

Cooperative Upper Class E Airspace: Concept of Operations and Simulation Development for Operational Feasibility Assessment

Hyo-Sang Yoo*, Jinhua Li,
Universities Space Research Association (USRA) - NASA Academic Mission Services (NAMS)
NASA Ames Research Center, Moffett Field, CA

Jeffrey Homola and Jaewoo Jung
NASA Ames Research Center, Moffett Field, CA

08/02/2021

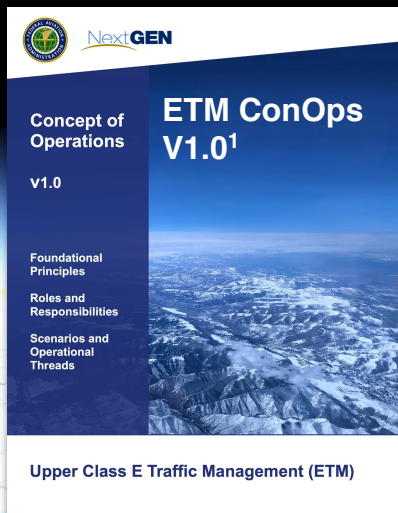
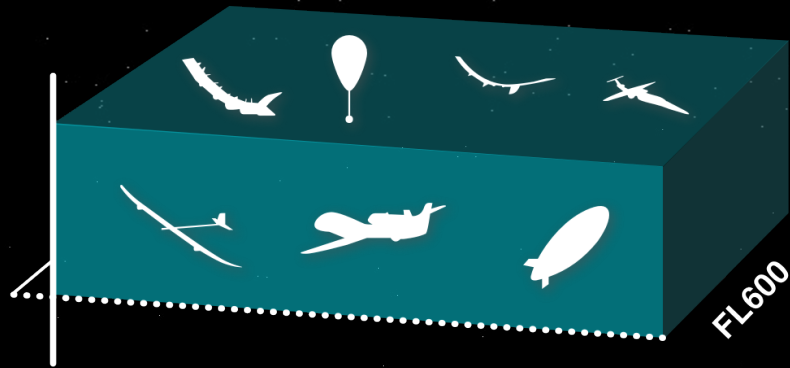
* *Hyo-Sang.Yoo@nasa.gov*

Why upper Class E Traffic Management (ETM) ?

New types of operations in upper Class E airspace

Limited scalability of existing National Airspace System (NAS)

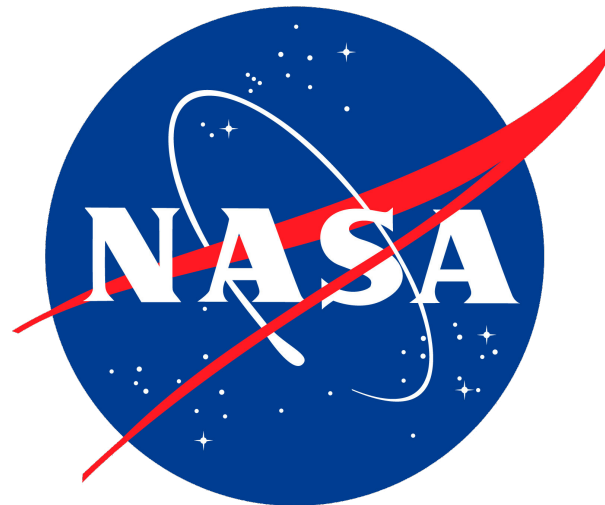
upper Class E airspace



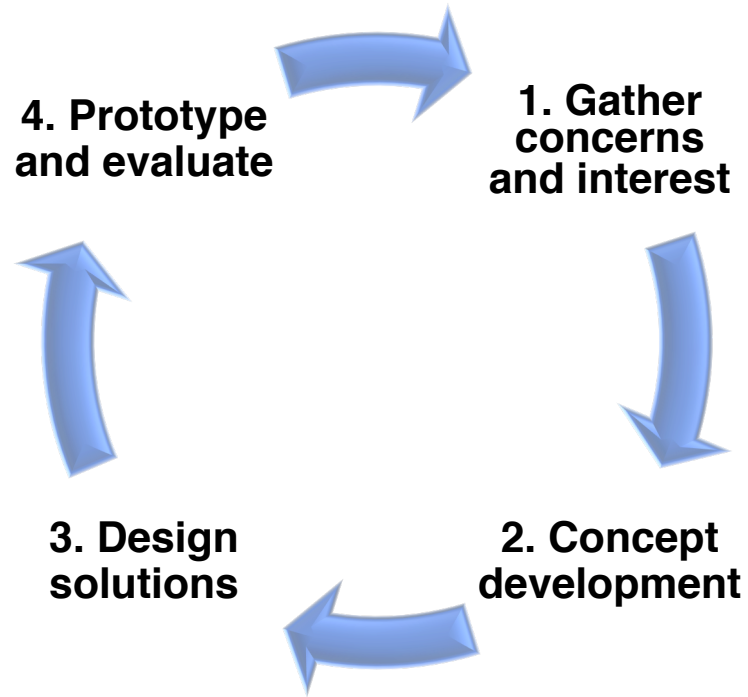
Development of **ETM concept** to provide information architectures, requirements for the operations, roles and responsibilities of actors, core ETM services functionalities, as a pathway to handle projected traffic density

1. FAA. (2020). Upper Class E Traffic Management (ETM) Concept of Operations v1.0

ETM Research Transition Team (RTT)



