Exploring Future Aviation Operations at NASA

w/ MAVLink, PX4, QGroundControl

Mike Politowicz & Robert McSwain
NASA Langley Research Center
Hampton, VA

6/23/2022

Outline

- **Future Aviation Operations**
  - Advanced Air Mobility (AAM)
  - Emergency Response (e.g., Wildfire)
- **NASA Research & Technology**
  - Beyond Visual Line of Sight (BVLOS) / Remote Operations
    - Human Factors (HF) Research
    - Ground Control Station (GCS)
    - Real-time Data Exchange
  - Advanced Automation
    - High Value Automation Use Cases
    - NASA STEReO Flight Test Airborne System Architecture
    - Off-Nominal Traffic Avoidance
    - Off-Nominal Landing
    - Digital Flight Data
- **Next Steps**
  - Collaboration with open-source community

Future Aviation Operations

Credits: NASA / Graphics

- **Advanced Air Mobility (AAM)**
  - Small UAS (sUAS/UTM) → e.g., Package Delivery
  - Urban Air Mobility (UAM) → e.g., Air Taxis
  - Regional Air Mobility (RAM) → e.g., Autonomous Cargo

**UAS = Uncrewed Aerial Systems*
**UTM = UAS Traffic Management*

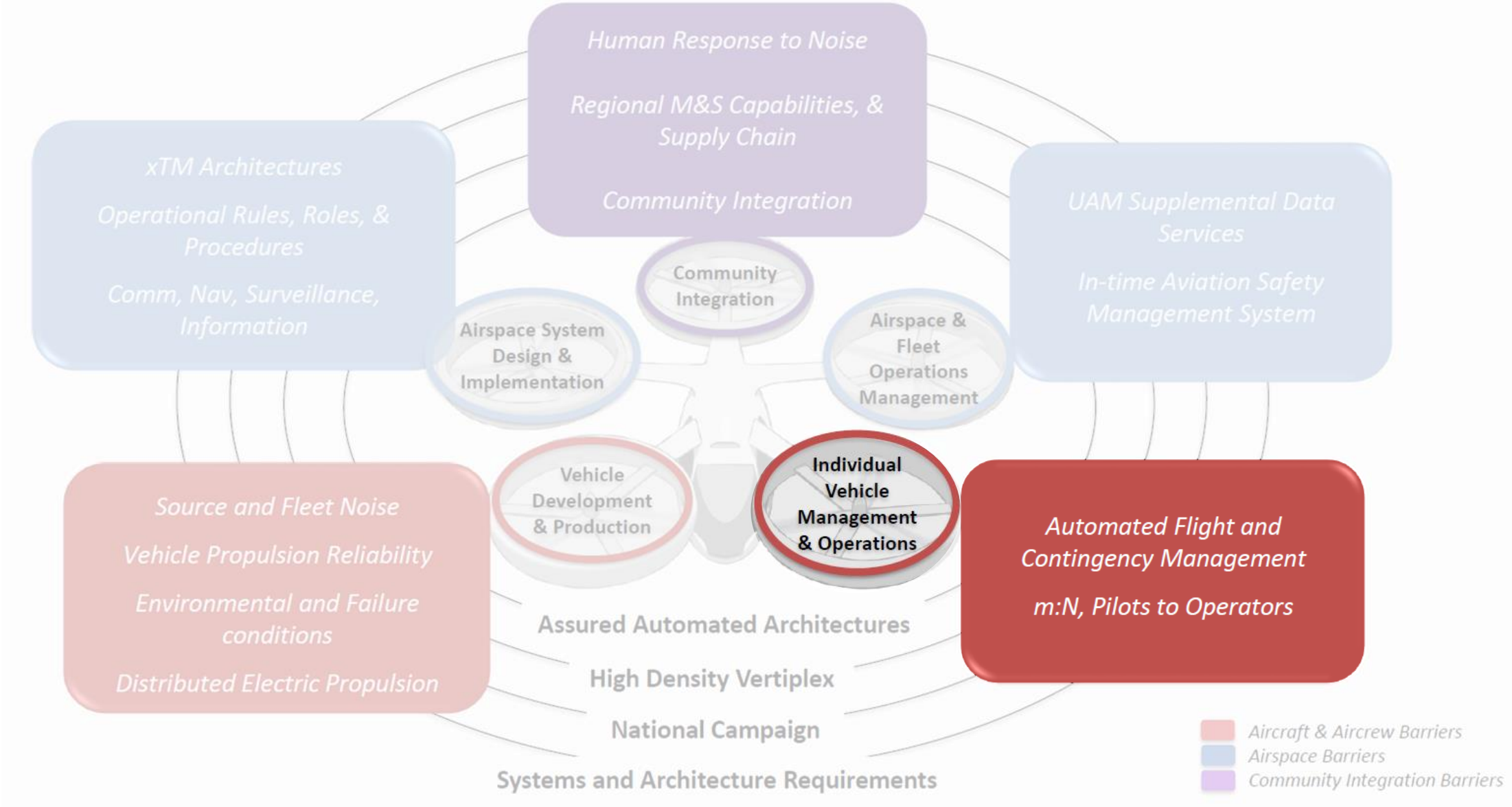
Future Aviation Operations

- **Emergency Response Operations**
  - Wildfire
  - Hurricane
  - Flood
  - Earthquake

Credits: NASA / Graphics

Credits: National Park Service / Joe Suarez

NASA AAM Mission Priorities



Credits: NASA 2021

BVLOS / Remote Operations Research

- **Human Factors Research**
  - ↑ Automation / ↓ Flight crew cost
    - ⚠ Reduced training
    - ⚠ Remote location
    - ⚠ Multi-aircraft control
  - Humans are poor system monitors
  - Data collection
    - iPad-based questionnaires
    - Eye tracking

Despite warnings from Tesla, Autopilot drivers still aren't paying enough attention, study finds

