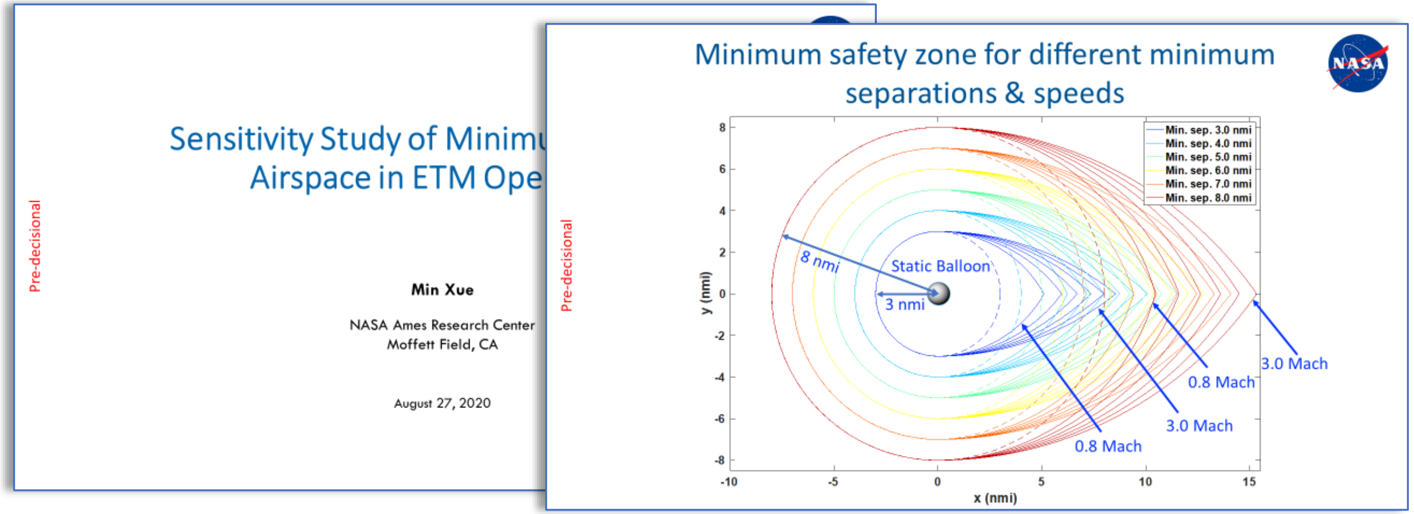
ETM: Upper E Traffic Management

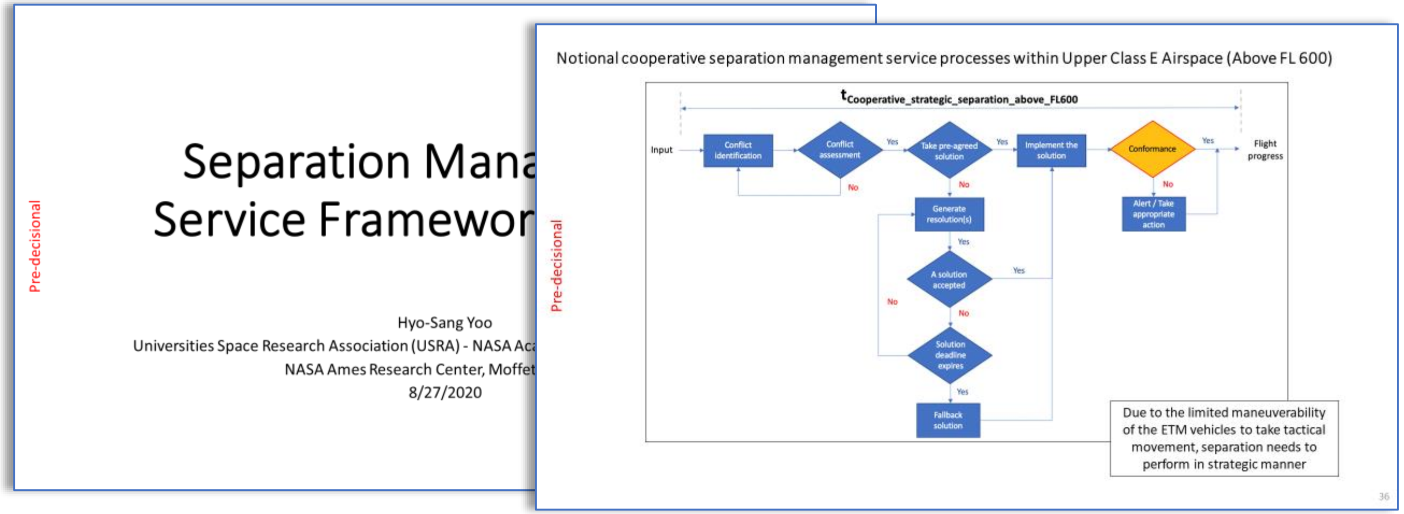
October 23, 2020

Recap

Pre-decisional

- Meeting August 27
  - Dr. Min Xue presentation: Sensitivity Study of Minimum Reserved Airspace in ETM Operations
  - Dr. Hyo-Sang Yoo presentation: Separation Management Service Framework for ETM
- AIA Meeting October 14
  - Industry principles and initial position





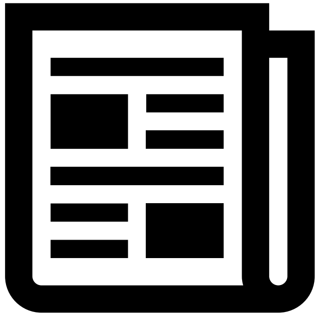
Agenda

- Industry Updates
- Direction recap
- Industry principles for ETM rules of the road: Conflict identification and resolution
- Simulation roadmap
- Wrap up

