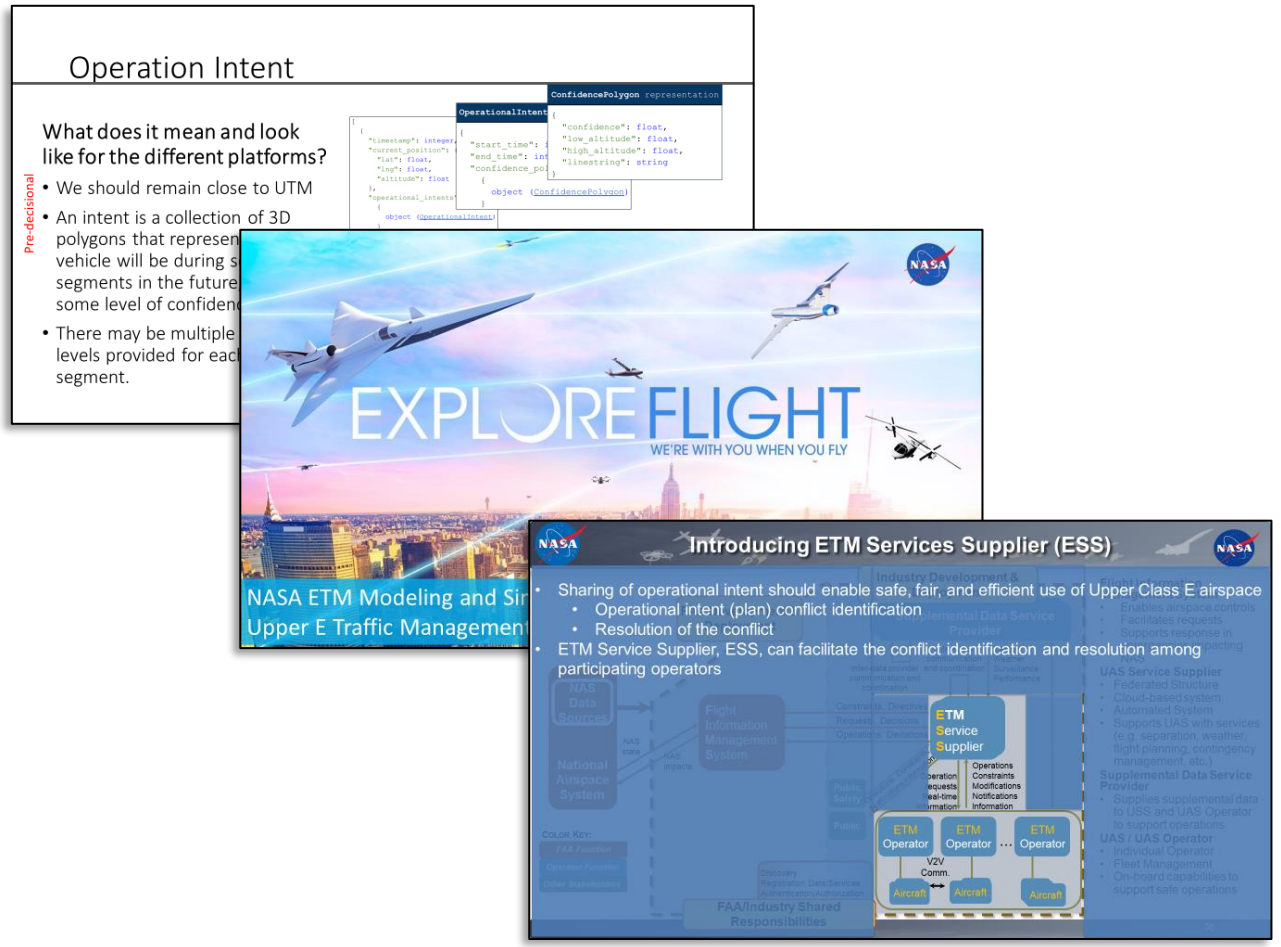
ETM: Upper E Traffic Management

March 12, 2021

Recap

- Meeting December 10, 2020
  - Initial discussion on intent and negotiation
  - Brief use case discussion
  - Presentation of NASA ATM-X Project and ETM
- AIA Meeting March 4
  - Use case #1 discussion
  - Outcomes delivered to NASA

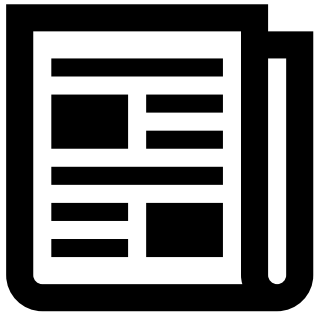


Pre-decisional

Agenda

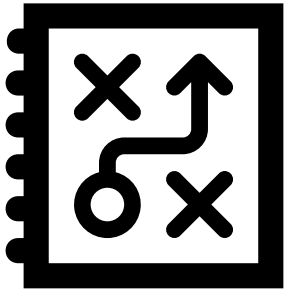
- News and Updates
- US Army Zephyr Program Overview
- Use Case #1 Walkthrough
- Lexicon
- Modeling and Simulation Updates
- Wrap up

