# Development of a Graphical User Interface for the Advanced Capabilities for Emergency Response Operation's Portable Airspace Management Concept


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# Uncrewed Aircraft Systems (UAS)

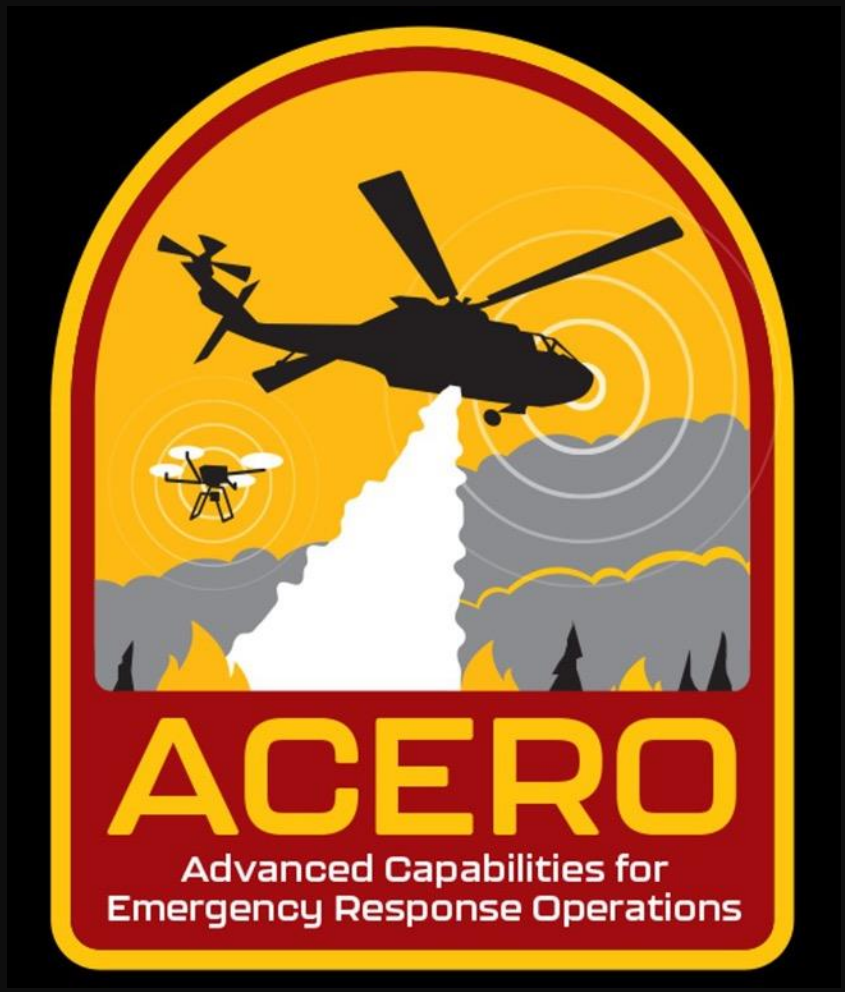
- UAS are increasingly being used to support wildland fire management
- Missions include:
  - Real-time fire mapping
  - Perimeter monitoring
  - Prescribed burns
  - Aerial ignition
- Can operate in conditions or altitudes too hazardous for crewed aircraft
- Particularly well-suited for nighttime or low-visibility

# Integrating UAS in Wildland Fire Management

- Challenge to safely integrate UAS into the shared airspace around a wildland fire
- Safe integration is hindered by their lack of visibility
- It is critical to develop tools that provide a common picture of airspace activity
- Situation awareness of the airspace is vital for safety

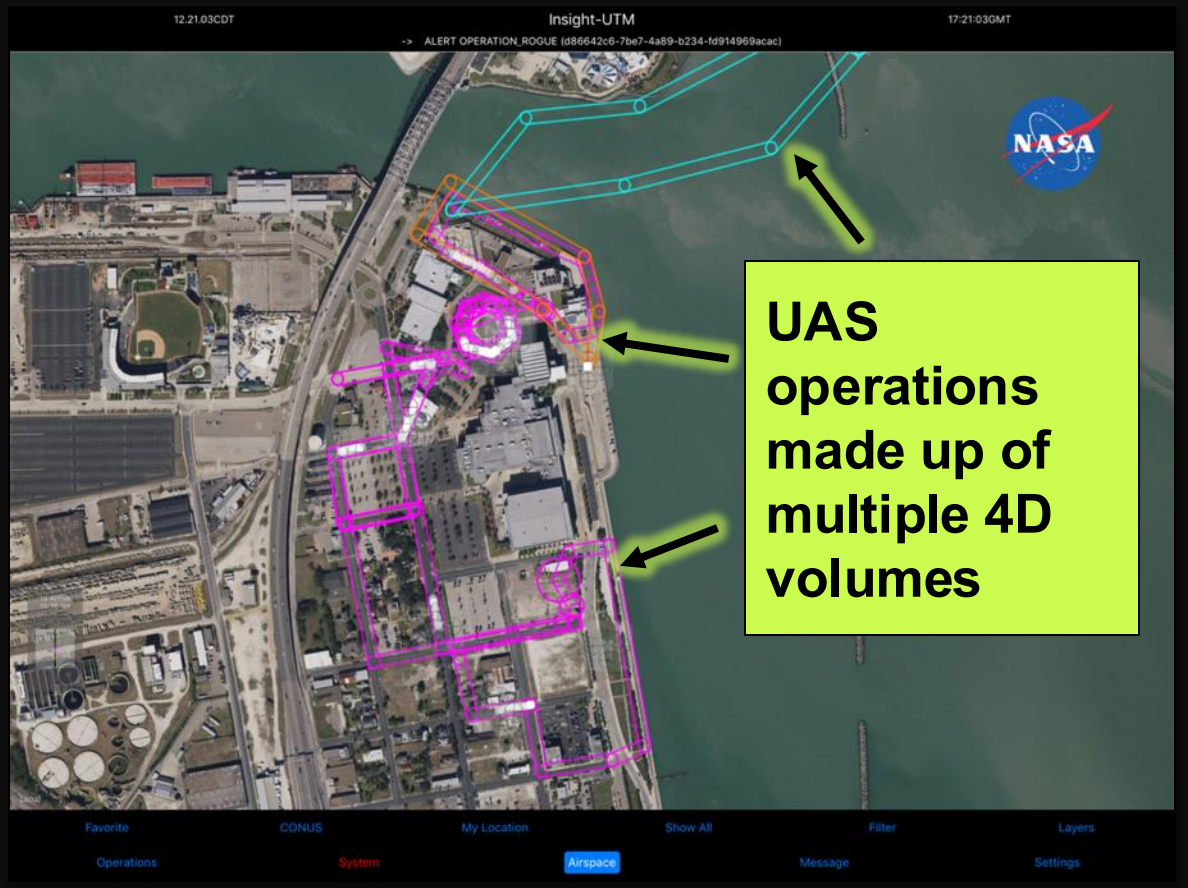
# Advanced Capabilities for Emergency Response Operations

- Multi-year project, launched in 2023
- Led by NASA Ames Research Center
- Seeks to enhance the safety, effectiveness, and efficiency of emergency response operations, with a particular focus on wildland firefighting
- Second Shift Capabilities (SSC) explores how UAS can extend aerial support in **low-visibility conditions** while addressing some of the challenges that UAS operators face in the wildland firefighting environment



# UAS Traffic Management (UTM)

- UTM laid the groundwork for coordinating operations through **digital flight intent sharing**
- UTM Service Supplier (USS):
  - Check for volume conflicts
  - Provides feedback
  - Monitor conformance
- However, UTM relies on persistent network connectivity, creating challenges in the wildland fire environment