Pre-decisional

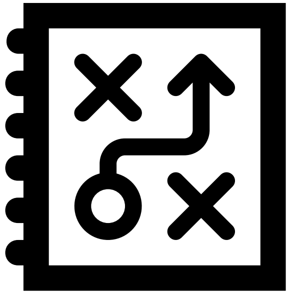
Industry Updates

Pre-decisional



News

Testing



Plans

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Pre-decisional

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Upper Class E Traffic Management (ETM)

Defining Upper Class E Operations

Upper Class E airspace operations refer to those that take place over 60,000 feet above mean sea level (MSL) in the National Airspace System (NAS). Operations in upper Class E airspace have historically been limited due to the challenges faced by conventional fixed wing aircraft in reduced atmospheric density. However, recent advances in power and propulsion technology, aircraft structures, flight automation, and aerodynamics have increased the number of vehicles that can now operate in the low atmospheric density airspace that is characteristic of upper Class E. This means that sophisticated high altitude, long endurance (HALE) vehicles, unmanned free balloons, airships, and supersonic/hypersonic aircraft can now efficiently and economically satisfy research objectives, demands for broad coverage services (i.e., earth sensing, telecommunications), and supersonic passenger flight.

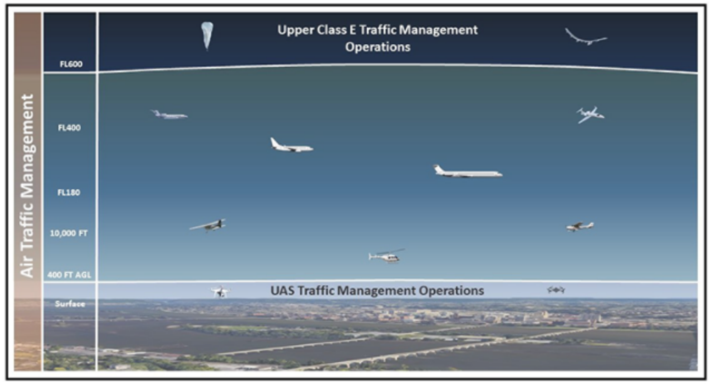


Figure 1: National Airspace System, depicting Upper Class E traffic management (ETM) operations

The Need for ETM

In the United States, there are no specific provisions for aircraft operations above 60,000 feet for civil aircraft, and most existing applications are limited to military operations. Existing Air Traffic Management (ATM) systems are unable to cost-effectively accommodate upper Class E airspace needs, and they are not necessarily feasible or desirable for upper Class

https://www.faa.gov/uas/advanced_operations/upper_class_etm/

New Kid on the Block: An Introduction to Upper Class E Airspace

Upper Class E Traffic Management, or ETM, is the latest in traffic management approaches to emerge from the innovative collaboration between the FAA, NASA, and the aerospace industry.

Federal Aviation Administration Follow
Oct 21 · 4 min read

By Nikki Jedlicka, Michelle Cady, and Sherri Magyarits, FAA Office of NextGen

When most of us think about very high altitude, practically futuristic aviation, we think of covert military operations and stealthy spy vehicles — mysterious, top secret, and beyond the realm of reasonable

https://medium.com/faa/new-kid-on-the-block-an-introduction-to-upper-class-e-airspace-d0ef37001839

Pre-decisional

Recap on collective direction

FAA ETM Development Contributions

✓ **Conducted Tabletop Sessions with FAA, NASA, industry, State agency, and other stakeholders to inform the ETM concept development**

- **Tabletop #1 conducted in April 2019**
  - Focused on understanding planned operations above FL600 and began discussions around a concept of operations for ETM
  - Established ETM foundational principles and assumptions for the cooperative environment
  - Established ETM development responsibilities for Industry, FAA, and NASA
- **Tabletop #2 conducted in Dec 2019**
  - Explored ETM concept considerations associated with ATC interactions
  - Identified operational issues/considerations associated with operations transiting to/from ETM environment, operations that occur both above and below FL600, contingency operations, and other issues that impact air traffic control operations
  - Informed FAA ETM Concept of Operations document development
  - Informed engineering plans and considerations