By Matt McFarland, CNN Business
Updated 5:35 PM ET, Thu September 24, 2020

https://www.cnn.com/2020/09/24/cars/tesla-autopilot-study/index.html

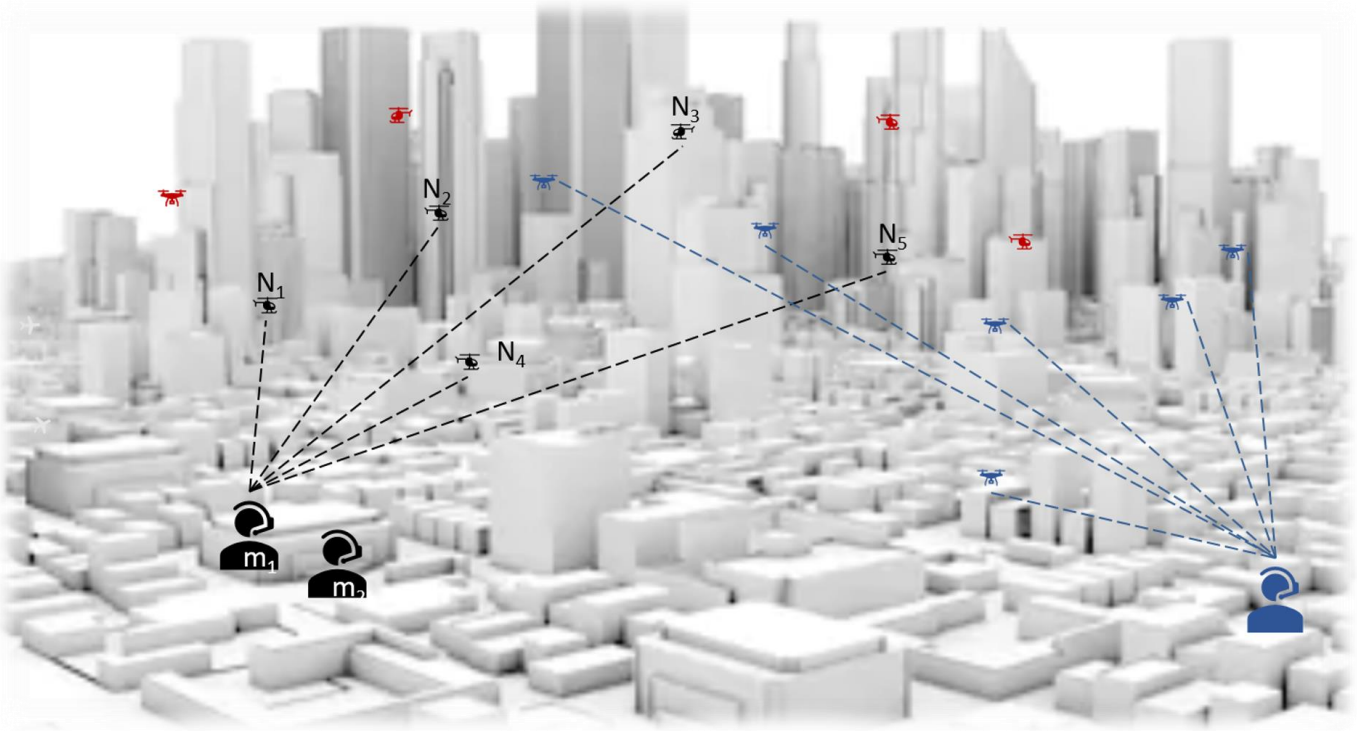
iPad-based Questionnaire

Research Participant (with Eye Tracking Glasses) at NASA Langley

BVLOS / Remote Operations Research

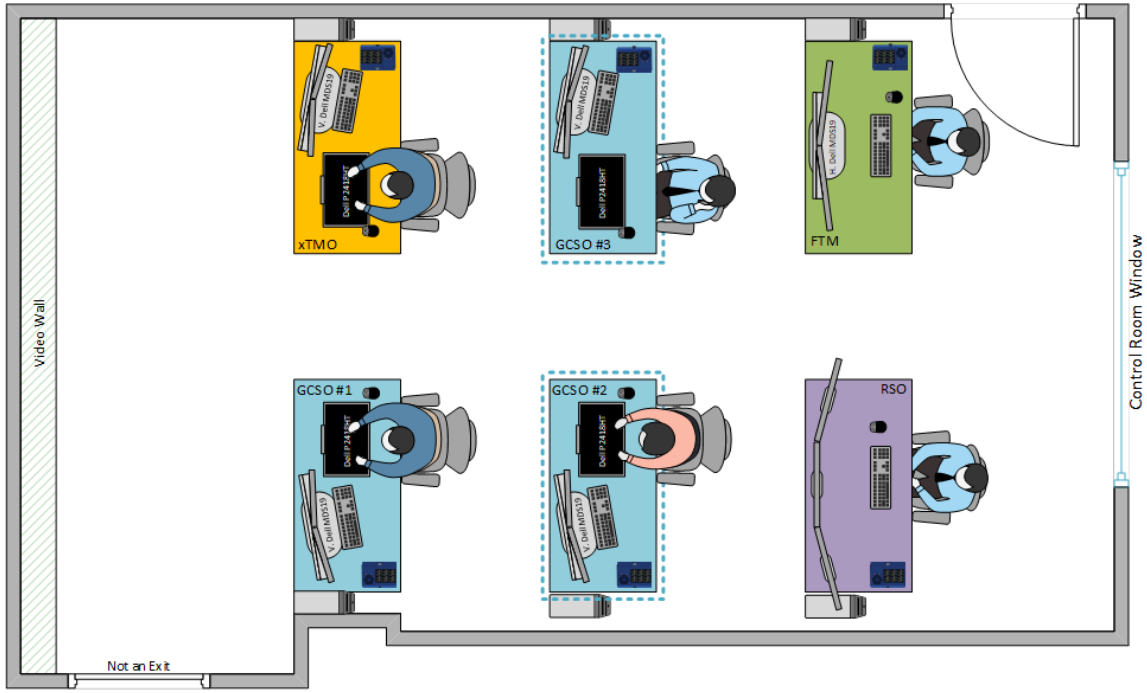
- **m:N Operations**
  - "m-to-N": Few operators (m) controlling many vehicles (N)
  - Enabled by vehicle handoffs
  - Evolving operator role (authority / responsibility)
    - Control → Manage → Assist

- **Human-Autonomy Teaming (HAT)**
  - Trust calibration
  - Shared mental models
  - Bi-directional communication



BVLOS / Remote Operations Research

- **ROAM UAS Operations Center**
  - NASA Langley Research Center, Hampton, VA



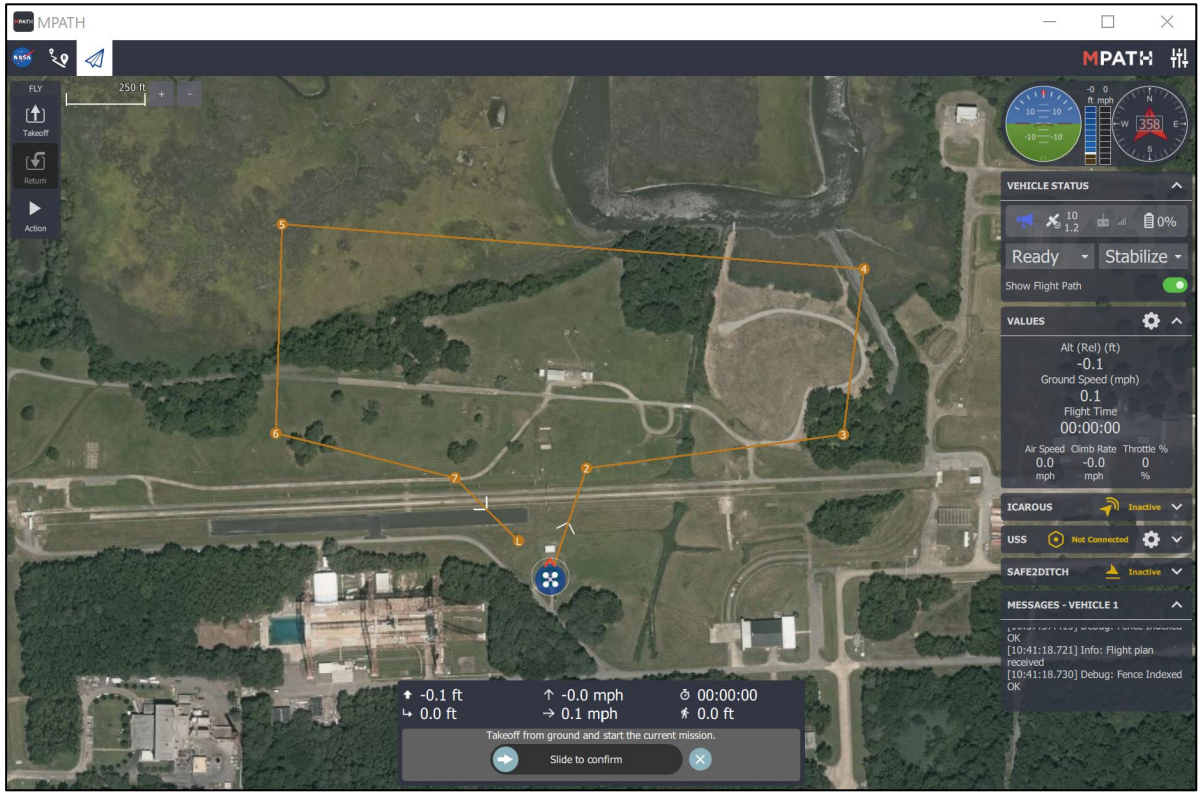
RSO = Range Safety Officer FTM = Flight Test Manager GCSO = Ground Control Station Officer xTMO = xTM Operator

*ROAM = Remote Operations for Autonomous Missions

BVLOS / Remote Operations Research

- **NASA's MPATH Ground Control Station**
  - Modified version of **QGroundControl**
  - Crowdsourced design & development
  - Developed to support remote operations & human factors research

MPATH
GROUND CONTROL STATION



*MPATH = Measuring Performance for Autonomy Teaming with Humans

MPATH Ground Control Station

- **MPATH v1.0.0**

***HAT Goal**: Resolve existing HF design concerns*

– **General UI design**
  - **Modular 'widget' design**
  - **Dual display support**