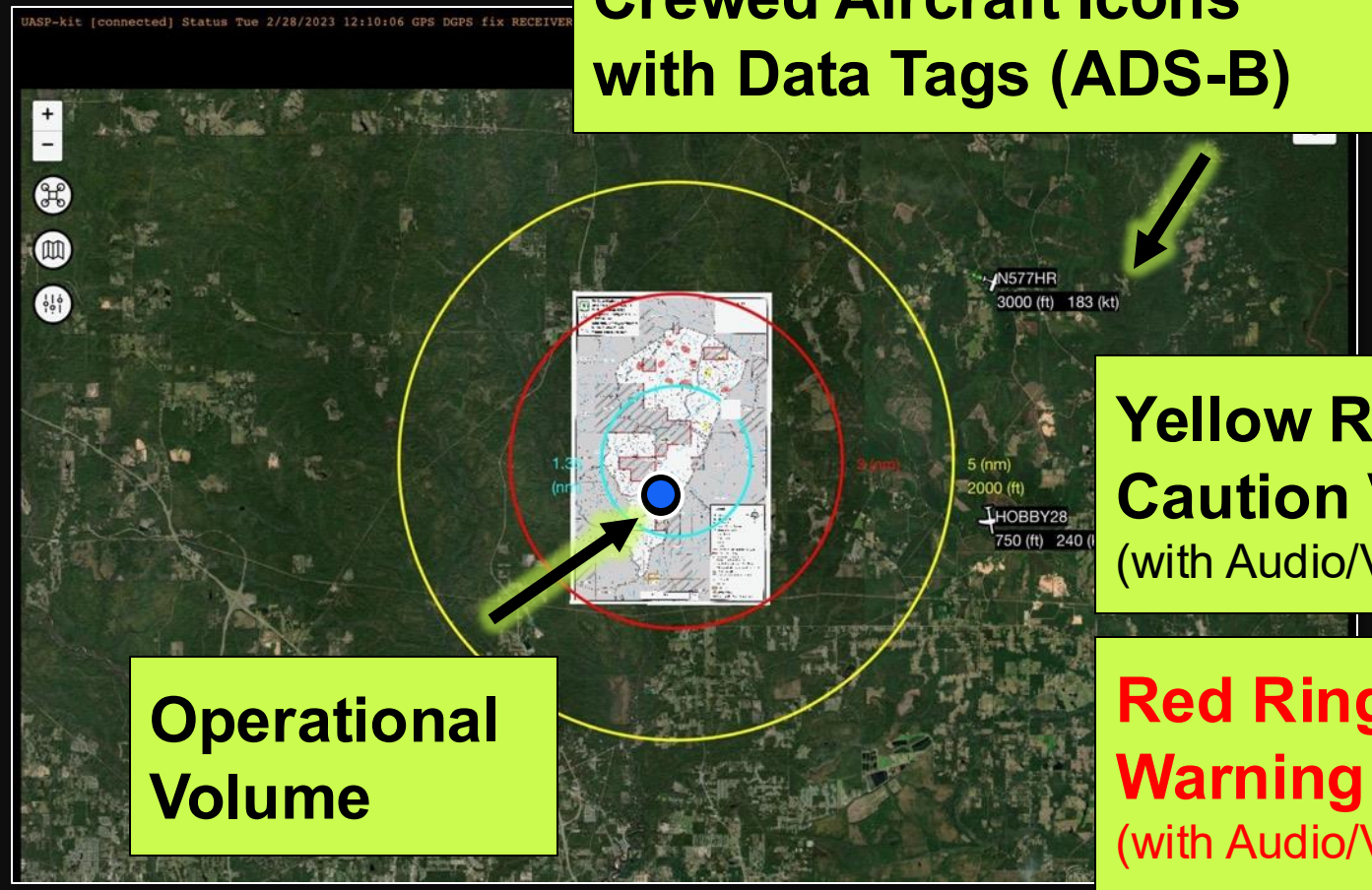

UTM Service Supplier (USS) User Interface

# Scalable Traffic Management for Emergency Response Operations (STEReO)

- To address some of the challenges in the **wildland fire environment**, elements of UTM were adapted to support the UAS operator's situation awareness of the airspace
- The **UAS Pilot (UASP)-kit** supports situation awareness and uses volume-based UAS operations

# Scalable Traffic Management for Emergency Response Operations (STEReO)

- However, the UASP-kit does not facilitate the exchange of operational data between users
- Built for a single UAS
- Can't see other UAS operations




**Crewed Aircraft Icons with Data Tags (ADS-B)**

**Yellow Ring: Caution Volume**
(with Audio/Visual alert)

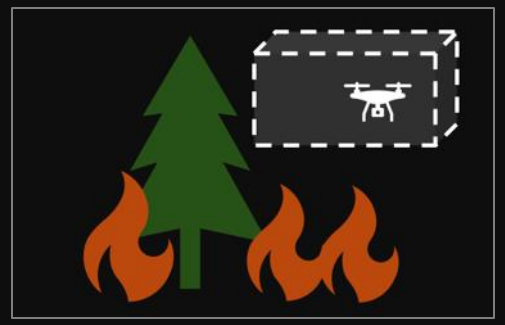
**Red Ring: Warning Volume**
(with Audio/Visual alert)

**Operational Volume**

UAS Pilot (UASP)-kit User Interface

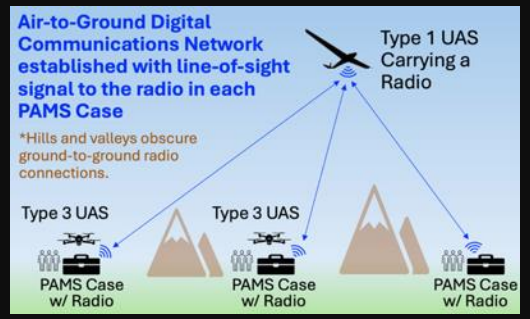
# ACERO's Portable Airspace Management System (PAMS)

- Field-deployable research prototype
- Allows users to coordinate multiple operations
- Consolidates key airspace, operation, and system information into a single viewpoint with interactive features



WFSS Airspace Management System

PAMS Cases

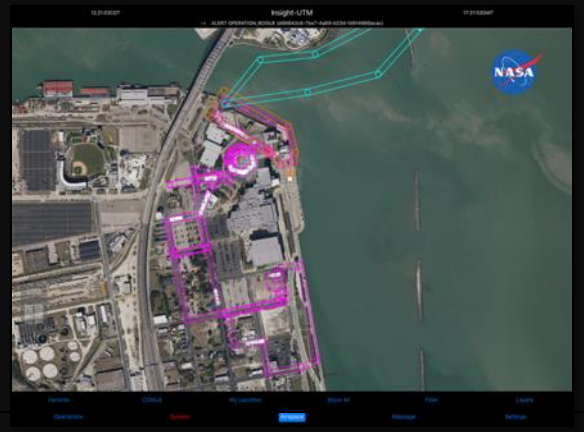



Air-to-ground Digital Communication System

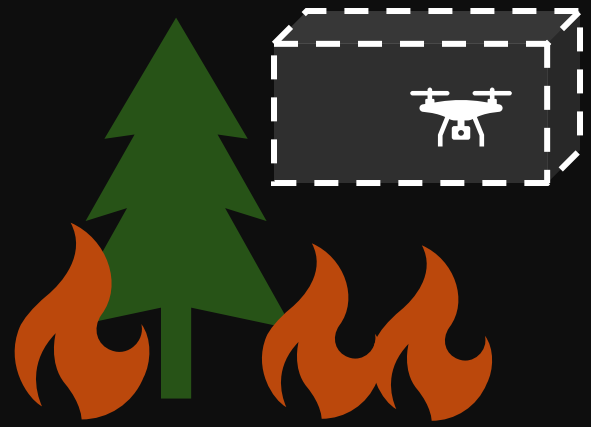
User Interface


Decision Support Tool

# ACERO's Portable Airspace Management System (PAMS)



UTM Service Supplier (USS)



Wildland Fire Service Supplier (WFSS) "wolfs"

- Modeled after UTM's USS architecture
- Compares all UAS operations submitted to the system to prevent spatial and temporal conflicts between UAS operations
- Monitors conformance to the 4D volumes
- Checks for violations of airspace constraints / boundaries

# PAMS User Interface

- The PAMS UI is displayed on touchscreen tablet, housed in the PAMS Case
- Enables the UAS operator to interact with WFSS
- Building and submitting their operational volumes
- Receive feedback and notifications from WFSS
- Receive conformance monitoring alerts if the UAS deviates from the 4D volume

# PAMS User Interface – Requirements

- ACERO adopted a systems engineering process to define the UI requirements
- The Systems Engineering team conducted interviews with the technical team to identify development priorities
- Translated them into formal “shall” statements for clear, testable descriptions

# PAMS User Interface – Requirements

| ID | Title | Requirement Test |
|---|---|---|
| UI.1 | User Interface | System shall provision user accessibility and awareness through a field-deployable interactive display |
| UI.1.1 | WFSS Interface | User Interface shall provide an interface to WFSS |
| UI.1.2 | Data Processing Tool Interface | UI shall provide an interface to the data processing tool (Fire data and ADS-B data display) |
| UI.1.3 | UI System Data Logging | UI system shall record user interface data as specified in the Data Management Plan |

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| | Sub-Level Requirements | **Support the full lifecycle of UAS operations:**<br>- Create, Modify, Send, Receive, and Display 4D volumes<br>- Depict Operational States: Validated, Active, or Closed<br>- Receive / depict airspace constraints conflicts, telemetry |
| UI.1.2 | Data Processing Tool Interface | UI shall provide an interface to the data processing tool (Fire data and ADS-B data display) |
| UI.1.3 | UI System Data Logging | UI system shall record user interface data as specified in the Data Management Plan |

# WFSS Operational States

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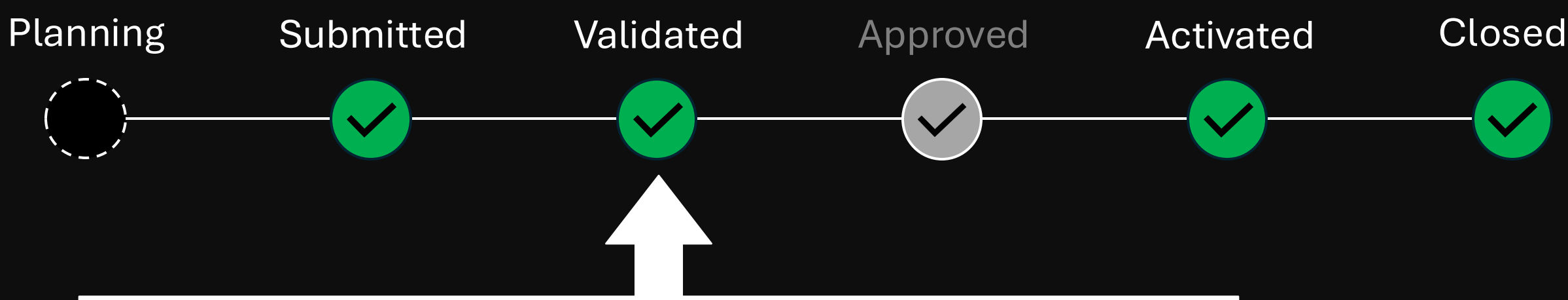
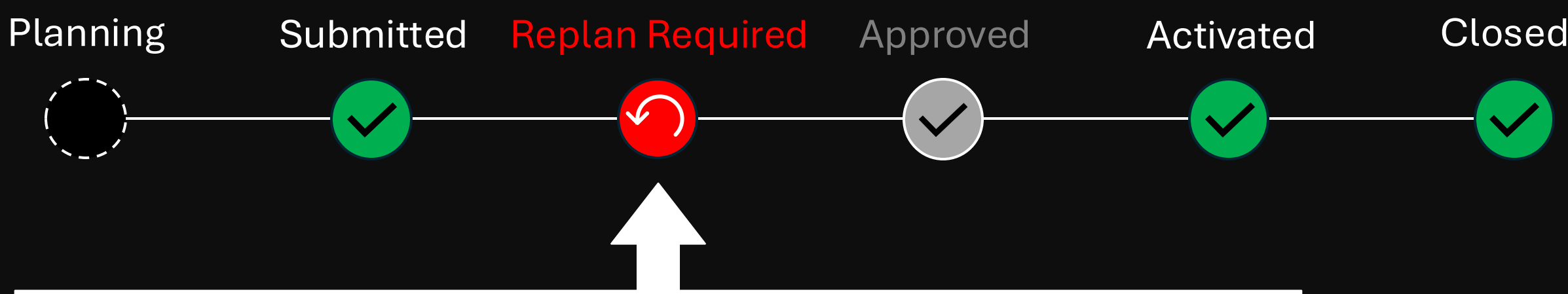