Industry Updates



News

Testing



Plans

Level Set

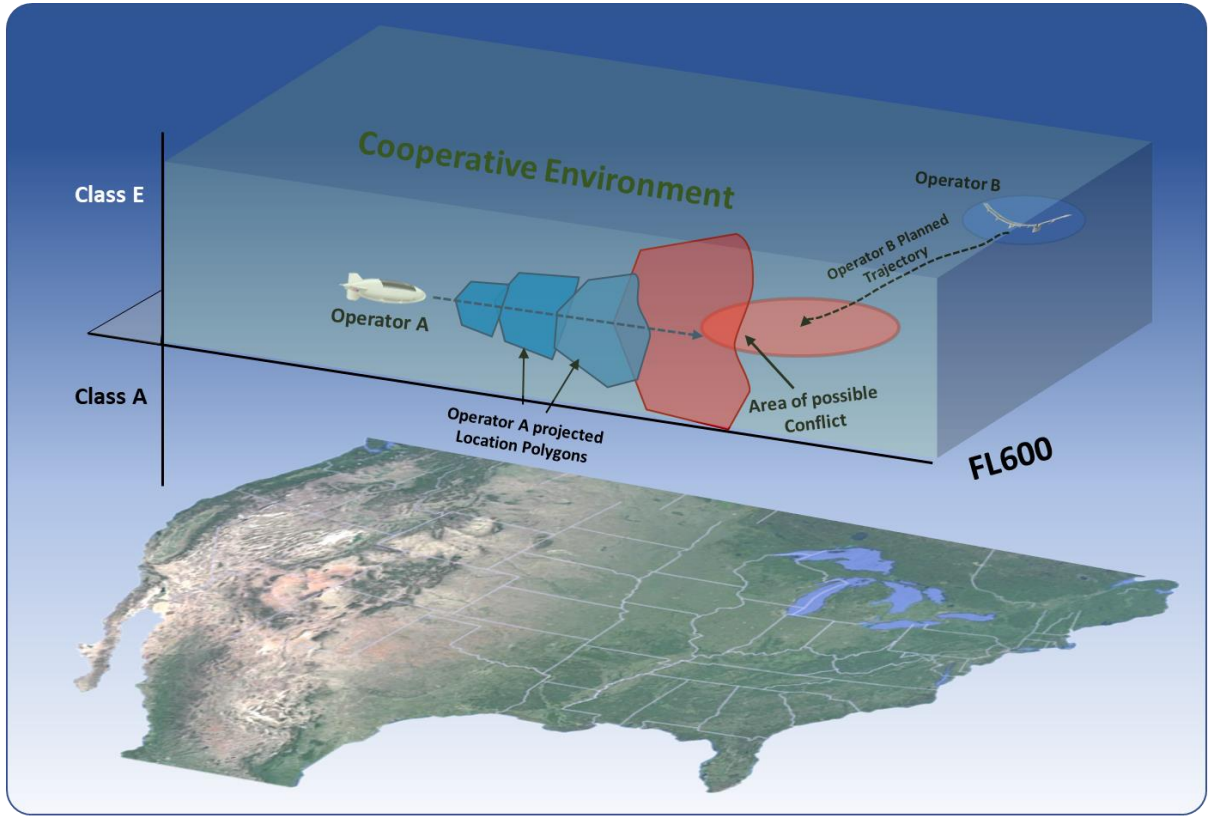
- Developing a cooperative concept based on Industry input
- Focusing initially on:
  - “nominal” operations
  - Strategic processes
  - Development of Cooperative Operating Practices
- Apply outcomes to additional use cases for rigor
- Process informs simulation work with feedback loop to the concept