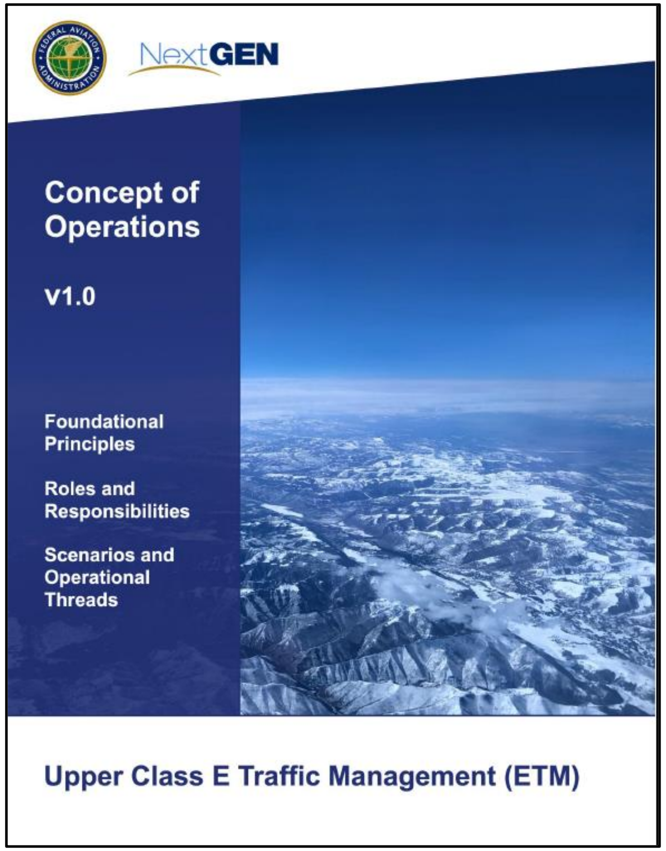
FAA ETM Development Contributions

✓ **Developed initial ETM ConOps v1.0**

- Finalized May 2020
- Documents vision to date:
  - Detailed Overarching foundational principles for cooperative traffic management, plus foundational principles and assumptions, and
  - Operational threads, roles and responsibilities, and high level operational requirements for transit to/from Upper E, contingencies during these phases, and a flexible floor concept for operations just below FL600.

❑ **ETM ConOps v2.0**

- Expected Release July 2021
- Document industry vision of Cooperative ETM environment and foundational as developed by industry and agreed upon by FAA
- Further refine and expand upon existing material
- Feedback/input from industry is necessary to mature the ETM concept and develop a relevant ConOps version 2.0



Industry Actions

- ETM cooperative operations concept and sharing architecture
- Rules of the road (e.g., right of way rules)
  - ✓ Negotiation-based, rather than current rules of the road
- De-confliction strategies (conflict identification and resolution)
  - ✓ Conflicts identified in time to enable resolution through negotiation (mutual agreements, ad-hoc)
- Equity and access rule development and enforcement guidelines (e.g., priority)
- Determine pair-wise vehicle separation envelopes
- Industry will identify information requirements and/or considerations for FAA/ATC systems (e.g., flight planning needs, vehicle performance/separation envelopes)
  - ✓ Separation based on vehicle characteristics, performance, and equipment with safety margins
- Industry will work with NASA to develop simulations and conduct research to further development efforts

Pre-decisional

Industry principles for ETM rules of the road

Conflict identification and resolution

Context

Pre-decisional

- Right of way rules were established to codify conflict resolutions between different aircraft:
  - VFR: Coordination between vehicles is very limited, and it was therefore necessary to define static rules that would ensure a consistent and predictable pilot behavior during a conflict to ensure safety.
  - IFR: There are established protocols, but controllers take responsibility and decide which aircraft needs to give way to ensure a safe, orderly, and expeditious flow of air traffic. Doing so the controller's "objective" is to balance fairness among airspace users, typically with similar needs, performance, mission, and costs of deviation.
- While adequate to ensure safety in the current environment, the rules of the road as defined today are not equitable:
  - Permanent advantage given to least performing actor
  - Designed based on human capabilities and are not likely well adapted to new types of missions which may desire to station keep to occupy a portion of the airspace for durations as long as a year (acting like a permanent obstruction).

Context

Pre-decisional

- The high-altitude environment also presents new challenges:
  - In the stratosphere, vehicles have wide ranging and very different performances and mission objectives.
  - Some missions will extend to entire years, some stationary, some others in constant movement.
  - Operators have different business models, varying constraints, and costs to maneuver, all of which change as a function of time.
- In this context it is challenging (if not impossible) for a controller to effectively and fairly balance the constantly evolving missions, objectives, utility functions, cost functions and performance characteristics of all actors.

Context

Pre-decisional

- The envisioned collaborative environment of the stratosphere offers new possibilities:
  - In this highly automated digital environment, operators can easily and effectively communicate with one another, and share their intents, vehicle performance, preferences, constraints, utility and cost functions.
  - Much of the interchange would be through machine to machine communications to enable complex intent sharing (e.g. probabilistic 4D volumes), frequent updates (hundreds per minute fleetwide), and complex preference/constraints sets.
  - Through automated negotiation, operators can maximize the overall efficiency of the airspace and fairness to its access.

Previous Work

Pre-decisional

- Negotiation to resolve conflicts that arise during strategic deconfliction of operational intent in UTM has been a topic of interest over the last six years. NASA has proposed and advocated some simple approaches to deconfliction, such that negotiation would occur very seldom.
- There was an attempt in the later TCLs to explore how negotiations could work. NASA reviewed their catalog of existing approaches to "negotiations" in the NAS such as credits, option sets, etc., but the work was discontinued due to other pressing issues with developing and testing UTM.
- The simple approach used in the first version of the ASTM UTM standard is "First Reserved – First Served". A series of tiebreakers to reward the most efficient user was also added, within some bounds. NASA assumed this would encourage efficient planning and minimize intersections, at least in the short to medium term. More complex negotiation is deferred from the first version of the ASTM UTM standard due to the perception that "First Reserved – First Served" will be acceptable for some time until the density of drones increases substantially.

Previous Work

Pre-decisional

- However, in ETM many vehicles in the stratosphere are airborne for months and must share a rolling intent window, which is one major difference from UTM. The concept of “First Reserved – First Served” makes little sense - if all vehicles plan on a 12-hour rolling window and conflicts can be detected 12 hours in advance, who reserved first? Additionally, in ETM we do not want to incentivize operators to reserve too far in the future (to be “first come”) and block airspace that they are unlikely to use.
- For “ETM” the team must start discussing how to bring some negotiation capability into the upcoming simulation events. In the stratosphere, negotiation is key. In the UTM environment, strategic conflicts are resolved prior to departure, but in ETM, vehicles may already be airborne when most strategic conflicts are identified. We will therefore discover situations where, if no-vehicle changes intent and continues their trajectory, conflicts will arise. So, negotiation must take place and deconfliction decisions made while both vehicles are still capable of moving (otherwise there is no negotiation to have).