If the **Submitted** operation:

- Meets the parameter requirements
- Does not overlap with another operator's volume
- And, is within the Temporary Flight Restriction

Then the operation advances to the **Validated** state

# WFSS Operational States

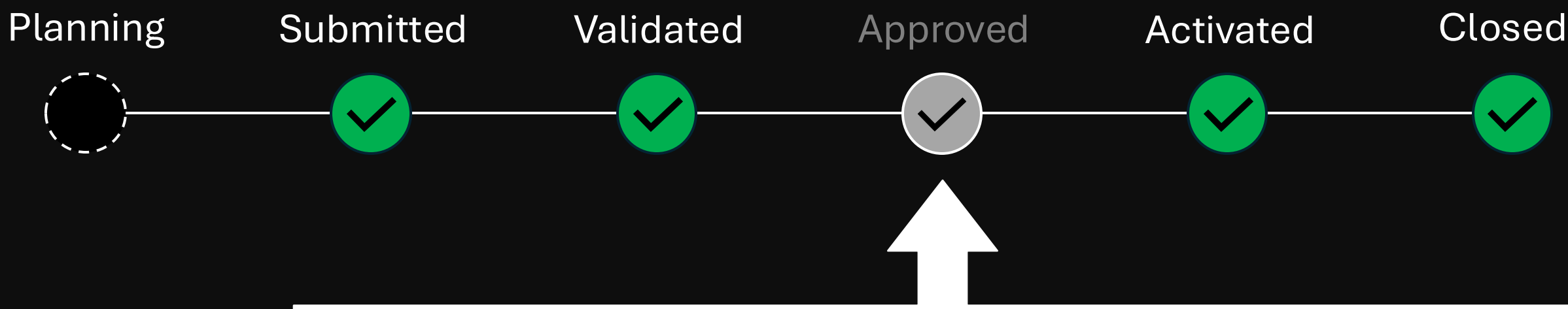



If the volume:

- Overlaps with another operator,
- Or is outside of the TFR boundary

Then the user is prompted with a “Replan Required”

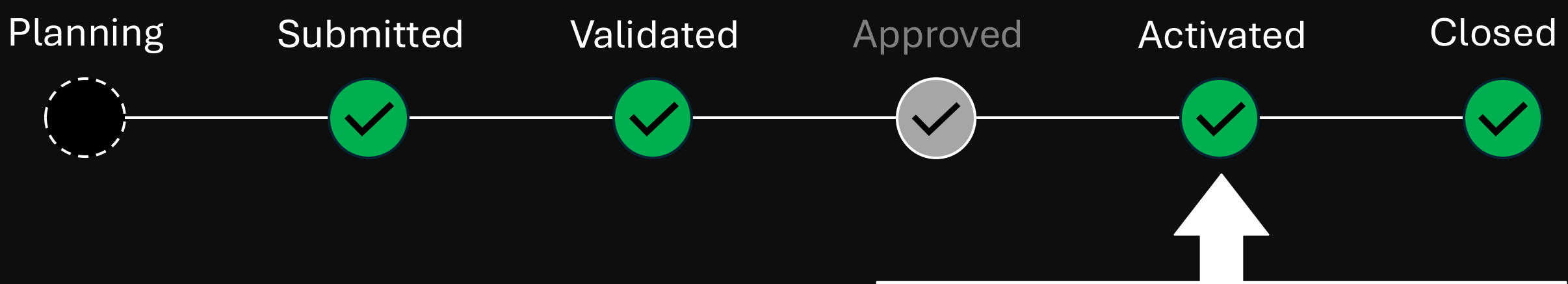
# WFSS Operational States




The **Approved** state:

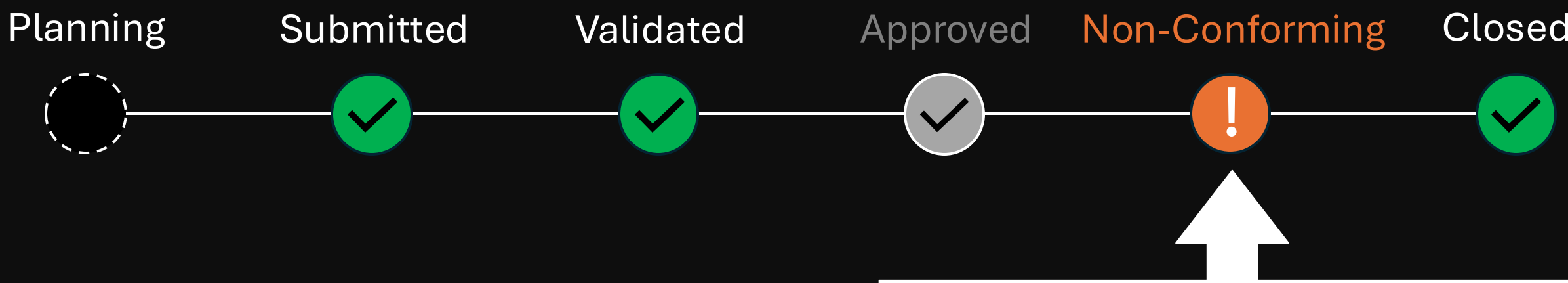
- Not a formal WFSS state
- Rather a verbal communication incorporated into the PAMS workflow to simulate an Aerial Supervisor.

# WFSS Operational States



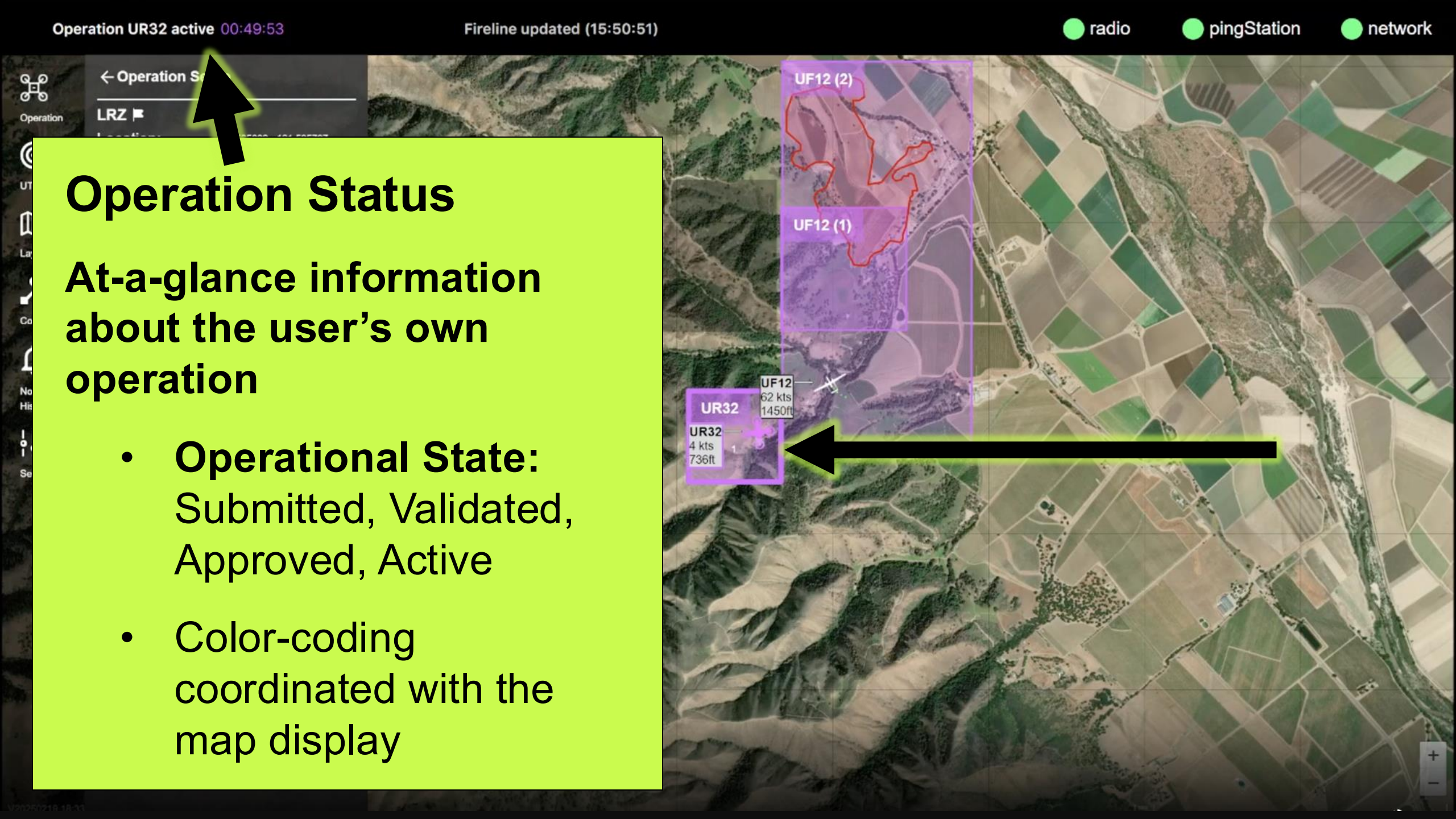

The operation transitions to the **Activated** state upon takeoff.