***HAT Goal**: Provide automation transparency*

– ICAROUS integration

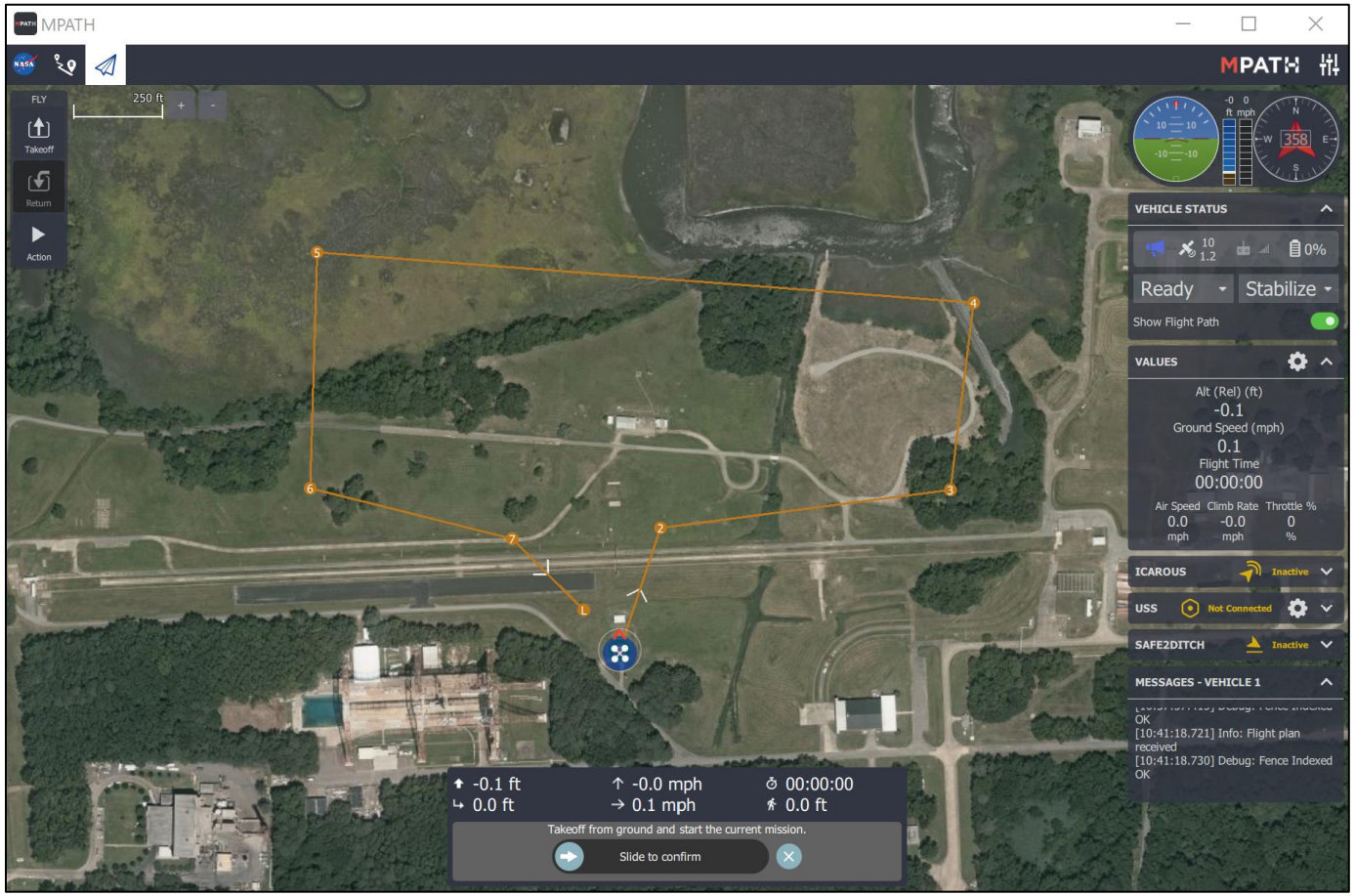
– Safe2Ditch integration

***HAT Goal**: Improve situation awareness*

– NASA USS (TCL-4) integration

***HAT Goal**: Support routine human factors data collection with minimal effort*

– Human factors data collection



MPATH GCS – General UI Design Updates

Screenshot

MPATH Ground Control Station

- **MPATH v1.0.0**

HAT Goal: Resolve existing HF design concerns

– General UI design
  - Modular ‘widget’ design
  - Dual display support

HAT Goal: Provide automation transparency

– **ICAROUS integration**

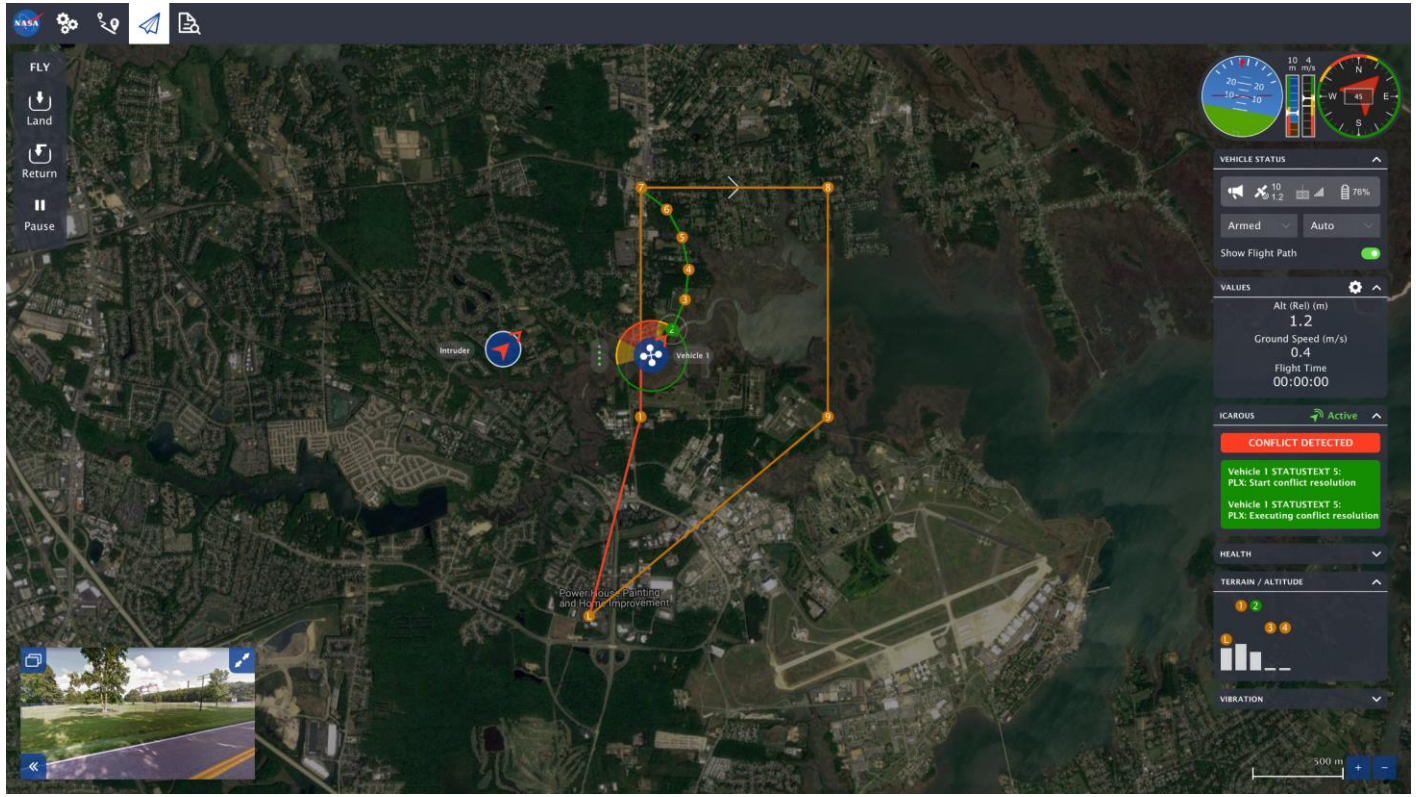
– Safe2Ditch integration

HAT Goal: Improve situation awareness

– NASA USS (TCL-4) integration

HAT Goal: Support routine human factors data collection with minimal effort

– Human factors data collection



MPATH GCS – ICAROUS Integration
Design Mockup

MPATH Ground Control Station

- **MPATH v1.0.0**

HAT Goal: Resolve existing HF design concerns

– General UI design
  - Modular ‘widget’ design
  - Dual display support

HAT Goal: Provide automation transparency

– ICAROUS integration

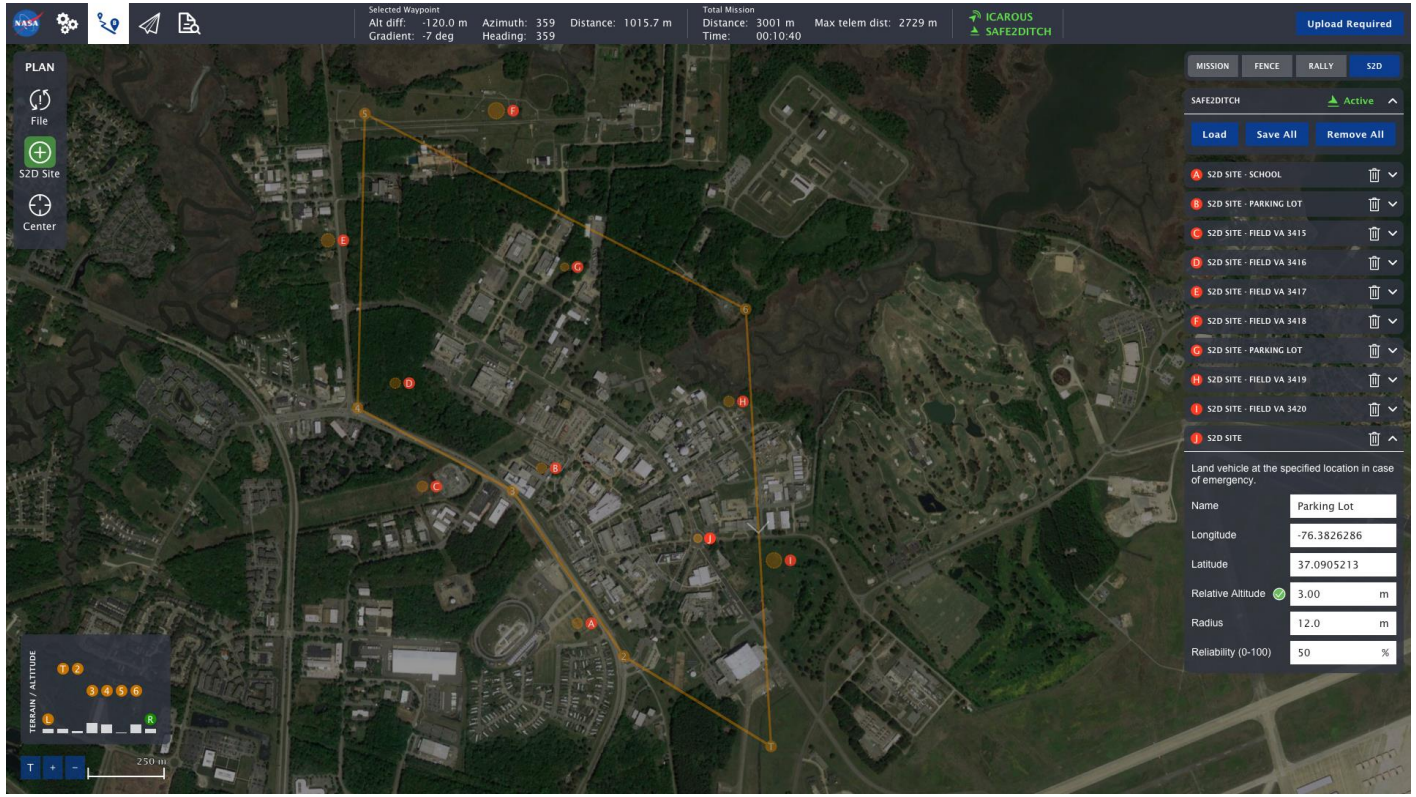
– **Safe2Ditch integration**

HAT Goal: Improve situation awareness

– NASA USS (TCL-4) integration

HAT Goal: Support routine human factors data collection with minimal effort

– Human factors data collection



MPATH GCS – Safe2Ditch Integration (Planning View)