Pre-decisional

Use Case Discussion

Scenario 1: Airship/Fixed Wing Planning Ahead

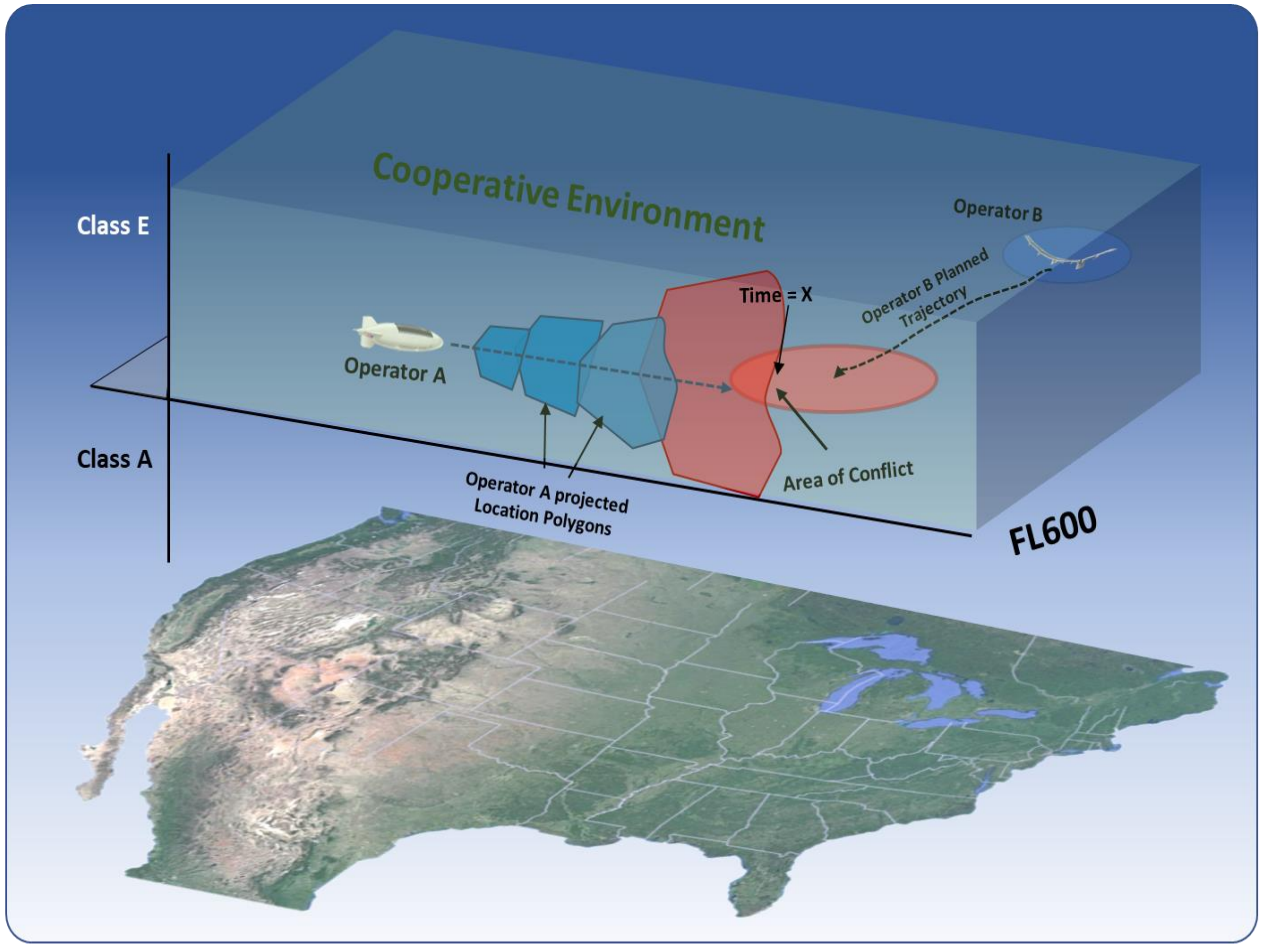
- Assumption – Operators cooperatively separate from one another; ATC is not providing separation services to either.
- HALE airship Operator A is flying at FL610 over the Western US and continues to forecast its flight path Southeastward across the country.
  - Based on current wind speed and direction, Operator A calculates the airship will be over the central Florida in approximately 30 hours.
- HALE Fixed-Wing Operator B is flying over the Northeastern US and is planning its flight path at FL610 south towards the Gulf of Mexico.
  - Operator B calculates the fixed wing vehicle will be over central Florida in 30 hours.



Scenario 1: Airship/Fixed Wing Planning Ahead

- Operator A and B share and receive a rolling series of updated/extended intent information. With each update, the certainty of each vehicle's position/flight path/trajectory over central Florida increases.
  - How are the operators exchanging intent information?
  - If rolling segments are used to specify intent, how far ahead should intent be shared and for what duration (e.g., 36 hours ahead in 120-minute segments)
  - How often should intent be updated?
    - At a set rate (e.g., every 30 minutes)?
    - At a certain threshold (e.g., if trajectory deviates by a certain metric or there is a plan update)?
    - Combination of the above or another approach?
- Intent for each operation continues to be updated on a rolling window and shared between each operator (and broader system).
- At a specified time, a potential conflict is identified.
  - How are operators characterizing their own intent? How are they analyzing their intent against the other operator's such that they both identify the same conflict?
  - What constitutes a conflict or potential conflict?
- The potential conflict is **not flagged for resolution / deconfliction**
  - What might be a reason that deconfliction is not needed? Too far in the future? Certainty or probability of the conflict is below some threshold? Other factors/considerations?

Pre-decisional



Operation Intent

Pre-decisional

What does it mean and look like for the different platforms?

- An intent is a collection of 3D polygons that represent where a vehicle will be during some time segments in the future, with some level of confidence.
- There may be multiple confidence levels provided for each time segment.

