# Roadmap to Cooperative Operating Practices for Strategic Conflict Detection and Resolution in the Upper Class E Traffic Management Concept


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***Abstract*— As the governing body of flight operations in the highly anticipated emergent area of Upper Class E airspace (60,000 ft and above), the Federal Aviation Administration (FAA) has recognized the potential for a possible extensible traffic management system for new entrants into this domain. Following the success with the Unmanned Aircraft Systems (UAS) Traffic Management (UTM) program, the FAA put forth an initial concept of operations for supporting the start of the Upper Class E Traffic Management (ETM). Like UTM, ETM is envisioned to be a community-based, industry-driven cooperative management concept. However, tailoring it to be adaptable to the atmospheric communication, navigation, and surveillance deficits, as well as the diverse vehicle and mission profiles that operate in the ETM environment, will be the challenge.**

**As such, the National Aeronautics and Space Administration (NASA) Ames Research Center has been investigating several technologies that will help enable industry in the development of this new type of cooperative environment. These technologies are being prototyped and will be tested with ETM industry partners in a collaborative evaluation of an initial ETM system in late 2023. The evaluation will concentrate on building out ETM system technologies that will inform the industry participants regarding operational intent sharing, strategic conflict detection, and the resultant deconfliction process. In addition to the technical aspects, key roles and responsibilities need further definition. This will be done through exploring community-agreed upon Cooperative Operating Practices (COPs) that include procedures and capabilities to aid in timely, strategic conflict identification and resolution to be developed during the evaluation.**

**As an initial step to the evaluation, the ETM research team at NASA Ames solicited industry feedback on various aspects of ETM operations from these subject matter experts. A virtual tabletop walkthrough session was held over a two-day period to follow a roadmap through the functional steps needed to build COPs, focusing on strategic conflict detection and resolution.**

**Overall, the ETM tabletop provided insights into how the community wanted to instantiate the generation and sharing of operational intent, detect strategic conflicts, and resolve those conflicts using a preliminary set of community-agreed upon COPs.**



***Keywords—Cooperative Operating Practices, COPs, Strategic Conflict Detection, Upper Class E Traffic Management, ETM***


## I. Introduction

In recent years, innovative companies have been developing and operating new types of groundbreaking high-altitude, uncrewed vehicles, with a range of performance capabilities and varying mission profiles. In the stratospheric part of the national airspace system, new business opportunities are being considered that could significantly increase the traffic levels of this widely underutilized airspace [1]. As the market for High Altitude Platform Stations (HAPS) utilizing High Altitude Long Endurance (HALE) vehicles increases, so too will the need to accommodate these operations at scale. This ultra-high-altitude airspace in the United States is known as Upper Class E (UCE), encompassing 60,000 ft and above. Currently, air traffic management services are fairly limited in this airspace and are typically used for military or state operations. Although there are some standards for radar and non-radar operations in UCE, the narrow provisions and highly regulated accessibility for civil aircraft operations, along with the potential for increased demand in this arena, have pushed the Federal Aviation Administration (FAA) to recognize the likely gap in traffic management capabilities. As such, the FAA, along with input from the National Aeronautics and Space Administration (NASA) and industry partners, published an initial Concept of Operations (ConOps) for Upper Class E Traffic Management (ETM) [2].

The initial ConOps for ETM utilizes the Unmanned Aircraft Systems Traffic Management (UTM) precedent of a "community-based, cooperative traffic management system where the operators are responsible for the coordination, execution, and management of operations, with rules of the road established by the FAA" [3]. It is anticipated that the foundation of UTM's [4] principal framework, elements, concept development, and system architecture could be adopted for ETM. In the context of ETM, however, the diversity of vehicles with a wide range of performance characteristics (speeds and maneuverability), the stratospheric airspace conditions which make communication, navigation, and surveillance challenging, the potential longevity of missions and assortment of operating modes (e.g., point-to-point, loitering patterns, or hovering) will all need to be incorporated into the concept. All these unique traits within ETM make it suitable for the further research and development needed to design a fair and equitable approach to cooperative and collaborative traffic management.

## II. Background: ETM Research

In support of the FAA's next iteration of the ConOps for ETM, NASA Ames Research Center has been investigating several technologies that will help enable industry to develop their own software and tools that can function in the ETM cooperative operating environment. An operational feasibility assessment was conducted at NASA Ames to instantiate an initial set of ETM services and ETM cooperative operating procedures [5]. The assessment helped to clarify the details of the primary actors within the ETM architecture as seen in Fig. 1: the ETM service supplier (ESS) and the ETM operator. ETM operator refers to the person responsible for the vehicle planning, and / or the remote-pilot-in-command (RPIC), or pilot-in-command (PIC) who is piloting / controlling the vehicle. In this generalized ETM system, cooperative operations are established through sharing of the operation plan / intent to an industry established service-oriented architecture (ESS) which ingests the operation plan / intent, looks for possible intent intersections and likelihood of vehicle-to-vehicle conflict, and facilitates the proper communication back to the operators.

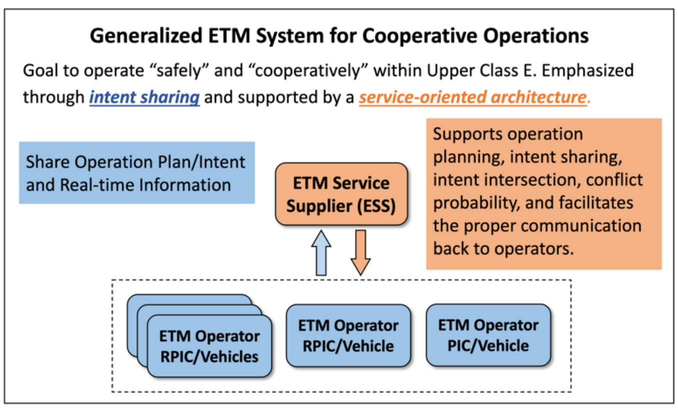


Fig. 1. Generalized ETM System.