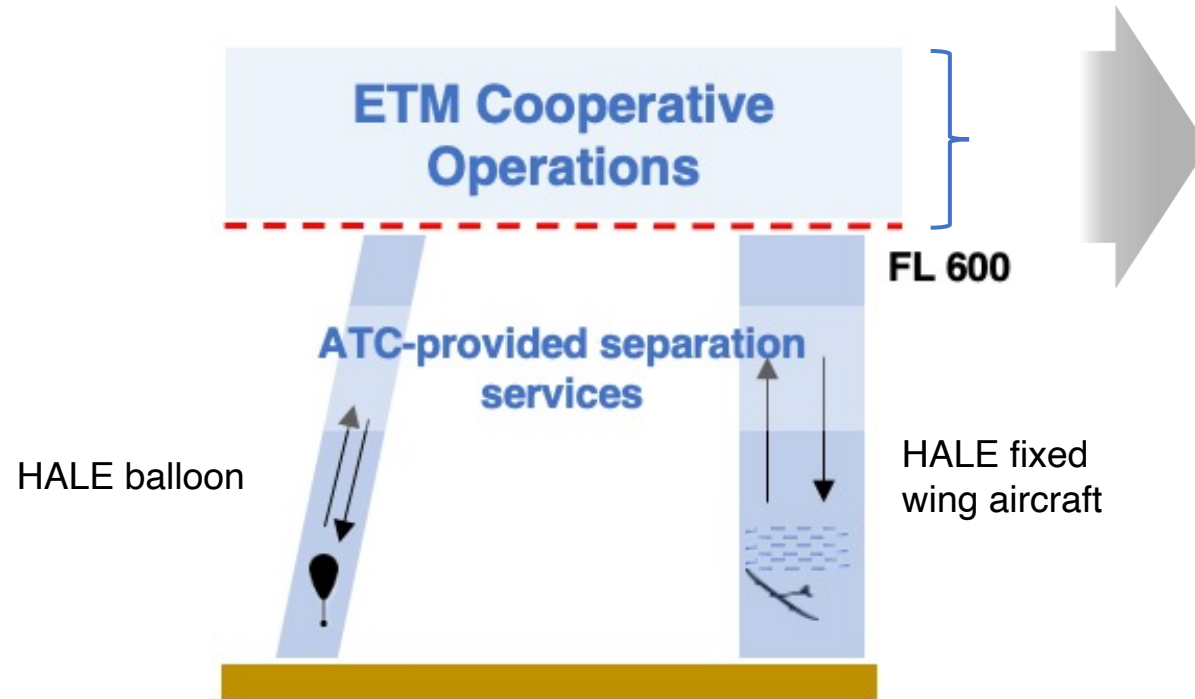
Research Approach



*The above process from 1 to 4 will be **iterative** to continuously refine the concept*

Goal : To allow for current and new entrant vehicles to operate “**safely**” within the upper Class E airspace

Initial Scope and Assumptions

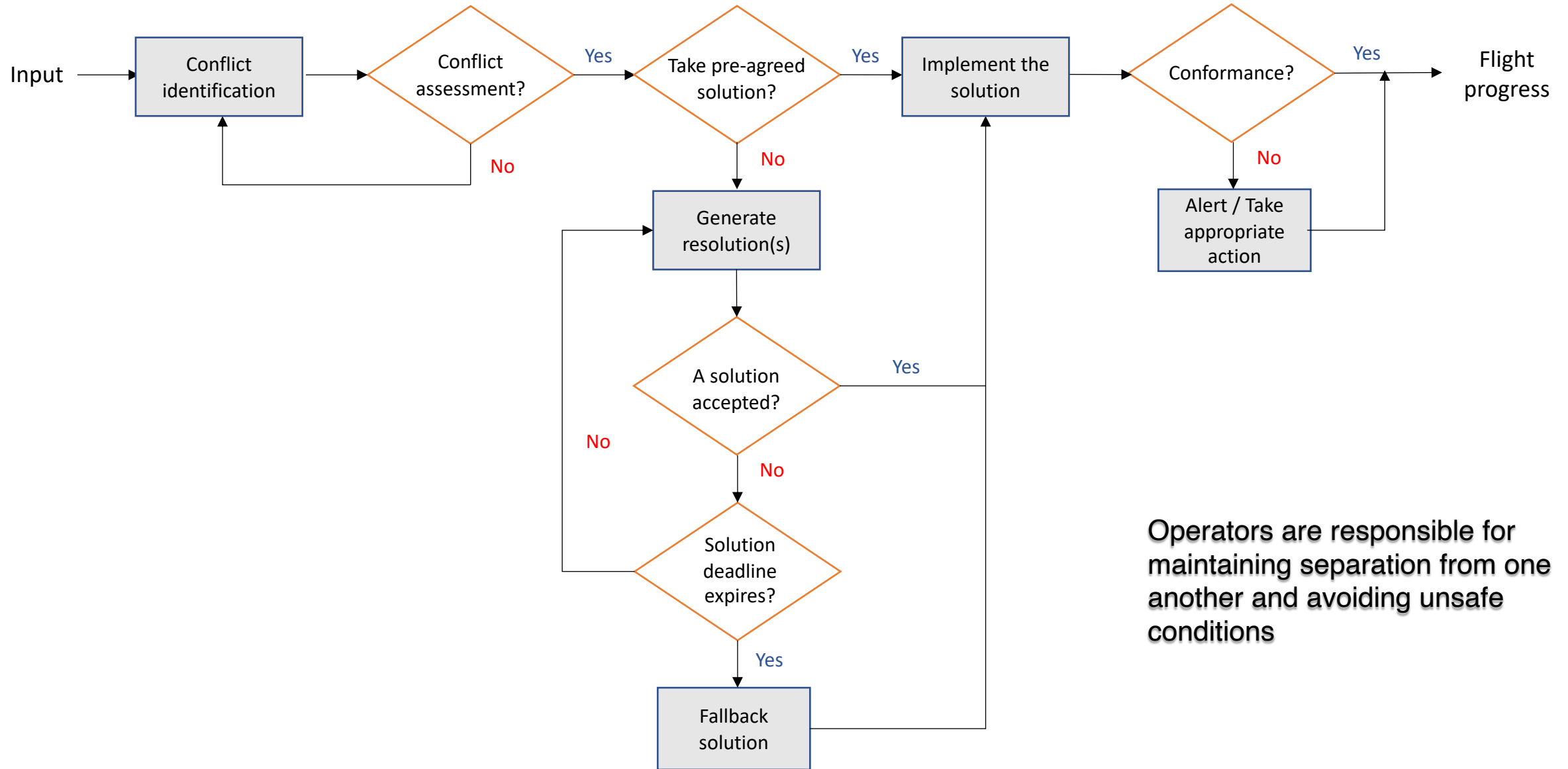


Depiction of Initial Scope

“**Cooperative operations**” are organized, coordinated, and managed by a federated set of participants/stakeholders through FAA-approved cooperative operating practices (COPs)