Design Mockup

MPATH Ground Control Station

- **MPATH v1.0.0**

HAT Goal: Resolve existing HF design concerns

– General UI design
  - Modular ‘widget’ design
  - Dual display support

HAT Goal: Provide automation transparency

– ICAROUS integration

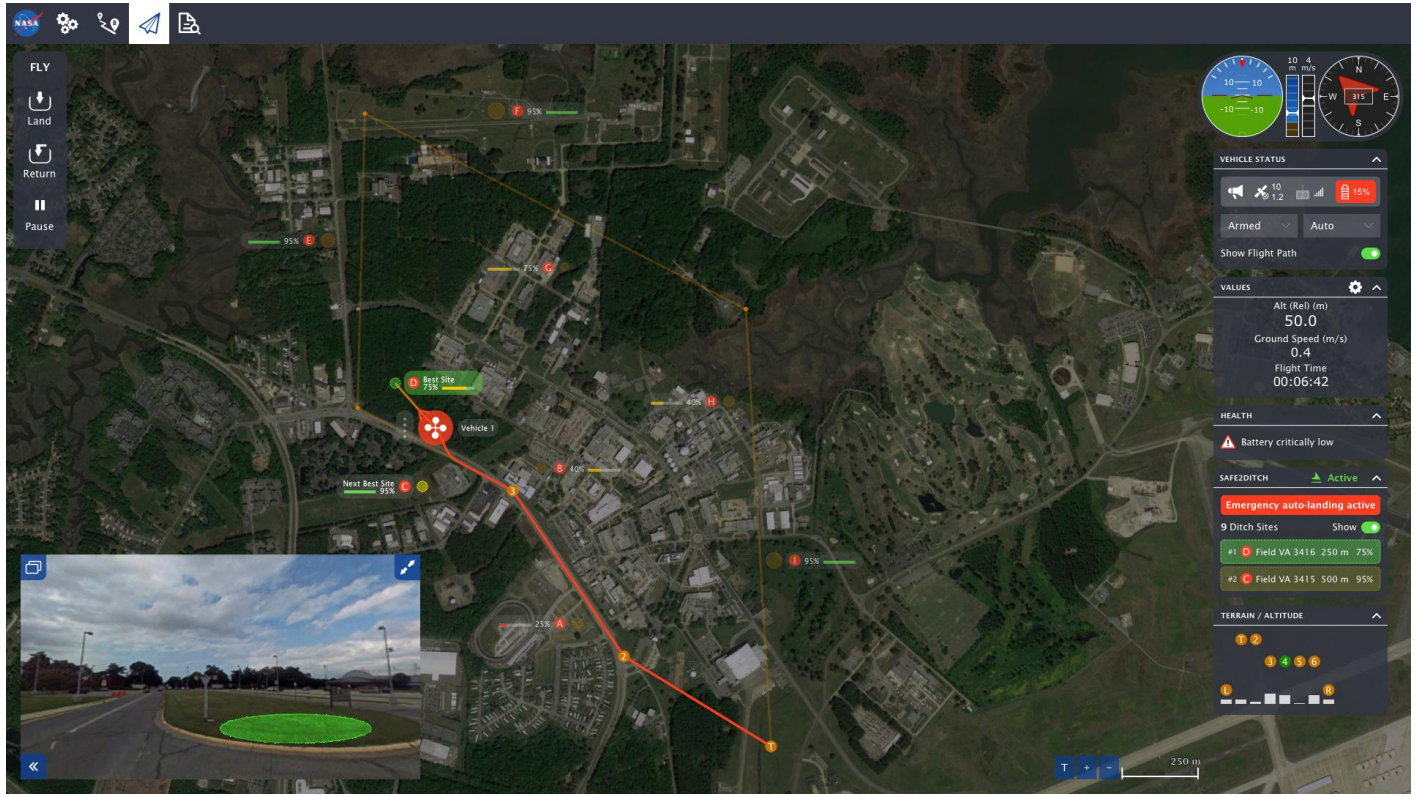
– **Safe2Ditch integration**

HAT Goal: Improve situation awareness

– NASA USS (TCL-4) integration

HAT Goal: Support routine human factors data collection with minimal effort

– Human factors data collection



MPATH GCS – Safe2Ditch Integration (Flight View)

Design Mockup

MPATH Ground Control Station

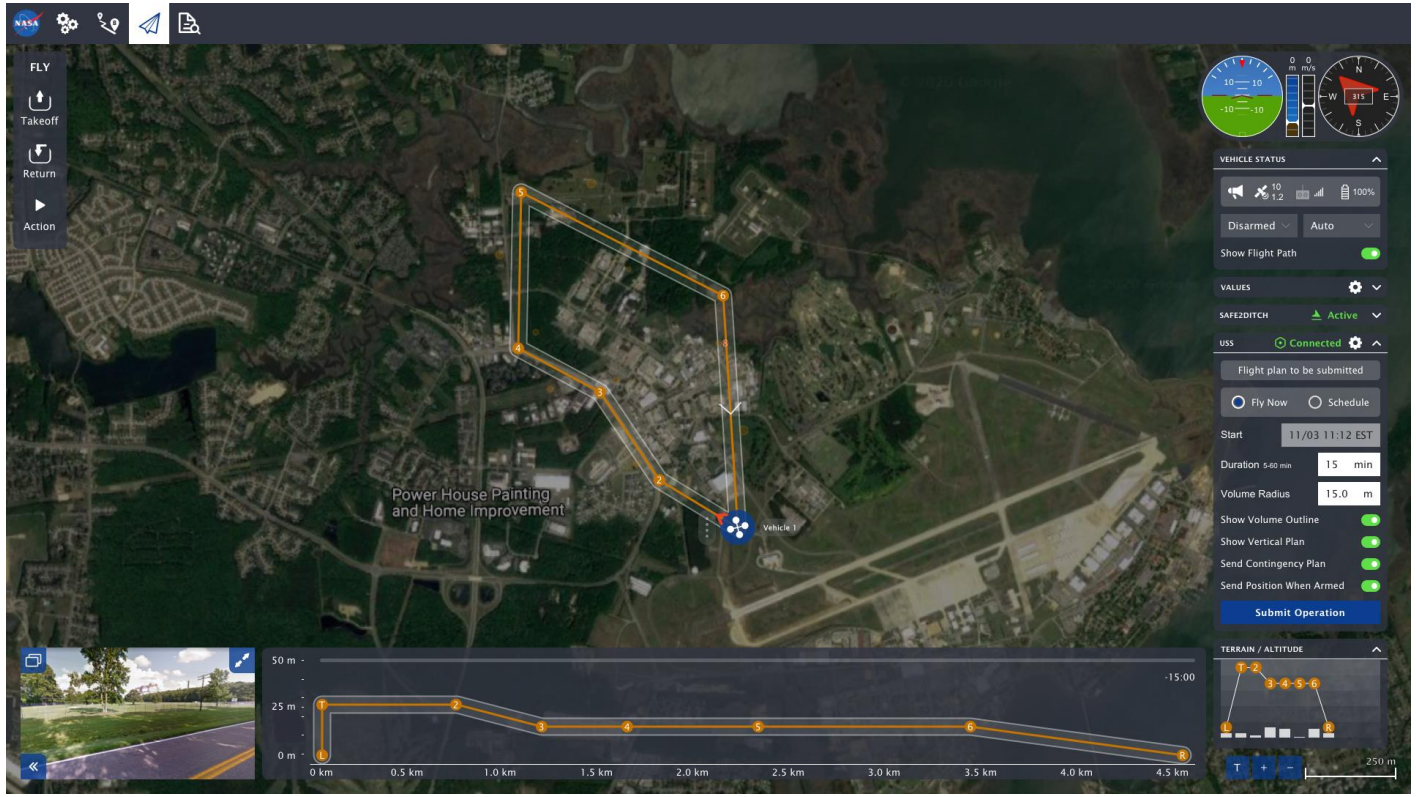
- **MPATH v1.0.0**

HAT Goal: Resolve existing HF design concerns
- General UI design
  - Modular 'widget' design
  - Dual display support

HAT Goal: Provide automation transparency
- ICAROUS integration
- Safe2Ditch integration

HAT Goal: Improve situation awareness
- **NASA USS (TCL-4) integration**

HAT Goal: Support routine human factors data collection with minimal effort
- Human factors data collection



MPATH GCS – NASA USS (TCL-4) Integration (Operation Submission View)
Design Mockup