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OperationalIntent

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ConfidencePolygon representation

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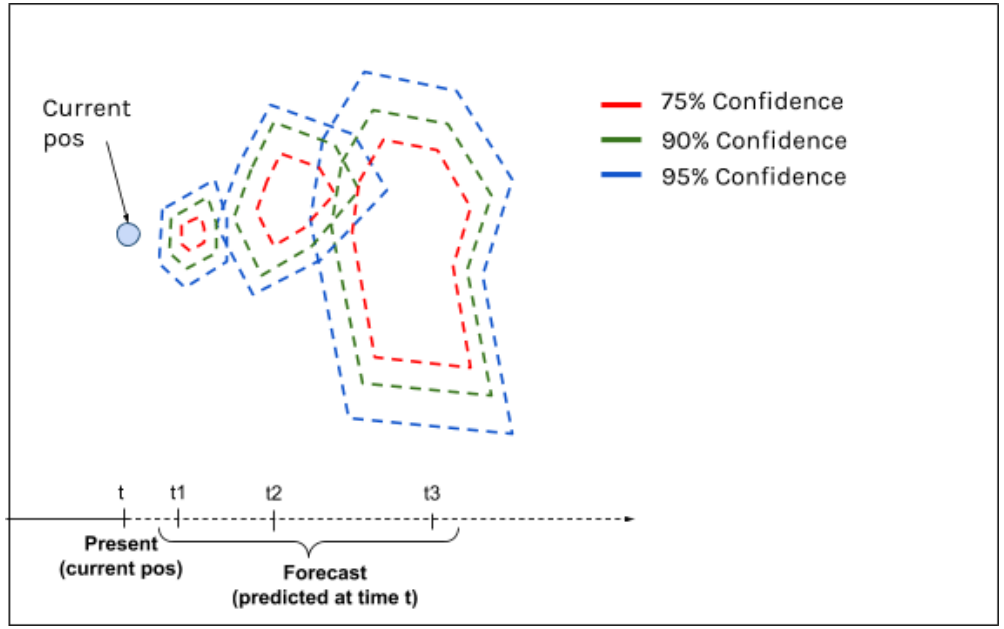


Scenario 1: Airship/Fixed Wing Planning Ahead

Operator A and B share and receive a rolling series of updated/extended intent information. With each update, the certainty of each vehicle's position/flight path/trajectory over central Florida increases.

- How are operators characterizing their own intent?
  - Each vehicle carries a separation volume of size determined by own and aggressor vehicle (e.g., HALE vs supersonic = margin for shock wave dissipation) characteristics with a future location/size uncertainty
- How are the operators exchanging intent information?
  - Can and likely will be an evolutionary process that builds toward a standardized, service-based approach (i.e., ETM Service Supplier and supporting architecture)
- If rolling segments are used to specify intent, how far ahead should intent be shared and for what duration (e.g., 36 hours ahead in 120-minute segments)
  - Depends on how well (future) positions can be predicted (e.g., SSTs likely very predictable vs balloons less predictable over time)
  - Time horizons for sharing could be based on minimum level of fidelity or predictability: those that have higher fidelity can (and should) share further into the future than those with less fidelity
- How often should intent be updated?
  - Open area of research. Should also look at differences in phase of flight (e.g., pre-departure, entry to Upper E, in transit to station, on station, etc.)

Scenario 1: Airship/Fixed Wing Planning Ahead

Intent for each operation continues to be updated on a rolling window and shared between each operator (and broader system). At a specified time, a potential conflict is identified.

- What constitutes a conflict or potential conflict?
  - 4D volume(s) overlap with the added nuance of probability contours = potential conflict but it doesn't need to be flagged until it's within a certain time horizon
  - More stochastic than UTM
- How are Operators A and B analyzing their intent against the other operator's such that they both identify the same conflict?
  - NASA/FAA UTM RTT subgroup on Strategic Deconfliction had a requirement for a predictable conflict detection algorithm. Same is likely needed in ETM with the need for design rules for the separation volume size and the de-confliction trigger criteria.