# WFSS Operational States




**Non-Conforming:**

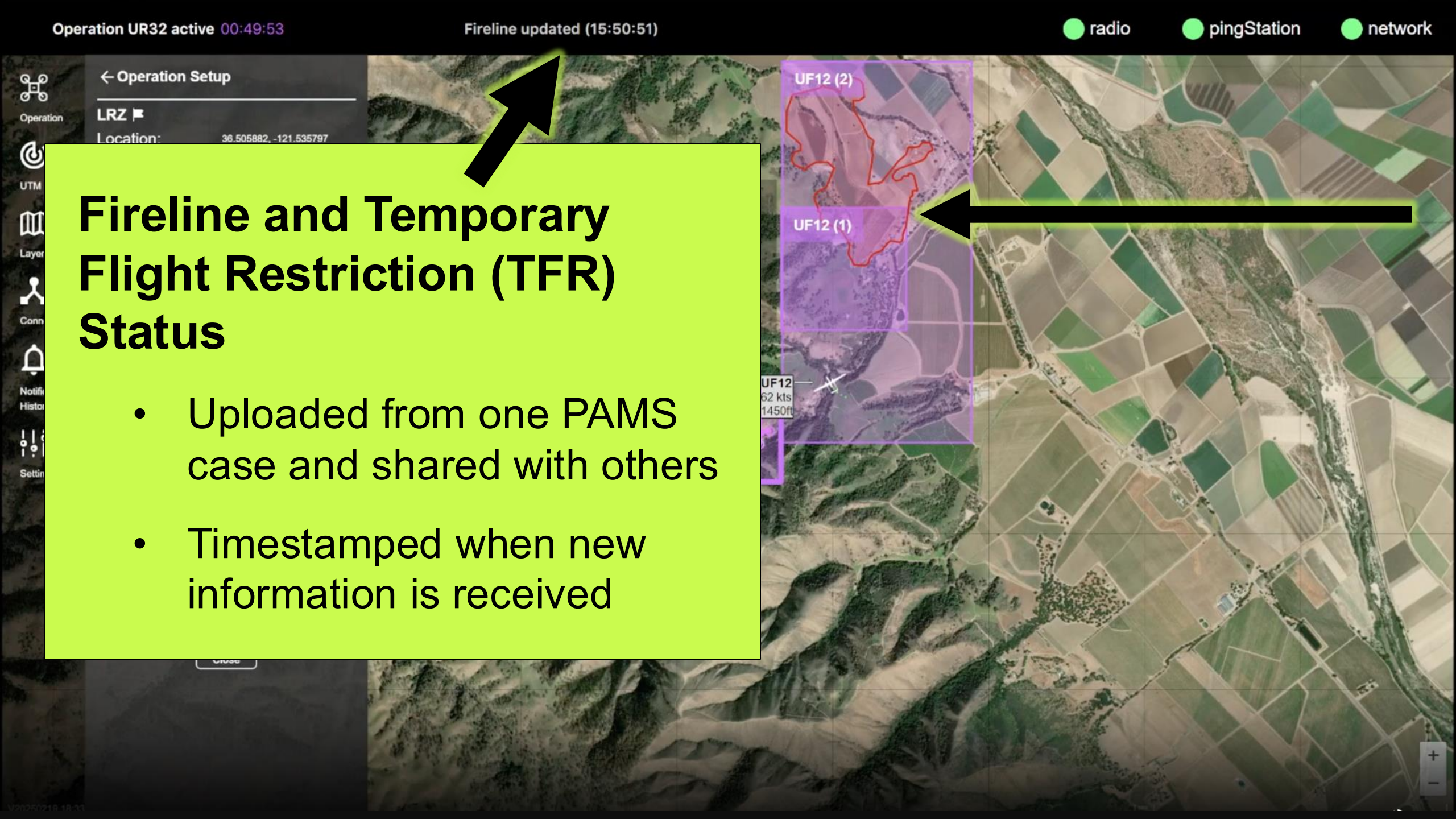
- Deviates from volume (laterally, above, below)
- Or operates outside of the approved time window




# Operation Status

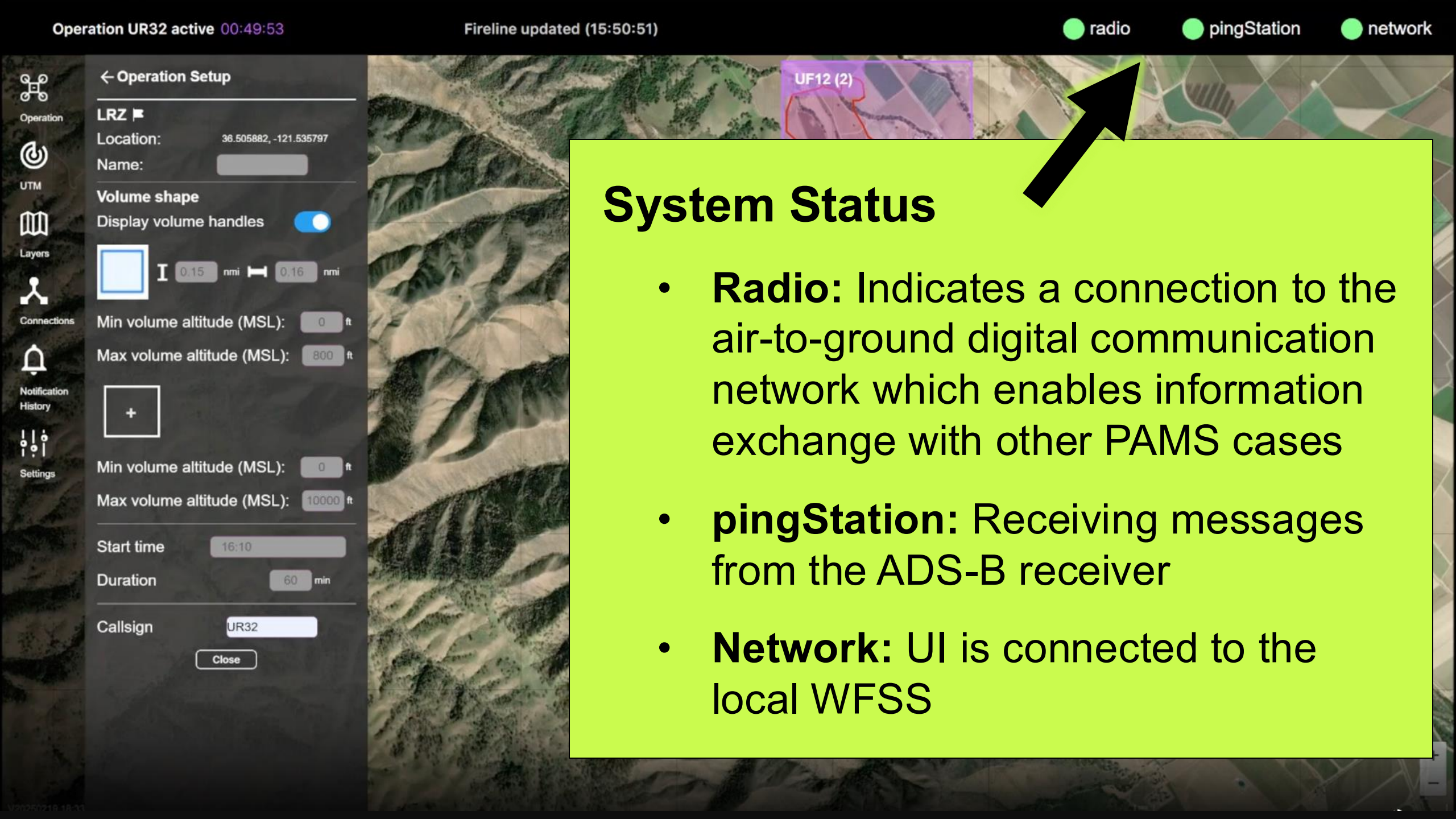
**At-a-glance information about the user's own operation**

- **Operational State:** Submitted, Validated, Approved, Active
- Color-coding coordinated with the map display



