nomenclature	Data Category	Source	API Data Type Nomenclature	API Format
UTM Operation Volume Lower Alt Units	UTM Operations Data	USS	Operation > Details > Volumes > Volume > Altitude_Lower [units]	String (units == M)
UTM Operation State	UTM Operations Data	USS	Operation > Details [state]	Enum: Accepted, Activated, NonConforming, Contingent, Ended
UTM Operation Type	UTM Operations Data	USS	Operation > Details [vlos]	Boolean (True/False)
UAS Telemetry ID	UAS Telemetry	USS	Telemetry [id]	UUIDv4 (String)
UAS Telemetry Latitude	UAS Telemetry	USS	Telemetry > Position [latitude]	Number <double> [-90..90]
UAS Telemetry Longitude	UAS Telemetry	USS	Telemetry > Position [longitude]	Number <double> [-180..180]
UAS Telemetry Horizontal Accuracy	UAS Telemetry	USS	Telemetry > Position [accuracy_h]	Enum: HAUnknown, HA10NMPlus, HA10NM, HA4NM, HA2NM, HA1NM, HA05NM, HA03NM, HA01NM, HA005NM, HA10m, HA3m, HA1m
UAS Telemetry Vertical Accuracy	UAS Telemetry	USS	Telemetry > Position [accuracy_v]	Enum: VAUnknown, VA150mPlus, VA150m, VA45m, VA25m, VA10m, VA3m, VA1m
UAS Telemetry Origin	UAS Telemetry	USS	Telemetry > Position [extrapolated]	Boolean (True/False)
UAS Telemetry Altitude Value	UAS Telemetry	USS	Telemetry > Position > Altitude [value]	Number <double> [-8000..10000]
UAS Telemetry Altitude Reference	UAS Telemetry	USS	Telemetry > Position > Altitude [reference]	String (reference == W84)
UAS Telemetry Altitude Units	UAS Telemetry	USS	Telemetry > Position > Altitude [units]	String (units == M)
UAS Telemetry Velocity Value	UAS Telemetry	USS	Telemetry > Velocity [speed]	Number <float>
UAS Telemetry Velocity Units	UAS Telemetry	USS	Telemetry > Velocity [units_speed]	String (units_speed == MetersSecond)
UAS Telemetry Heading	UAS Telemetry	USS	Telemetry > Velocity [track]	Number <float>
UAS Telemetry Report Time	UAS Telemetry	USS	Telemetry > Time_Measured [track]	String <date-time> (RFC3339 formatted, Time Zone == Z)
UAS Telemetry Report Time Format	UAS Telemetry	USS	Telemetry > Velocity > Time_Measured [value]	String (format == RFC3339)
UVR ID	UVR Data	DSS	Constraint_References [id]	UUIDv4 (String)
UVR Publisher (USS)	UVR Data	DSS	Constraint_References [owner] Constraint_Reference [owner]	String
UVR Publisher (USS) Base URL	UVR Data	DSS	Constraint_References [uss_base_url] Constraint_Reference [uss_base_url]	String
UVR Start Time	UVR Data	DSS	Constraint_References > Time_Start [value] Constraint_Reference > Time_Start [value]	String <date-time> (RFC3339 formatted, Time Zone == Z)
UVR Start Time Format	UVR Data	DSS	Constraint_References > Time_Start [format] Constraint_Reference > Time_Start [format]	String (format == RFC3339)
UVR End Time	UVR Data	DSS	Constraint_References > Time_End [value] Constraint_Reference > Time_End [value]	String <date-time> (RFC3339 formatted, Time Zone == Z)
UVR End Time Format	UVR Data	DSS	Constraint_References > Time_End [format] Constraint_Reference > Time_End [format]	String (format == RFC3339)



NASA TCL4 UTM Data Structures

TCL4 API Field	Data Category	Req / Op	API Data Type Nomenclature	API Format	API
gufi	Operations Data	Required	Operation [gufi]	String(\$uuid)	GET/operations GET/operation/{gufi}
uss_name	Operations Data	Required	Operation [uss_name]	String	GET/operations GET/operation/{gufi}
discovery_reference	Operations Data	Optional	Operation [discovery_reference]	String String(\$uuid)	GET/operations GET/operation/{gufi}
submit_time	Operations Data	Required	Operation [submit_time]	String(\$date-time)	GET/operations GET/operation/{gufi}
update_time	Operations Data	Required	Operation [update_time]	String(\$date-time)	GET/operations GET/operation/{gufi}
aircraft_comments	Operations Data	Optional	Operation [aircraft_comments]	String	GET/operations GET/operation/{gufi}
flight_comments	Operations Data	Optional	Operation [flight_comments]	String	GET/operations GET/operation/{gufi}
volumes_description	Operations Data	Optional	Operation [volumes_description]	String	GET/operations GET/operation/{gufi}
registration_id	Operations Data	Required	Operation>uas_registration [registration_id]	String(\$uuid)	GET/operations GET/operation/{gufi}
registration_location	Operations Data	Required	Operation>uas_registration [registration_location]	String(\$url)	GET/operations GET/operation/{gufi}
flight_number	Operations Data	Optional	Operation [flight_number]	String	GET/operations GET/operation/{gufi}
contact [name]	Operations Data	Required	Operation>contact [name]	String	GET/operations GET/operation/{gufi}
contact [e-mail_addresses]	Operations Data	Required	Operation>contact [email_addresses]	Array String(\$email)	GET/operations GET/operation/{gufi}
contact [phone_numbers]	Operations Data	Required	Operation>contact [phone_numbers]	Array String(\$phone-number)	GET/operations GET/operation/{gufi}
contact [comments]	Operations Data	Optional	Operation>contact [comments]	String	GET/operations GET/operation/{gufi}
state	Operations Data	Required	Operation [state]	Enum/String	GET/operations GET/operation/{gufi}
controller_location [type]	Operations Data	Required	Operation>controller_location [type]	String	GET/operations GET/operation/{gufi}
controller_location [coordinates]	Operations Data	Required	Operation>controller_location [coordinates]	number(\$double)	GET/operations GET/operation/{gufi}



TCL4 API Field	Data Category	Req / Op	API Data Type Nomenclature	API Format	API
gcs_location [type]	Operations Data	Optional	Operation>gcs_location [type]	String	GET/operations GET/operation/{gufi}
gcs_location [coordinates]	Operations Data	Optional	Operation>gcs_location [coordinates]	number(\$double)	GET/operations GET/operation/{gufi}
faa_rule	Operations Data	Required	Operation [faa_rule]	Enum/String	GET/operations GET/operation/{gufi}
priority_elements [priority_level]	Operations Data	Dependent	Operation>priority_elements [priority_level]	Enum/String	GET/operations GET/operation/{gufi}
priority_elements [priority_status]	Operations Data	Dependent	Operation>priority_elements [priority_status]	Enum/String	GET/operations GET/operation/{gufi}
operation_volumes [ordinal]	Operations Data	Required	Operation>operation_volumes [ordinal]	integer	GET/operations GET/operation/{gufi}
operation_volumes [volume_type]	Operations Data	Required	Operation>operation_volumes [volume_type]	String	GET/operations GET/operation/{gufi}
operation_volumes [near_structure]	Operations Data	Optional	Operation>operation_volumes [near_structure]	Boolean	GET/operations GET/operation/{gufi}
operation_volumes [effective_time_begin]	Operations Data	Required	Operation>operation_volumes [effective_time_begin]	String(\$date-time)	GET/operations GET/operation/{gufi}
operation_volumes [effective_time_end]	Operations Data	Required	Operation>operation_volumes [effective_time_end]	String(\$date-time)	GET/operations GET/operation/{gufi}
operation_volumes [actual_time_end]	Operations Data	Optional	Operation>operation_volumes [actual_time_end]	String(\$date-time)	GET/operations GET/operation/{gufi}
min_altitude [altitude_value]	Operations Data	Required	Operation>operation_volumes>min_altitude [altitude_value]	number(\$double)	GET/operations GET/operation/{gufi}
min_altitude [vertical_reference]	Operations Data	Required	Operation>operation_volumes>min_altitude [vertical_reference]	Enum/String	GET/operations GET/operation/{gufi}
min_altitude [units_of_measure]	Operations Data	Required	Operation>operation_volumes>min_altitude [units_of_measure]	Enum/String	GET/operations GET/operation/{gufi}
min_altitude [source]	Operations Data	Optional	Operation>operation_volumes>min_altitude [source]	Enum/String	GET/operations GET/operation/{gufi}
max_altitude [altitude_value]	Operations Data	Required	Operation>operation_volumes>max_altitude [altitude_value]	number(\$double)	GET/operations GET/operation/{gufi}
max_altitude [vertical_reference]	Operations Data	Required	Operation>operation_volumes>max_altitude [vertical_referenc]	Enum/String	GET/operations GET/operation/{gufi}
max_altitude [units_of_measure]	Operations Data	Required	Operation>operation_volumes>max_altitude [units_of_measure]	Enum/String	GET/operations GET/operation/{gufi}
max_altitude [source]	Operations Data	Optional	Operation>operation_volumes>max_altitude [source]	Enum/String	GET/operations GET/operation/{gufi}
operation_geography [type]	Operations Data	Required	Operation>operation_volumes>operation_geography [type]	Enum/String	GET/operations GET/operation/{gufi}
operation_geography [coordinates]	Operations Data	Required	Operation>operation_volumes>operation_geography [coordinat]	Array number(\$double)	GET/operations GET/operation/{gufi}