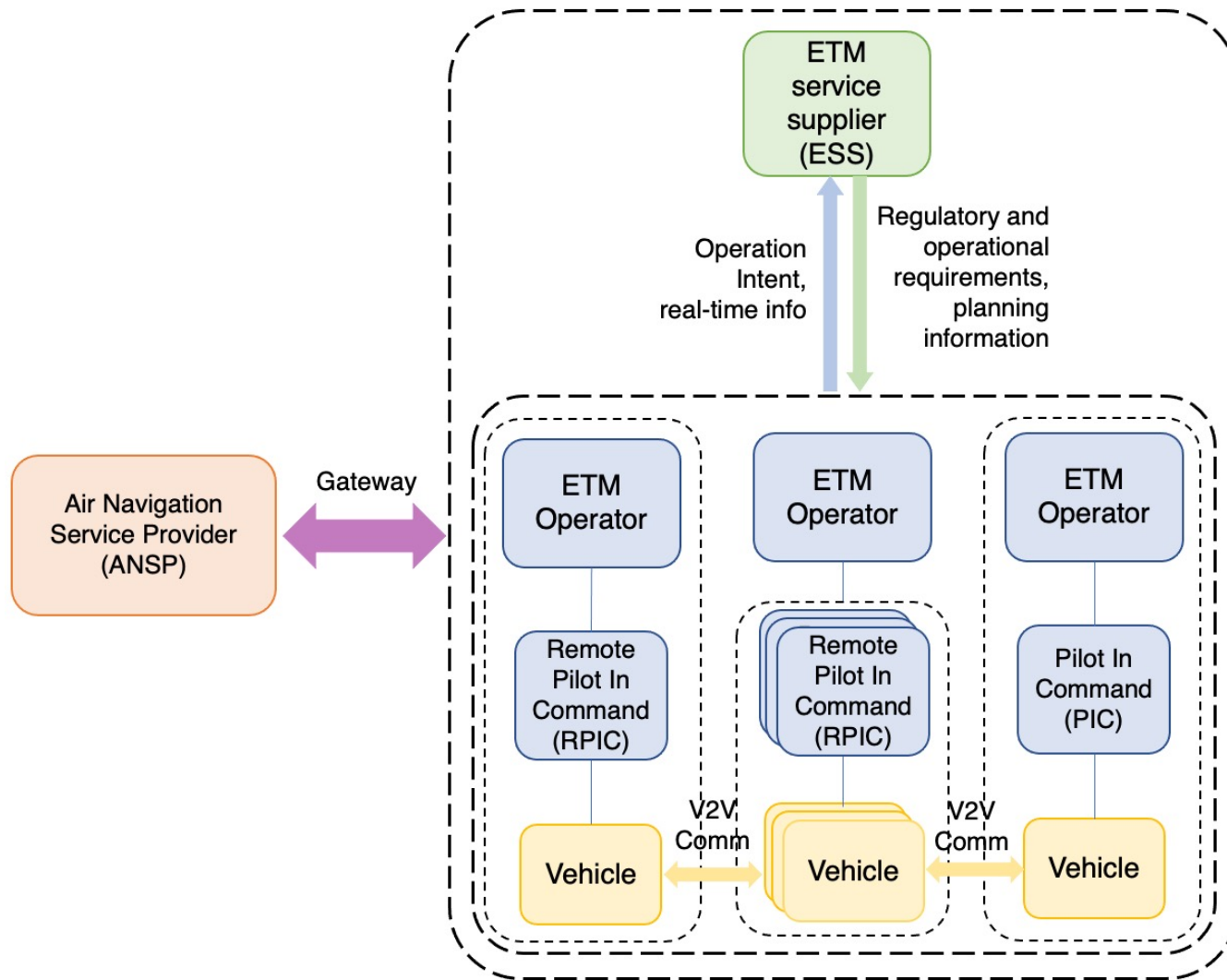
*HALE: High Altitude Long Endurance

Inflight Cooperative Separation Management (CSM) Concept



Operators are responsible for maintaining separation from one another and avoiding unsafe conditions