Scenario 1: Airship/Fixed Wing Planning Ahead

The potential conflict is **not flagged for resolution / deconfliction**

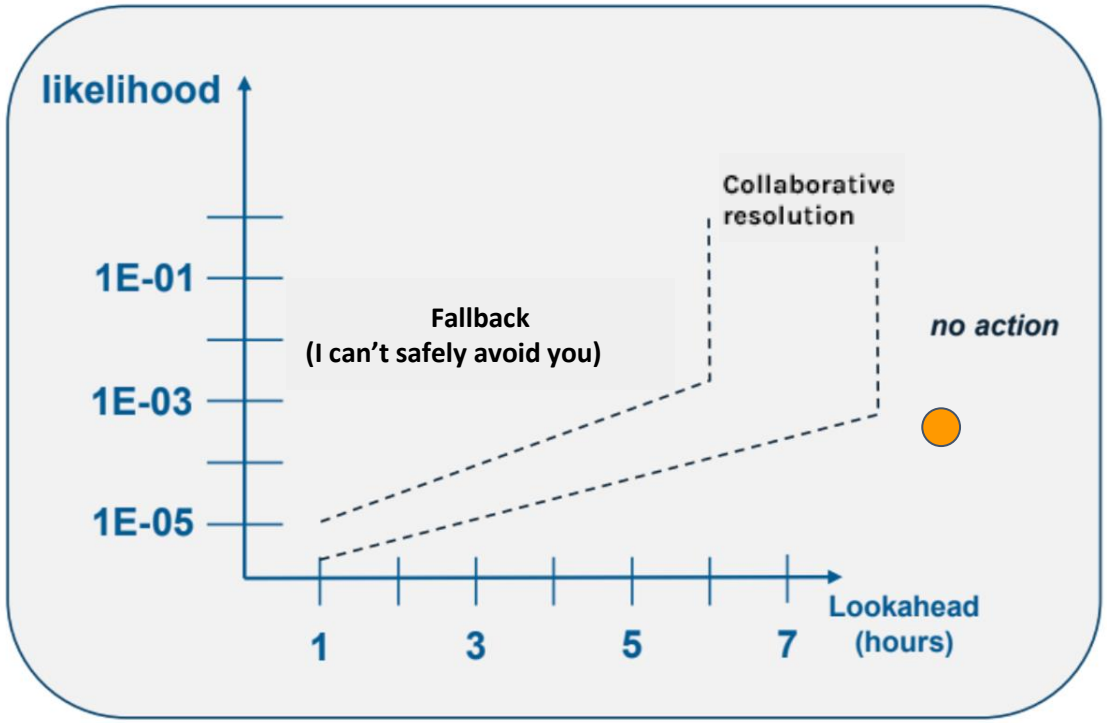
- What might be a reason that deconfliction is not needed? Too far in the future? Certainty or probability of the conflict is below some threshold? Other factors/considerations?
  - Too low a fidelity prediction of a conflict, or so many options for deconfliction available far enough in the future so as not to need to worry right now
  - As late as precautionary safety margins will allow. We don't want to be constantly de-conflicting and deviating from intent unless there's a reason. Evidently, this will be a function of vehicle agility. We could group similar vehicles and adopt a class standard agility model – trying to KIS.
  - Too far in the future or too unlikely (see Risk Matrix)