Overall, the ETM concept assessment identified a key set of supporting enablers, including sharing flight intent attributes, a conflict detection capability based on the shared intent, an approach to evaluate the conflict severity in terms of risk, the ability to revise and update the flight intent (*rolling window* approach), and a conformance monitoring functionality to ensure vehicles comply with their shared flight intent.

According to the ETM ConOps [1], cooperative operations are enabled by *sharing the operational intent (OI)* for common situational awareness. The OI is represented as four-dimensional (4D) information (latitude, longitude, altitude, and time) that is indicative of where the vehicle would be contained within a defined volume of time and space. However, *sharing of flight intent* for ETM vehicle types is very different than in other domains due to varying performance characteristics and mission needs. Compared to the trajectory-based vehicle operations and point-to-point missions in UTM operations, ETM slow HALE vehicles (balloons, airships, and slow fixed-wing) have little to no controllability to follow a predefined flight path with a high level of precision. In addition, their mission dependencies (e.g., length, flight mode, and battery lifecycle) can lead to vastly different OI shapes and sizes. These differences led to research in the development of OI generation for the diverse vehicle types in the ETM environment [6, 7].

Given the impact of potential long-duration missions and the different shape and size of OIs, the ETM industry requested that operators also share their known *level of confidence* to remain within their OI, which research has termed, the *Containment Confidence Level (CCL)* [6,8]. In order to maintain this level of confidence, operators would need to flexibly update their OI to support and maintain the integrity of the mission parameters. This method is referred to as the *rolling window* approach to OI update rates [5,6]. To moderate fair and equitable access in ETM, *conformance monitoring* will be used to ensure vehicles stay within their active 4D OI volume [8].

The notion of sharing OIs within the ETM system gives credence to the idea of cooperative separation practices. Cooperative separation management success is contingent on conflict notification done in a timely manner and is referred to as *strategic conflict detection*. If an OI intersection is detected, the parties involved must be notified in a timely manner and have information to assess the severity of conflict [7,8]. To resolve the OI intersection, *strategic conflict management (deconfliction)* would utilize industry-defined practices, herein referred to as *Cooperative Operating Practices (COPs).* In the context of this paper, the designation of COPs is a set of pre-agreed operating rules and procedures to maintain separation while promoting safety, cooperatively, fairly, and equitably.

## III. Tabletop Research Approach

Following a collaborative effort in recent years, baseline functional requirements have been laid out by NASA [8], FAA [9], and industry [10] for ETM cooperative operations. Some of these technologies are being prototyped at NASA Ames and will be tested in a collaborative evaluation of an initial ETM system in late 2023. The evaluation will concentrate on building out system technologies that will inform the industry partners regarding OI sharing, strategic conflict detection, and the resultant deconfliction process. In addition to the technical aspects, key roles and responsibilities will need to be defined. This will be done through exploring COPs that include procedures and capabilities that aid in the strategic conflict identification and resolution. Overall, the goal of the upcoming evaluation is for industry partners to improve access to UCE and operate within the ETM arena safely and cooperatively.

To provide knowledge of these supportive technologies to the industry and gain feedback from them to inform the ETM prototype system development, NASA conducted a virtual tabletop session with high-altitude vehicle and operations experts. Seven different industry partners were represented in the tabletop: one light-payload high-altitude balloon representative, two representatives who defined their vehicles as hybrid balloon / airship lighter-than-air vehicles, and four representatives of slow fixed-wing HALE solar-powered aircraft companies. The tabletop event was conducted over the course of two days, utilizing a 4-hour period each day. The tabletop team followed an agile and iterative research approach where feedback was collected quickly to help test, iterate, and adapt the concepts for the upcoming evaluation using the data collected herein. The remainder of this paper will focus on the tabletop objective and goals, followed by a knowledge elicitation roadmap to establish COPs for strategic conflict detection and resolution, the results of directed discussion questions and subjective written online questionnaires, and closing with the conclusion and next steps.

## IV. Tabletop Overview

### A. *Objective and Goal of the Tabletop*

The objective was to conduct a walkthrough of NASA-developed concepts and technologies to be used in the upcoming evaluation and to elicit industry expert opinions and professional experiences to help identify gaps and errors in our assumptions, practices, procedures, and technologies that might present barriers to a proper evaluation of the ETM concept. An additional objective was to make recommendations to facilitate the further identification and development of an initial set of COPs to support the integration of ETM.

The goal of the tabletop was to move the ETM community partners toward a consensus on functionalities developed for demonstrating the feasibility of cooperative operations using a prototype research ETM system in the upcoming evaluation. As described above in Fig. 1, the prototype research ETM system consists of an ETM Service Supplier (ESS) and an operator client that connects and communicates to the ESS. The functionalities included an OI generation service, algorithms for determining the CCL of OI volumes, strategic conflict detection of OI intersection, conflict assessment parameters, and the likelihood risk of vehicle-to-vehicle conflict, as well as an initial set of COPs introduced for strategic conflict management discussions.

### B. *Industry Role in the Tabletop*

Community partners were invited to participate as a representative of their vehicle type, not to necessarily share any business / mission insights. Participants were 1) told to assume *nominal* operating conditions within ETM when discussing each event, 2) asked to give honest opinions based on previous meeting, workshops, papers, operation experiences, and knowledge that they have acquired in the UCE domain space, 3) instructed to feel free to share conflicting points of view as that helps mold the whole process together and ensure that they are all on the same page, and 4) encouraged to utilize an open online questionnaire to share any further dialogue opportunities.