TCL4 API Field	Data Category	Req / Op	API Data Type Nomenclature	API Format	API
operation_volumes [beyond_visual_line_of_sight]	Operations Data	Required	Operation>operation_volumes [beyond_visual_line_of_sight]	Boolean	GET/operations GET/operation/{gufi}
contingency_plans [contingency_id]	Operations Data - Contingency	Required	Operation>contingency_plans [contingency_id]	integer(\$int32)	GET/operations GET/operation/{gufi}
contingency_plans [contingency_cause]	Operations Data - Contingency	Required	Operation>contingency_plans [contingency_cause]	Enum/String	GET/operations GET/operation/{gufi}
contingency_plans [contingency_response]	Operations Data - Contingency	Required	Operation>contingency_plans [contingency_response]	Enum/String	GET/operations GET/operation/{gufi}
contingency_polygon [type]	Operations Data - Contingency	Required	Operation>contingency_plans>contingency_polygon [type]	String	GET/operations GET/operation/{gufi}
contingency_polygon [coordinates]	Operations Data - Contingency	Required	Operation>contingency_plans>contingency_polygon [coordinates]	Array number(\$double)	GET/operations GET/operation/{gufi}
loiter_altitude [altitude_value]	Operations Data - Contingency	Dependent	Operation>contingency_plans>loiter_altitude [altitude_value]	number(\$double)	GET/operations GET/operation/{gufi}
loiter_altitude [vertical_reference]	Operations Data - Contingency	Dependent	Operation>contingency_plans>loiter_altitude [vertical_reference]	Enum/String	GET/operations GET/operation/{gufi}
loiter_altitude [units_of_measure]	Operations Data - Contingency	Dependent	Operation>contingency_plans>loiter_altitude [units_of_measure]	Enum/String	GET/operations GET/operation/{gufi}
loiter_altitude [source]	Operations Data - Contingency	Optional	Operation>contingency_plans>loiter_altitude [source]	Enum/String	GET/operations GET/operation/{gufi}
contingency_plans [relative_preference]	Operations Data - Contingency	Optional	Operation>contingency_plans [relative_preference]	number(\$double)	GET/operations GET/operation/{gufi}
contingency_plans [contingency_location_descriptor]	Operations Data - Contingency	Required	Operation>contingency_plans [contingency_location_descriptor]	Enum/String	GET/operations GET/operation/{gufi}
contingency_plans [relevant_operation_volumes]	Operations Data - Contingency	Optional	Operation>contingency_plans [relevant_operation_volumes]	integer(\$int32)	GET/operations GET/operation/{gufi}
contingency_plans [valid_time_begin]	Operations Data - Contingency	Required	Operation>contingency_plans [valid_time_begin]	String(\$date-time)	GET/operations GET/operation/{gufi}
contingency_plans [valid_time_time]	Operations Data - Contingency	Required	Operation>contingency_plans [valid_time_end]	String(\$date-time)	GET/operations GET/operation/{gufi}
contingency_plans [free_text]	Operations Data - Contingency	Optional	Operation>contingency_plans [free_text]	String	GET/operations GET/operation/{gufi}
negotiation_agreements [message_id]	Negotiations Data	Dependent	Operation>negotiation_agreements [message_id]	String(\$uuid)	GET/operations GET/operation/{gufi}
negotiation_agreements [negotiation_id]	Negotiations Data	Dependent	Operation>negotiation_agreements [negotiation_id]	String(\$uuid)	GET/operations GET/operation/{gufi}
negotiation_agreements [uss_name]	Negotiations Data	Optional	Operation>negotiation_agreements [uss_name]	String	GET/operations GET/operation/{gufi}
negotiation_agreements [uss_name_of_originator]	Negotiations Data	Dependent	Operation>negotiation_agreements [uss_name_of_originator]	String	GET/operations GET/operation/{gufi}



TCL4 API Field	Data Category	Req / Op	API Data Type Nomenclature	API Format	API
negotiation_agreements [uss_name_of_reciever]	Negotiations Data	Dependent	Operation>negotiation_agreements [uss_name_of_receiver]	String	GET/operations GET/operation/{gufi}
negotiation_agreements [gufi_originator]	Negotiations Data	Dependent	Operation>negotiation_agreements [gufi_originator]	String(\$uuid)	GET/operations GET/operation/{gufi}
negotiation_agreements [gufi_reciever]	Negotiations Data	Dependent	Operation>negotiation_agreements [gufi_receiver]	String(\$uuid)	GET/operations GET/operation/{gufi}
negotiation_agreements [free_text]	Negotiations Data	Optional	Operation>negotiation_agreements [free_text]	String	GET/operations GET/operation/{gufi}
negotiation_agreements [discovery_reference]	Negotiations Data	Optional	Operation>negotiation_agreements [discovery_reference]	String	GET/operations GET/operation/{gufi}
negotiation_agreements [type]	Negotiations Data	Dependent	Operation>negotiation_agreements [type]	Enum/String	GET/operations GET/operation/{gufi}
message_id	UVR Data	Required	UASVolumeReservation [message_id]	String(\$uuid)	PUT/uvrs/{message_id}
uss_name	UVR Data	Required	UASVolumeReservation [uss_name]	String	PUT/uvrs/{message_id}
type	UVR Data	Required	UASVolumeReservation [type]	Enum/String	PUT/uvrs/{message_id}
permitted_uas	UVR Data	Required	UASVolumeReservation [permitted_uas]	Enum/String	PUT/uvrs/{message_id}
required_support	UVR Data	Dependent	UASVolumeReservation [required_support]	String	PUT/uvrs/{message_id}
permitted_gufis	UVR Data	Optional	UASVolumeReservation [permitted_gufis]	String(\$uuid)	PUT/uvrs/{message_id}
cause	UVR Data	Required	UASVolumeReservation [permitted_gufis]	Enum/String	PUT/uvrs/{message_id}
geography [type]	UVR Data	Required	UASVolumeReservation>geography> [type]	Enum/String	PUT/uvrs/{message_id}
geography [coordinates]	UVR Data	Required	UASVolumeReservation>geography> [coordinates]	Array number(\$double)	PUT/uvrs/{message_id}
effective_time_begin	UVR Data	Required	UASVolumeReservation [effective_time_start]	String(\$date-time)	PUT/uvrs/{message_id}
effective_time_end	UVR Data	Required	UASVolumeReservation [effective_time_end]	String(\$date-time)	PUT/uvrs/{message_id}
actual_time_end	UVR Data	Optional	UASVolumeReservation [actual_time_end]	String(\$date-time)	PUT/uvrs/{message_id}
min_altitude [altitude_value]	UVR Data	Required	UASVolumeReservation>min_altitude [altitude_value]	number(\$double)	GET/operations GET/operation/{gufi}



TCL4 API Field	Data Category	Req / Op	API Data Type Nomenclature	API Format	API
min_altitude [vertical_reference]	UVR Data	Required	UASVolumeReservation>min_altitude [vertical_reference]	Enum/String	GET/operations GET/operation/{gufi}
min_altitude [units_of_measure]	UVR Data	Required	UASVolumeReservation>min_altitude [units_of_measure]	Enum/String	GET/operations GET/operation/{gufi}
min_altitude [source]	UVR Data	Optional	UASVolumeReservation>min_altitude [source]	Enum/String	GET/operations GET/operation/{gufi}
max_altitude [altitude_value]	UVR Data	Required	UASVolumeReservation>max_altitude [altitude_value]	number(\$double)	GET/operations GET/operation/{gufi}
max_altitude [vertical_reference]	UVR Data	Required	UASVolumeReservation>max_altitude [vertical_reference]	Enum/String	GET/operations GET/operation/{gufi}
max_altitude [units_of_measure]	UVR Data	Required	UASVolumeReservation>max_altitude [units_of_measure]	Enum/String	GET/operations GET/operation/{gufi}
max_altitude [source]	UVR Data	Optional	UASVolumeReservation>max_altitude [source]	Enum/String	GET/operations GET/operation/{gufi}
reason	UVR Data	Optional	UASVolumeReservation [reason]	String	GET/operations GET/operation/{gufi}



Appendix J: Weather Risk Mitigation Analysis

Weather Risk Mitigation Techniques for Unmanned Aerial Vehicles using Alerts that Incorporate the Internet of Things and Machine Learning: An In-Depth Analysis

By: Nicholas Rodick
TWS UAS Meteorologist

Background:

As of early 2021 it is abundantly clear that the Unmanned Aerial Systems (UAS) industry is destined for rapid growth throughout the rest of the 2020s in to the 2030s. The beginning of this current decade brought a global pandemic, COVID-19, that has and will bring immense socioeconomic change to the world and could serve as an inflection point for the UAS industry. In the not-so-distant future, Unmanned Aerial Vehicles (UAVs) will play an increasing role in the world around us, becoming critical assets. The year 2020 also served as a big milestone in terms of regulation with both the United States and Europe ruling on remote ID which will enable a drone in flight to provide and transmit identification and location information which lays the foundation for more complex drone operations to occur. More complex operations include Beyond Visual Line of Sight (BVLOS) missions which is the next frontier within the drone industry. A substantial risk to these types of drone operations, in addition to airborne collisions, are atmospheric impacts which can be critical for the safety and efficiency of drone operations. Currently Part-107, the small, unmanned aircraft regulation of the Federal Aviation Administration within the United States, has several rules relating to weather including flight operations must have at least 3 statute miles of visibility and the UAV must be no less than 500 feet below a cloud. In other words, operations must be within Visual Flight Rules (VFR). Part 107 specifically is for Visual Line of Sight UAS operations, where the pilot must have a clear view of their UAV. Current weather regulations and standards are not sufficient to support BVLOS operations let alone for Advanced Air Mobility (AAM) as pointed out in version 1.0 of the UAM Vision Concept of Operations at UAM Maturity Level (UML) 4 by NASA. As our society enters the new frontier that will bring much more complexity to Unmanned Aerial System Traffic Management (UTM), sufficient weather standards and risk mitigation techniques by operators and their associated Supplemental Data Service Providers (SDSP's) need to be available for true safety and efficiency within the ecosystem presented.