**USS = UAS Service Supplier*
**TCL-4 = Technical Capability Level 4*

MPATH Ground Control Station

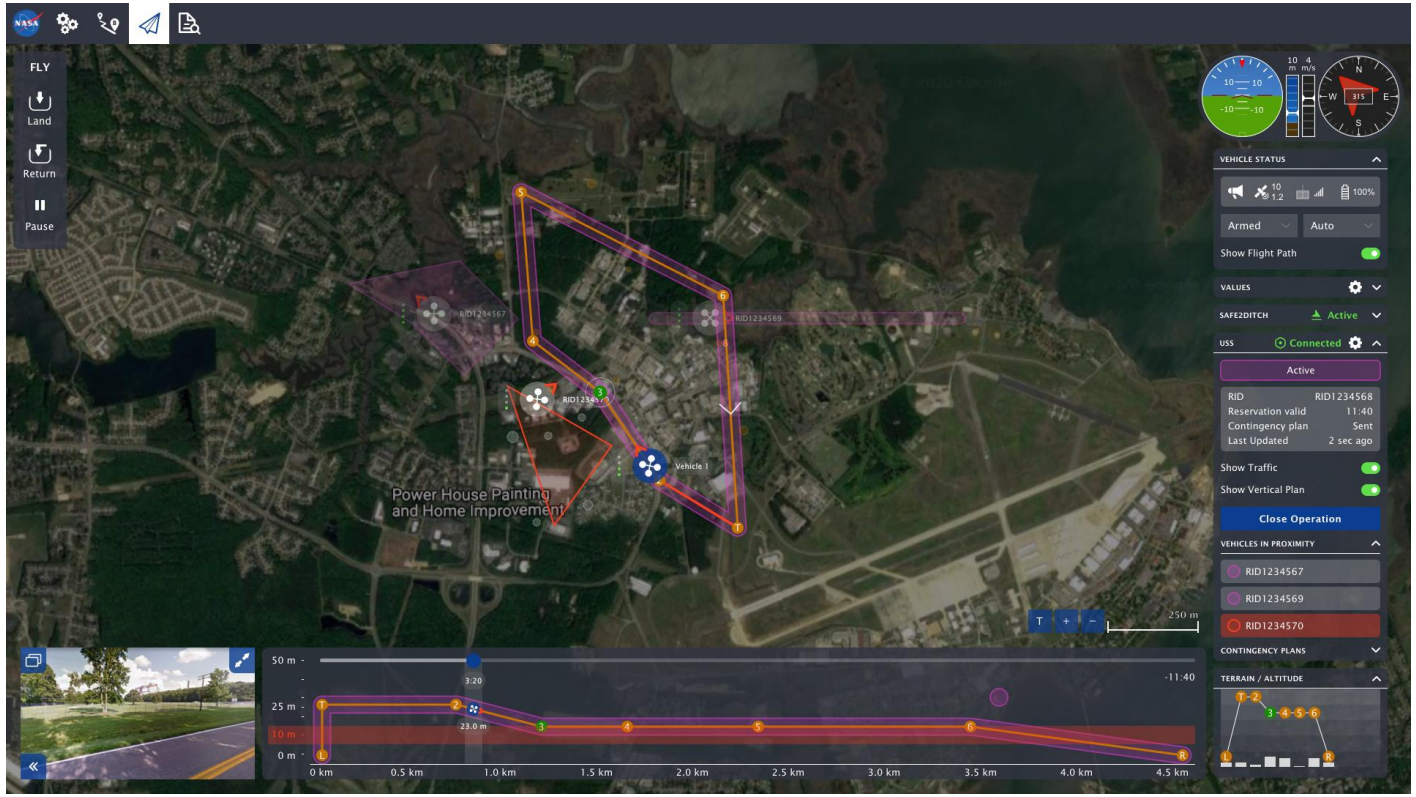
- **MPATH v1.0.0**

HAT Goal: Resolve existing HF design concerns
- General UI design
  - Modular 'widget' design
  - Dual display support

HAT Goal: Provide automation transparency
- ICAROUS integration
- Safe2Ditch integration

HAT Goal: Improve situation awareness
- **NASA USS (TCL-4) integration**

HAT Goal: Support routine human factors data collection with minimal effort
- Human factors data collection



MPATH GCS – NASA USS (TCL-4) Integration (Active Operation View)
Design Mockup

**USS = UAS Service Supplier*
**TCL-4 = Technical Capability Level 4*

MPATH Ground Control Station

- **MPATH v1.0.0**

HAT Goal: Resolve existing HF design concerns

– General UI design
  - Modular 'widget' design
  - Dual display support

HAT Goal: Provide automation transparency

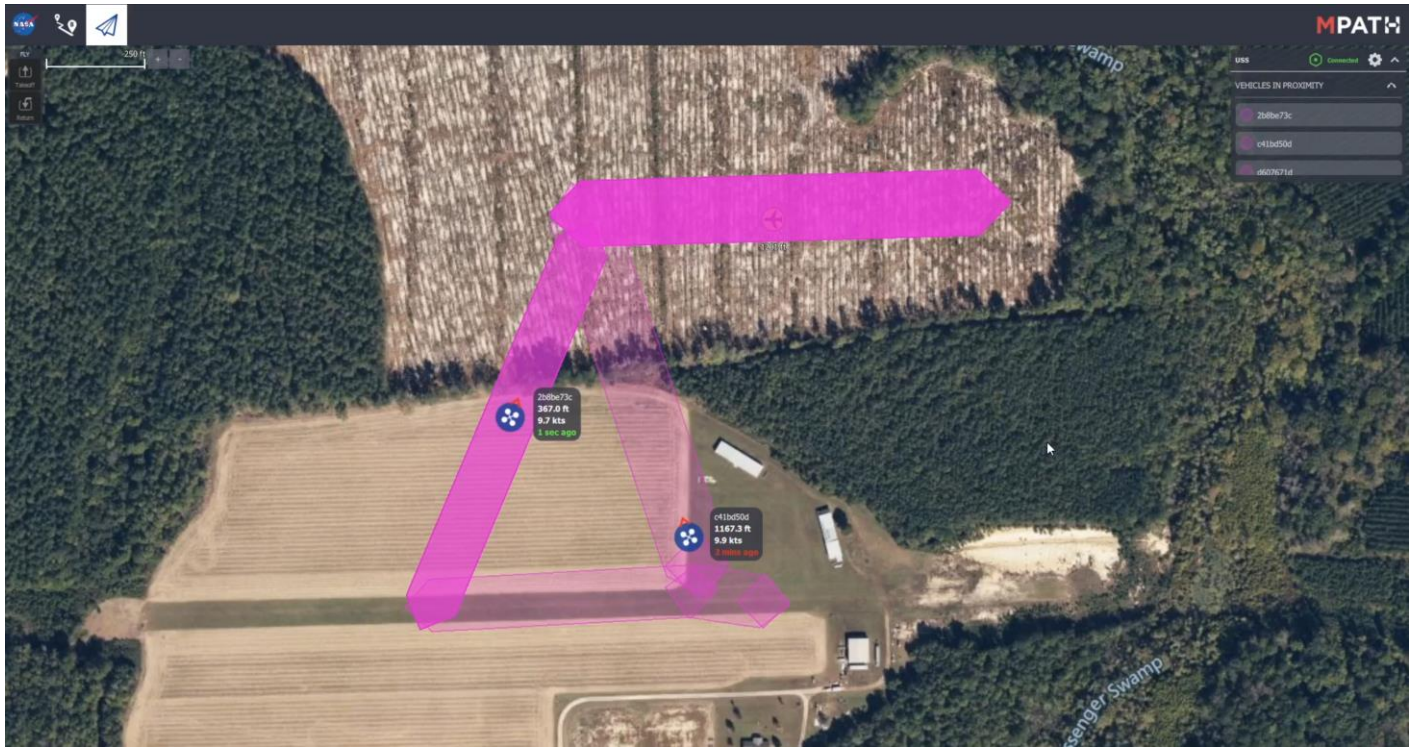
– ICAROUS integration
– Safe2Ditch integration