## V. Tabletop Procedures

The interactive sessions focused on the development of COPs regarding strategic conflict detection and resolution centering solely on uncrewed, slow, HALE aircraft (i.e., balloon, airship, and fixed-wing vehicle types). The first day included participant introductions, followed by an overview and descriptions of the background, lexicon, and overall goal of the event. The approach to this tabletop was to guide the participants along a path to understanding the ETM system research and development underway at NASA Ames and explain how the initial development and evaluation will be used to further define the concept and inform future evaluations.

The first discussion topic focused on the fundamental elements pertaining to the creation of operation plans and corresponding operational intents. An initial familiarization session was followed by an interactive discussion with valuable participant input. The first day concluded with the administration of an online questionnaire corresponding with the day’s discussions on operation plans and operational intents.

On day two, the second discussion topic was introduced, which focused on familiarization with strategic conflict detection research and a deep dive on the related topic of operational intent intersections and likelihood of conflict. The final topic of discussion was the notion of using COPs as part of the strategic management process through the resolution of strategic intent intersections. Both focus areas on the second day also concluded with a discussion session and administration of a corresponding online questionnaire.

## VI. Tabletop Training

To facilitate in-depth discussions and to be able to arrive at a consensus on each of the ETM system processes, a training session was given to cover each of the technical or procedural topics that the ETM team needed to gain insight on during the tabletop. Upon completion of the training, all participants were more familiar with the path to COPs for strategic conflict detection and resolution. The two-day tabletop was structured to focus on three main topics, or *rounds:*

- Round 1: Creation and Submission of the Operation Plan with Operational Intent
- Round 2: Strategic Conflict Detection
- Round 3: COPs for Strategic Deconfliction

The ETM system roadmap and corresponding functional steps (100, 110, 120, 130, and 140) included in each of the three rounds are shown in Fig. 2 and described in detail in the following sections.

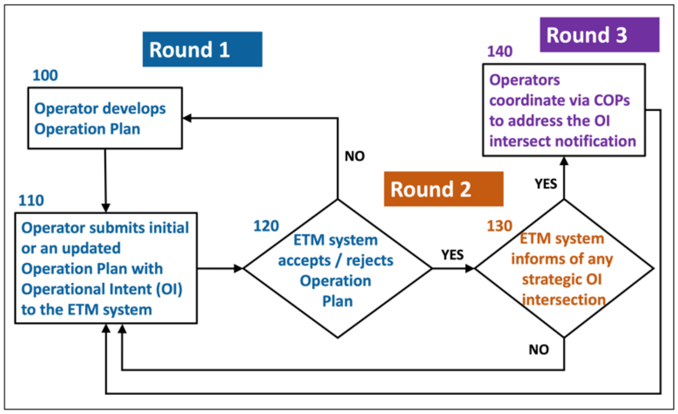


Fig. 2. Functional Steps of an ETM System Roadmap to Cooperative Operating Practices (COPs) for Strategic Conflict Detection and Resolution.

## A. *Round 1: Submit Operation Plan with Operational Intent*

### *1) Operator Develops Operation Plan (OP) [Step #100]*

The Operation Plan (OP) includes comprehensive operator, vehicle, and mission information, as well as OI, that the operator submits as required to inform the cooperative ETM system. The OI itself, as represented in Fig. 3, is comprised of the spatial (lateral and vertical aspects of the estimated trajectory) and temporal (duration of estimated trajectory) elements of a planned operation. The OI is indicative of where the vehicle would be flyin within and can be used to gain situation awareness of nearby operations and identify potential conflicts. The specific OI characteristics that were presented to participants included the required parameters to build each OI volume segment. The resulting 4D block of airspace, shared in a series of segments which represent full flight intent prediction over the next 'x-hours,' is referred to as the *time horizon*. The CCL represents the estimated value of how confident the operator is that the vehicle will stay in each volume.

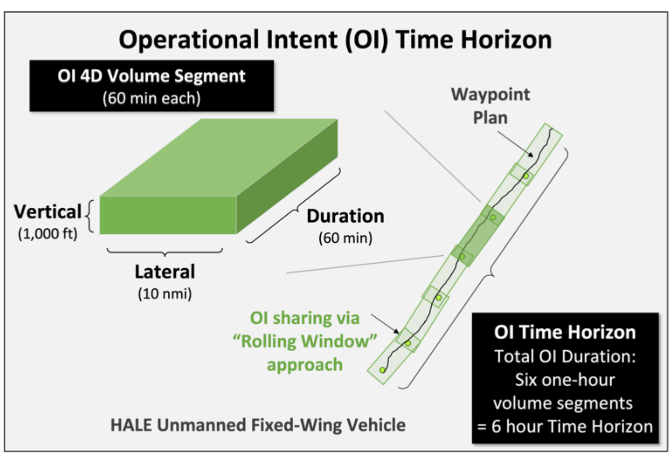


Fig. 3. Example OI Time Horizon with 4D Volume Segment.

### *2) Operator submits initial (or updated) OP with OI to the ETM system [Step #110]*

This step is where the concept of OI update rates or the *rolling window* approach to updates [5] was introduced; regular and frequent updates to the OI are important to ensure confidence in the operator's OI size and duration.