When weather thresholds of a UAV are known, then alerts can be tailored to those thresholds. Each UAV manufacturer will need to produce air worthiness data on their aircraft for integration into the UTM. Therefore, when a threshold is predicted or occurring, the airspace manager is enabled to make clear decisions when performing contingency management. The thresholds of UAVs within the airspace can be broken down to the individual aircraft or binned into several different categories. An alert is issued when a threshold is met or forecast. The alert indicates the area effected via a polygon. Another method is to alert based on the level of airspace. This method assumes that more 'weather robust' aircraft will fly at higher altitudes than smaller, more weather sensitive aircraft. For both these weather risk mitigation methods to work, we must understand each weather threshold and its impact to the safety and efficiency of UAS operations. This paper will focus on 7 different weather parameters:

1. Winds and Turbulence
2. Fog/Low Stratus
3. Icing
4. Temperature
5. Precipitation
6. Space Weather



For each weather parameter and its associated thresholds, UAS operators must also understand the gaps in weather data both spatially and temporally for true safety and efficiency in the ecosystem. TruWeather Solution’s has developed several weather risk mitigation techniques for weather alerting that incorporate several weather sensor providers that will be a critical part of smart cities to address these weather gaps. Once this data becomes available in the ecosystem, machine learning will then become essential for making operational decisions. This will take a wide range of in depth and updated standards that the ASTM F38 Weather Supplemental Data Service Provider group is working on currently.

Winds and Turbulence

During Shakedown 2 of UPP2 (UTM Pilot Program Phase 2), TruWeather Solutions and Vaisala worked together to bring a Leosphere Windcube to the New York State UAS Test Site. On Monday October 5th, 2020, the first day of Shakedown 2 at the NYS test site, a pilot reported that when the Skyward Pucks (a small payload) for Remote ID were put on the aircraft (DJI Phantom 4). The aircraft become hard to control and started drifting to where he was concerned for safety going forward the pilot was flying near 80 meters. This was not the first time we saw occur as it happened during Shakedown 1 of UPP2 as well. Usually, the Phantom 4 has a wind threshold of 19kts set by the manufacturer. During the time at which the pilot was experiencing control issues due to wind, according to the Windcube LIDAR the winds were 4-8kts. While the winds were not near the aircraft thresholds, with the payload the winds could have been strong enough that the wind gusts at UAV flight level were interfering with the wind flow around the aircraft therefore lowering the drone thresholds. Knowing the winds from the LIDAR, NUAIR took extreme caution the rest of the week, paying close attention to the weather forecast. Without the LIDAR and TruWeather Solutions, NUAIR would have not known what the winds aloft at flight level were at that time, ultimately not realizing a decrease in UAV thresholds with the payload. This illustrates two risks winds can create in the UAS ecosystem:

1. Flight Trajectory -Displacement in Aircraft Route
2. Aircraft Control- especially with payloads

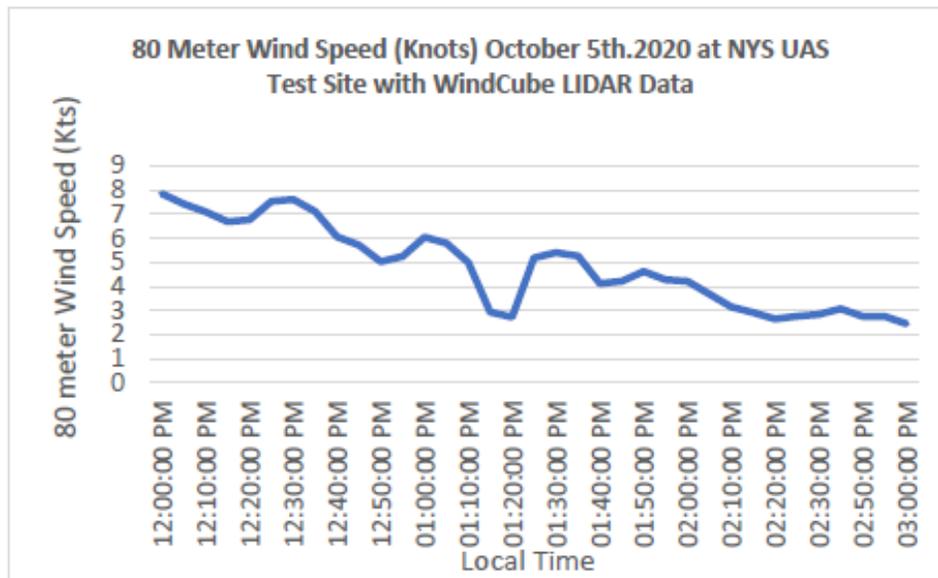


Figure 1

During the LIDAR case study at the NYS UAS test site, TruWeather Solutions identified the usefulness of remote sensing for wind shear which poses a risk to UAS operations, especially for cargo drones and fixed wing aircraft during landing or delivering in diverse terrain. More research is needed for classifying the levels of wind shear that impact different types of UAVs.



Figure 2

Winds can also adversely affect battery degradation and having alerts on both real time winds and forecast winds will be critical for both safety and efficiency for operations. Remote sensing and IoT will be the main inputs for real time alerts. TruWeather Solutions uses weather risk mitigation techniques such as micro weather models at higher resolutions than what the government can currently provide along with CFD modeling for urban areas that can be used for forecasted alerts and route optimization. There is a major need for both more observations but also the ability to certify and use machine learning techniques for safer, more efficient operations.

Fog/Low Stratus

Traditionally aircraft takeoff and land largely at airports where there is access to weather data from Automated Surface Observation System (ASOS) units. This is critical for knowing if takeoff and landing at any given airport is in VFR or IFR. According to Part 107 regulations, operators must know if they are operating in VFR or not able to fly because of IFR. In addition to this, operators must be always 500 feet below at cloud ceiling so other manned pilots can see the UAV. The problem is many drone operations do not happen near these ASOS units across the country. It is to expensive to put more ASOS units across the country to solve this issue, rather utilizing remote sensing from the best available sources as possible is a much more cost effective and realistic solution.

Fog and Low Stratus (FLS) creates several risks for the UAS ecosystem such as:

1. Visual line of sight for other aircraft
2. In cloud icing with FLS in cold weather regimes
3. Increased wind shear with the inversion
4. Moisture to flight sensors that are not moisture proof
5. Negatively impacting the usefulness of some sense and avoid technologies such as LIDAR

Due to regulatory restrictions, weather alerting becomes more broad and less of a individual UAV threshold alert. TruWeather uses current observation network from private and public weather stations, statistical analysis and GOES. There is a major need for both more observations but also the ability to certify and use machine learning techniques for safer, more efficient operations and that can better serve real time alerts.



Icing

Icing is a dangerous risk to UAS in the current ecosystem as many UAS are not certified to fly in icing conditions. Icing, especially freezing fog, and freezing drizzle are often hard to forecast and TruWeather is currently developing icing alerts. Major risks to UAS created by Icing are:

1. Negatively affect aerodynamic performance, reduces lift and increases drag.
2. Negatively impacts risk mitigation techniques such as emergency parachute deployment.

Additional icing forecast products are needed along with current weather alerts. These will most likely have to incorporate remote sensing. Currently TruWeather is taking part of discussions for the Terminal Area Icing Weather Information for NextGen (TAIWIN) project to address this problem.

Temperature

Extreme temperatures in respect to the battery thresholds for individual aircraft can often be overlooked. Major risks to UAS created by temperature:

1. Temperature extremes impact on Battery Degradation, especially cold temperatures.
2. Hot temperatures impact on lift.
3. Airframe - plastic can crack.

Although most weather models are pretty good at forecasting temperatures, data gaps in measuring temperatures in urban heat islands and very remote regions remain. In this case alerting for individual aircraft thresholds will be critical.

Precipitation

Precipitation poses multiple threats to the UAS ecosystem including the fact right now some aircraft are not waterproof and when precipitation occurs it often creates decreased visibility which that can often create less than 3 miles visibility. Other risks to UAS created by precipitation:

1. Aircraft control.
2. Negatively affect aerodynamic performance.
3. Reduction in visibility.
4. Convective turbulence.
5. Icing with precipitation.

It should be noted there remains lots of data gaps in measuring precipitation, data gaps with radar where the beam cannot reach precipitation or dry air in the low levels creating evaporation where the radar could be showing precipitation be there is not any near the surface. Risk mitigation using weather alerts will be a very important part of the UAS ecosystem. TruWeather uses proprietary logic that incorporates current observation networks with artificial intelligence for real time and forecast alerts in addition to radar data. There is a major need for both more observations but also the ability to certify and use machine learning techniques for safer, more efficient operations and that can better serve for real time alerts.

Space Weather

Space weather occurs when there are solar flares from the sun occur which causes electromagnetic disturbances on the earth that can impact GPS and other forms of communication. The major risk to UAS operations occurs regarding loss of link. Alerting on space weather is a crucial part of TruFlite Core Services.



Conclusion:

Weather events can often have several interconnected risks to the UAS ecosystem with both alerting on the airspace but also alerting on individual aircraft thresholds and certifications are needed. With the advance of technology, new, better and more cost-efficient ways of certifying weather data is needed along with a focus on hyper local weather forecasts which will most likely be a combination of numerical weather models and machine learning. The rise of smart cities will further enhance how weather data can be used to make a more efficient and safer ecosystem.



Appendix K: CMP Cognitive Walkthroughs

The title slide features a large white arrow pointing right, set against a light blue background. Inside the arrow are the logos for KONGSBERG, RESILIENX, ais, and TruWeather SOLUTIONS. To the right of the arrow, the FAA logo is at the top, followed by the text "FAA BAA Program", "FAA Walkthrough of UTM Contingency Management Platform (CMP)", and the date "25 February 2021".