HAT Goal: Improve situation awareness

– **NASA USS (TCL-4) integration**

HAT Goal: Support routine human factors data collection with minimal effort

– Human factors data collection



MPATH GCS – NASA USS (TCL-4) Integration (Active Operation View)
Screenshot

**USS = UAS Service Supplier*
**TCL-4 = Technical Capability Level 4*

MPATH Ground Control Station

- **MPATH v1.0.0**

HAT Goal: Resolve existing HF design concerns

– General UI design
  - Modular 'widget' design
  - Dual display support

HAT Goal: Provide automation transparency

– ICAROUS integration

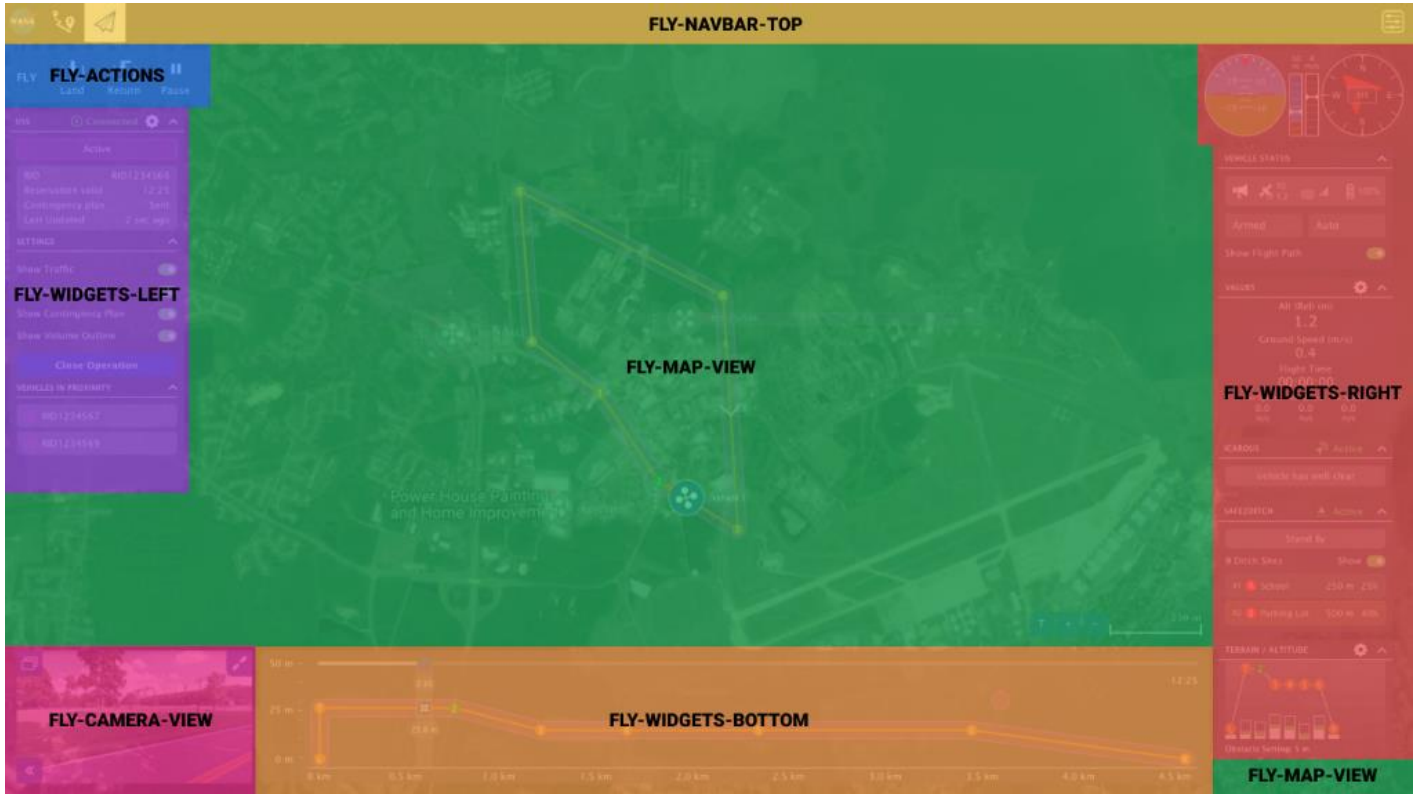
– Safe2Ditch integration

HAT Goal: Improve situation awareness

– NASA USS (TCL-4) integration

HAT Goal: Support routine human factors data collection with minimal effort

– **Human factors data collection**



MPATH GCS – Human Factors Data Collection (Example AOIs)
Design Mockup

**AOIs = Areas of Interest*

MPATH Ground Control Station

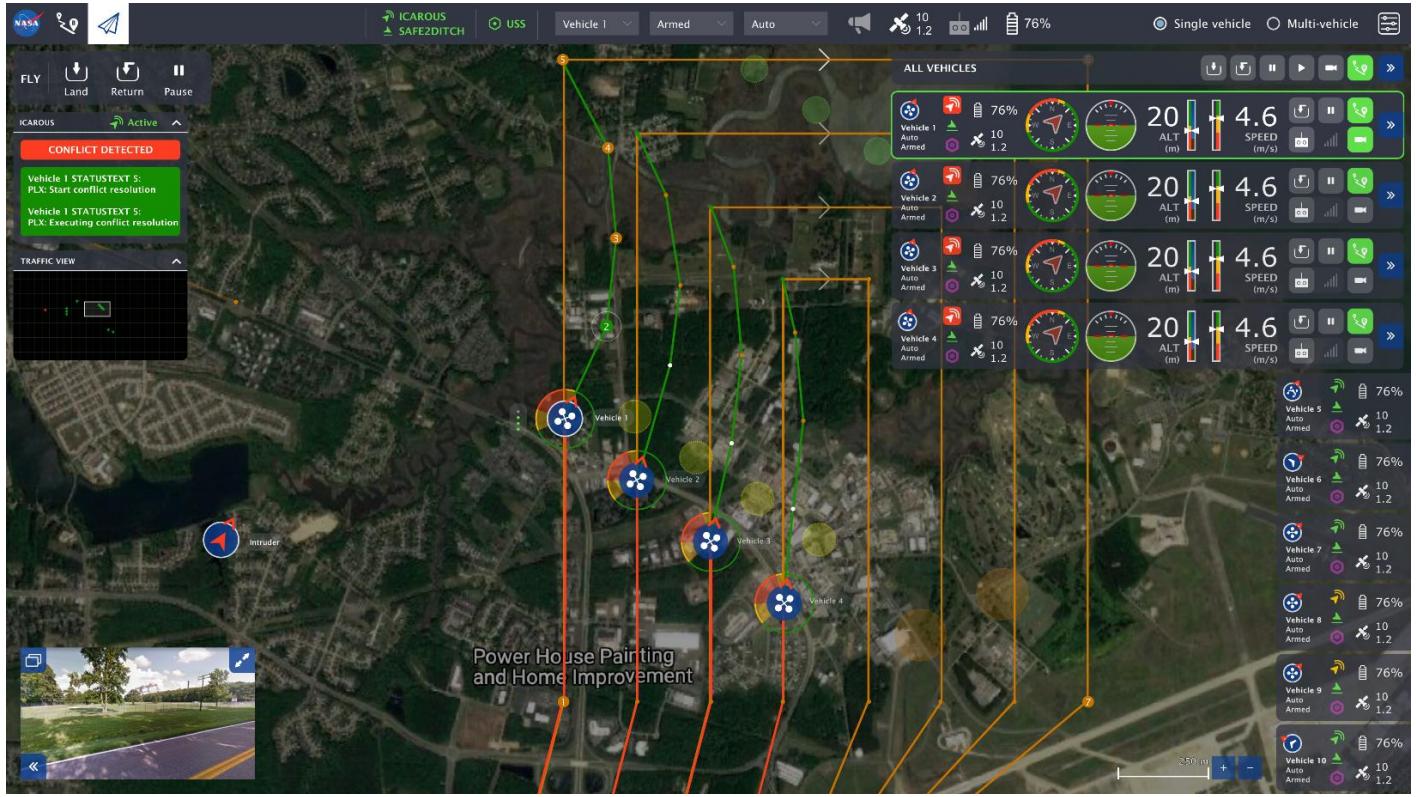
- **MPATH – *Future Updates***

***HAT Goal*: Resolve existing HF design concerns**

– **Multi-vehicle UI design**

***HAT Goal*: Improve situation awareness**

– **IoT/MQTT Integration**



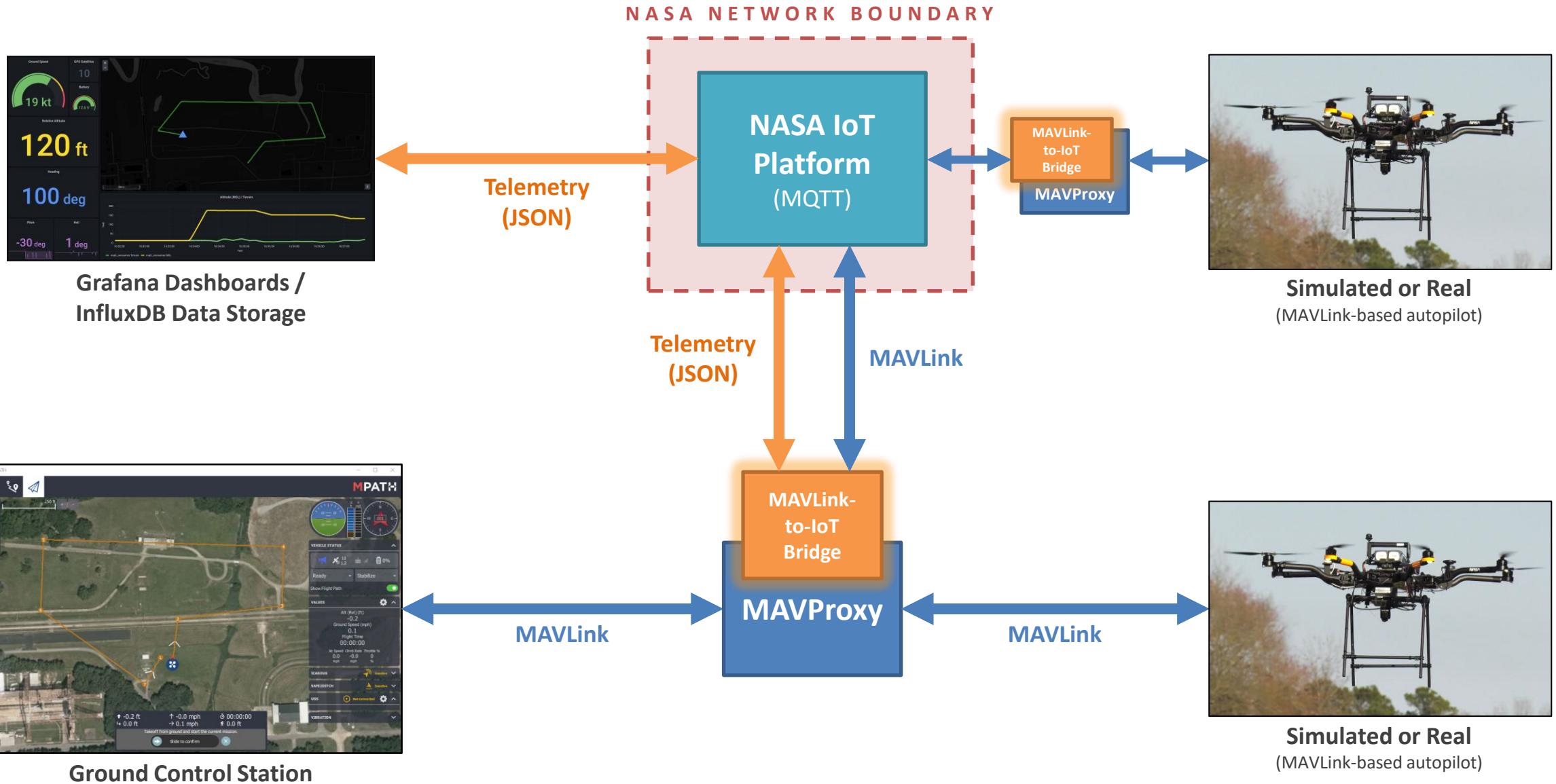
MPATH GCS – Multi-Vehicle UI Design

Design Mockup

**IoT = Internet of Things*

**MQTT is a network protocol*

MAVLink-to-IoT Bridge Software



Advanced Automation

High Value Automation Use Cases

NASA STEReO Flight Test Airborne System Architecture (MAVLink, PX4)

Off-Nominal Traffic Avoidance (MAVLink, PX4)