Principles of conflict identification and resolution for ETM

- Industry believes that simulations should provide the answers necessary for the design of the ETM rules of the road. As such, the simulation framework should be flexible enough to simulate different sets of assumptions, rules of the roads and measure their impact.
- Industry would like to simulate what would happen if the current rules of the road were kept unchanged. This can act as a baseline to compare other approaches.

Principles of conflict identification and resolution for ETM

Pre-decisional

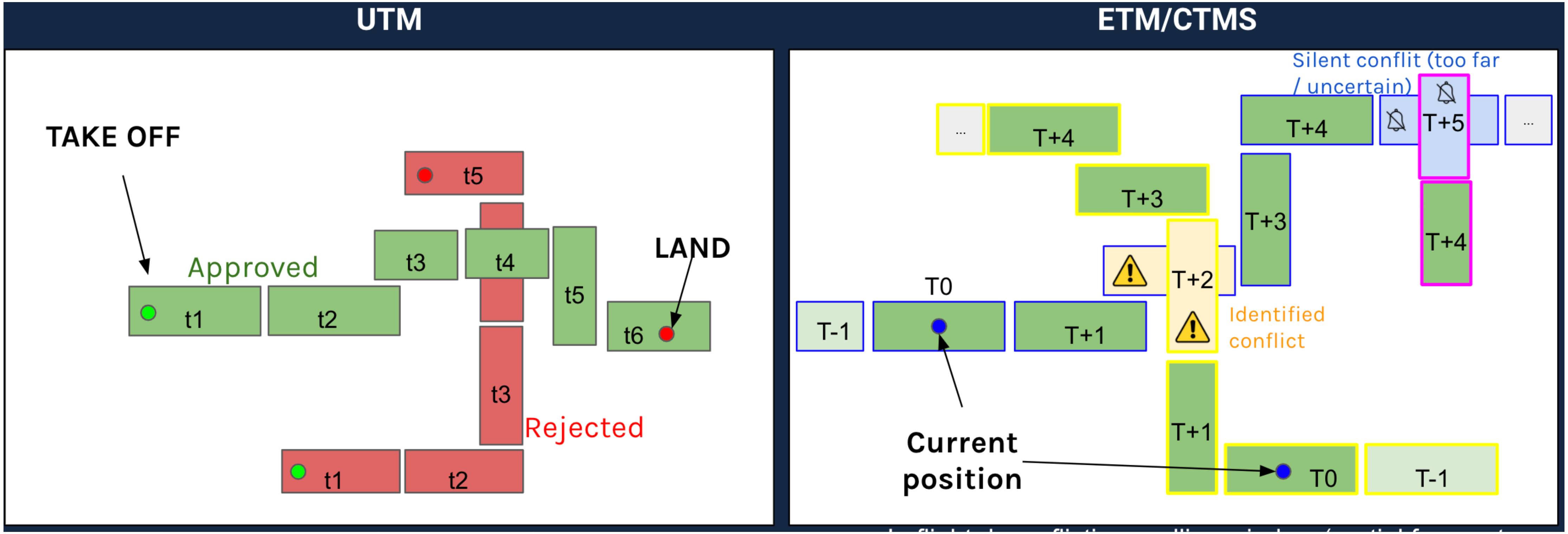
1. Sharing of intents on rolling windows
2. Minimum separation depending on vehicle performance
3. Resolution through negotiation
4. Exchange of vehicle performance to define conflict identification timing
5. Conflicts identified in-time to enable negotiation
6. A tiebreaker that does not rely on 3rd party in case of negotiation deadlock
7. Negotiation protocols designed to optimize efficient use of a limited resource
8. Observe, record, learn and evolve

1. Sharing of intents on rolling windows

- The stratosphere will be composed of many operations airborne for months or years at a time, some frequently replanning, and with varying and sometimes substantial uncertainty when projecting flight paths into the future.
- As visibility far in the future may be too uncertain, it is expected that operators will share their intents for a limited forward looking horizon that is useful for deconfliction, and they will update and extend their intents on a regular basis to create a "rolling intent window".
- The size or length of this window is one topic that the ETM simulations should investigate.

1. Sharing of intents on rolling windows

Pre-decisional



As visibility far in the future may be too uncertain, it is expected that operators will share their intents for a limited forward-looking horizon that is useful for deconfliction, and they will update and extend their intents on a regular basis to create a "rolling intent window".

2. Minimum separation depending on vehicle performance

Pre-decisional

- It is expected that the minimum separation between two vehicles will be dependent on the characteristics, performance and equipage of the vehicles, as well as a safety margin adapted to the vehicles and context.
- For example, the minimum vertical separation between two vehicles will be a function of their respective equipment accuracy and frame of reference.
  - Two vehicles could be vertically separated using pressure altitude, GPS, or a mix of the two, the position error can be adequately characterized, and provided that conversion between frames of references are possible (along with the characterization of the error associated with the conversion).

3. Resolution through negotiation

Pre-decisional

- Given the wide variety, and ever-changing set of mission objectives, constraints, vehicle performance, cost and utility functions, industry believes that the dominant means to resolve conflicts should be via **“negotiation”.**
- During this process, operators can exchange preferences and constraints to find an optimal collective solution to a conflict.
- Multiple mechanisms of “negotiation” can/should be considered and may be used in combination (for example, the ad-hoc negotiation may be used in absence of bilateral agreement):

3. Resolution through negotiation

Pre-decisional

- Bilateral / multilateral agreements - between operators which can pre-define a set of rules that would apply in various circumstances. Those are negotiated between operators well in advance of operations.