Agenda



- Meeting Purpose
- CMP Overview
 - Role & Functionality of Platform
 - Overview of CMP User Interface Features
- Contingency Scenario Overview
 - Purpose of Contingency Scenario Analysis
 - Scenario Descriptions
 - Preliminary Findings
- Scenario Walkthroughs
- Request for Feedback
- Q&A



Meeting Purpose

- The objectives of this meeting include:
 1. Convey capabilities and highlight functionalities of the UTM Contingency Management Platform (CMP) to FAA stakeholders.
 2. Walkthrough condensed contingency scenarios we are using to evaluate the CMP.
 3. Solicit feedback on platform approach and capabilities from FAA Subject Matter Experts (SMEs).
- Suggest FAA stakeholders consider the following questions:
 1. Is the overall platform role and concept of operations as depicted feasible?
 2. Are the existing capabilities of the CMP of substantial value to the UTM ecosystem?
 3. Are there additional contingency measures or responses that airspace authorities or delegates may want in a platform such as this?

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CMP Overview



- The CAL Analytics led Contingency Management Platform (CMP) is an aggregate of products and services from multiple UTM industry partners, with the intent of providing UTM airspace supervisors, authorities, or delegates with enhanced Situational Awareness (SA), Oversight, and Contingency Mitigation capabilities.
- The CMP targets users with an Area of Regard (AOR) beyond that of a single operation. Although the goal of UTM is full autonomy, CAL and our partners anticipate the need for UTM capabilities akin to many existing ATM capabilities in the near term.
 - A completely federated system will require extremely high levels of automation, which won't exist for some time
 - Even under such conditions, a layer of monitoring and oversight is likely required

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CMP Overview – User Interface Walkthrough



- This walkthrough will highlight the basic components and some general features of the CMP user interface. Items of interest include:
 - ✓ IRIS-UAS Airspace GeoViewer Display (2D and 3D)
 - ✓ Display Layers and Configurations
 - ✓ Web Card Integrations
 - ✓ FRAIHMWORK Health & Integrity Display
 - ✓ TWS Weather Services – MissionCast, Weather Web-Tile Overlays
 - ✓ Surveillance Data Ingestion and Display

Contingency Scenario Overview



- CAL and CMP Partners are in the process of conducting a series of Cognitive Walkthrough sessions with customer and industry stakeholders to solicit feedback on CMP capabilities and usability
- We have condensed these walkthroughs to provide a comprehensive overview to the FAA

Scenario	Description
Faulted Component	A ground-based surveillance sensor encounters and reports a fault to the CMP. The CMP alerts the airspace supervisor and prompts a corrective action in the form of an autogenerated UVR.
Rogue Operation	AUTM operations deviated from their approved operational volume, entering a 'Contingent State.' CMP alerts the airspace supervisor of this conditions and offers sufficient SA to aide the manual creation and publishing of a UVR to support deconfliction with other operations.
Hazardous Weather	A geo-localized weather alert is translated by an airspace supervisor into a UVR, providing sufficient contextual information to support operator responses.
External Emergency	Airspace around a forest fire must be cleared in order to provide emergency responders unincumbered access. The airspace supervisor utilized a UVR to clear UTM operation in the vicinity.
Lost Link	Following report of an ongoing lost link event from a UTM RPIC, the airspace supervisor decides to issue a UVR in the last known location of that operation to support deconfliction.



Purpose of Cognitive Walkthroughs



- Understand how an experienced operator would react to contingencies in a UTM environment
- Evaluate how desired contingency management procedures or responses align with CMP capabilities
- Identify system-wide capabilities and procedures for mitigating contingencies
- When we conduct these analyses, we remind participants...
 - The intent is technology evaluation not participant evaluation
 - To immerse themselves in the scenarios and react according to the information provided
 - To accept the scenarios as presented – less realistic elements may be discussed at the end
 - To ask for more information if you feel it is required to make decisions

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Preliminary Findings



1. Developing UTM standards and environments include limited supervisory or authority behavior influencing mechanisms – UAS Volume Reservations (UVR) are the primary constraint.
2. UVRs alone and as defined (ASTM Inter-USS Interfaces) are not dynamic enough to provide informed, nuanced decision making on behalf of operators or authorities:
 - UVRs (or analogous constraints) should accommodate mission priority
 - UVRs should accommodate aircraft class / performance capabilities
 - UVRs should accommodate mission needs (reliant functional services)
 - Sufficient details of UTM airspace constraints must be conveyed for operators to act appropriately and for supervisors to evaluate the compliance of specific operations
3. Additional means of supporting monitoring, assessing and mitigating for emergent UTM/AAM conditions are required
 - Reporting requirements on UA's and supporting services
 - Digital hooks for guidance or vectoring of traffic (procedural transitioning to automated)

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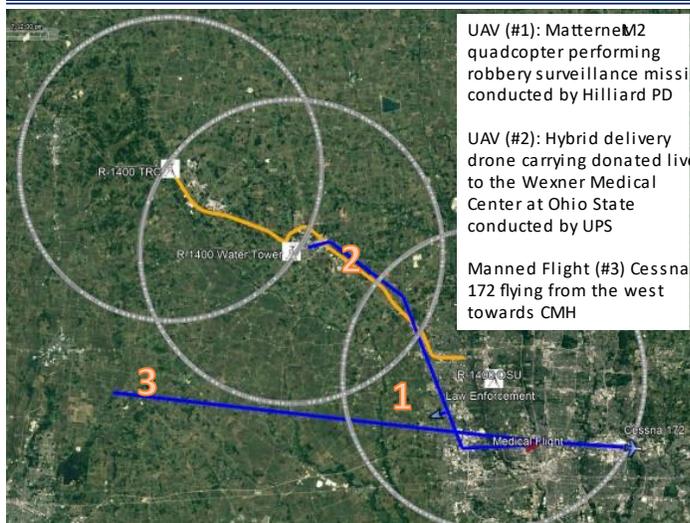
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Scenario Faulted Component

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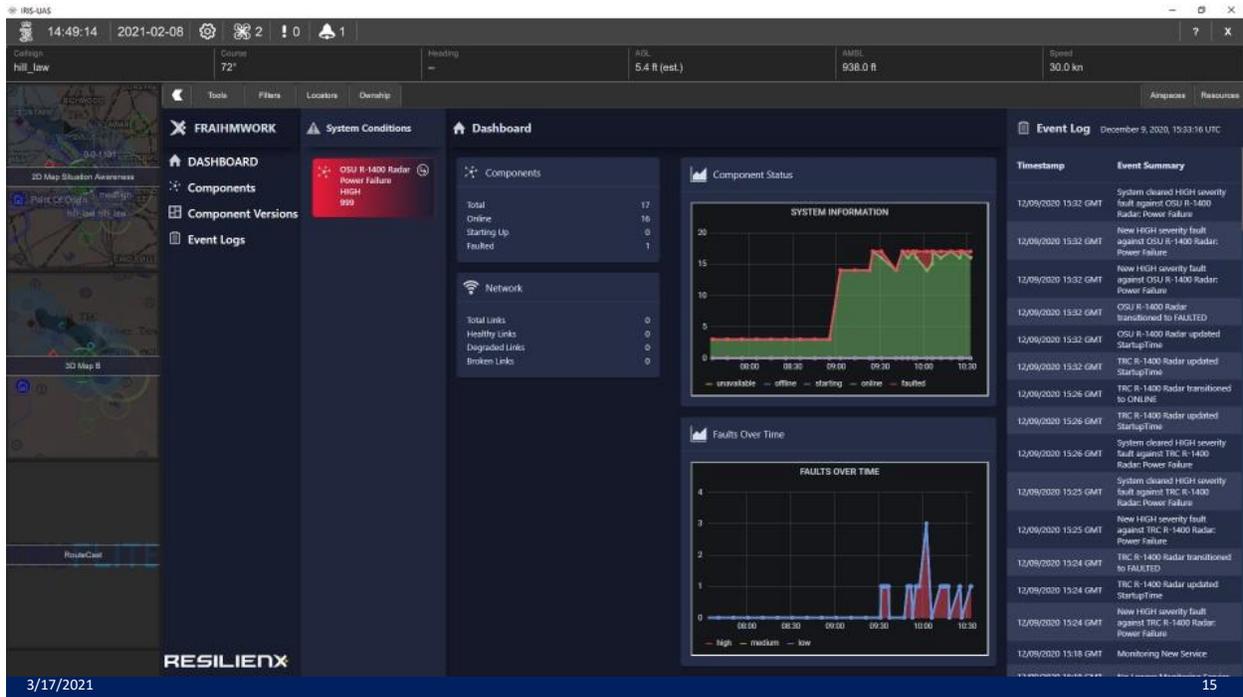
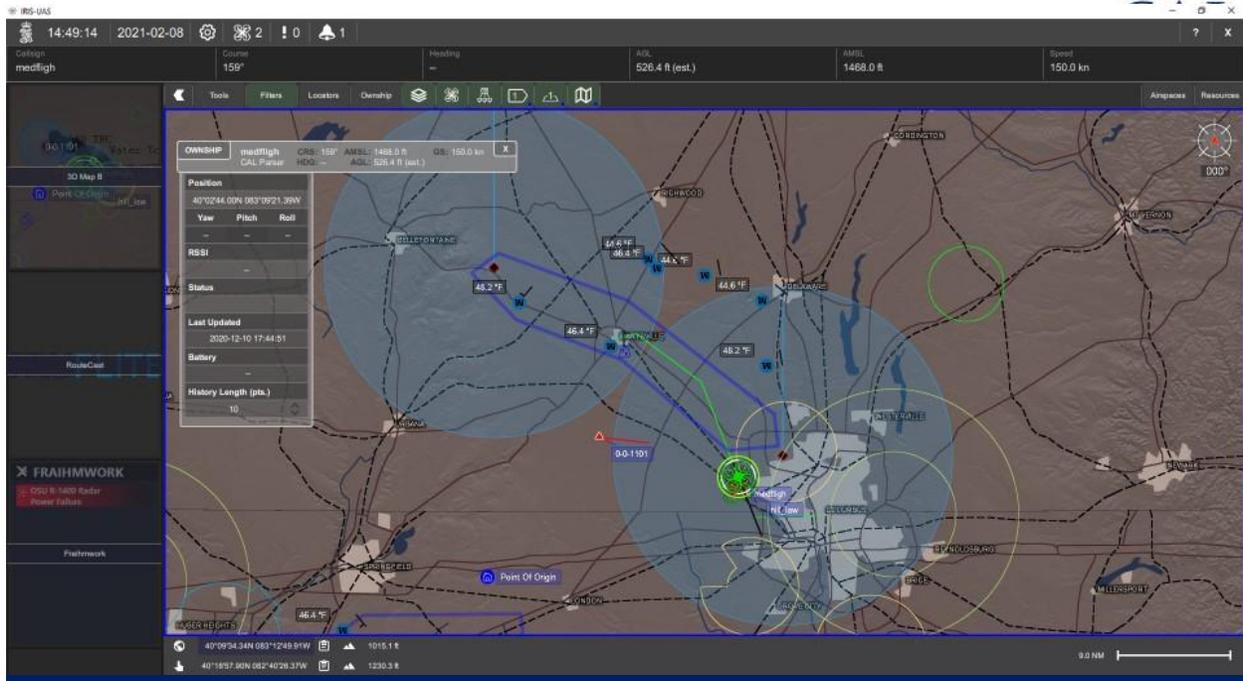
Scenario: Faulted Component