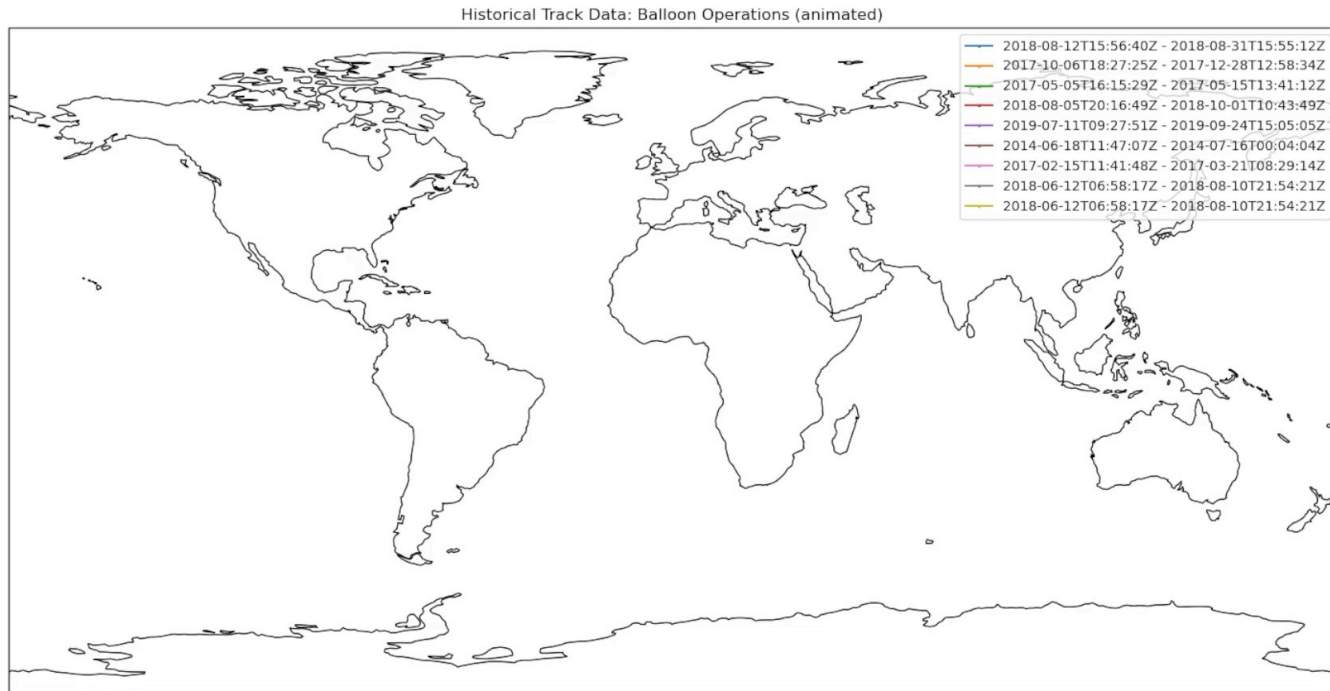
Primary actors of the ETM's inflight CSM



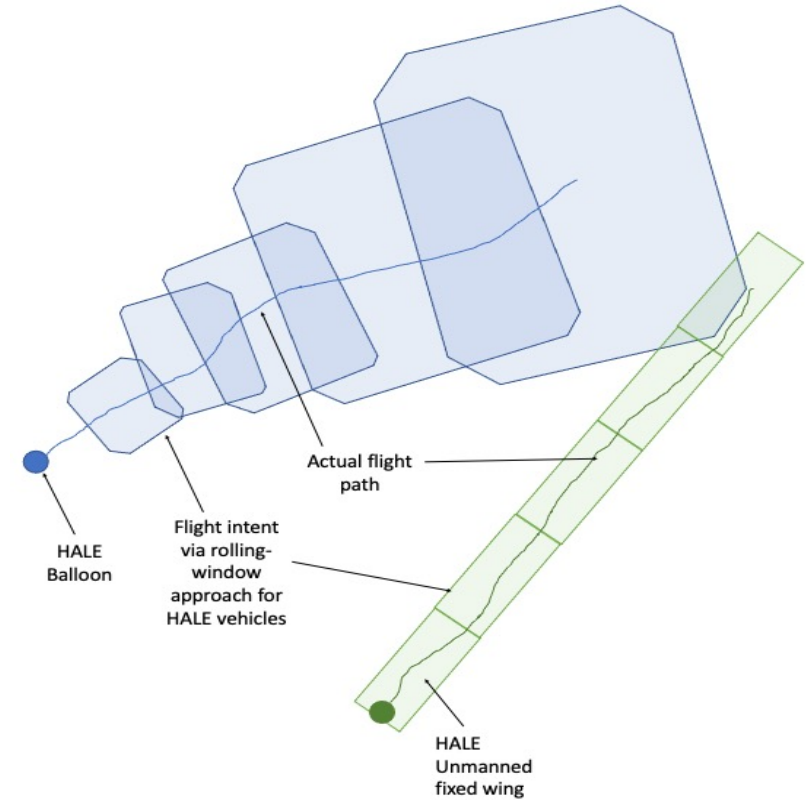
Inspired by Unmanned Aircraft Systems Traffic Management (UTM)'s conceptual elements

Notional representation of potential interaction between the ANSP, ESS, ETM operators

Flight intent sharing



Historical balloon operations (using a publicly available data set²)



A generic illustration of the rolling-window approach with a HALE balloon and a HALE unmanned fixed-wing through flight intent sharing

Successful inflight cooperative separation management requires each ETM operator to share its flight intent via the ESS

The “rolling-windows” concept is proposed³ to enable the HALE vehicles to operate for a long duration and serve a wide range of areas with flexibility to replan frequently