- Ad-hoc negotiation - enables operators to negotiate the resolution of a conflict as it is identified, provided the conflict is identified sufficiently early for the negotiation and resolution/maneuver that result to safely take place.

Multiple mechanisms of ad-hoc negotiation can/should be considered: these may include human to human negotiation (adequate in the short term / low density) but will automated negotiation protocols (e.g. option sets) or market like systems such as bidding systems (e.g. similar to those used in financial markets or online advertising, spectrum allocation, etc...)

3. Resolution through negotiation

Pre-decisional

It is worth noting that the outcome of the negotiation need not be a binary outcome:

1. The burden of avoidance could be shared between operators/vehicles. For example, a negotiation outcome may be that both vehicles perform a maneuver to yield a collectively lower disturbance to both Operators' plans.
2. An operator may offer to move one or more other vehicles (adjacent to the one originally in conflict) to provide an alternative passage to the other operator's vehicle.

4. Exchange of vehicle performance to define conflict identification timing

Pre-decisional

- Because much of the deconfliction will happen while airborne, it is essential to compute how long a conflict will take to resolve (time to maneuver + time to send updated instructions to the vehicle + time to negotiate the resolution).
- It is expected that operators will need to provide some maneuverability envelope (time to control / change course). This is necessary to compute how much time before an expected loss of safe separation a conflict must be identified in order to avert it.
- Exchanges of maneuverability and controllability (maneuverability envelope), performed in real time through API protocols, is likely to become necessary for vehicles that have performance profiles that change in time (e.g. function of the battery state of charge or flight environment).

4. Exchange of vehicle performance to define conflict identification timing

Pre-decisional

- Operators need a way to communicate concisely and digitally where the flexibility in their mission planning lies in order to choose the most collectively advantageous maneuver.
- Determining an appropriate standard to exchange maneuverability will be necessary. Such a standard should be as generic as possible to represent all possible types of operations/vehicles.
- As an analogy, in composite structures, we use a "stiffness" matrix to represent the moduli along the material axes. The inverse of this being the "compliance matrix" and showing in what directions the material is more flexible. Perhaps something like this could be established using the dimensions of lateral, vertical, and temporal (along flight path) flexibility or "compliance".

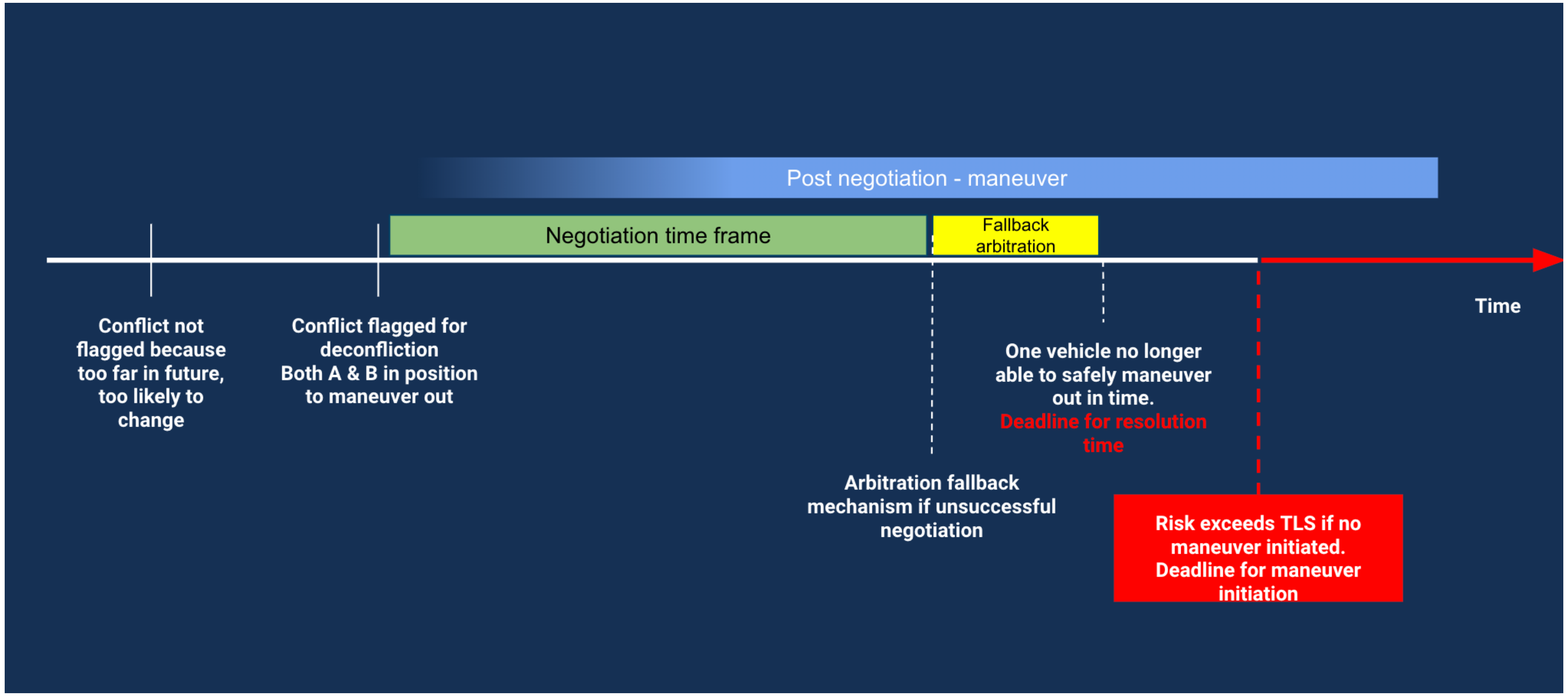
5. Conflicts identified in-time to enable negotiation