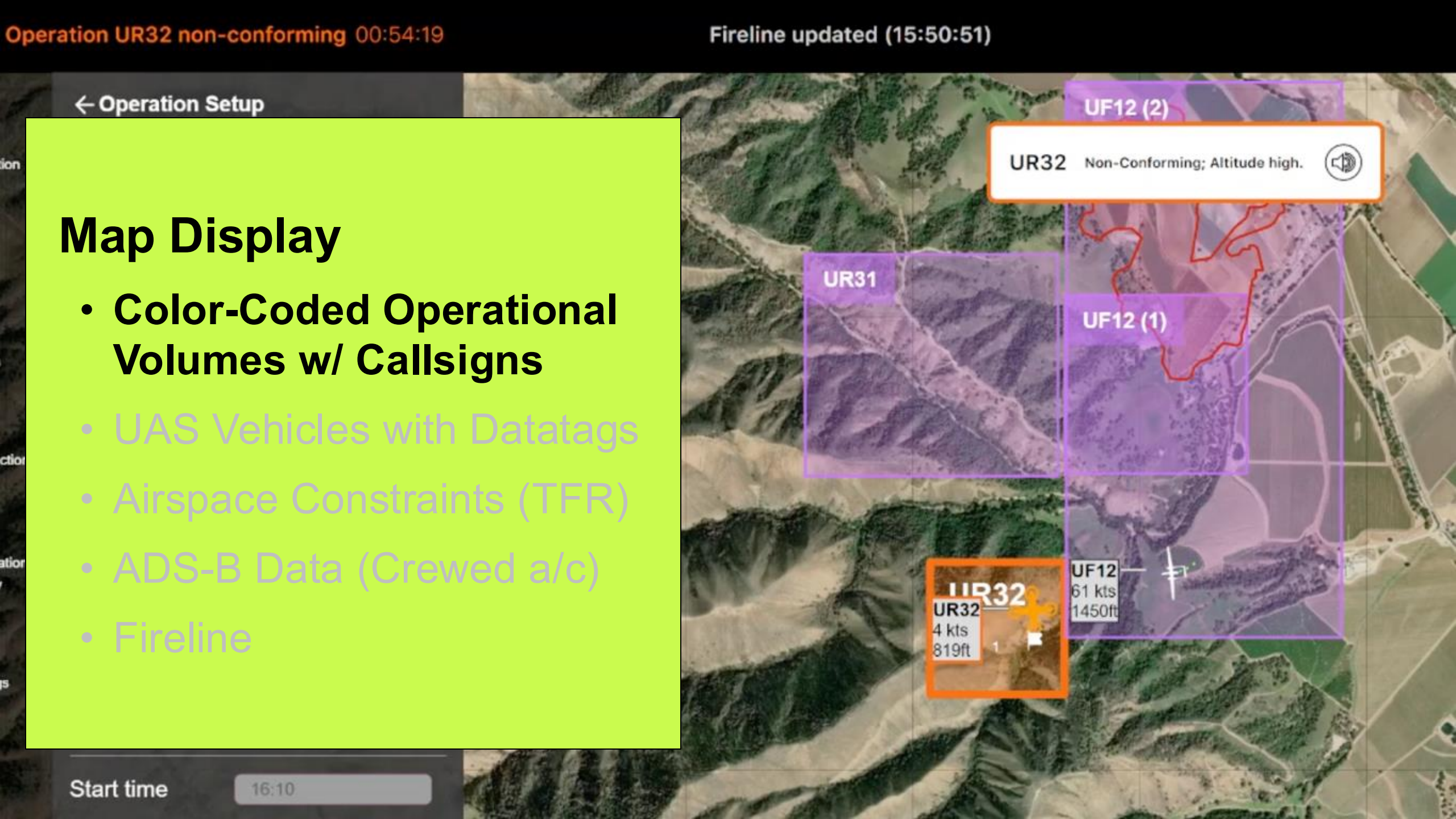

# Fireline and Temporary Flight Restriction (TFR) Status

- Uploaded from one PAMS case and shared with others
- Timestamped when new information is received



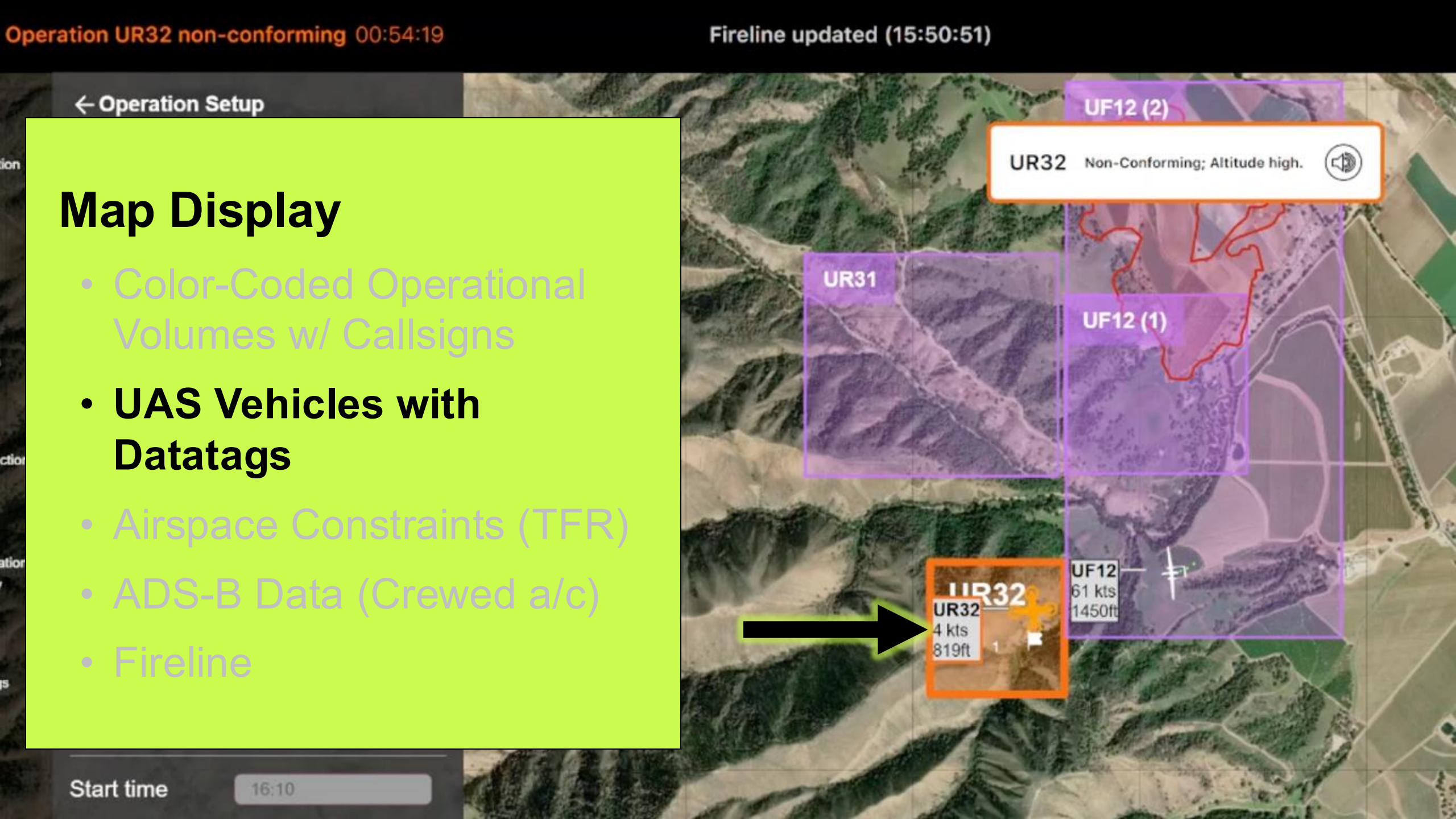

# System Status

- **Radio:** Indicates a connection to the air-to-ground digital communication network which enables information exchange with other PAMS cases
- **pingStation:** Receiving messages from the ADS-B receiver
- **Network:** UI is connected to the local WFSS




# Map Display

- **Color-Coded Operational Volumes w/ Callsigns**
- UAS Vehicles with Datatags
- Airspace Constraints (TFR)
- ADS-B Data (Crewed a/c)
- Fireline

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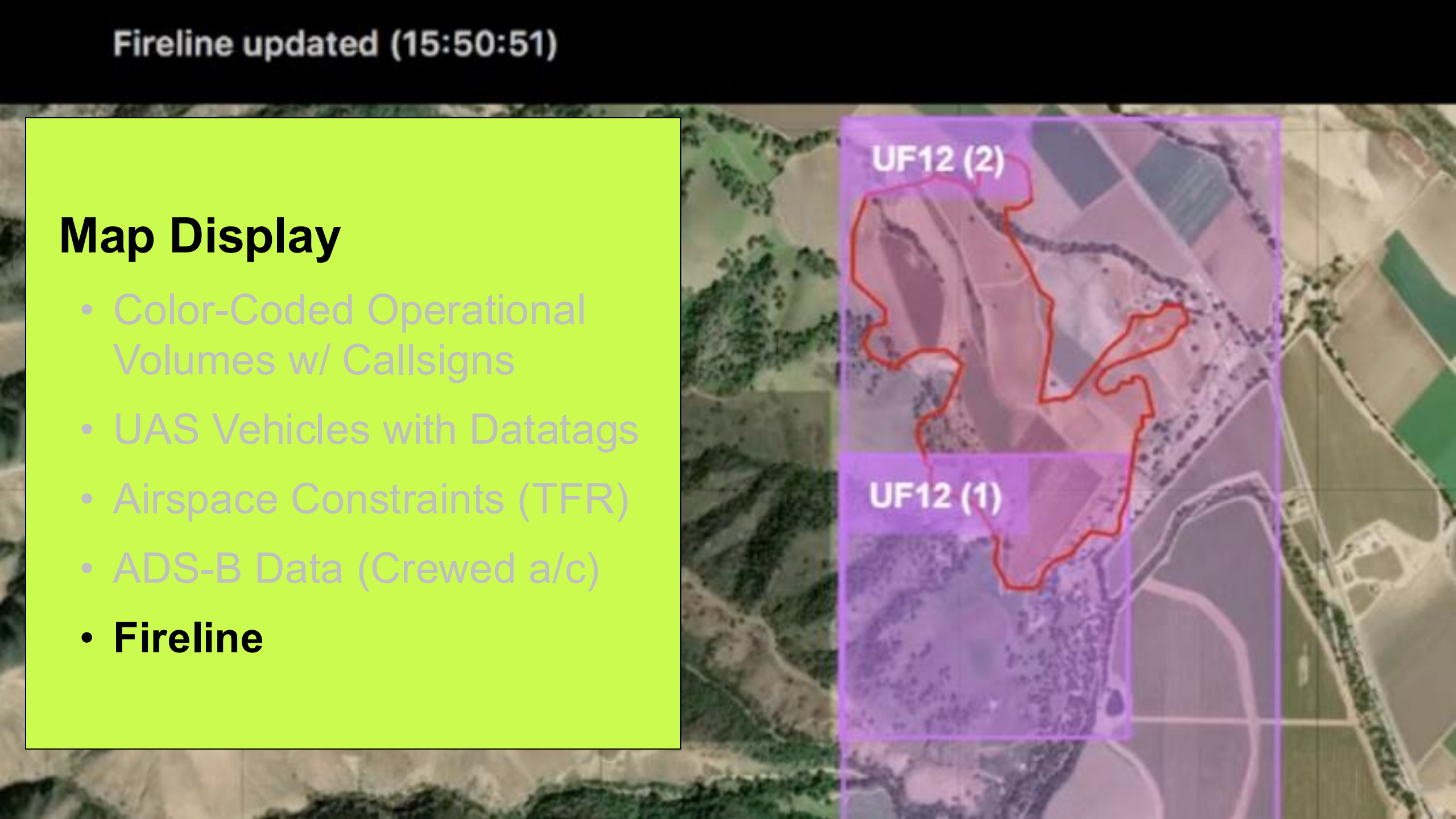