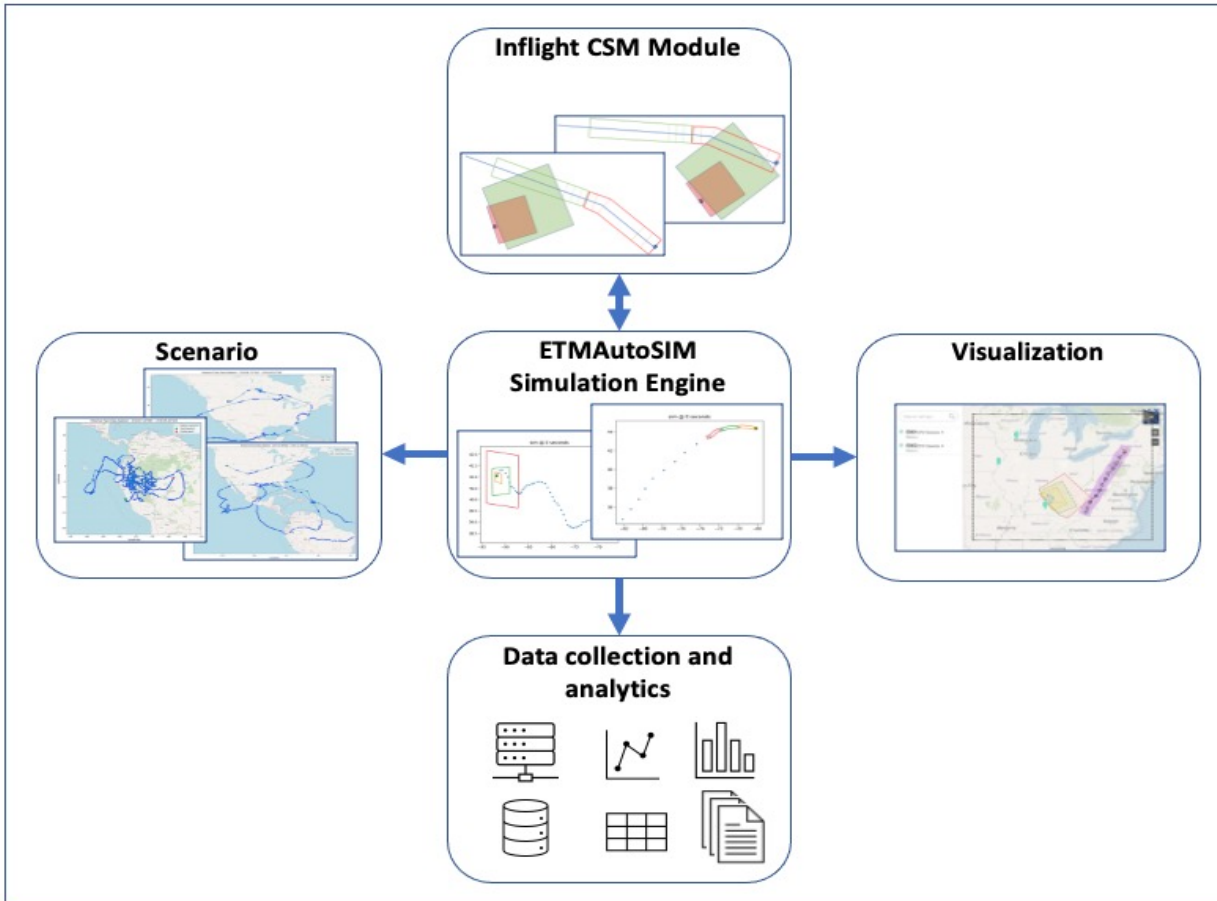
2. Candido, S. (2020). Loon stratospheric sensor data. <https://doi.org/10.5281/zenodo.3763022>

3. Leonard Bouygues, et al (2020) Adaptive Risk-Based Conflict Detection for Stratospheric Flight Operations, *Air Traffic Control Associate (ATCA)*

Simulation Development (ETMAutoSIM)

- 1) **Proof of concept** of the flight intent sharing and inflight CSM functionalities for operational feasibility verification and validation
- 2) **Provision of interactive demonstrations** for stakeholders to visualize the rolling-windows approach concept and collaboratively refine the concept
- 3) **Delivery of research insight and software subsystems** as an integral part of the ETM ecosystem accessible by NASA and its partners to facilitate research and software development

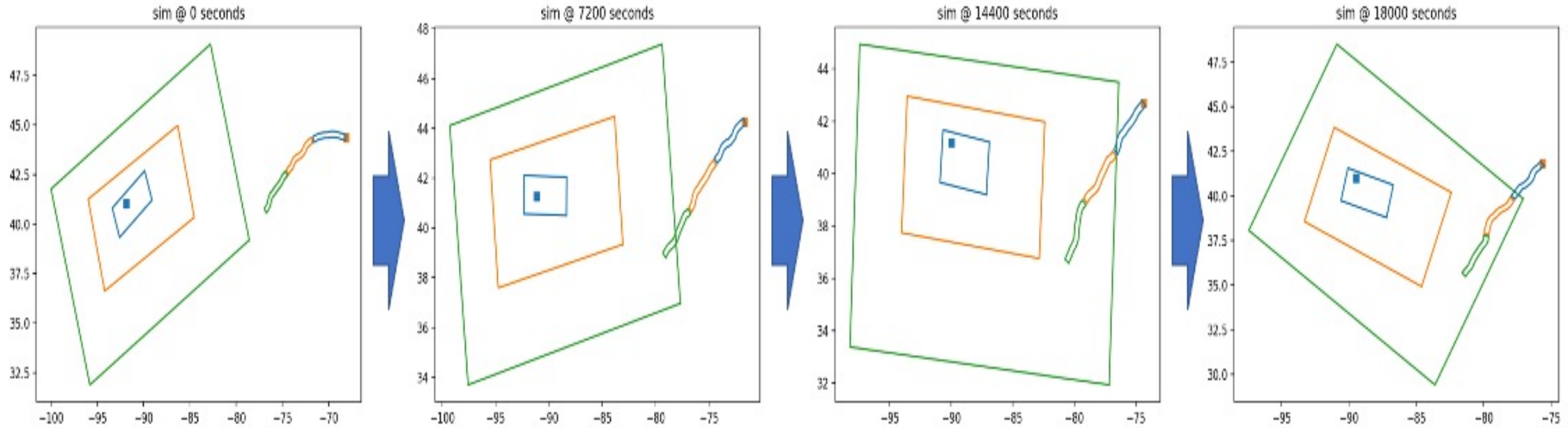
ETMAutoSIM simulation architecture and key attributes



Notional ETMAutoSIM simulation architecture

- 1) **Scenario:** Mimicking the actual operations data shared at a user-specified update rate
- 2) **Simulation engine:** Generating each vehicle's flight intent using the rolling-window approach
- 3) **Inflight CSM:** Detecting overlapping flight intent polygons at the same temporal instance
- 4) **Visualization:** Visualizing ETM operations in both real-time and fast-time simulation mode
- 5) **Data collection and analytics:** Archiving data from the simulation for both real-time analysis and post-simulation analysis

Initial Implementation – Conflict detection logic and preliminary results



Snapshots from a full ETMAutoSIM simulation run at different time instance (0, 2, 4, and 5 hours) to assess the conflict detection logic