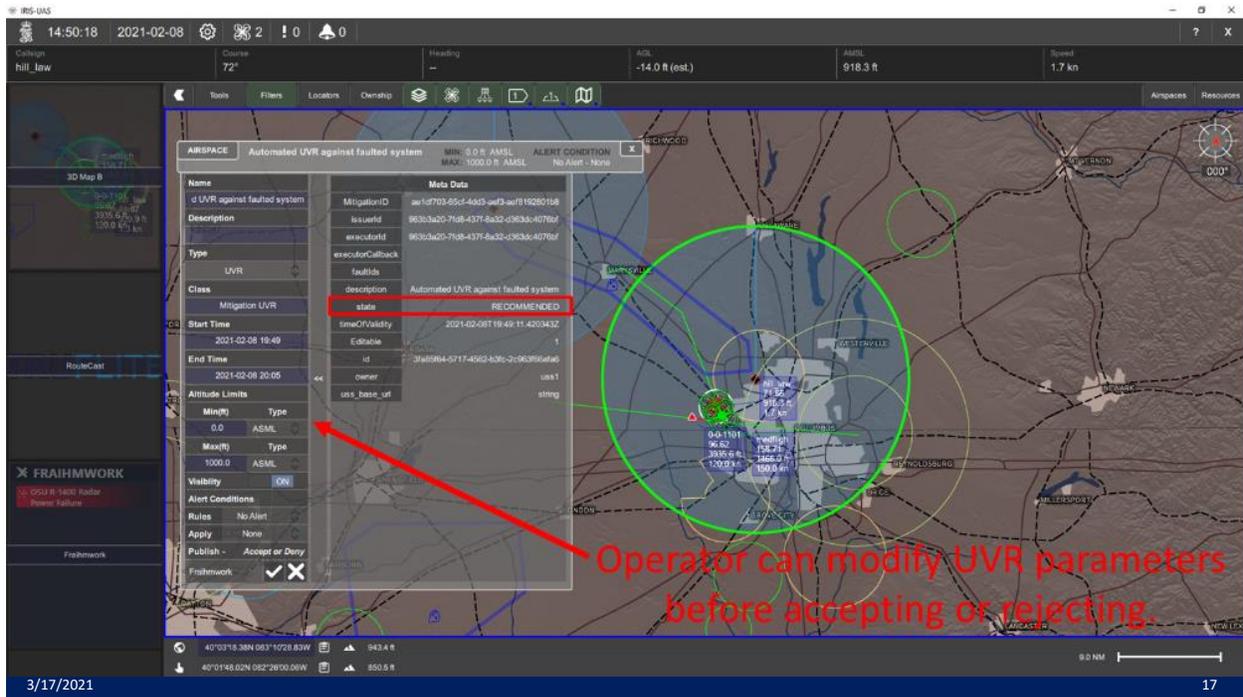
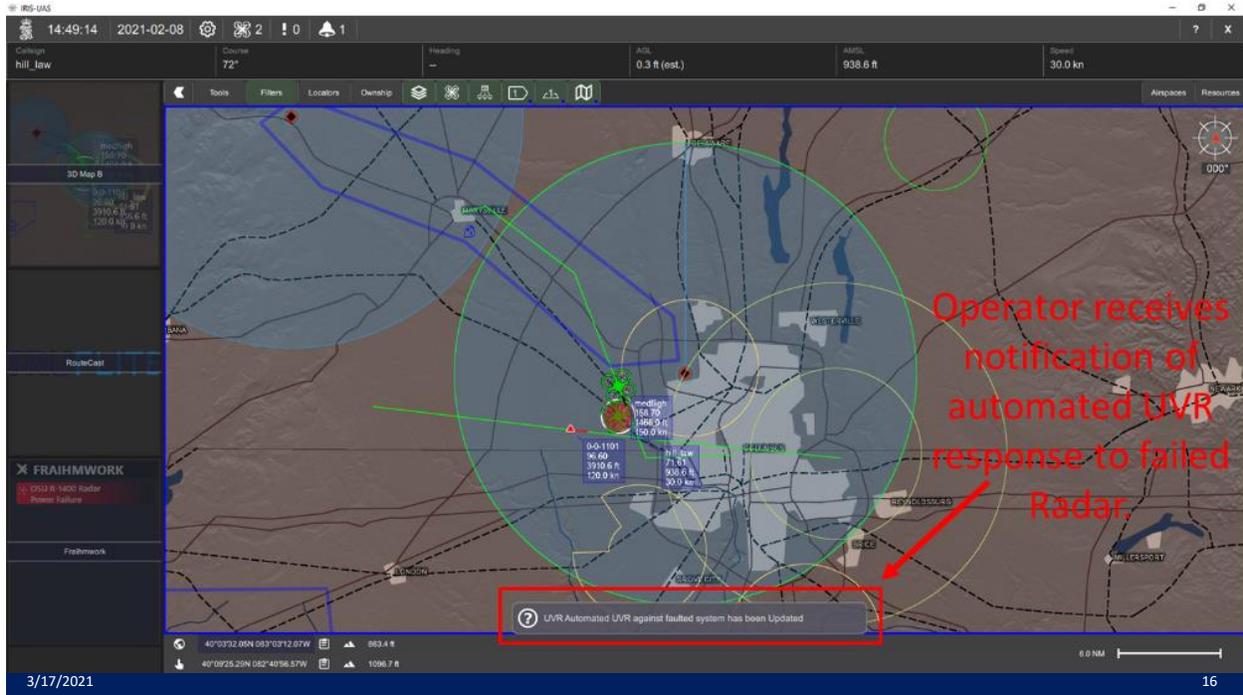


- UTM Supervisor sees UAS missions commence promptly at 2:45pm. The supervisor monitors the flights and the UTM system.
- At approximately 2:49pm, the UTM Supervisor observes a fault within the UTM ecosystem.
- After further inspection, the UTM supervisor notices that an R -1400 ground radar sensor has failed and assesses impact to UTM ecosystem operations.
- Given the observed failure, the UTM supervisor receives a notification that an auto-generated UAS Volume Reservation (UVR) was created in the area impacted by the sensor failure.

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UVR state changes from Recommended to Accepted after UVR approval.

Meta Data	
description	Automated UVR against faulted system
state	ACCEPTED
timeOfValidity	2021-02-08T14:50:28Z
id	35a8954-5717-4562-b3f0-2c963956af46
owner	usr1
usr_base_url	string

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Scenario Rogue Operation

Scenario: Rogue Operation

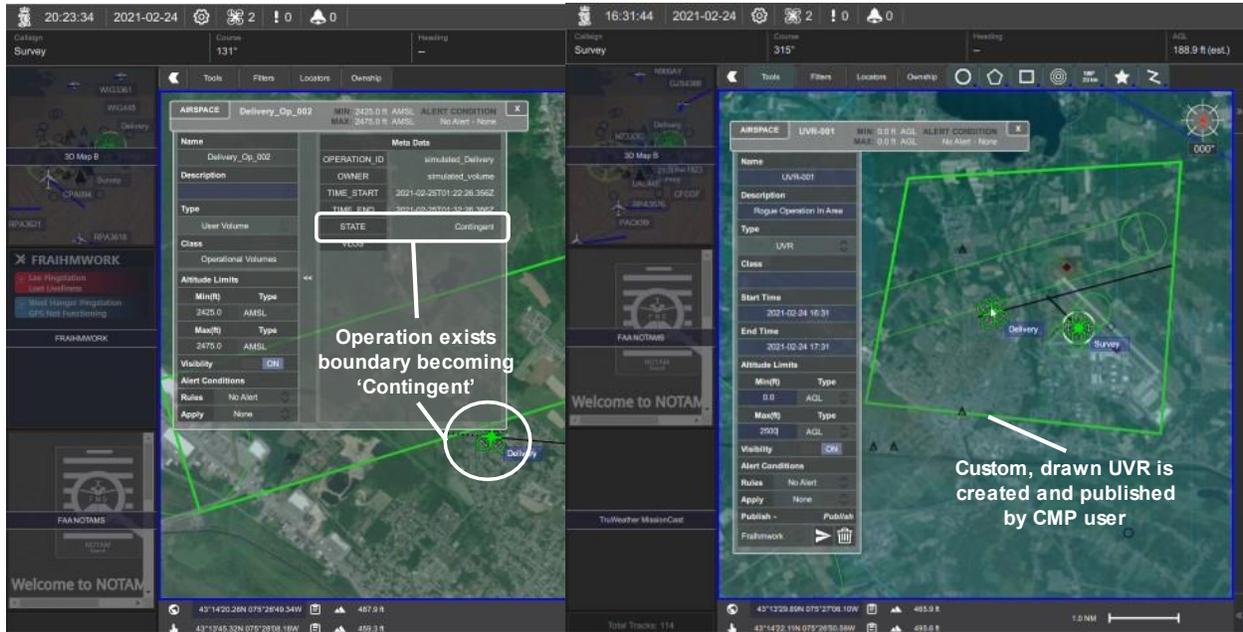
Narrative: A BVLOS operation veers outside of its approved operational volume, entering a ‘Contingent’ state. Having observed this non-compliance, a UTM supervisor decided to issue a UVR in the general area surrounding the Contingent operation to support deconfliction with nearby operations. This UVR is published to inter-USS network(s) for dissemination to individual operators to respond accordingly.