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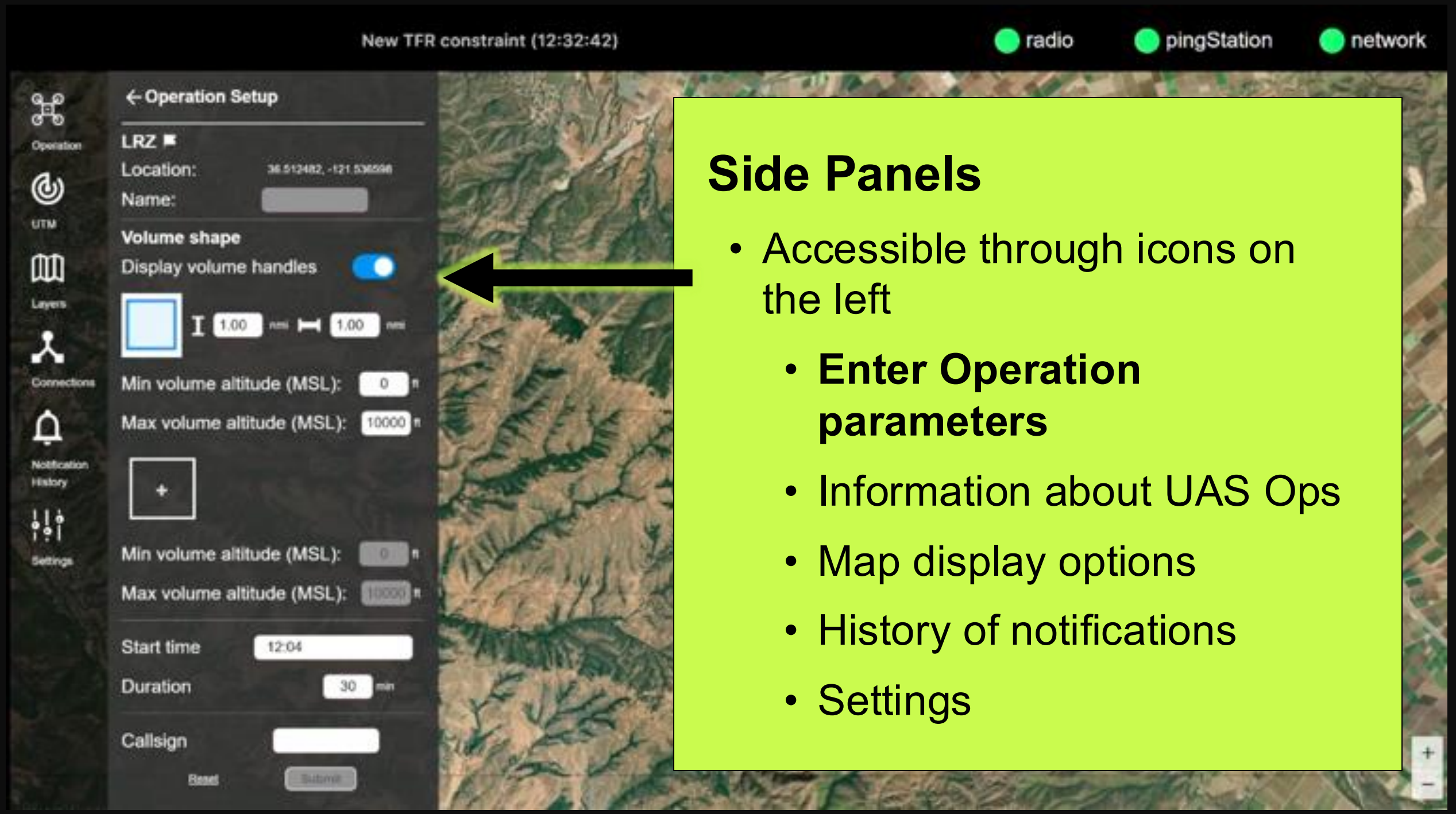
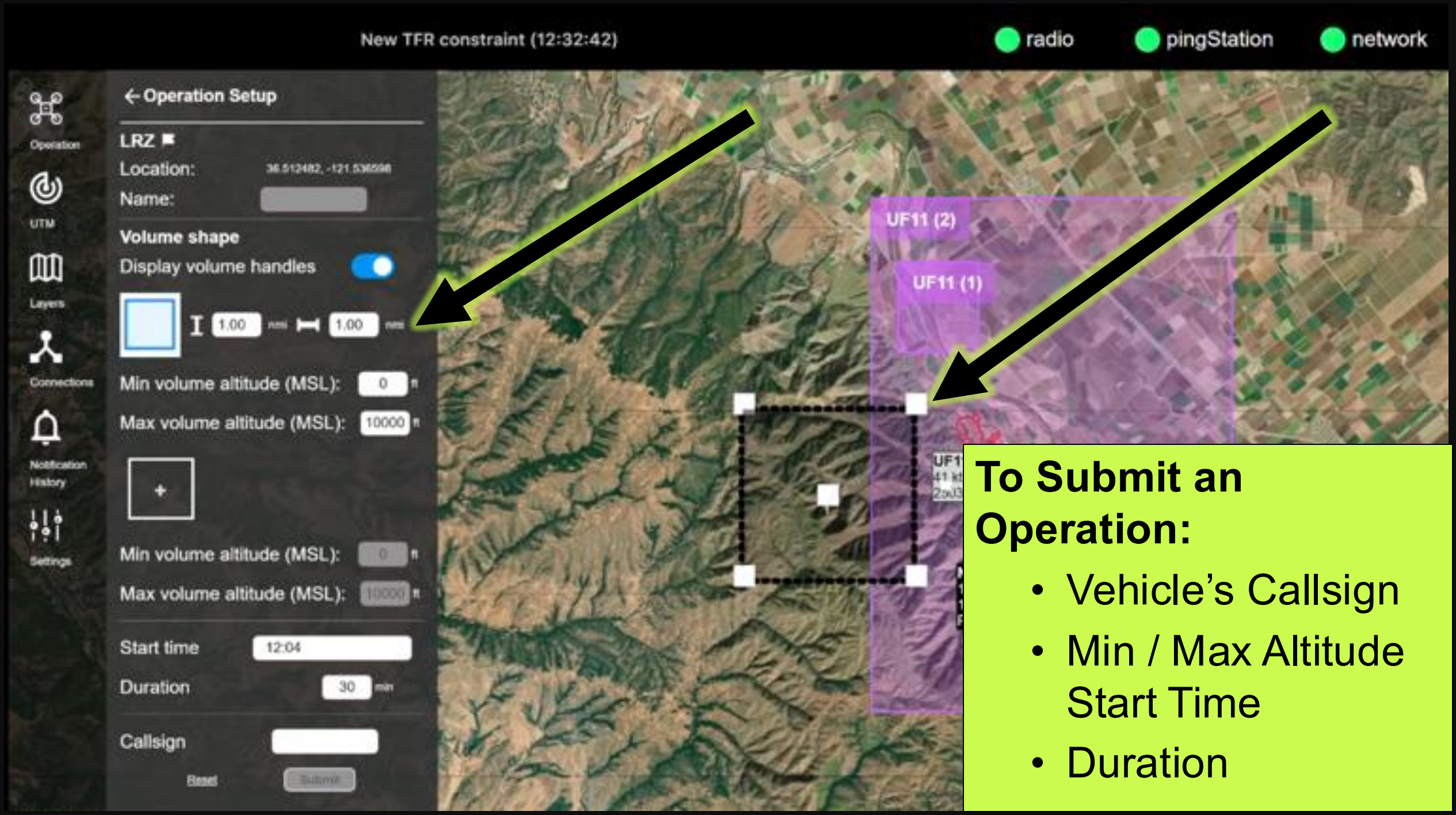



## Side Panels

- Accessible through icons on the left
  - **Enter Operation parameters**
  - Information about UAS Ops
  - Map display options
  - History of notifications
  - Settings


New TFR constraint (12:32:42)
radio
pingStation
network
Operation
UTM
Layers
Connections
Notification History
Settings
← Operation Setup
LRZ
Location:
Name:
Volume shape
Display volume handles
1.00
1.00
Min volume altitude (MSL):
0
Max volume altitude (MSL):
10000
Min volume altitude (MSL):
Max volume altitude (MSL):
Start time
12:04
Duration
30
min
Callsign
Reset
Submit
UF11 (2)
UF11 (1)
To Submit an Operation:
• Vehicle's Callsign
• Min / Max Altitude
Start Time
• Duration

# UI Development and Evolution

- The UI was developed through ongoing collaboration between researchers and developers
- Tested in laboratory settings with simulated data
- And outdoor environments at NASA Ames using live data
- Assessed how well the UI supported functional requirements
- Implemented improvements