Future plans

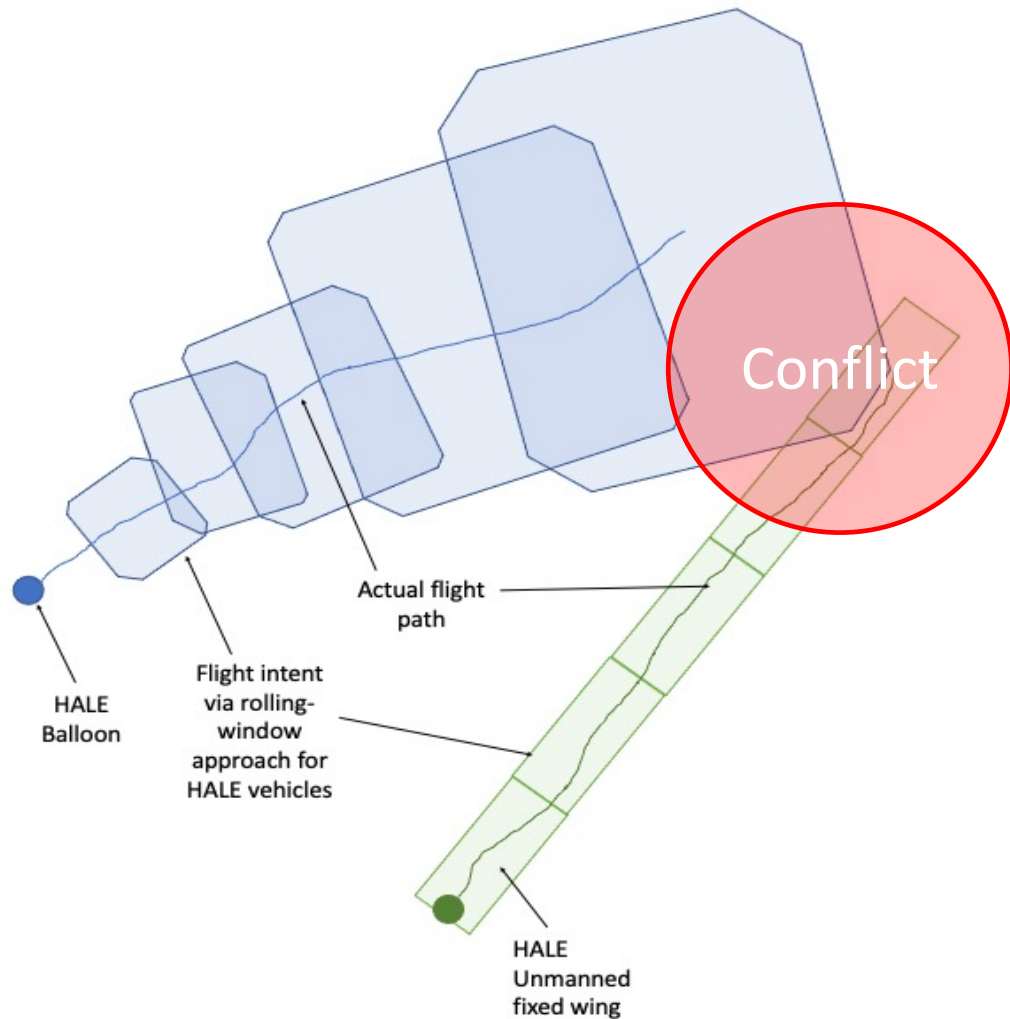
- The NASA team will work collaboratively with the FAA and industry partners to mature the ETM concept
- New concepts, procedures, and functionalities will be rapidly prototyped, visualized and validated using ETM AutoSIM simulation tool
- Other ETM vehicle types such as supersonic transport, airship, and high speed unmanned fixed wing aircraft will be gradually explored and integrated

Summary

- Developed an initial inflight CSM concept for ETM
- Identified an initial set of functionalities and implemented with a new simulation tool called ETMAutoSIM
- Described the initial simulation capabilities and the plan for extending the capabilities for further human/system simulation research
- Presented the preliminary results

Backup slides

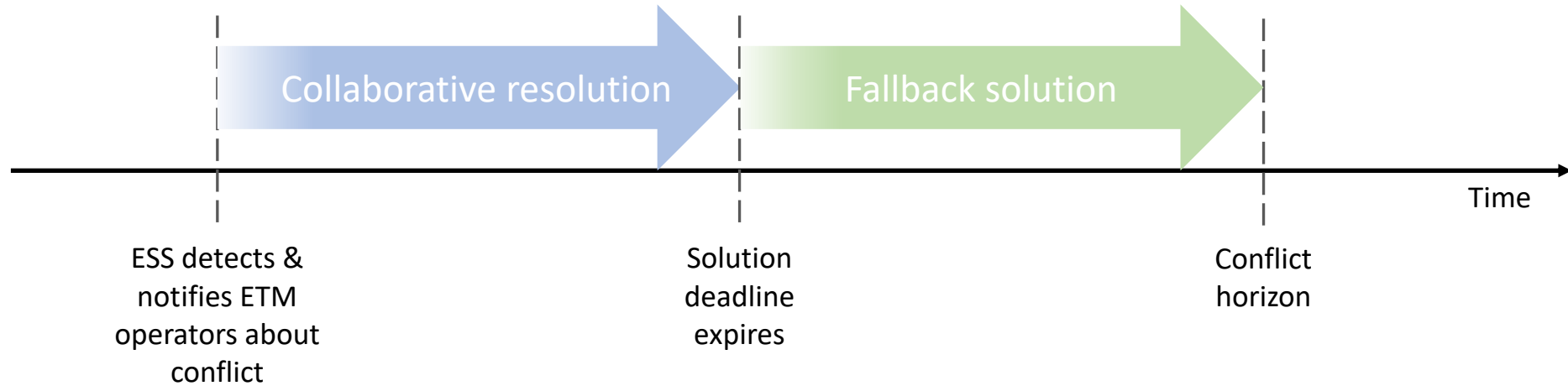
Conflict detection and assessment



A generic illustration of the “rolling-window” approach with a HALE balloon and a HALE unmanned fixed-wing through flight intent sharing

The **ESS** is responsible for notifying ETM operators immediately when the estimated collision probability exceeds the pre-determined threshold