Risk Matrix

Each operator provides their risk matrix, combined in a most conservative one

Pre-decisional

My tolerance to the conflict

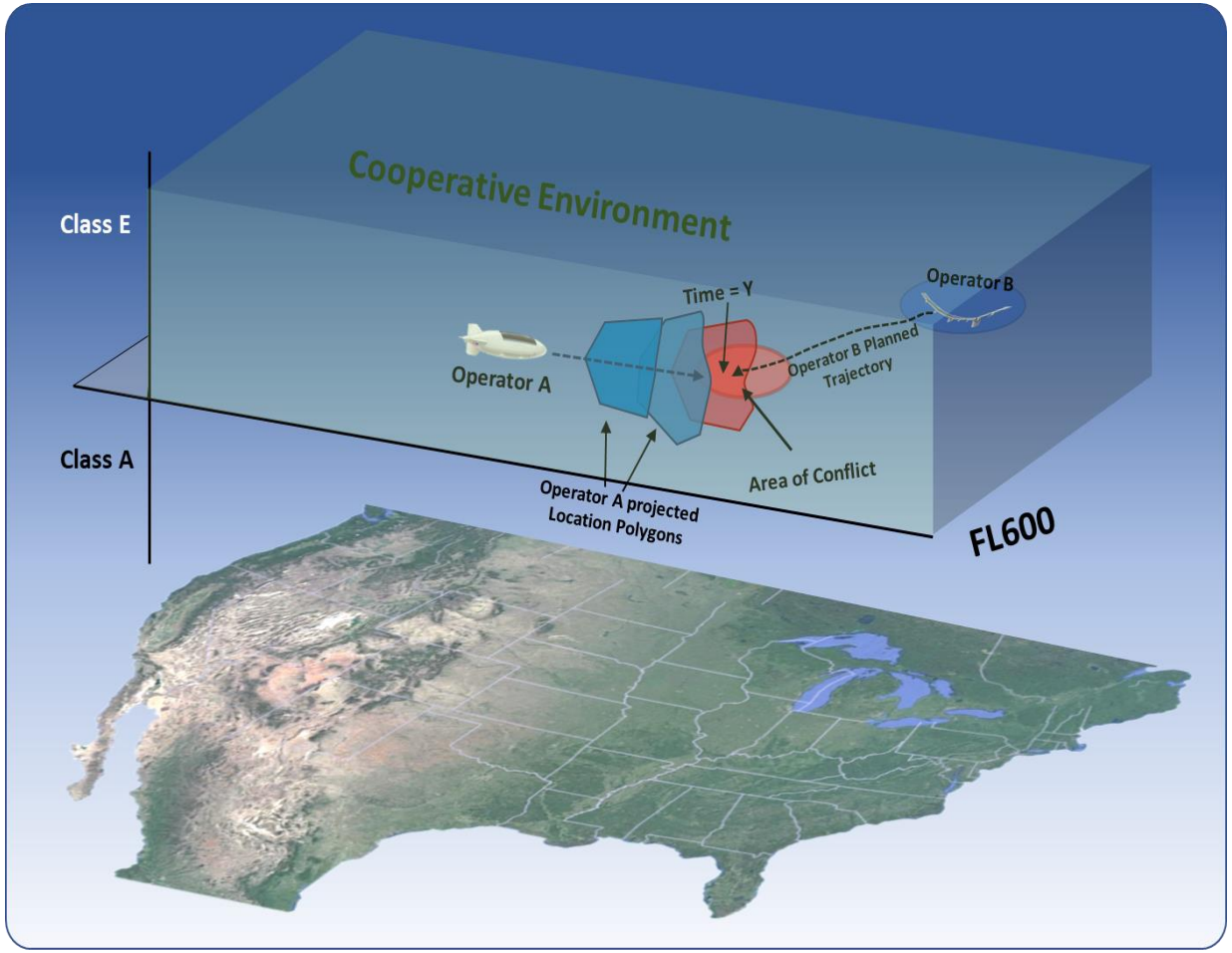


How long I need to avoid your bubble

Scenario 1: Airship/Fixed Wing Planning Ahead

Pre-decisional

- Eventually, a conflict is identified that is **flagged for resolution / deconfliction**
  - What factors determine that the conflict now necessitates coordination and possible action?
  - What is the deconfliction/resolution process?
    - How are the operators notified of conflict and need for resolution?
    - How is agreement reached for the resolution?
    - How is a successful deconfliction verified?
- The Operators negotiate a resolution and **successfully deconflict**
  - How is the negotiation accomplished? Manual coordination? Automated information exchange and decision making? Something in between? Is coordination directly between the operators? Is a service provider involved for either one?
  - Any thoughts on pre-defined rules that would be followed and guide the process of resolving the conflict?
  - What are the set of actions that each operator could take that might factor into a pre-defined ruleset?
    - Will differences in vehicle performance create differences in the time horizons needed to take action?
- What off-nominal conditions might cause a failure in deconfliction?
  - What pre-defined rules might exist that guide actions in such a situation?

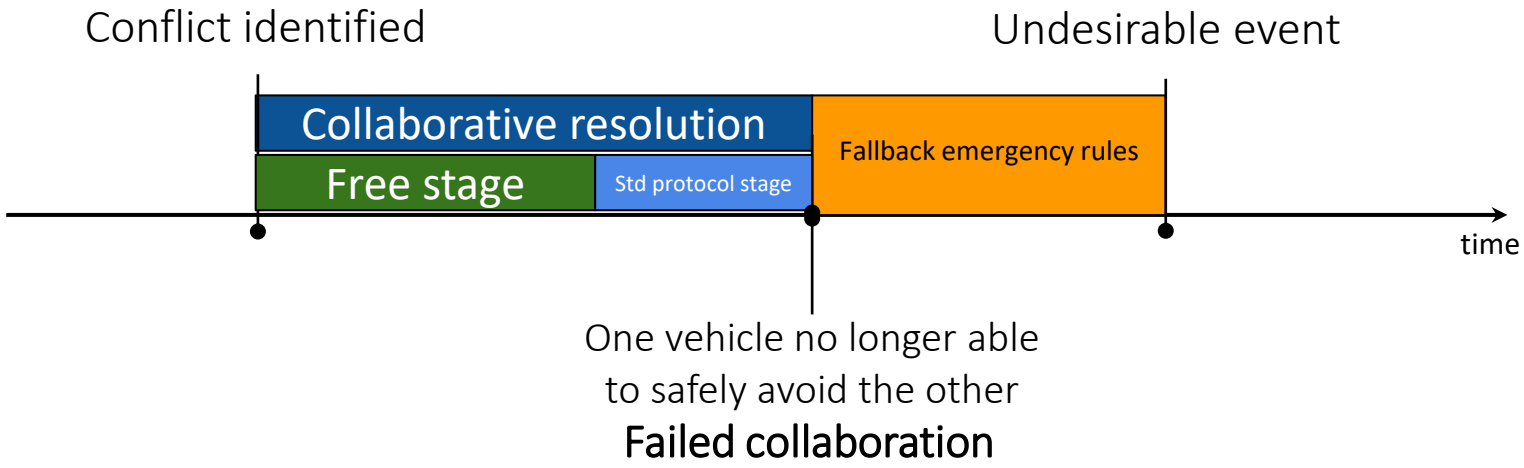


Scenario 1: Airship/Fixed Wing Planning Ahead

Eventually, a conflict is identified that is flagged for resolution / deconfliction