Testing at NASA Ames

# ACERO's First Field Demonstration (TCL-1)

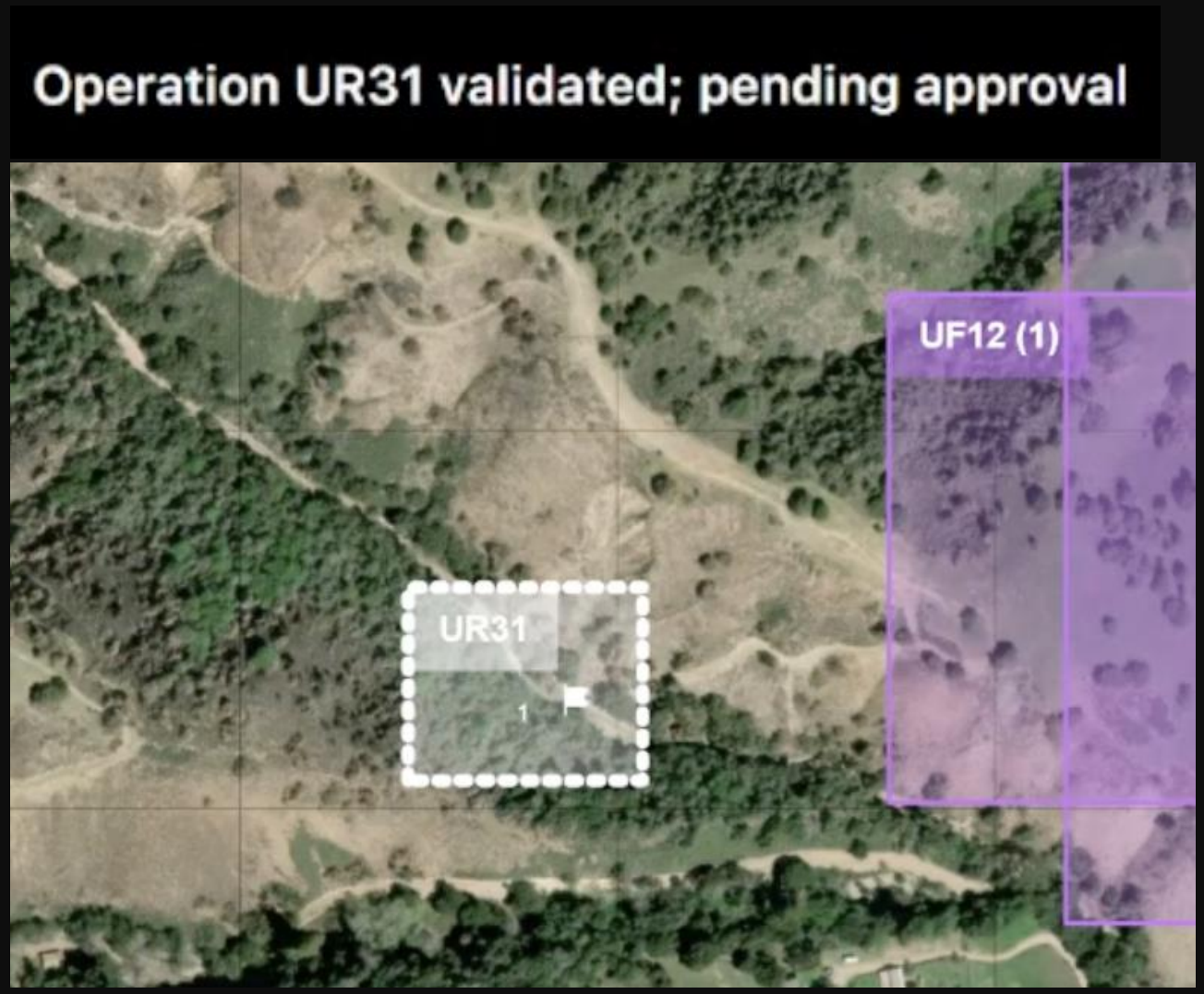
- Salinas, CA
- March 2025
- Foothills of the Sierra de Salinas mountains
- Flight tests with live UAS operations
- Evaluate the PAMS UI in realistic conditions


# ACERO's First Field Demonstration (TCL-1)

- Subject Matter Experts (SMEs) used the PAMS UI to build operations and monitor UAS operations during flight
- Test scenarios were designed to evaluate the system's performance in real-world settings
- Completed a series of tasks intended to validate key requirements

# Functional Testing to Validate Requirements

- **Nominal**
- TFR Violation
- Overlapping Volume Conflict
- Non-Conformance
- No Radio Connection



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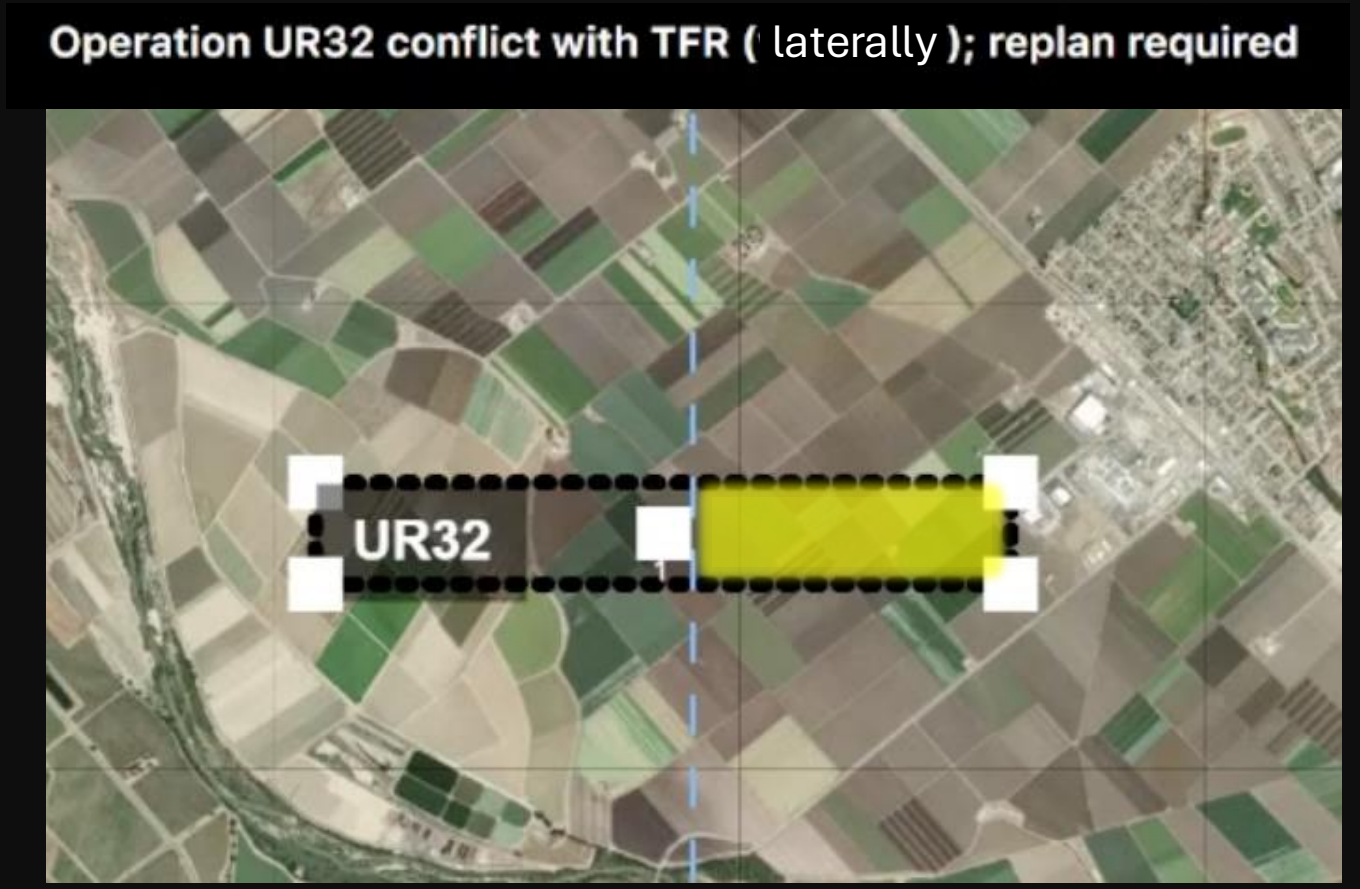

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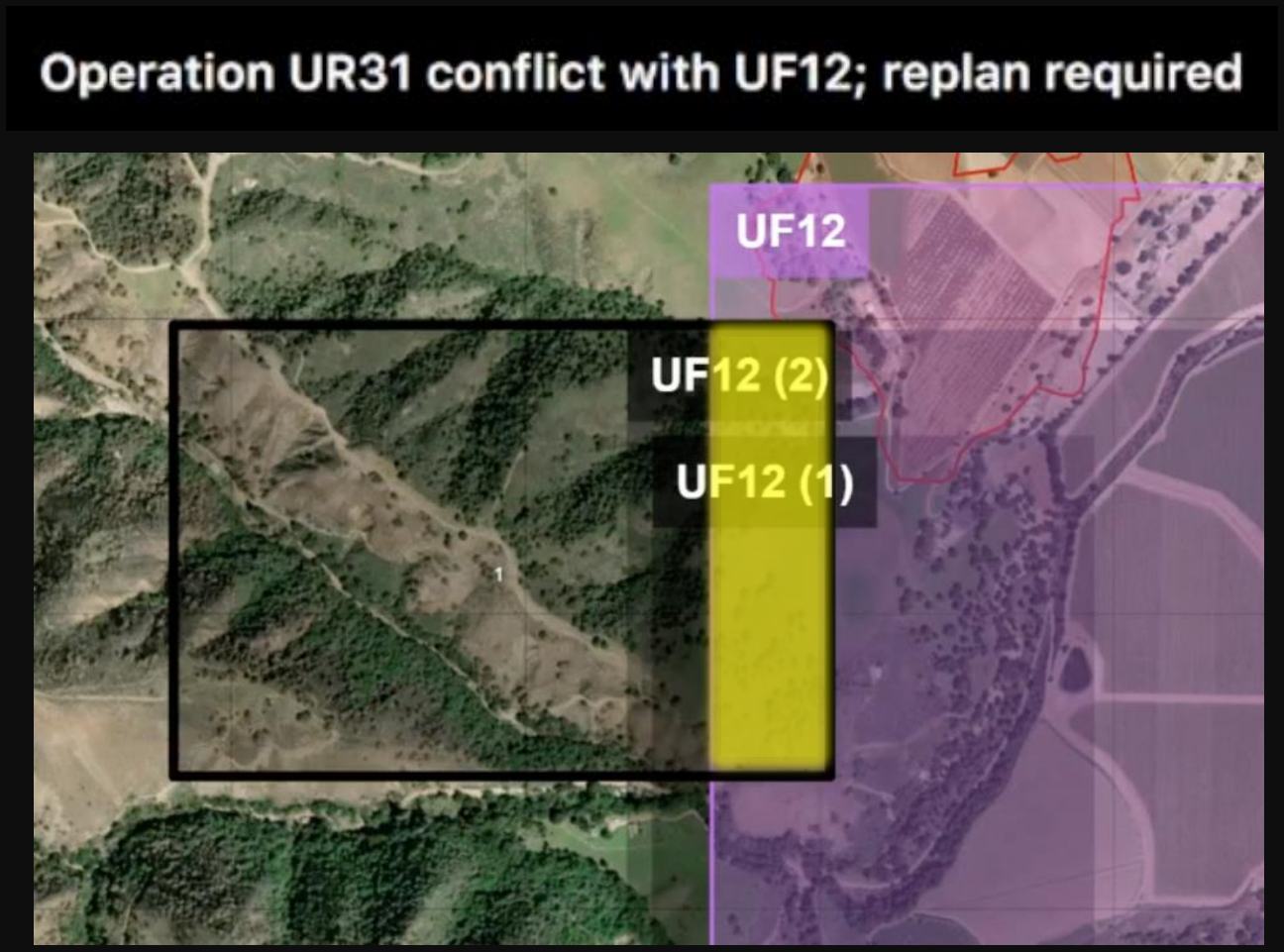