### *3) ETM System Accepts / Rejects Operation Plan [Step #120]*

This was the step that introduced and discussed the various ETM system responses once an operator has submitted their OP. The moderator focused on two responses, an *accepted* OP, indicating that the OI meets all the required formats to access and operate in the ETM environment (but is not yet active) and a *rejected* OP, indicating that something in the OP is not valid (i.e., wrong format or outside defined limits).

## B. *Round 2: Strategic Conflict Detection*

### *1) ETM System Informs of any Strategic OI Intersection [Step #130]*

This is the step where strategic conflict detection was introduced as being two or more OI volumes intersecting in time and space. When an OI intersection is detected, the ETM system would notify each operator of the intersection in a timely manner, that is, with enough time to negotiate and then take an action. During training, participants were shown how they might want to set *alerting thresholds* that would notify them of strategic conflicts and discussed whether they should be individual or community-defined cooperative standards. As part of training, the moderator demonstrated how the OI characteristics that were introduced in *Round 1* might impact the OI intersect notification window; OI size, update cycle, and time horizon all play a role in the triggering of an OI intersect. Fig. 4 shows an example of an OI intersection.

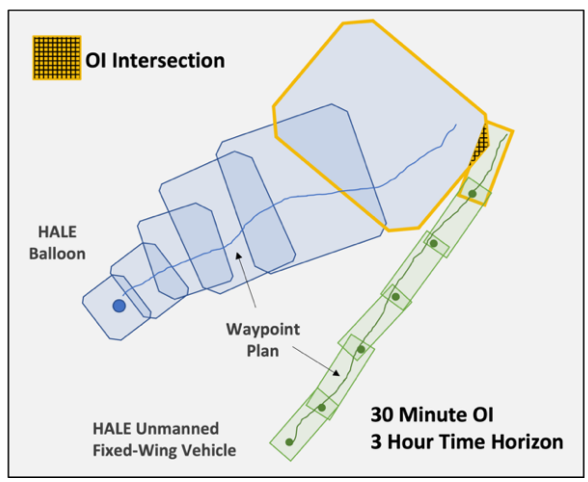


Fig. 4. Example of Operational Intent (OI) Intersect.

In *Round 2*, participants were introduced to the concept of Conflict Probability (CP), described as the likelihood of *vehicle conflict* based on predicted vehicle paths, which would be calculated independently from OI intersection. CP is a proximity estimate of actual vehicle separation using a *separation envelope* buffer. Separation envelope is defined as the minimum distance between predicted vehicle locations at which a conflict is triggered, as seen in Fig. 5. The CP algorithm uses the industry-provided waypoint plan (latitude, longitude, altitude, and speed) and trajectory performance characteristics (cross track error and along track error) as well wind forecast error [7]. As with OI intersect settings, CP alerting thresholds were discussed as to whether they should be individual, that is, based on each operator's own risk tolerances, or common, community-defined cooperative standards.

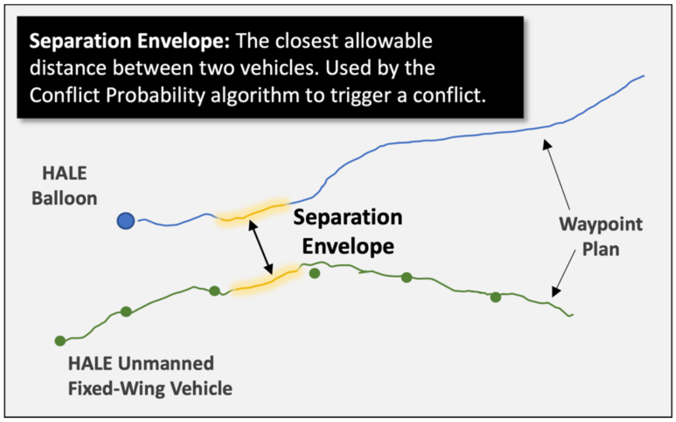


Fig. 5. Example of Separation Envelope.

After introducing both OI intersect and CP as possible strategic conflict notification triggers, considerations turned to how they would assess the situation and what factors they would like to know in order to come to a decision point about whether they will *wait-and-see* or *take-action* (i.e., enact COPs).

### C. *Round 3: COPs for Strategic Deconfliction*

#### *1) **Operators coordinate to address the conflict notification [Step #140]***

In this final step in the functional roadmap, the idea of predefined agreements to be used as COPs for strategic management of OI intersect was presented. It was presumed that, in ad-hoc negotiations, there are likely several similar methodologies that would be enacted over time. If this was indeed true, then the operator could turn similar methodologies into predefined agreements. This would allow operators to pre-select their preferred method prior to operations. The predefined agreements presented during the tabletop included the following strategies or actions for conflict resolution:

- a wait-and-watch strategy,
- the most performant operator moves,
- both operators move,
- vehicle-to-vehicle agreements,
- company-to-company agreements,
- shrink the OI for x amount of time, or
- stop and hover / loiter for x amount of time.

In addition, 'baseline' standard resolution options were considered, like *first-reserved-first served* or a *50 / 50 random choice* option.

## VII. Tabletop Questionnaire Results

Following the knowledge elicitation of each of the rounds, a series of directed research questions related to each topic were asked of the industry participants along with a follow-up online questionnaire. This section will highlight some of the questions with analogous data graphs, and corresponding verbal and written responses.

Many of the directed questions had to do with *standardization*. It seemed that to establish COPs for negotiation of strategic conflict detection, there would be a need for operators to have a common picture of the strategic conflict parameters. One of the ways to agree on a common picture would be to have a set of standards. While the research team believed that having a consensus on these standards would help build out the ETM cooperative operations and the evaluation methodology, industry participants had a different take on the initial instantiation of the COPs for ETM. Participants envisioned COPs to be more procedural in their initial practices rather than an agreement on a fixed set of standards. The detailed results are described in the following sections.