- What factors determine that the conflict now necessitates coordination and possible action?
  - Level of certainty that there is indeed a need to maneuver, exigency of the maneuver, i.e., how close we are to when a maneuver should occur (while both vehicles can contribute)/must occur (where only one vehicle can generate the requisite separation, i.e., “fallback”)
  - Intents with confidence, protection bubble size, associated lookahead/risk matrix
- What is the deconfliction/resolution process?
  - How are the operators notified of conflict and need for resolution?
    - Service-based approach
  - How is agreement reached for the resolution?
    - Negotiation (see later slide)
  - How is a successful deconfliction verified?
    - New intent shared and the same deconfliction scheme verifies no 4-D intersection of operations
    - 4D intersection is fine if far enough in the future / risk is low

Resolution flow



Pre-decisional

- **Free stage** - Any negotiation protocol of operator's choice (electronic, manual, etc.)
- **Std. Protocol stage** - A simple, fast, automated and guaranteed outcome protocol (no disagreement possible), designed for fairness, that must be used if operators cannot agree in a free stage. (prevents to rely on fall back). can also be used by operators in the free stage if they chose to do so.
- **Fallback rules** - If for some reason (should not happen if std protocol was used), we are in a situation where one vehicle can't avoid, the one that can should. Designed for safety, should not be used if std protocol stage implemented correctly.

Scenario 1: Airship/Fixed Wing Planning Ahead

The Operators negotiate a resolution and **successfully deconflict**

- How is the negotiation accomplished? Manual coordination?
  - Manual comms and coordination/negotiation is practicable for now (for slow flyers). Sharing of key information –Some information could/should be shared up-front, the rest when a confliction is identified. Obligation on all parties to engage. Time limit on resolution.
- Automated information exchange and decision making?
  - Eventually, yes. Std protocol must be automated.
- Will differences in vehicle performance create differences in the time horizons needed to take action?
  - Absolutely, but if the idea that only one vehicle maneuvers is dropped, you allow a situation to resolve like the following – A balloon and a HALE detect a conflict and agree that each will maneuver to stay in their respective “side” of some line of demarcation, this might make the balloon start to maneuver well in advance of the HALE in order to stay clear of that “line in the sand”

Scenario 1: Airship/Fixed Wing Planning Ahead

What off-nominal conditions might cause a failure in deconfliction?

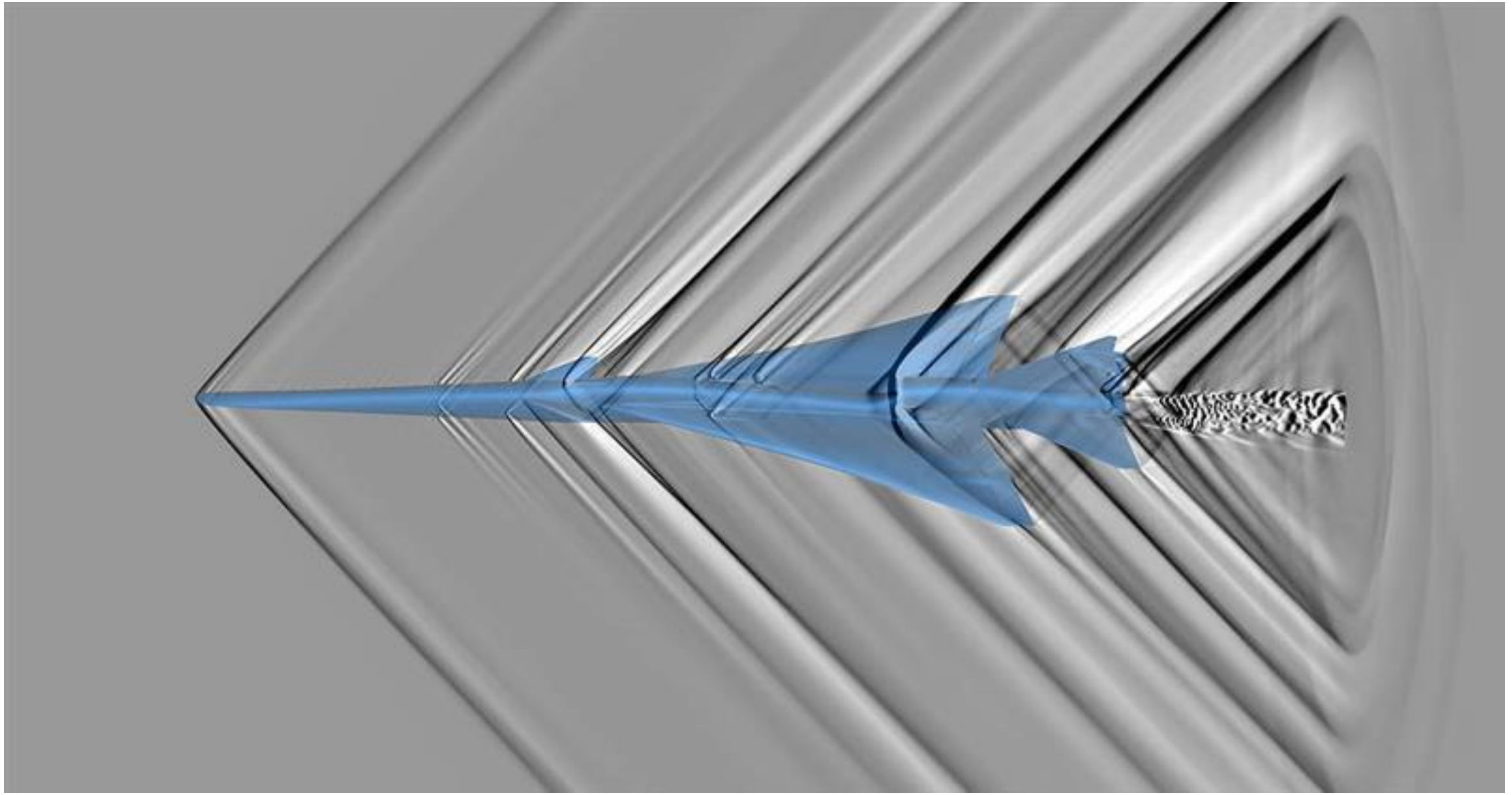
- What pre-defined rules might exist that guide actions in such a situation?
  - Rules of the Road-Community agreed behavior prior to collision avoidance maneuvers. Negotiation process. Pre-departure/planning:…