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The screenshot shows the Contingency Management Platform interface. At the top, the date is 2021-02-24 and the time is 20:23:03. The map displays a 'Delivery' operation (green circle) and a 'Survey' operation (red circle). A pop-up window titled 'AIRSPACE Delivery_Op_002' provides the following details:

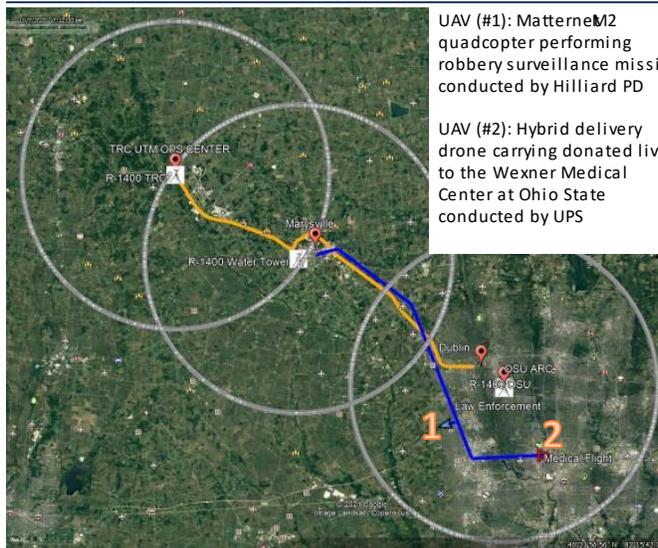
Name		Meta Data	
Delivery_Op_002		OPERATION_ID	simulated_Delivery
Description		OWNER	simulated_volume
Type		TIME_START	2021-02-25T01:22:26.306Z
User Volume		TIME_END	2021-02-25T01:32:26.356Z
Class		STATE	Activated
Operational Volumes		VLOS	
Altitude Limits			
Min(ft)	Type		
2425.0	AMSL		
Max(ft)	Type		
2475.0	AMSL		
Visibility			ON
Alert Conditions			
Rules			No Alert
Apply			None

Annotations on the map include: 'Operation taking bearing indicative of future non-conformance' pointing to the 'Delivery' operation, and 'Operational details of suspect operation' pointing to the pop-up window.



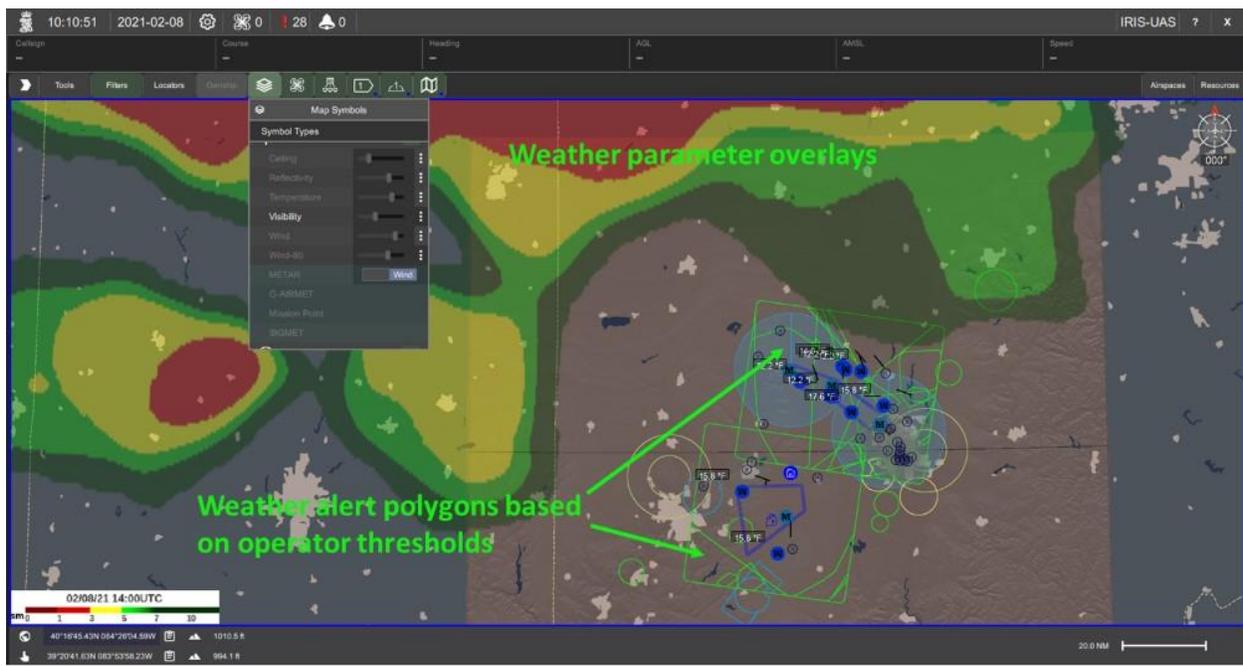
Scenario Hazardous Weather

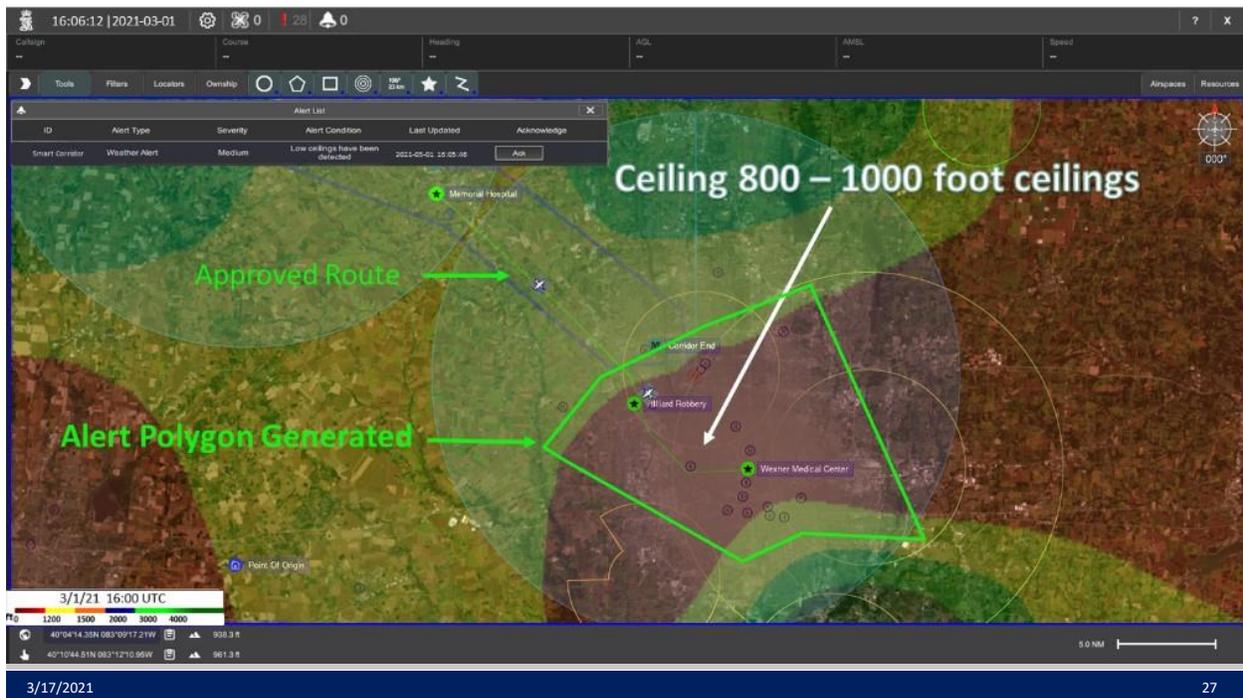
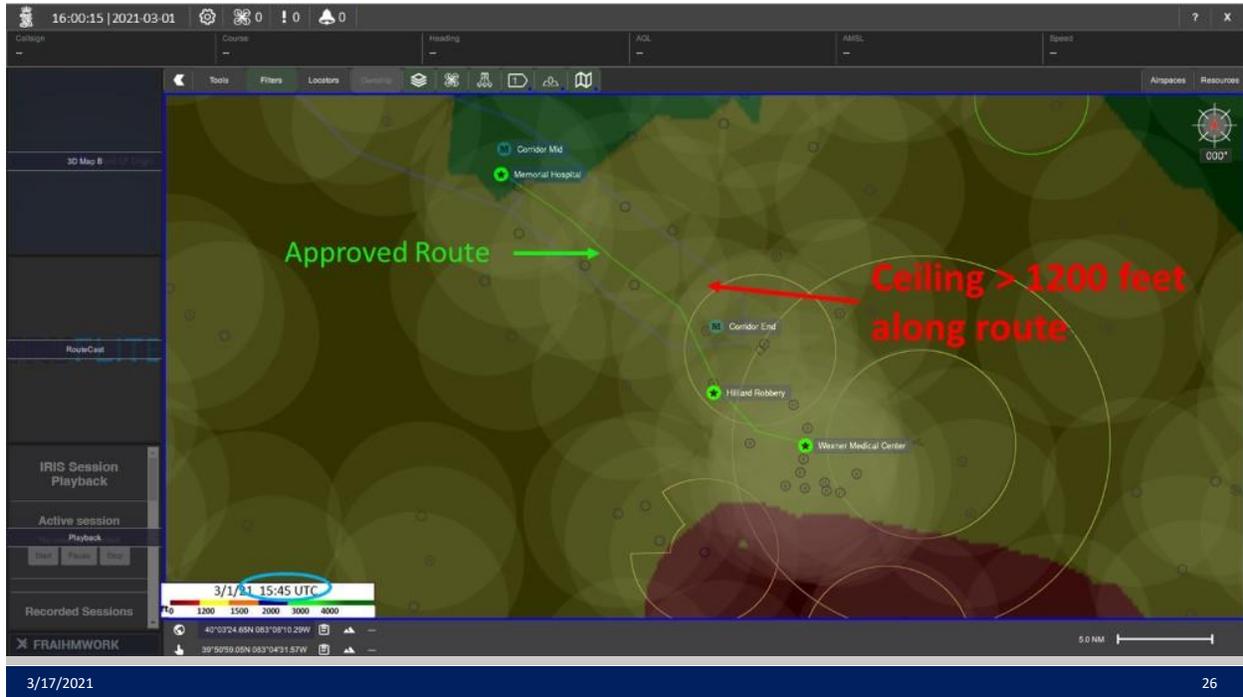
Scenario: Hazardous Weather