### A. *Round 1: Submit Operation Plan with Operational Intent*

#### *1) Should **lateral or vertical** OI volumes be **standardized** by vehicle type?*

Generation of OI and the corresponding characteristics seemed to be a critical part of the COPs for ETM cooperative operations. The research team was looking to get a consensus from industry on OI volume size restrictions that might be generalizable across vehicle types, so the vehicle experts were asked about standardizing the lateral and / or vertical aspects of the OI volume. Fig. 6 and Fig. 7 indicate a unanimous decision among all the participants that "no", OIs should not be standardized by vehicle type. Both written and verbal responses indicated that standardization reduces the flexibility, and the actual size depends on too many factors (i.e., type of platform, mission type (mode and duration), payload dependent, power and propulsion dependencies, surrounding traffic volumes (fleet operations), time of day, seasonal challenges, weather / environmental factors, and just basic laws of physics operating in the hard stratospheric conditions). Any standardization should come in the form of specific lookahead time horizons with level of confidence to stay within one's OI.

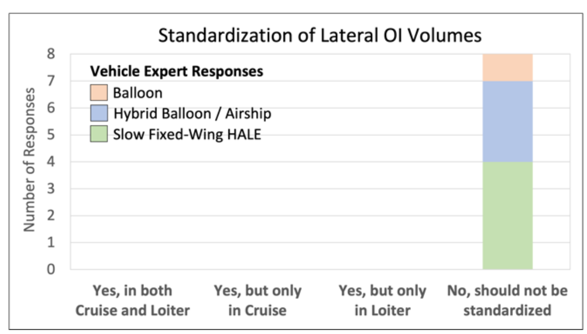


Fig. 6. Should *lateral* OI volumes be standardized by vehicle type?

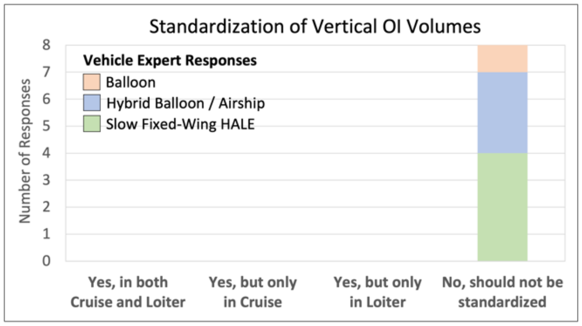


Fig. 7. Should *vertical* OI volumes be standardized by vehicle type?

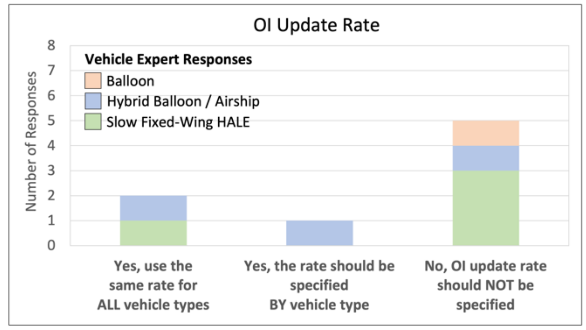


Fig. 8. Should OI update rate be specified?

*2) Should **OI update rate** be **specified**? And if so, how?*

The rate at which the operators would update their OI is important to ensure that as a community they would be agreeing to generate the smallest OI volumes in order to maintain a pre-determined level of conformance. Knowing that the *rolling window* approach to update rates has been proposed by industry [5,6,10], there was still a question as to whether that rate should be specified.

Fig. 8 indicates a split decision from the participants. The three participants who said yes, thought that standardization of OI update rate should be based on time horizons of their model forecast accuracy. The closer the time frame, the better the models are, and the faster the update rate can be. With a longer time-horizon, models are less accurate, so it does little good to update the future uncertainties. They also thought that a minimum update rate made more sense than a standardized rate and that it should be situational. A minimum base rate would provide big picture awareness (i.e., still active in the system). They also felt that a *rolling window* approach would increase the rate at which they update OI, based on conditions (i.e., conflict notification or within a higher density traffic area).

Participants who thought that OI update rate should *not* be standardized reported that update rate should be mission/phase of flight dependent. If the vehicle is stationary, there is no need to update often; if it is transiting and has a low confidence on position, then update more often. If more accurate data becomes available, then update so that OI is reflective of the most recent information. Another opinion was that the rate should be based on traffic density. If traffic density is higher, then update more frequently; if traffic density is lower, then update less frequently. An additional consideration was to update just enough to maintain proper lookahead time ensuring smallest OI with confidence to avoid conflicts.

*3) What is a <u>reasonable</u> **OI Time Horizon** for **<u>each vehicle type?</u>** Considering different factors that may impact OI Time Horizon, what do you think the **Minimum** OI lookahead **time horizon** should be? **Maximum**?*

For situational awareness purposes within the cooperative ETM environment, industry wanted to be able to show more than just the current active OI volume. Instead, they wanted to show a certain number of volumes over time, in order to show where vehicles anticipate being in the future. The ETM research team was looking to understand what a reasonable OI time horizon would be for each vehicle type. The consensus was that OI time horizon is dependent on vehicle control, that is, the less control, the shorter the lookahead time, the more control, the longer the lookahead time.