Conflict resolution

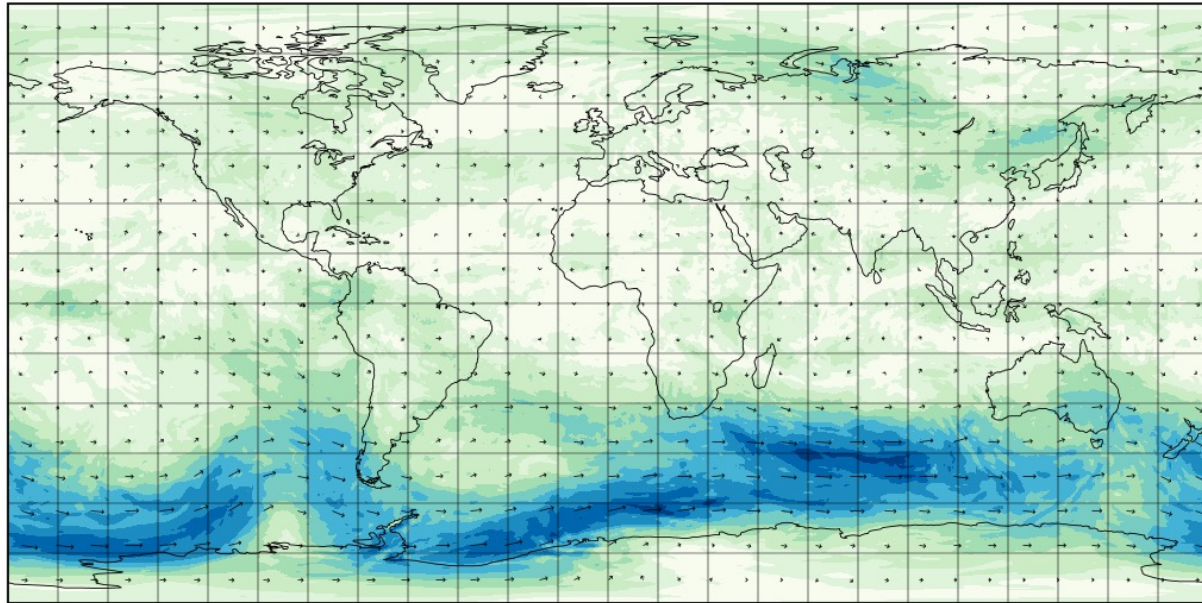


Notional conflict resolution timeline

An **ETM operator** would choose to either execute a pre-agreed resolution, or use an operator-preferred negotiation protocol to develop the final resolution action before the solution deadline

Conformance Monitoring

Global Forecast System (GFS) Data (2021-05-17-0Z)



$\text{Sqrt}[(u\text{-component of wind @ Isobaric surface})^2 + (v\text{-component of wind @ Isobaric surface})^2]$



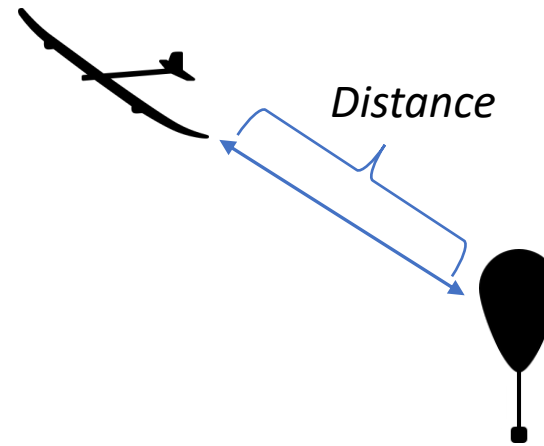
Data Min = 0.0, Max = 85.1, Mean = 21.2

Winds in the Stratosphere (2021-05-17- 0Z) at around 61400 ft (7000 pa)

Winds in the stratosphere > HALE vehicle's maximum speed

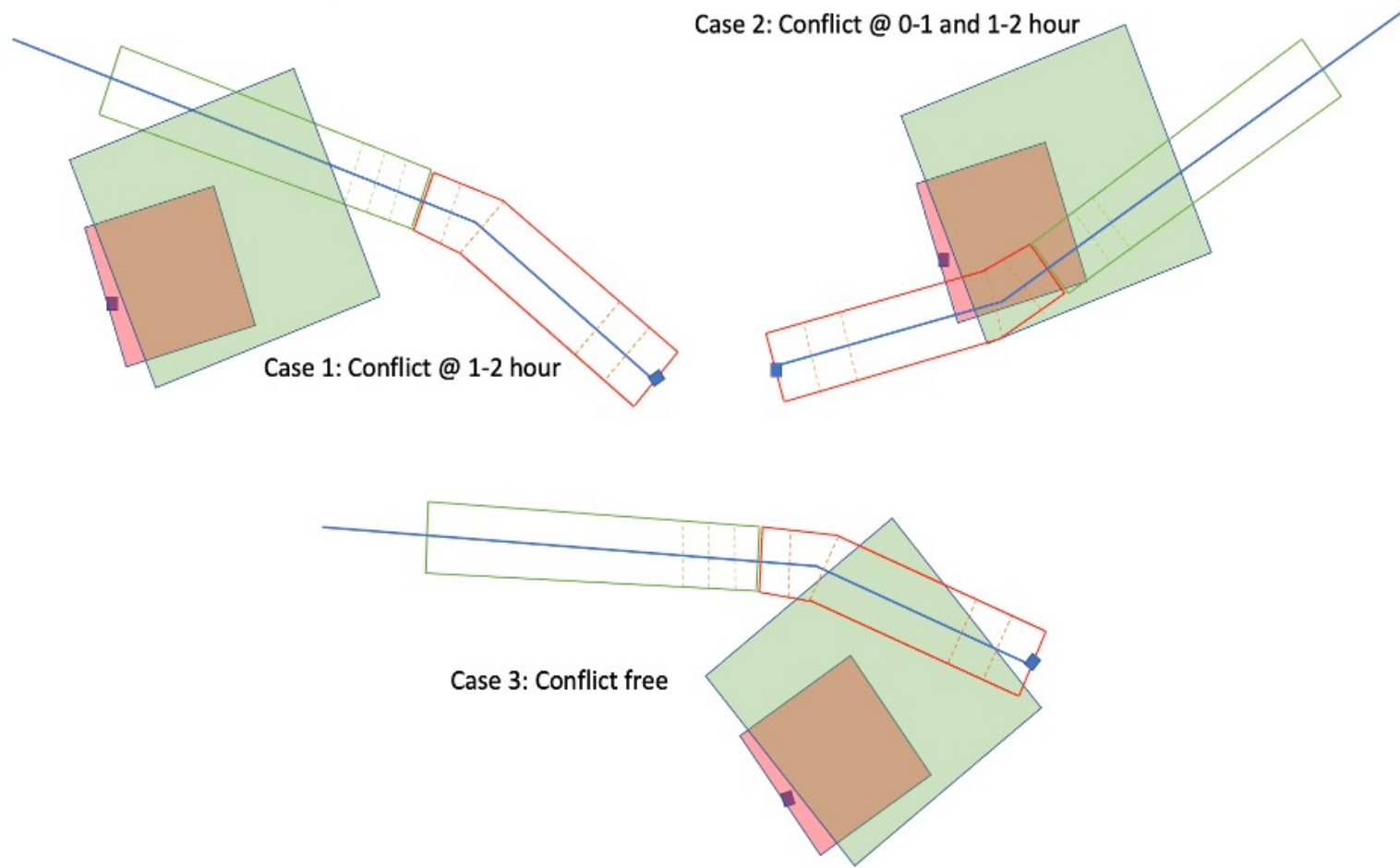
The **ESS** could serve as a conformance monitor to ensure ETM operators follow the agreed-upon resolution plan