Narrative:

- The supervisor checks the weather and notices marginal ceiling conditions along the flight route, with unfavorable conditions forecast after mission completion.
- Due to the nature of both flights, the risk to flight is accepted. At approximately 16:06 UTC, the UTM Supervisor observes an alert for ceilings less than 1000 feet along the route. Conditions have unexpectedly deteriorated rapidly within the UPS and HPD operational area.
- Given the observed conditions, the UTM supervisor has determined that the best course of action is to generate a UAS Volume Reservation (UVR) in the area impacted by the hazardous weather.







Scenario External Emergency

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Scenario: External Emergency

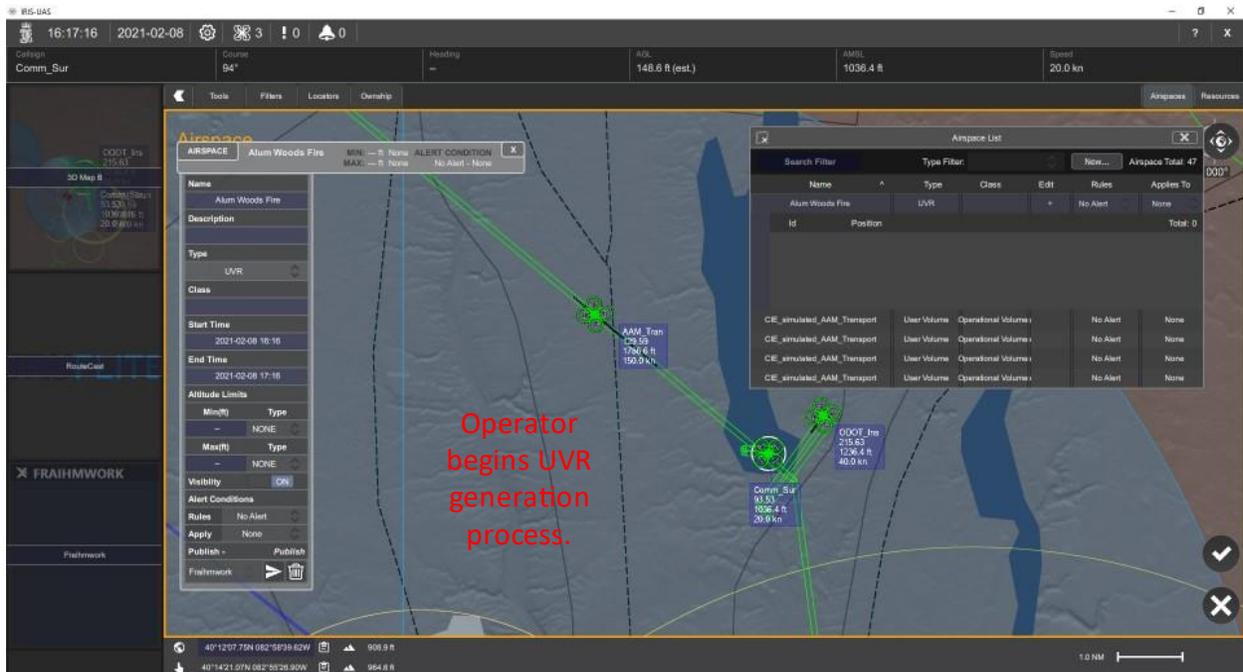
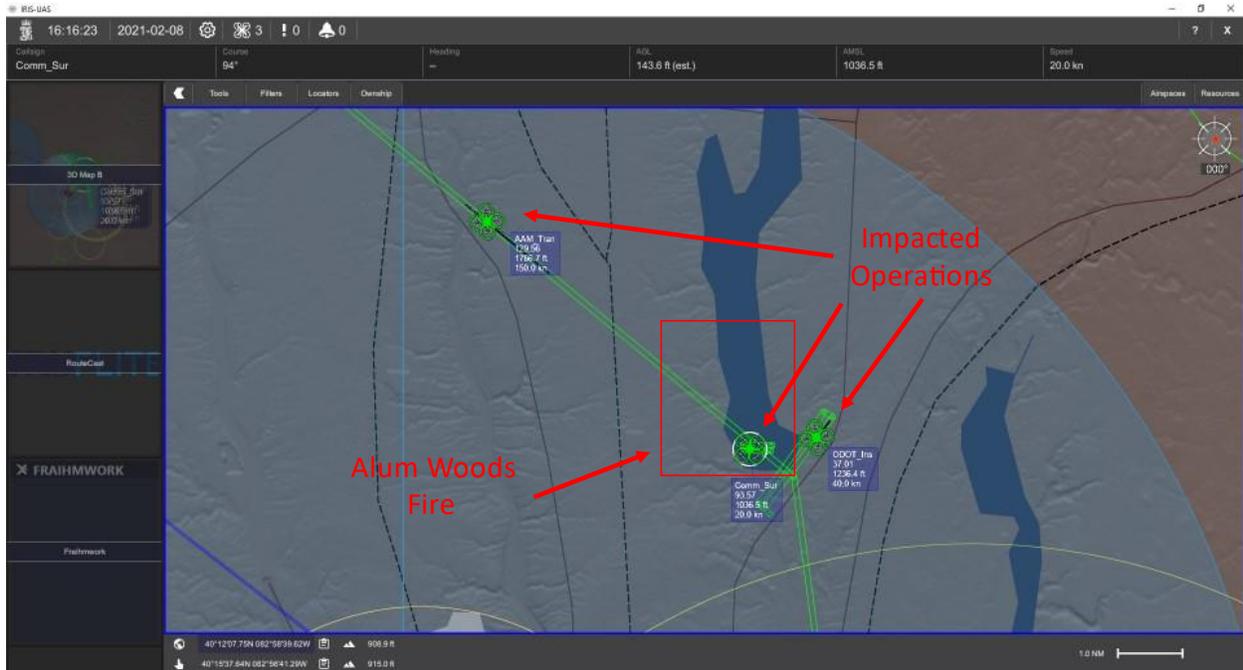


Narrative:

- At approximately 11:08 the UTM Supervisor receives new reports of a fire beginning in the woods around Alum Creek. Emergency ground support is headed to the area.
- After some communication with the Emergency ground support, the UTM Supervisor decides to issue a UVR in the area impacted to alert UAS operators of potential impacts to their operations.