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# Functional Testing to Validate Requirements

- Nominal
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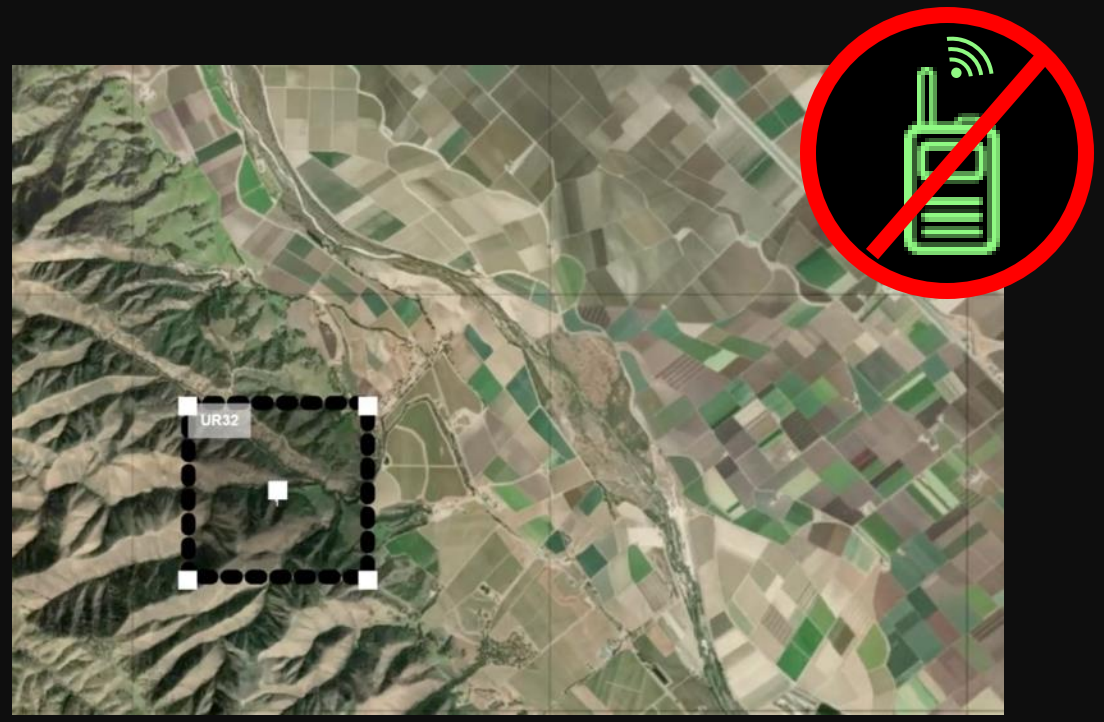
- Non-Conformance
- **No Radio Connection**

- No info about other UAS operations
- No fireline
- No TFR
- **No common operating picture**

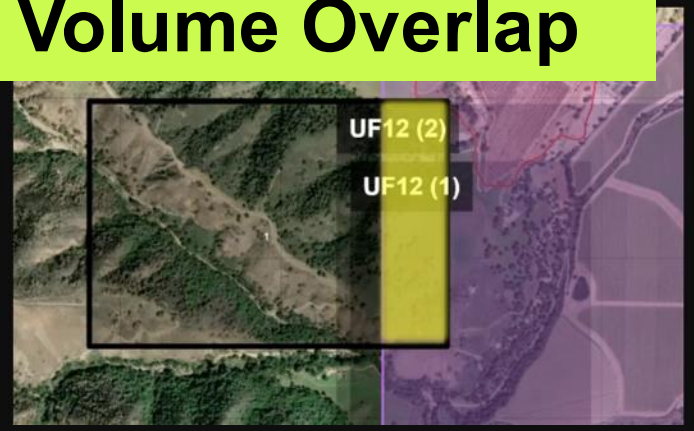


# Functional Testing to Validate Requirements

- These events were subsequently detected by the WFSS and depicted on the UI to validate system capabilities.
- Across all scenarios, users were able to interpret system response, manage operations, and maintain awareness of the airspace.

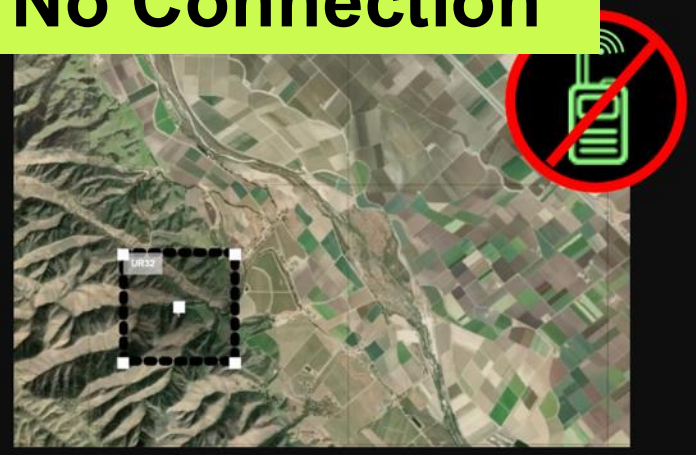
**TFR Violation**


**Volume Overlap**



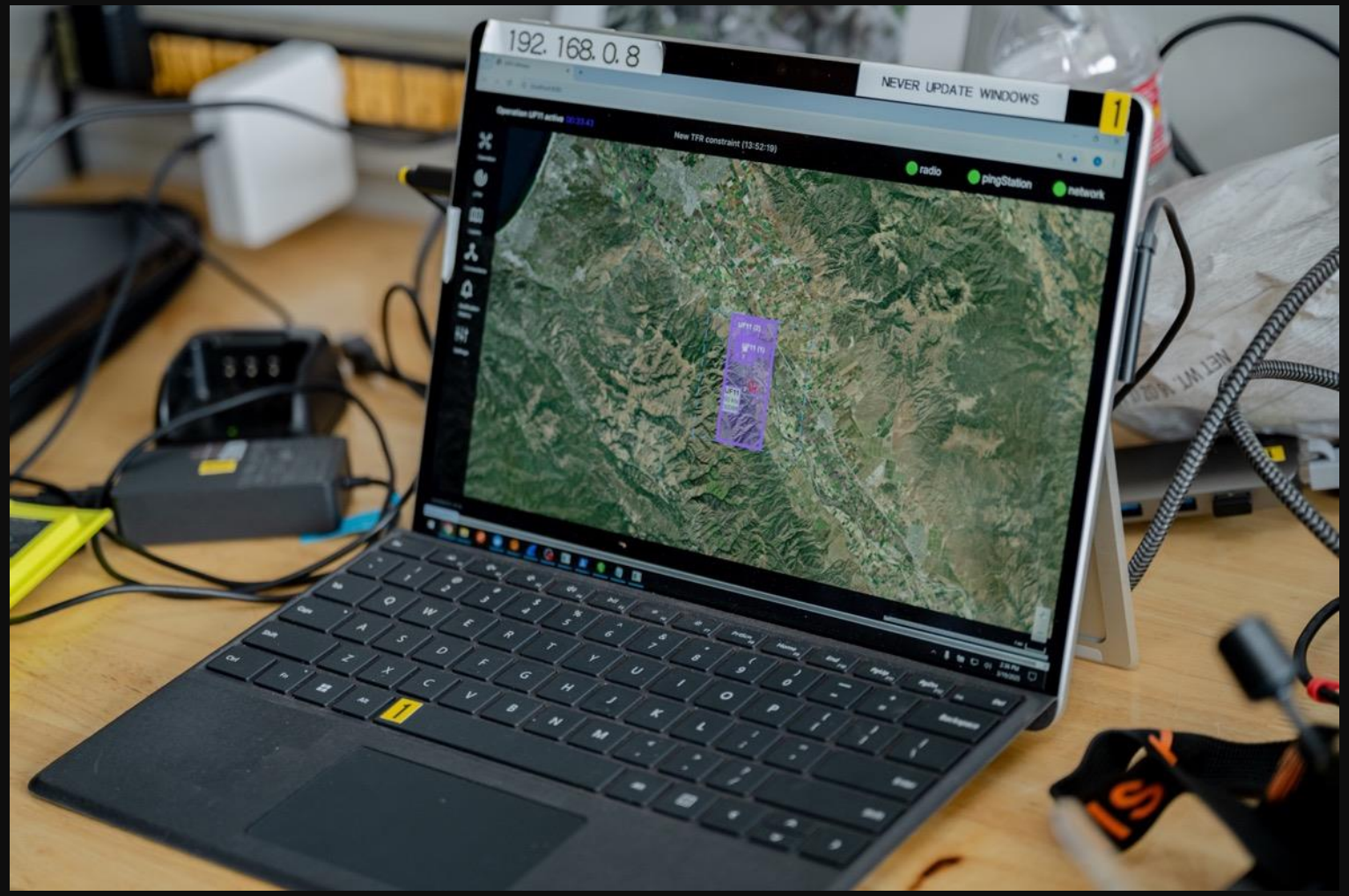

**Non-Conforming**


**No Connection**



# Toward ACERO's Second Field Demonstration

- Expanding and refining current features and improving overall system performance
- Different UI modes for different roles / users
- Incorporate polygon-shaped volumes
- Incorporate additional information (terrain, weather)




# Advanced Capabilities for Emergency Response Operations