Pre-decisional

- For negotiation to be possible, conflicts must be identified early enough such that both vehicles in conflict have enough time to give way to the other (there is no negotiation possible if only one vehicle is capable of moving).
- The negotiation process must yield a solution before either of the vehicles in conflict is no longer able to safely avoid the other one (which would force the more maneuverable vehicle to avoid the less maneuverable vehicle as we currently define in the rules of the road – which are obsolescent in this collaborative environment).

5. Conflicts identified in-time to enable negotiation

Pre-decisional



In cases where the vehicles in conflict have important maneuverability differences, the conflict will need to be flagged far in advance such that the lower performing vehicle has time to give way to the higher performing vehicle if such is the outcome of the negotiation process.

6. A tiebreaker that does not rely on 3rd party in case of negotiation deadlock

Pre-decisional

- Depending on the negotiation method used, a tiebreaker will be necessary if there is a possibility for the negotiation to not reach a solution in the imparted time (deadlock negotiation). Note: this is necessary because when conflict resolution is performed while airborne, the absence of a negotiation solution in a timely manner could lead to catastrophic situations.
- Third parties are not necessarily needed (or even desired) for arbitration in case of stale negotiation.
- Tie breaker mechanisms should be fast, last resort solutions, and used on rare occasions.

6. A tiebreaker that does not rely on 3rd party in case of negotiation deadlock

Pre-decisional

- Industry would like to consider simulating the use of the existing rules of the road as a possible “default right of way”. However, we should assess how this “known default outcome” can disincentivize an operator with a “default priority” to negotiate. We would like to compare this with an alternate tie-break mechanism that has an outcome that cannot be predicted in advance by the parties, so as not to influence the negotiation.
- Initially, we could simulate negotiation and tie-break solutions that yield a random “50/50” of obtaining priority.

7. Negotiation protocols designed to optimize efficient use of a limited resource

Industry believes that the negotiation framework established should be designed to maximize the efficiency and utility of airspace utilization.

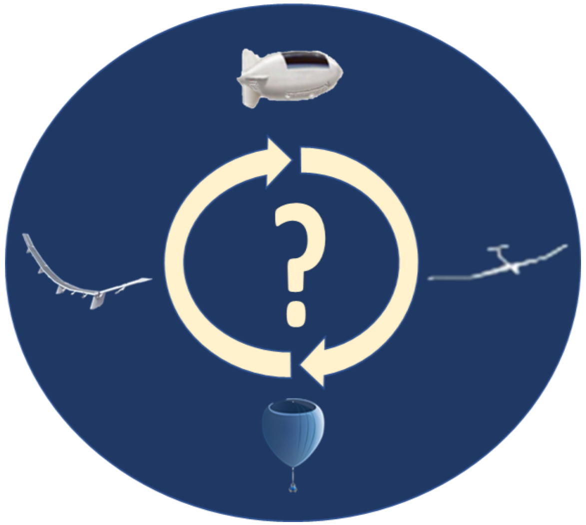
8. Observe, record, learn and evolve

Pre-decisional

- The stratospheric airspace will continue to evolve. It is important to learn from initial implementations and adapt as needed.
- As such, it is important to implement mechanisms to record dispute, inefficiencies, system abuse, and overall undesired effects of the system.

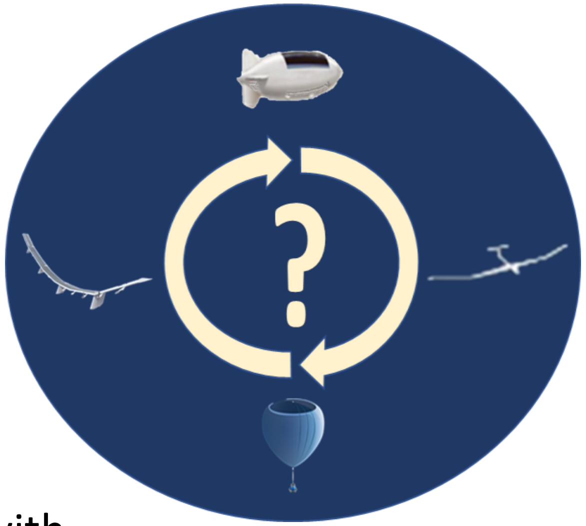
Industry Actions

Community Based Rules Development



- ❑ **Further Rules governing Deconfliction/Negotiation**
  - ❑ Conflict detection considerations
    - How are conflicts detected and communicated?
      - Uniform ETM-wide conflict detection and notification system/software?
      - Individual operator systems?
    - What are the time horizons? (e.g., minimum/maximum lookahead times)
    - Notifications (who, when, and how are those impacted notified?)
    - Different levels of non-conformance? (e.g., reduced maneuverability, loss of vehicle control)