Participants liked the 'confidence' approach; that is, using a high confidence (>95%) until 'some' lookahead threshold, but operators can show lower confidence further out until the next threshold for situational awareness. Wind conditions and navigational goals are other dependencies that need to be considered. The ***minimum*** **lookahead time** horizon would be the actionable, strategic deconfliction window (time to negotiate and maneuver). Participants felt there was no need to worry about a *maximum* time horizon if filtering for (conflict) alerting can be set properly for all vehicle types. When asked to provide specific time values, the *maximum* time horizon (informational OI) was 2 to 24 hours, the *minimum* time horizon (conflict OI) ranged from 1 to 4 hours, with the consensus being 1–2 hours.

### *B. Round 2: Strategic Conflict Detection*

*1) Operators will be **notified of an OI volume intersection** when the <u>thresholds</u> for a set of **OI intersection related criteria** are met (e.g., Start / End Times of the OI volume intersection). Should the <u>thresholds</u> for **OI intersection related criteria** be **standardized**?*

To establish common assumptions for strategic conflict detection, industry was asked about the notification threshold settings and whether they should be standardized within the community. Fig. 9 indicates a split among vehicle types. The hybrid airship/balloon representatives did not think the thresholds needed to be standardized. They stated that if standardized thresholds were too conservative, it could increase the burden on the operators. They thought that there was too much variability in missions and vehicle types and that conflict detection criteria can be decided independently by operators, provided there is some standardization of the accuracy of OIs. There was a belief that standardization sets a path to setting possible airworthiness requirements and that would reduce flexibility for ETM.

The slow fixed-wing HALE operators thought that there *should* be a standardization of OI intersect criteria based on platforms that are operating. They stated that, if left to individual operators, an operator using a more risk-tolerant setting may *not* be notified of a strategic conflict, while another operator using a less risk-tolerant setting would be notified. Standardization would help mitigate this and help with the communication and fairness aspect.

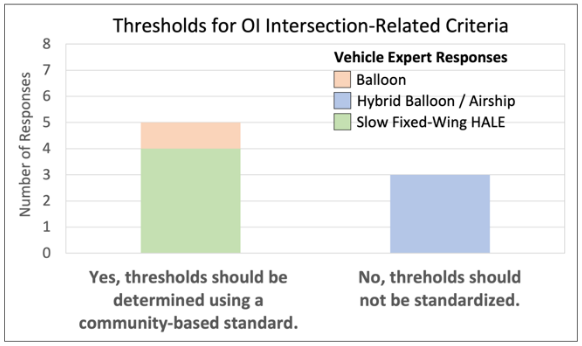


Fig. 9. Should the thresholds for OI Intersection-related criteria be standardized?

*2) When an **OI volume intersection** is detected between two vehicles, the ETM system will provide **OI intersection-related data elements.** Which **OI intersection-related data elements** would you find <u>useful</u> in deciding whether to **"wait-and-see"** or **initiate COPs for Strategic Deconfliction**?*

Visualizing and processing information required for the operators to reason about a strategic conflict is important to establishing COPs in order to deconflict. When assessing an OI intersect notification, participants thought the useful data elements would be the start / end time with geographic representation of intersecting OIs, as well as the CCL of the conflicting volumes. Vehicle type / class and mode of operation (transit, loiter, etc.) are needed, as well as, knowing performance / maneuvering capabilities to help identify which is the best vehicle to move in the circumstance presented. The specific wind source used by each operator was not deemed critical, but having awareness of other's OIs near the maneuver space was deemed important so that a move would not intersect with another operation.

*3) A **<u>conflict</u>** is identified when there is a high likelihood that a pair of aircraft will fly closer than their **separation envelope**. Should the **<u>separation envelope</u>** between **<u>vehicle pairs</u>** be based on a **common standard?***

When introducing conflict probability (CP) as the likelihood parameter as to whether two vehicle paths will be in conflict, further insight was needed from industry experts to determine if there needed to be a common standard regarding how far apart the vehicles should be to ensure safety. Fig. 10 indicates that most participants agree that the separation envelope between vehicle pairs should be based on a common standard. They cited that a standard separation distance is a well-understood practice in all aspects of aviation and that they did not feel confident that individual operators would have enough knowledge of other platform types to make an informed decision. They also indicated that they thought the separation envelope should be based on a set of maneuver capabilities dependent on the category of vehicle. Participants indicated that the separation standard should consider any communication latency and position accuracy measurements, and that the separation envelope value should increase when there is an off-nominal situation.

The two participants who responded "no" to this question said the separation envelope should be determined by individual operators rather than a common standard. These respondents believe that they need the flexibility to adapt to different vehicle types, their characteristics, and mission goals, and that it would be challenging to create a standard that is optimal for all.

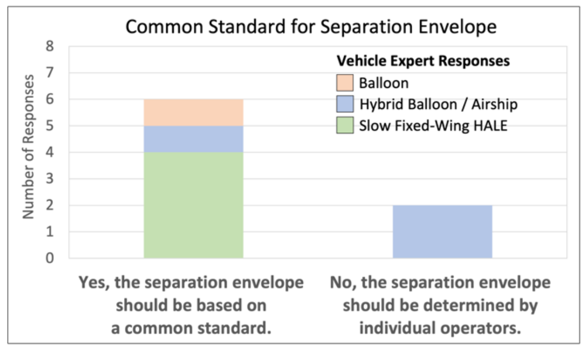


Fig. 10. Should the separation envelope between vehicle pairs be based on a *common standard*?

When asked to give a distance value for the *separation envelope* between vehicle pairs, participants responded with relatively short distances; for vehicles within the *same company*, 0–3 nautical miles (nmi) and for vehicles between *different companies*, 0–5 nmi. The zero values were from the hybrid balloon/airship representatives, making the point that it is virtually impossible to have those vehicle types come into conflict as they all float in the same wind field so they would not hit each other. Participants generally responded with very short distances for vehicles within the *same* company, suggesting that they expect to manage the separation of their vehicles within their own operations and do not want to receive conflict alerts between their own company vehicles.