Off-Nominal Landing (MAVLink, PX4)

Digital Flight Data (MAVLink, PX4, QGroundControl)

High Value Automation Use Cases

Emergency Response

Wildland Fire

Aerial Surveillance

- Fire Line Monitoring
- Fire Line Prediction Forecasting

Logistics

- Food/Water
- Aerial Ignition
- Fire Retardant

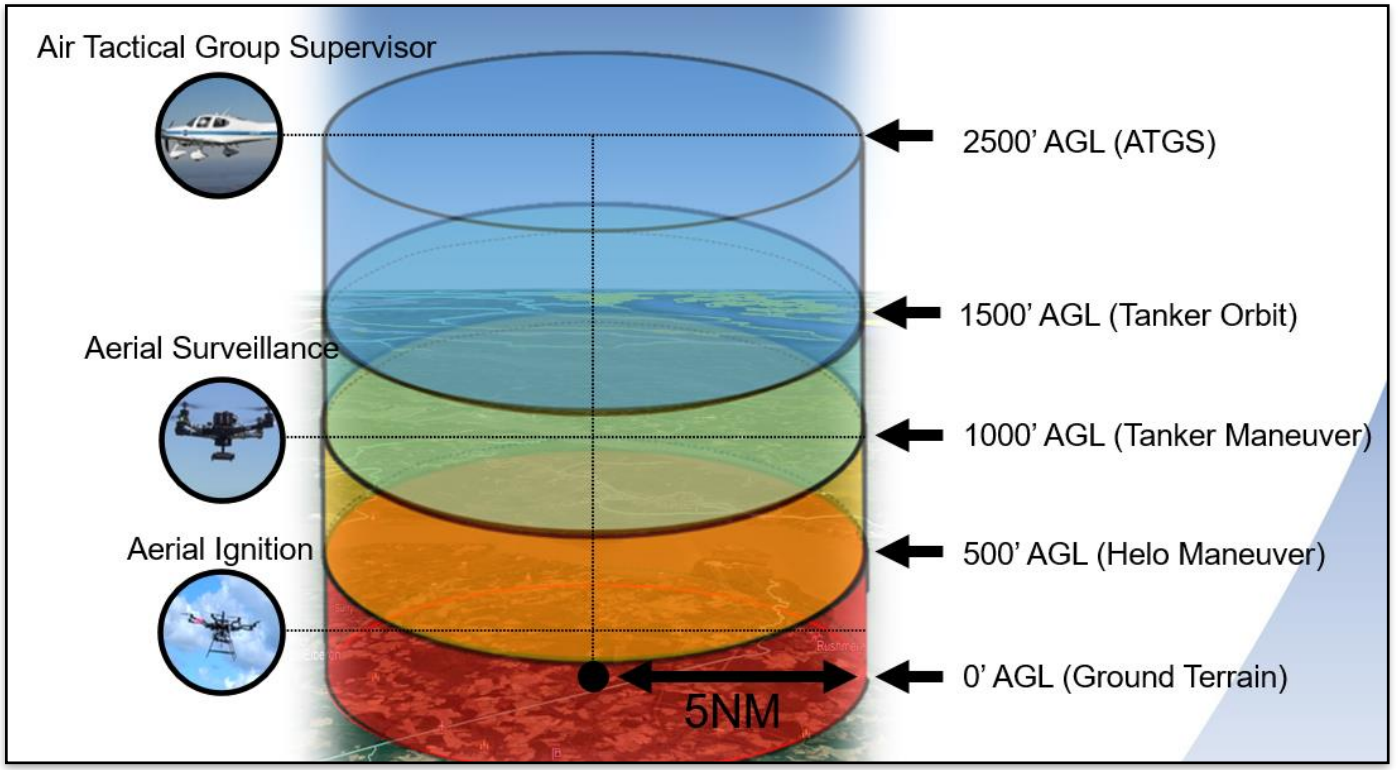
Hurricane

Aerial Surveillance

- Pre/Post Survey
- Search/Rescue

Logistics

- Food/Water



Fire Traffic Area for Wildland Fire Airspace

**AGL = Above Ground Level*
**ATGS = Air Tactical Group Supervisor*

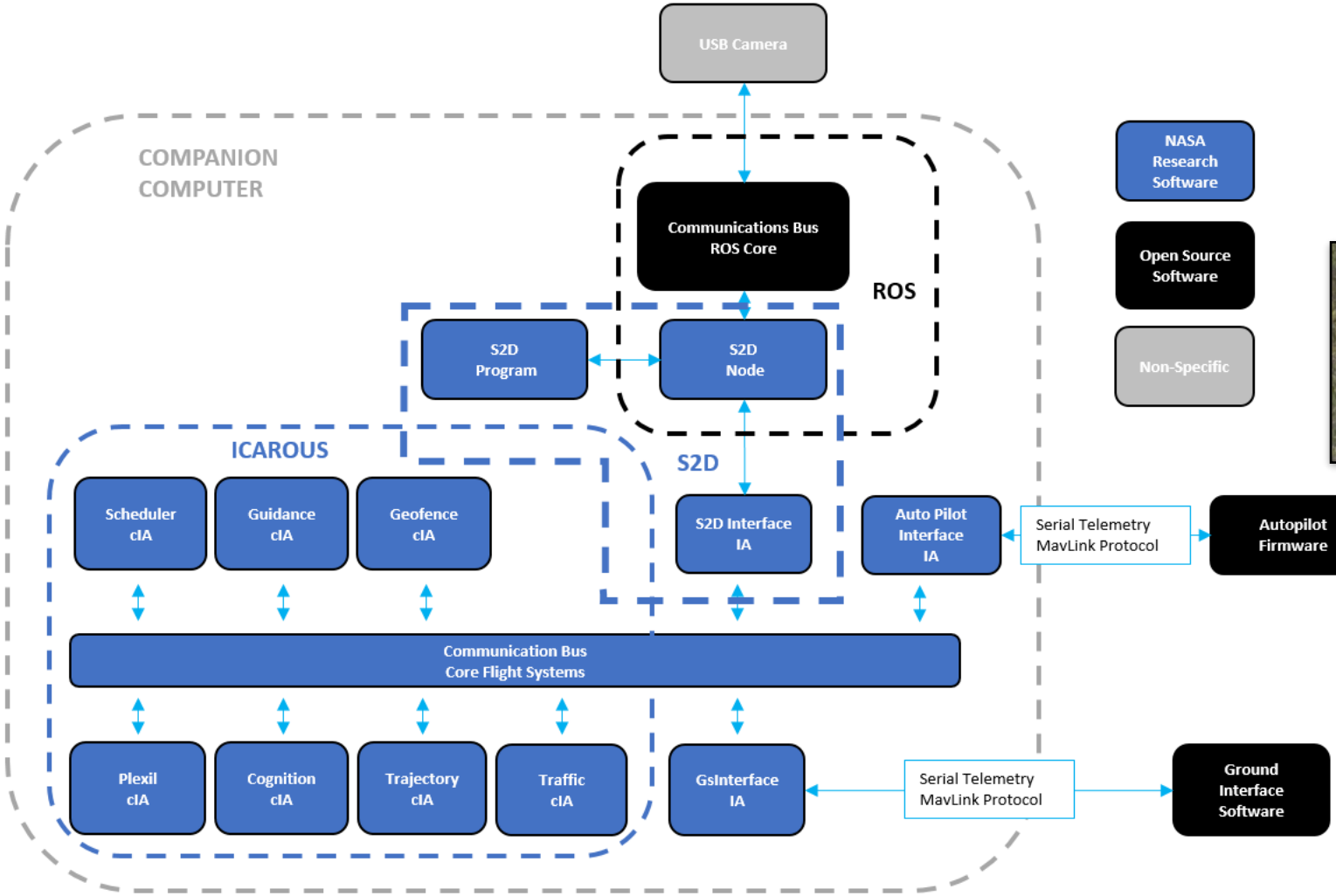
NASA STEReO Flight Test Airborne System Architecture

System Overview

Ownship
- MAVLink
- PX4

Air Traffic
- MAVLink

Multi-Modal
- MAVLink
- QGroundControl



Flight Test Vehicle

Ground Test Setup

**USB= Universal Serial Bus*
**ROS = Robot Operating System*
**S2D = Safe2Ditch*
**cIA = core ICAROUS Application*
**IA = ICAROUS Application*
**ICAROUS = Independent Configurable Architecture for Reliable Operations of Unmanned Systems*

Off-Nominal Traffic Avoidance Automation

Traffic Categories

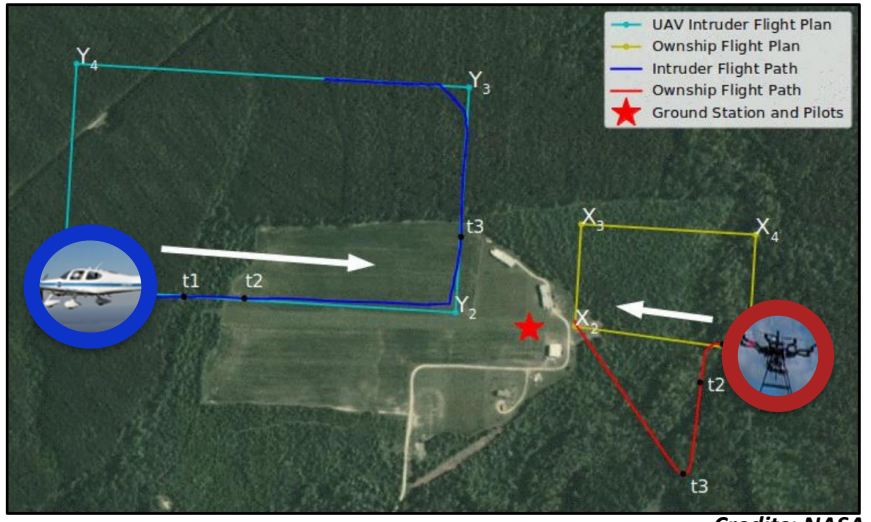
- Visual Flight Rules
- Instrument Flight Rules
- Digital Flight Rules (UTM,UAM)