Industry Actions



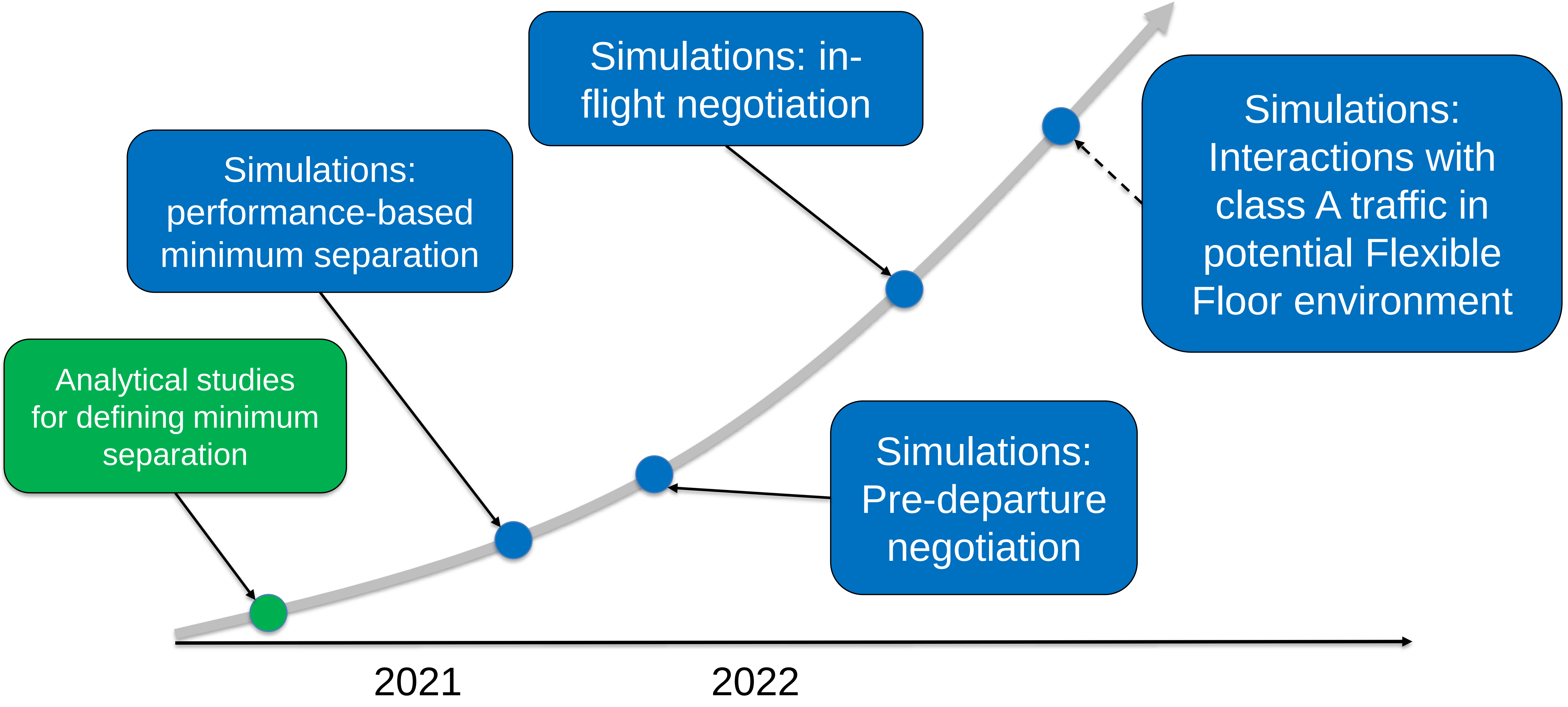
Community Based Rules Development

- ❑ **Further Rules governing Deconfliction/Negotiation (cont'd)**
  - ❑ Equity of airspace/Right of way rules?
    - Unresolved through Negotiation, who must move? (e.g., vehicle with greater maneuverability)
    - What dictates priority when negotiation fails?
- ❑ **Further considerations for intent sharing and replanning frequency?**
    - How are rolling intent windows determined for useful deconfliction? (e.g., vehicle characteristics)

Pre-decisional

Simulation Roadmap

Simulation Roadmap (draft)



Simulation Development

Modeling/data collection:

- **Vehicle Model**
- **Communication, navigation, and surveillance**
- Wind

Analytical studies

Simulations: performance-based minimum separation

Multiple Aerial Vehicle Simulations

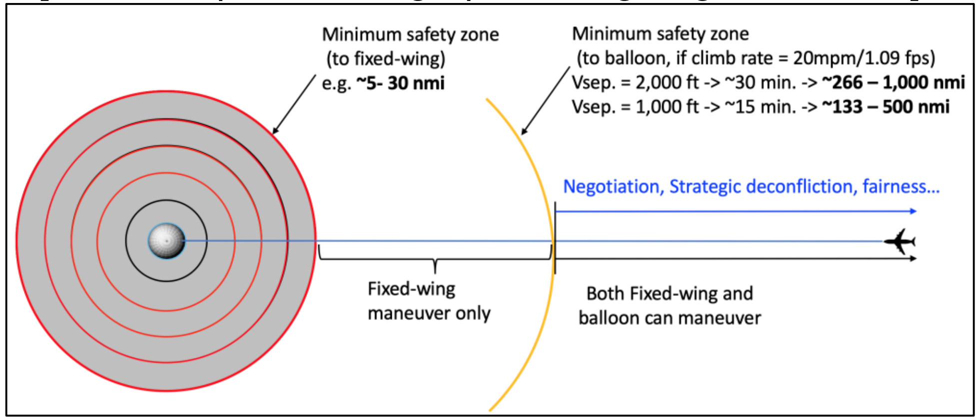
Negotiation/coordination models

- Intent sharing: format, rate, accuracy
- Methods (content/format):
    - Rules of road or agreements
    - Manuel/Automated (option sets)
    - Auction
- Communication
    - Response time
    - Latency
    - Accuracy