The stated buffer between *different* companies is a bit larger, leaving room for some conflict notification and negotiation time. All in all, industry recognizes that the separation envelope buffer is a regulatory value that will be determined by the FAA. Understanding what separation envelope values the industry is thinking about, is insightful to the process. The small range is indicative of their slow speeds, as well as their willingness to fly close to each other, but also be collaborative and cooperative to ensure safety.

*4) Do you think / agree that an independent method of calculating the* ***conflict likelihood*** ***(Conflict Probablity-CP)*** *between a pair of aircraft is a good idea? Instead of or in addition to detecting OI intersect for* ***Strategic Conflict Detection****?*

In the ETM cooperative environment there is an open question as to how to pursue the triggering and notification of strategic conflict. Research [7] has been done looking at conflict risk based on vehicle path in addition to, or instead of, OI intersect. Participants generally agreed that CP could eventually replace OI, but in the first years of ETM operations, they wanted to provide OIs with >95% confidence – therefore, no OI intersect would mean no conflict. Factors that go into determining a safe separation envelope are complex and situation dependent. Some thought it would be difficult to communicate the detailed set of parameters needed to be able to build a model capable of calculating meaningful probabilities several hours ahead of time, and that they would need more data. When asked about sharing their vehicle performance data for the CP algorithm, they did not want to mix the airworthiness performance of the vehicle with the ability and willingness to maneuver (e.g., based on mission or battery dependencies).

### *C. Round 3: COPs for Strategic Deconfliction*

*1) Should* ***COPs pre-negotiated agreements for Strategic Deconfliction*** *be* ***standardized by vehicle pair? Same*** *between* ***all companies?***

Looking ahead into how negotiations would take place in ETM cooperative operations, the research team expected that similar maneuvers or negotiations would take place when a strategic conflict was detected between pairwise vehicles. Based on that expectation, researchers started to develop the notion of *pre-negotiated* COPs agreements.

However, discussions during the tabletop revealed that participants generally agreed that they did not want to start with pre-negotiated COPs. Instead, they preferred ad hoc style negotiations as they had yet to experience the process of negotiation in ETM operations. Fig. 11 and Fig. 12 show the same trend as other standardization questions, that is, a preference for *no* standardization between vehicle pairs or between companies. Respondents that were against standardized pre-negotiated agreements thought there were too many variables to give a single solution. They felt that performance differences between vehicles could make standardization ineffective – even in the same vehicle class. Their preference was to have each vehicle share a range of possible maneuvers. Potentially, an algorithm could figure out optimal maneuvers, that would be fair to each party. Lastly, some believed that there is no need for predefined agreements, as everyone should be participating collaboratively with each other, which should ensure that the system is safe and efficient for everyone. However, given the question, the two participants who answered "yes" (Fig. 11) said that a default set of strategic, predefined COPs *between vehicle pairs* would be good, but modifications should be allowed on *company-to-company* basis.

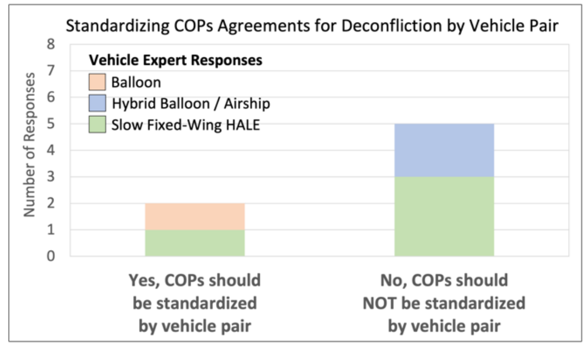


Fig. 11. Should COPs agreements for Strategic Deconfliction be standardized by vehicle pair?

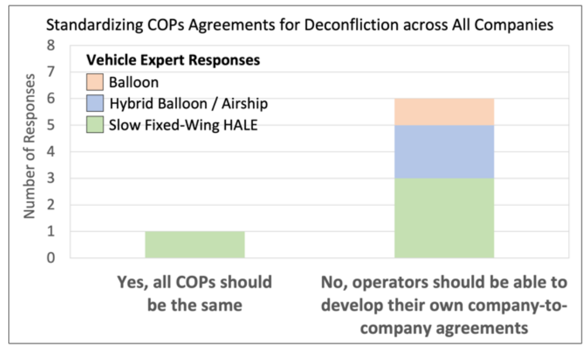


Fig. 12. Should COPs agreements for Strategic Deconfliction be the same across all companies?

*2) For each vehicle type below, please provide a list of possible* ***maneuvers / actions*** *that may be included in a* ***COPs pre-negotiated agreement*** *for responding to a Strategic Deconfliction issue.*

Although the participants did not concur about using COPs *pre-negotiated* agreements, they did agree on the kinds of maneuvers their vehicle would be capable of making, and those that they would be *willing* to make, when a strategic conflict was detected. Given the diverse performance and mission characteristics, it was an opportune time to learn about the various maneuver capabilities directly from the experts themselves.

*Balloon Maneuvers*: **Ascend, descend, temporary altitude hold, or terminate flight.** Depending on the technology deployed on the balloon, the fastest and simplest maneuver is to just cut down – that is, to create a hole in the balloon material – resulting in a rapid descent. Other options, which require more technology, are to hold altitude (float) or to control ascent or descent with ballast capabilities. A temporary (limited duration) altitude hold would be the most likely action for an operator to take. The action of holding altitude will significantly reduce the size of the very near-term OI.