Distance < a threshold value

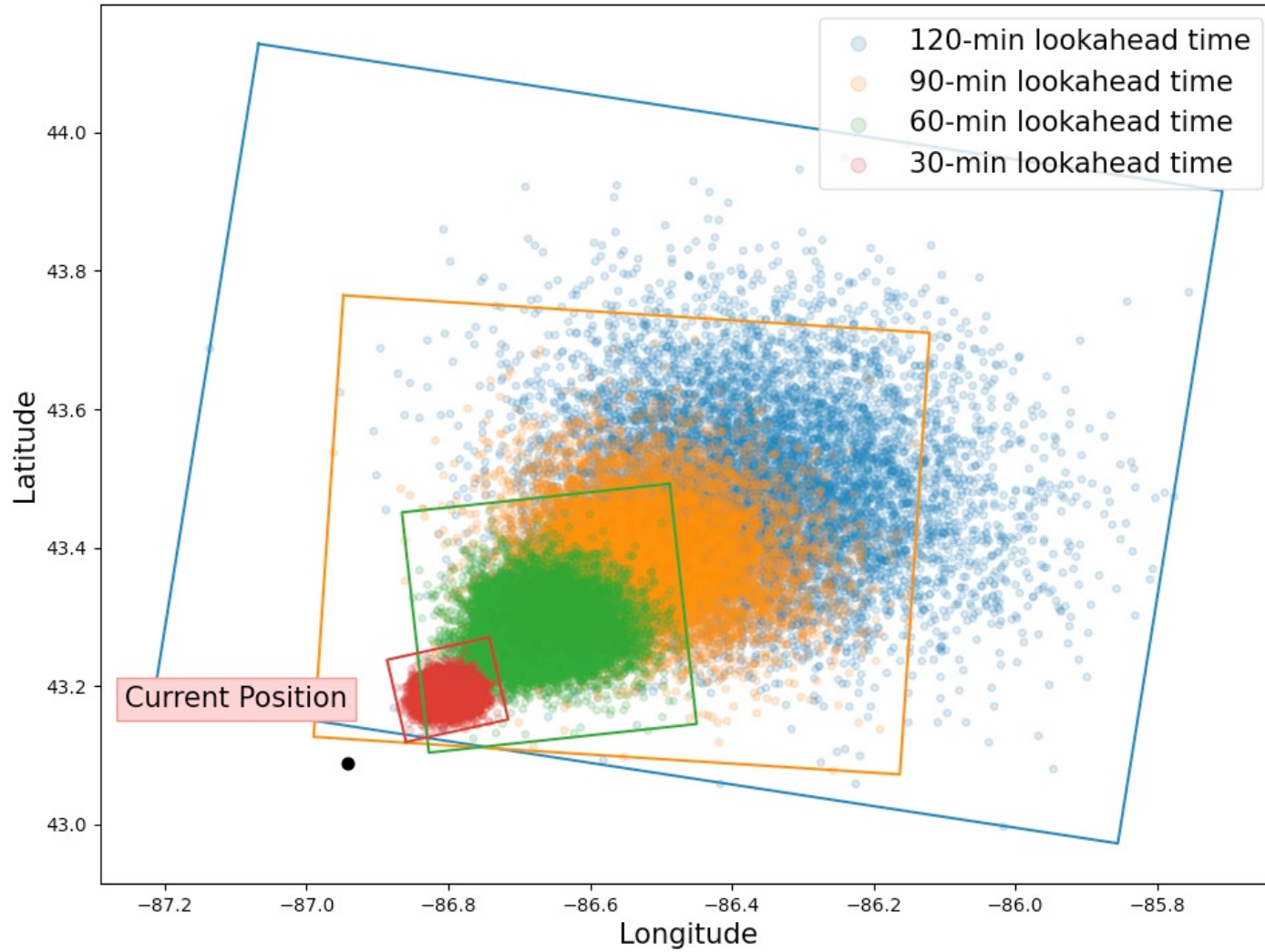


An experimental proximity "monitoring tool" for ESS to mitigate potential unexpected undesirable situation

■ HALE vehicle current position



Preliminary conflict detection logic



HALE balloon flight intent generation using Monte Carlo Simulation Approach