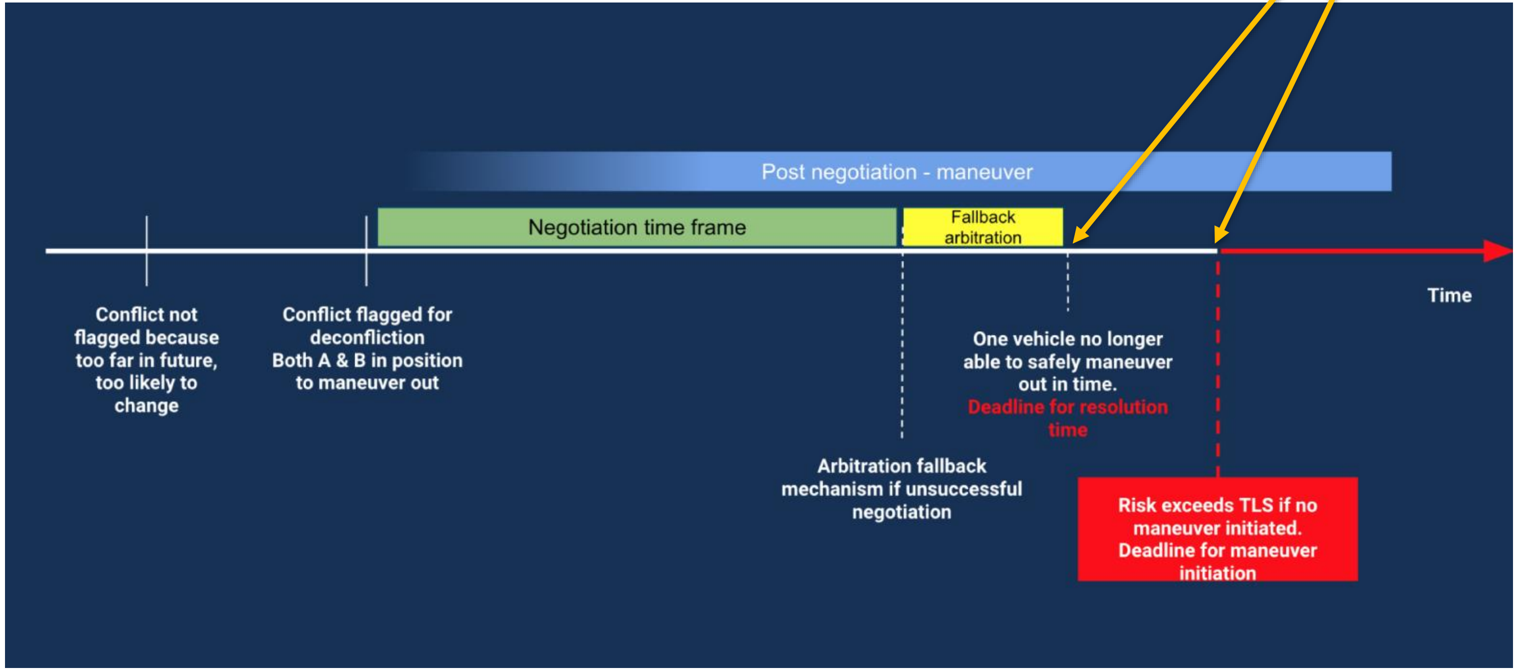
Scenarios

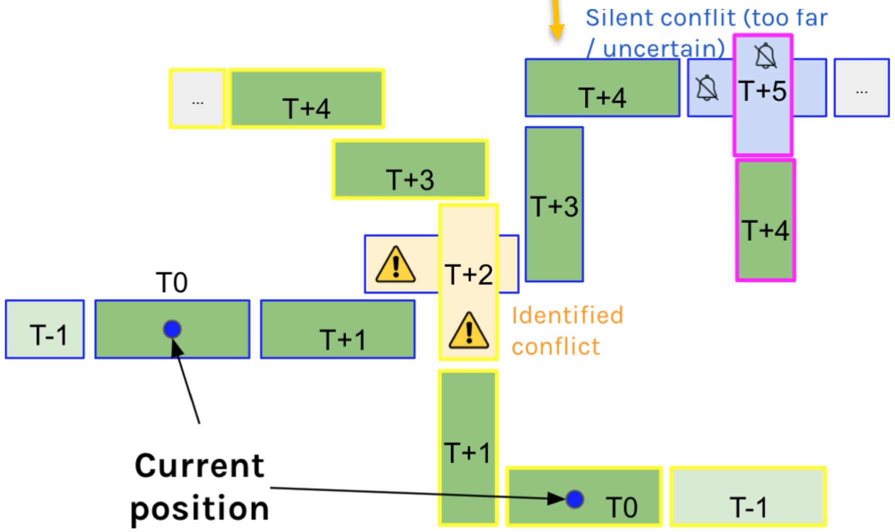
Research Questions to be addressed by simulations

[Plot from previous tag-up meeting Aug. 27th, 2020]



1. Timing and spatial boundaries for conflict resolution and negotiation
2. Size or duration of "rolling intent window"
3. CNS requirements





Research Questions to be addressed by simulations (cont'd)

For both pre-departure and in-flight, identify negotiation/coordination model(s) that are **safe, efficient, fair,** secure, and scalable:

- Intent sharing: content, format, rate, accuracy, and responsibility
- Methods:
    - Rules of road or predefined agreements
    - Manual/Automated (option sets)
    - Auction
- Communication: response time, latency, and accuracy
- Metrics: efficiency and fairness

Pre-decisional

Questions?

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