Super-pressure balloons will always be able to ascend, but it may cost them position (i.e., desired operating location) and it will cost them the power needed to descend back down. Limited pressure or power could impede a balloon's ability to descend.

*Airship Maneuvers*: **Increase speed, decrease speed, change course, ascend, descend, or hold altitude.** Although airships do have some propulsion capability (used to alter heading or change airspeed), they can typically be treated as balloons. Maneuvering to change path or speed can be done, but the energy required to do so may make this difficult depending on environmental factors and mission cost effectiveness.

*Slow Fixed-Wing Maneuvers*: **Increase speed, decrease speed, change course, ascend, or descend.** Lateral movement is the primary choice with this vehicle type, although most maneuvers are feasible. Altitude changes are very time consuming and require as much notice as possible. If the vehicle is solar- / battery-powered only, the biggest limitation is time of day. Solar charging dictates flight path to maximize sun angle, that is, the vehicle cannot turn in a way that significantly reduces sun exposure and cannot climb at night.

## VIII. Conclusions from Tabletop

There were several main takeaways from each of the three rounds. Both the directed verbal discussions and the online questionnaire gave the industry participants a good opportunity to voice their opinions about how the first collaborative evaluation of an ETM system and COPs for strategic conflict management should be shepherded. The following highlights from each round will be considered within the development of the NASA research ETM system prototype, as well as, in the process and procedures for establishing the roles and responsibilities of each entity.

### *A. Round 1: Submit Operation Plan with Operational Intent*

There was a consensus on OI volumes being generated based on vehicle performance, environmental factors, and mission needs; however, these factors are not something that could be standardized or shared with a common OI generation third-party service because needs change too quickly and mission flexibility must be key. Participants agreed that the OI should be the information vector that contains everything needed to identify strategic conflicts. Based on participant feedback, OIs are proposed in two stages:

1. Informational Volumes: In the first stage, *Informational volumes* provide situation awareness of the mission plan. They are designed to have a long duration, with low CCL, and no size constraint. In the event that an OI intersection is detected past the defined ***minimum* lookahead time** for conflict OI intersect notification threshold, no action would be taken. Informational volumes would have no set OI update rate, but participants agreed that a *minimum* update rate is needed (to serve as an "I am alive" indicator).
2. Conflict Intersect Volumes: In contrast, in the second stage, *Conflict Intersect volumes* will use a shorter duration with a higher CCL. Their time horizon will be based on the *minimum negotiation and maneuver time requirement* (***minimum* lookahead time)**. Thus, the OI volume should be the smallest size that the vehicle can conform to with a *high* CCL (95–99%). Because OI intersect detection is based on the *time horizon for negotiation and maneuver*, users agree to then update OI frequently, with the intent that frequent updates will strategically resolve most OI intersections.

### *B. Round 2: Strategic Conflict Detection*

During the tabletop, there was a consensus on COPs that the trigger for strategic conflict detection will be an *OI intersect* and that the ***minimum* lookahead time** – which includes the time for negotiation and the time to make a maneuver based on >95% CCL of position in OI – will be used as the trigger threshold. Participants expressed concern that *standardized* separation thresholds would be too conservative and they would, instead, prefer to set their own conflict alert notification thresholds, but did agree to some basic collaborative rules to form COPs (i.e., if one operator decides that they think an action should be taken, then both operators should engage).

A common wind source was not deemed critical to the strategic conflict detection process; their OI and CCL will be built from their best models and interpretations. Participants were interested in embedding the CP calculation within their OI. If the OIs reflect the best vehicle performance, environmental factors, and likelihood based on the separation envelope, then OI intersection and CP probabilities provide the same function. Participants also want to be able to fly much closer to each other by being collaborative, flexible, and open within the community.

### *C. Round 3: COPs for Strategic Deconfliction*

Based on the COPs discussed during the tabletop, participants thought there was potential in some *pre-negotiated* agreements, but that it was too soon to be sure. Rather, when a strategic conflict is detected, the consensus was to go through the *ad hoc, free negotiation* stage first and learn from the discussions in that process. Participant feedback indicated that they envisioned COPs to be more about procedures (e.g., both parties participate in a maneuver action, OI intersect enables free negotiation, or multiple operators in one area develop a set of COPs procedures amongst themselves) rather than requirements or standardization. Collectively, participants thought that it would be beneficial if they could become more comfortable with flying vehicles closer to one another and minimizing the separation envelope, thus, decreasing the incidence of conflict detection and the subsequent need for resolution. As a result, the administrative burden and cost to maneuver would be reduced and there would be less impact on the overall mission.

## IX. Next Steps Toward the Collabortive Evaluation

Overall, the ETM tabletop event provided great insight to the NASA research team by the industry partners and vice versa. The main goal of this tabletop was to drive the research and prototyping requirements to conduct a collaborative evaluation with a set of partners later this calendar year. With the data and insight gained over the two-day tabletop, the team will be ready and able to test and demonstrate an early reference ETM system that incorporates the current work with the community in designing COPs and evaluating strategic conflict detection between these highly diverse vehicle types.

Based on feedback from the tabletop, further research opportunities may include explicitly looking to define the ***minimum*** **lookahead time** (the time to negotiate and the time to make a maneuver) for each vehicle type. Development of an algorithm to help negotiate and / or decide who should make the maneuver to deconflict and what type of maneuver that should be. Also, look into the addition of an auditing service to ensure that users properly and accurately share OIs that their vehicle can, indeed, conform to at a 95% or greater level of confidence. Finally, participants requested extra testing and technical exchange regarding assessing the conflict probability / likelihood calculations, which will be included during the collaborative evaluation in late 2023.

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