Encounter Categories

- From Above
- From Below
- Co-Altitude (Front, Aft, Port, Starboard)

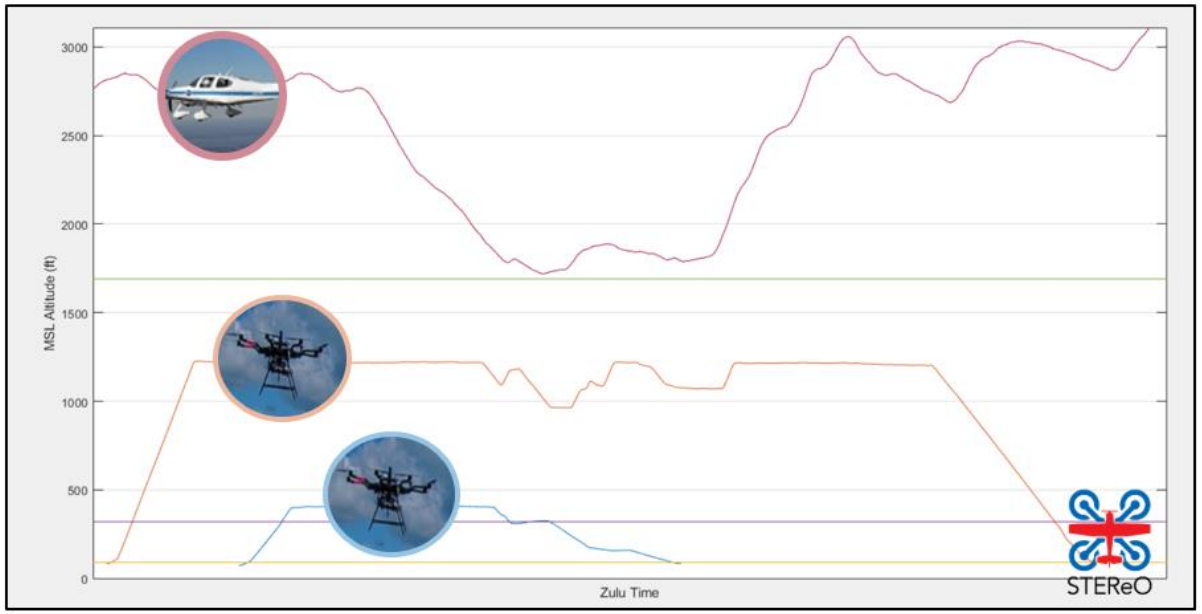
NASA Research

- ICAROUS
  - Co-Altitude
  - From Above
- S2D
  - Contingency Site



Co-Altitude Traffic Encounter *Credits: NASA*

From Above Traffic Encounter



**UTM= UAS Traffic Management*
**UAM = Urban Air Mobility*
**S2D = Safe2Ditch*
**ICAROUS = Independent Configurable Architecture for Reliable Operations of Unmanned Systems*

Off-Nominal Landing Automation

Landing Site Categories

Nominal

- Equipment and personnel

Off-Nominal

- Partial Equipment and Personnel
- No Equipment and Personnel

Landing Hazards

People

Buildings

Terrain

NASA Research

S2D

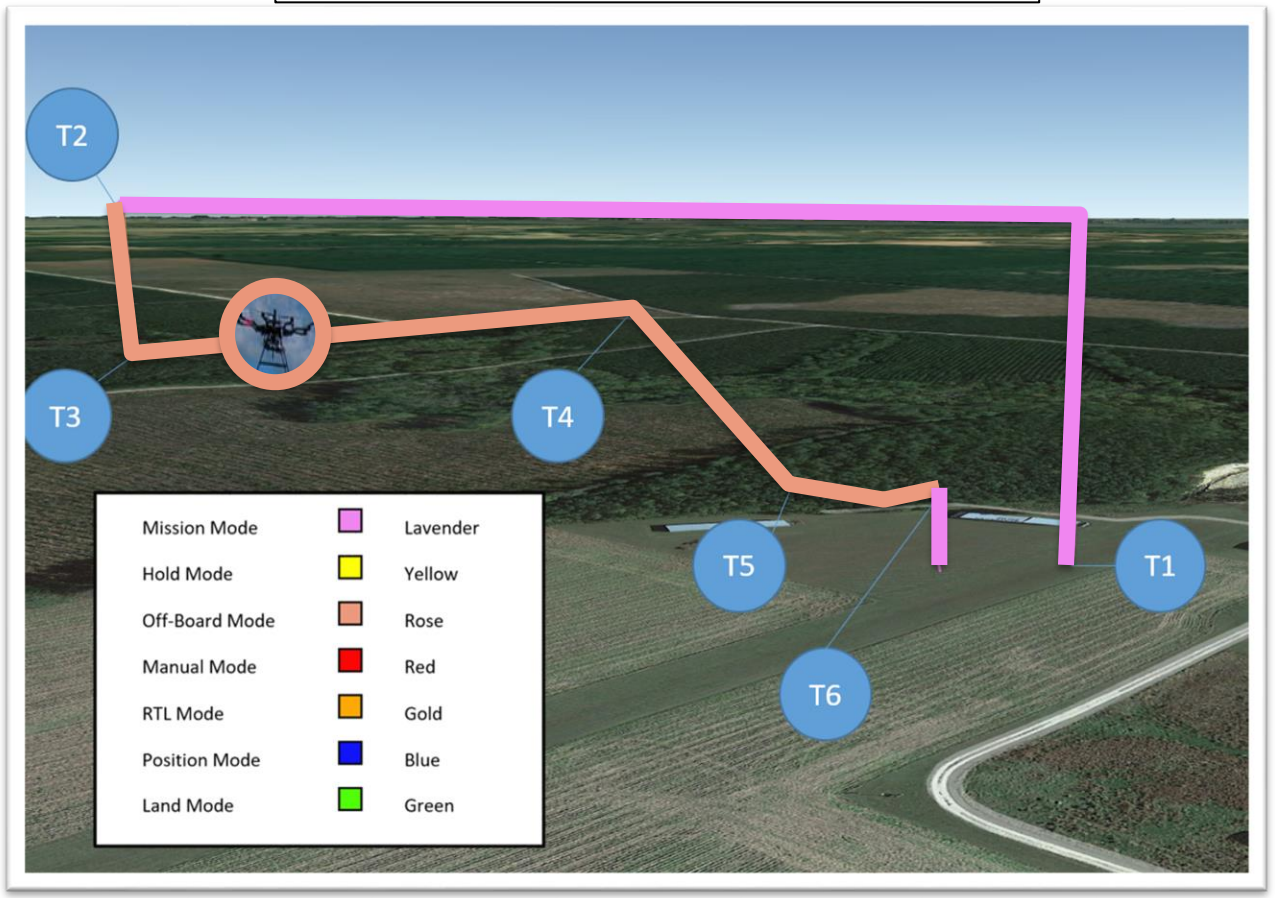
- Off-Nominal Landing Site Selection
- Dynamic Objects

HDS

- Humans

**HDS = Human Detection System*
**S2D = Safe2Ditch*

T1 - Take Off In Mission
T2 - From Above Traffic Avoidance
T3 - Ground Hazard Contingency Landing Initiated
T4 - Contingency Landing Site Approach and Inspection
T5 - Landing Altitude Hold
T6 - Landing Initiated



Emergency Landing Due To Traffic From Above

Digital Flight Data

Current Data
- Latitude
- Longitude
- Altitude
- Velocity
- Heading

Future Data
- Latitude
- Longitude
- Altitude
- Velocity
- Heading

Flight Plan Data
- Take Off Location
- Event Time
- Landing Location

Navigation Mode Data
- Automated Pre-Defined
- Automated Dynamic
- Human Direct Control

Controller Data
- Identification
- Qualifications
- Ground Radio Location
- Pilot/Operator Location

Aircraft Data
- Registration
- Type
- Performance Limits

Contingency Data
- Geofence/Operational Boundaries
- Off-Nominal Landing Site
- Fail Safe Settings

Keep Out Volumes

Planned Avoidance Trajectory

Actual Flight Trajectory

Data Sources

Moving Forward

- Collaboration with open-source community
  - Public Outreach
  - Workshops
  - Technology Transfer
- Researchers Future Technical Focus Areas
  - Email: robert.g.mcswain@nasa.gov; michael.s.politowicz@nasa.gov
  - Multi-Aircraft Operator
  - >55lb Commercial UAS
  - Multi-Aircraft Contingency Management
  - Air Traffic Speed Resolution
- Current Related Aeronautics Research Activities
  - High Density Vertiplex (HDV)
  - System Wide Safety (SWS)
  - Transformational Tools and Technologies (TTT)
  - Convergent Aeronautics Solutions (CAS)
- NASA Innovative Research Funding
  - Small Business Innovation Research (SBIR) & Small Business Technology Transfer (STTR) Program
  - NASA's Center of Excellence for Collaborative Innovation (CoECI)
- NASA Technical References
  - NASA Technical Report Server
    - Independent Configurable Architecture for Reliable Operations of Unmanned Systems (ICAROUS)
    - Safe 2 Ditch (S2D)

PX4 Flight Controlled UAS at NASA Langley Research Center


NASA