Lexicon

Lexicon

- ETM community proposed developing ETM airspace “rules of the road”, referred as Cooperative Operating Practices (COPs), to reduce the occurrence of ETM operations converging at approximately the same altitude
- Cooperative operating practices (COPs):
  1. A generalized set of practices for safety; static and conservative emphasizing safety
  2. Pre-defined agreement: a practice that deviates from the generalized set, may improve efficiency, the agreement is made before operations commence
  3. Dynamic agreement through negotiations: a practice that deviates from the generalized set, may improve efficiency, the agreement is made during operation via negotiations
     - Bidding based
     - Random-function based
     - …
- ETM operations are subject to CFR 91.113

Pre-decisional



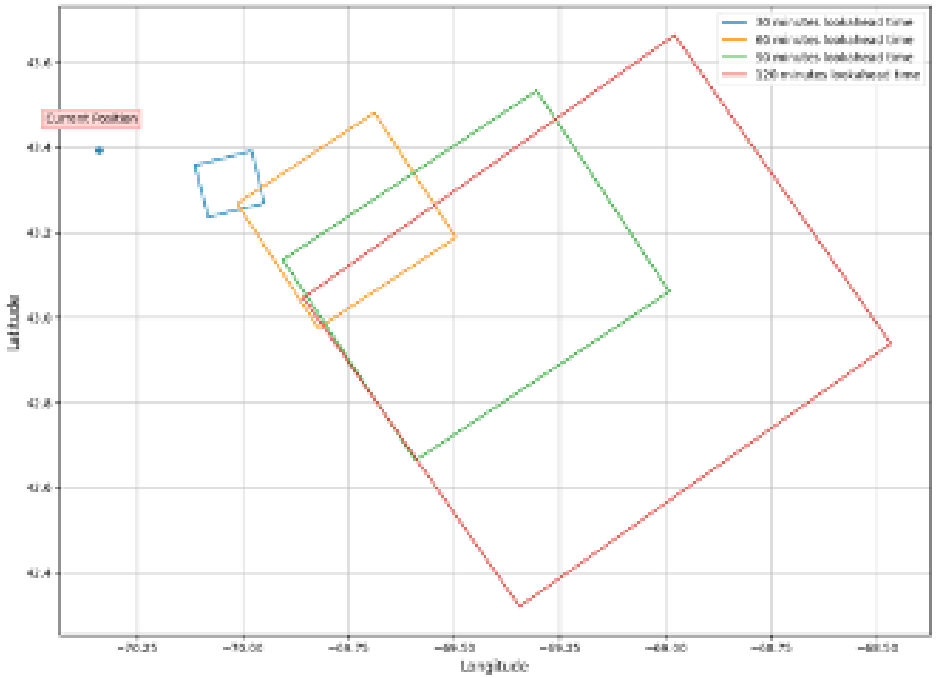
Pre-decisional

Modeling and Simulation Updates

Modeling and Simulation

- NASA
  - Fast-time simulation #1 preliminary experimental review completed (analysis reports by September):
    - Safe boundaries for cooperative operations
    - Probabilistic intent modeling
    - Intent conflict probability calculation
  - Development of initial cooperative strategy
- FAA

Pre-decisional



Loon Balloon Flight intent mock-up for the simulation

Conflict Detection & Resolution based on “Std. Protocol” as an initial cooperative separation strategy (First-Reserve-First-Served)

A scenario for testing operational feasibility of the concept based on the historical data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},
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Flight intent and telemetry data exchange protocols

Wrap up

Pre-decisional

Questions?

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