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Scenario Lost Link

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Scenario: Lost Link

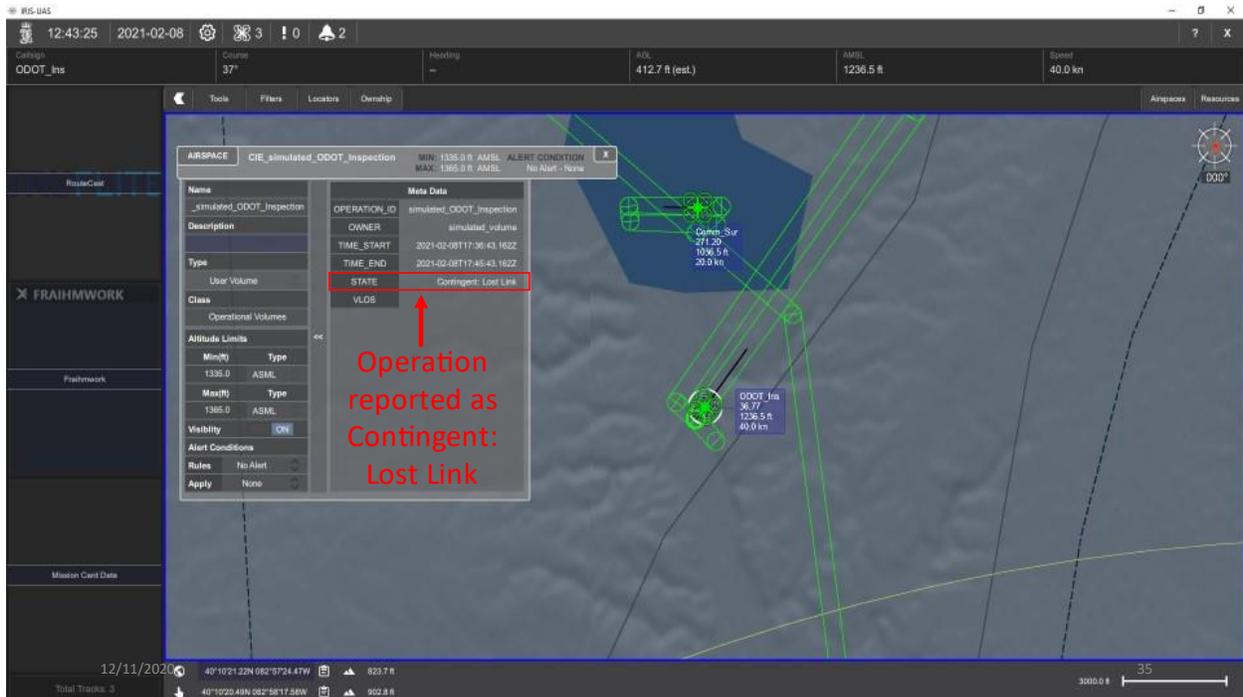
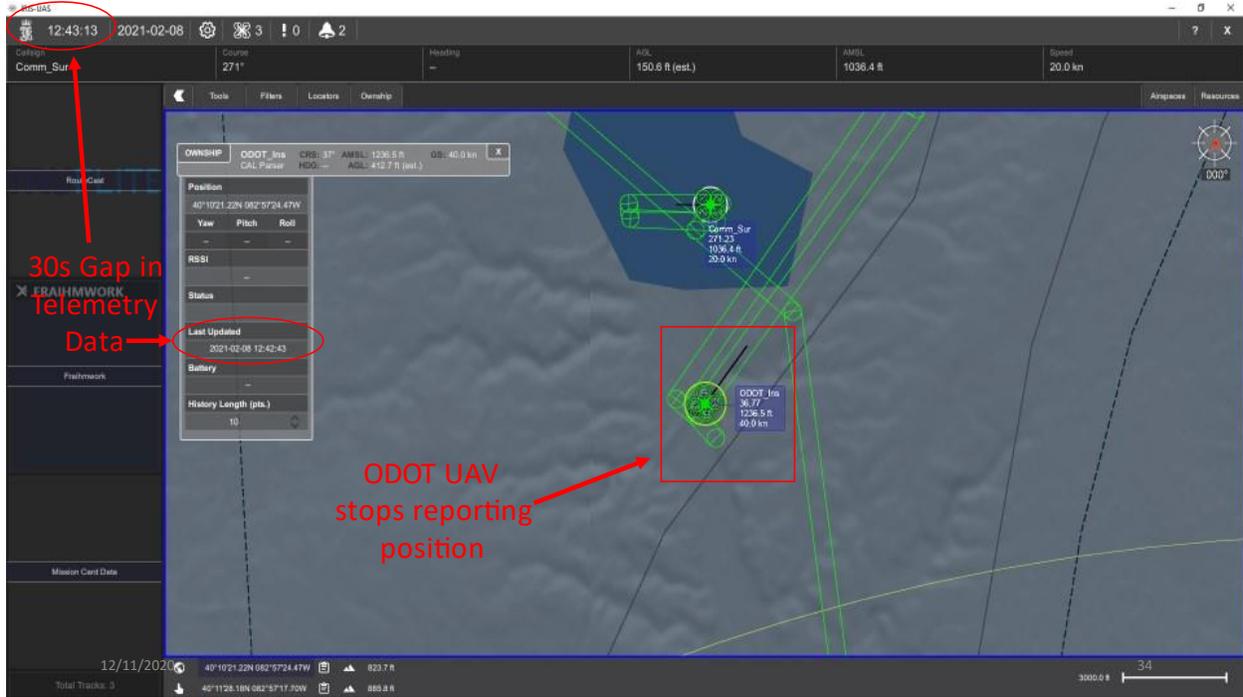


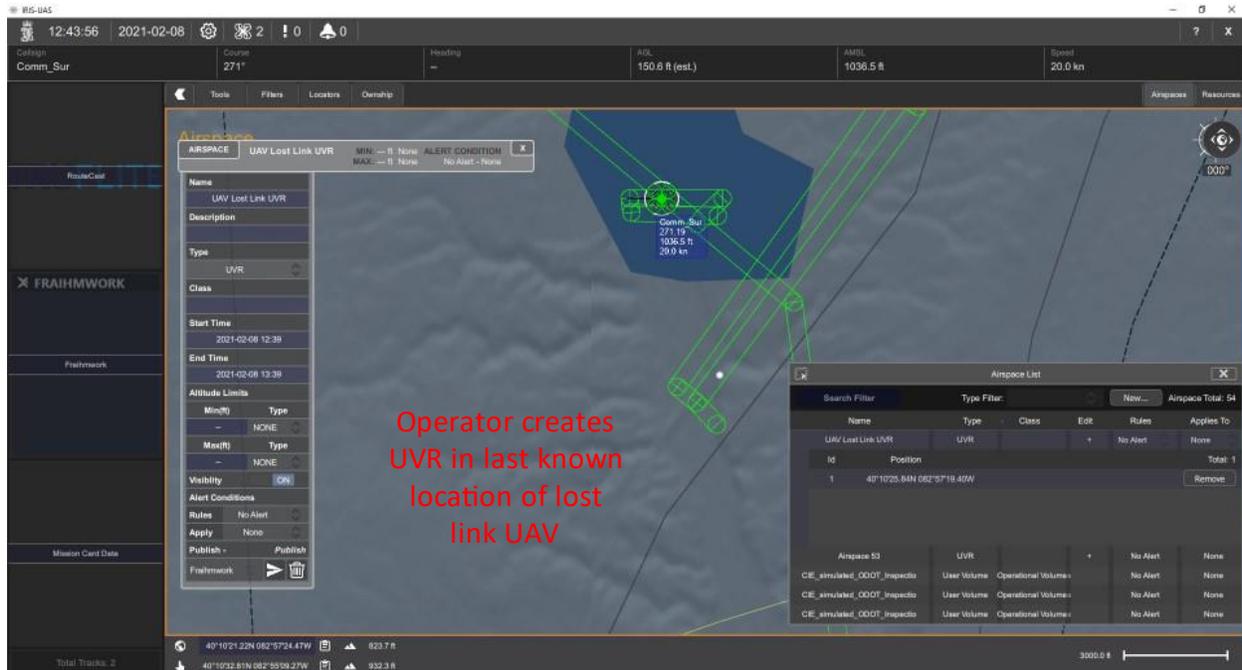
Narrative:

- At approximately 1:41PM the UTM Supervisor gets message from remote pilot in charge about loss of link. The operator is no longer able to receive telemetry data and is unable to send commands to and maintain control of the UAV.

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Summary and Future Work



- Completed development of several UTM contingency scenarios for evaluating the CMP and determining various mitigation means and procedures
- Will continue to meet with various stakeholders (UAS Test Sites, NASA, etc.) to gather feedback on the CMP’s role in contingency management
- Currently the CMP is deployed to two (2) sites (OH and NY), but looking to expand the deployment moving forward



Appendix L: CMP Hardware

The following hardware has been procured for deployment at the New York UAS Test Site (NYUASTS) under the CAL FAA BAA Program.

CMP Laptop

Device	Alienware m15
Processor	9th Generation Intel® Core™ i7-9750H (12MB Cache, up to 4.5 GHz, 6 cores)
Operating System	Windows 10 Pro 64-bit English
Video Card	NVIDIA® GeForce RTX™ 2060 6GB GDDR6
Display	15.6-inch FHD (1920 x 1080) IPS 300-nits Display
Memory	32GB 2x16GB DDR4-2666MHz
Security Software	McAfee LiveSafe 12 Month Subscription
Keyboard	English - Standard full-size, spill-resistant keyboard; Backlit full-size, spill-resistant WASD keyboard with numeric keypad
Ports	1. (2x) SuperSpeed USB 3.1 Gen 1 Type-A 2. HDMI 2.0b with HDCP 2.2 Output 3. Mini-Display Port 1.4 Output 4. Thunderbolt™ 3 Port 5. Alienware Graphics Amplifier Port 6. Power/DC-In Port 7. Noble Lock port (cable and lock sold separately) 8. Killer™ Networks E2600 Gigabit Ethernet NIC 9. USB 3.1 Gen 1 Type-A with Powershare Technology 10. Audio Out 1/8" Port (Compatible with inline mic headset)
Dimensions & Weight	1. Height (Front): 17.9mm (0.704") Height (Peak): 20.1mm (0.791") Height (Rear): 19.5mm (0.77") 2. Width: 360.5mm (14.19") 3. Depth: 276mm (10.9") Weight: 2.16kg (4.75lb)
Audio and Speakers	2 tuned speakers with Nahimic Sound Center 1 combo headphone / microphone jack
WIFI	802.11ax, WiFi and Bluetooth, 2 x 2
Battery	60 WHr, 4-Cell Battery (integrated)
Hard Drive	256GB PCIe M.2 SSD + 256GB PCIe M.2 SSD



External Storage

Device	Samsung T5 500GB USB External Solid-State Drive (MU-PA500B/AM)
Interface	USB 3.1
Capacity	500GB
Transfer Rate	540MB/Sec

Touchscreen Monitor

Device	Dell P2418HT touch monitor
Interface	HDMI

Peripherals

Item	Rationale
USB 2.0 male A to RJ45 female adapter supporting 10/100/1000 Ethernet at USB 2.0 speeds (480Mbps).	Required if connectivity to multiple networks is required.
Logitech MK270 Wireless Keyboard and Mouse Combo 920-004536 - USB 2.0 RF Wireless Ergonomic Keyboard & Mouse	If dedicated touch screen is preferred, then the following is required.
Ethernet Cables x 2 (25ft), HDMI Cable (12ft), USB patch cable (12ft)	If dedicated touch screen is preferred, then the following is required to connect touch screen to laptop.

Case

Product	Pelican Protector Case 1615 Air Case - With Foam
----------------	--