

AIAA Aviation Forum, June 8th - 12th , 2026, San Diego, CA

Coordinating the Sky Above:

NASA's Development and Evaluation of a Cooperative Higher Airspace Traffic Management (HATM) Concept

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Presentation Outline

- **HATM Background**

- Concept, motivation, and evolution
- Overview of NASA's HATM Effort
- Concept architecture and focus areas

- **Collaborative Evaluations: 1(CE-1) and follow-on 1.5 (CE-1.5)**

- Purpose and key findings of CE1
- What changed, why it mattered, and how the simulation was enhanced for CE-1.5

- **Scenario Design & Test Environment**

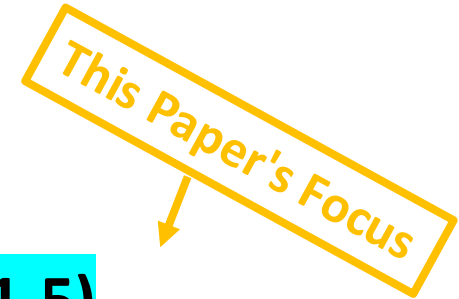
- Architecture, facility setup, and evaluated conditions

- **Results & Operator Insights**

- Partner feedback, and lessons learned

- **Summary & Next Steps**

- Key Takeaways
- FAA ConOps 2.0 alignment and research path toward CE-2.0

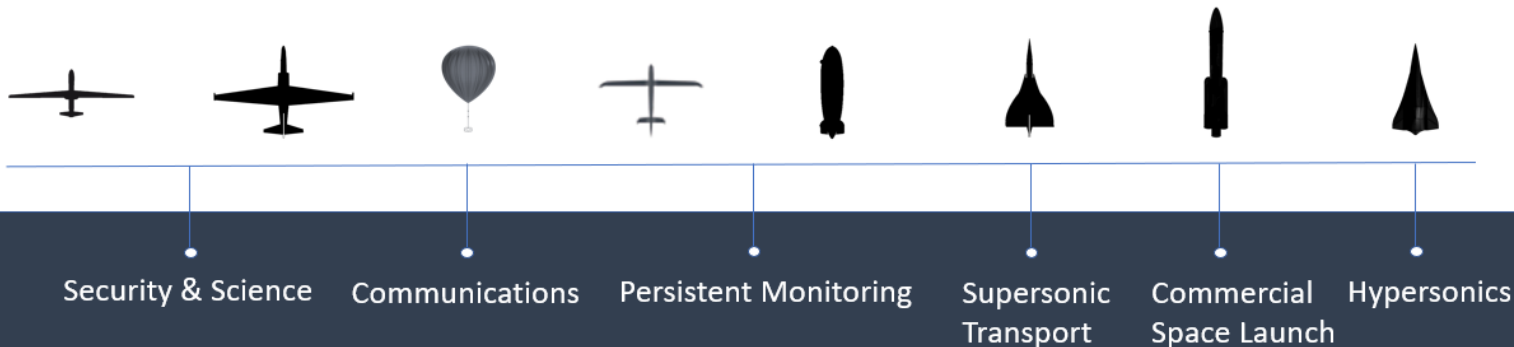


Higher Airspace Traffic Management (HATM) Concept

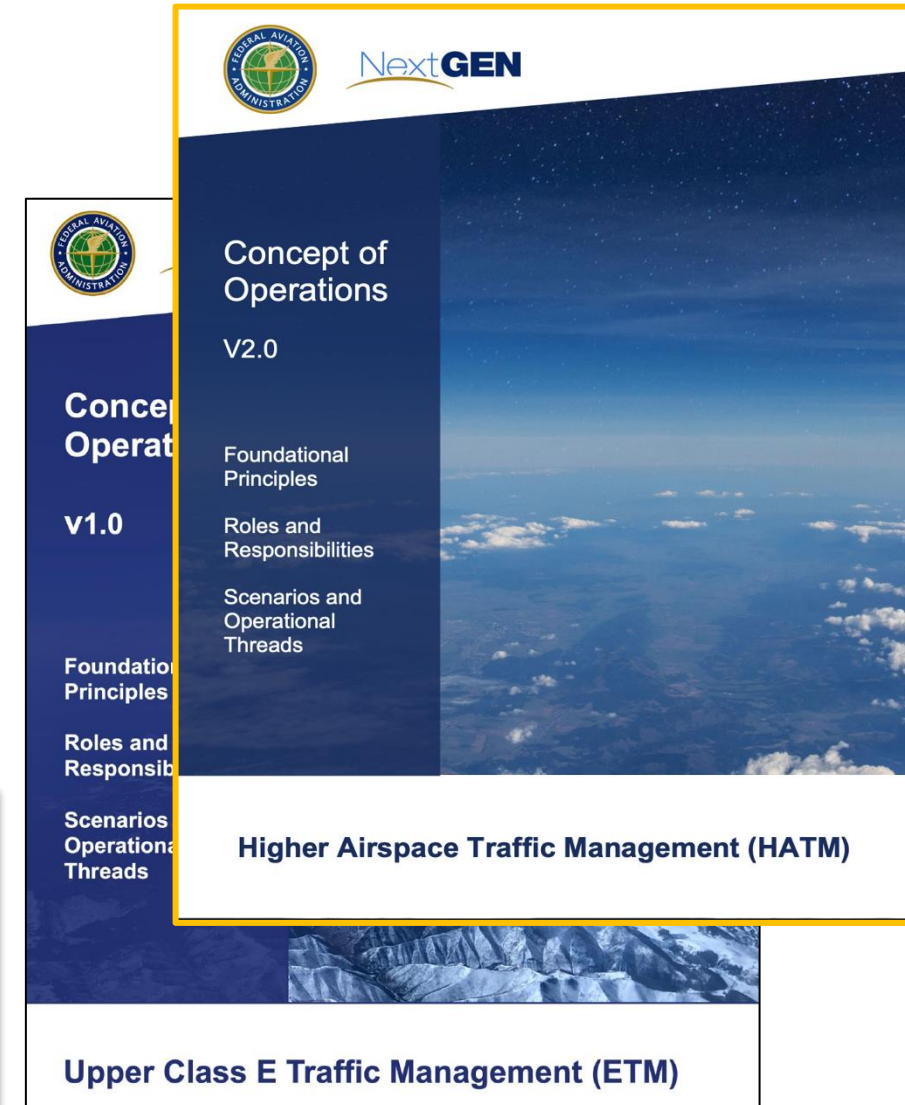
formerly known as Upper Class E Traffic Management (ETM)

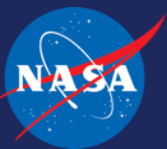
Concept of Operations- FAA/NASA/Industry

- Higher demand of civil operations +FL500
- Diverse vehicle entrants
- Unique mission types with extended duration
- Community-based, cooperative operations
- Operators share their Operational Intent
- Service Supplier automation supports planning, deconfliction, and conformance monitoring
- Flexibility for equitable competition



HATM ConOps v2.0 2025





HATM Collaboration between NASA, FAA, and Industry

HATM Development

*NASA / FAA / Industry Ongoing Collaboration

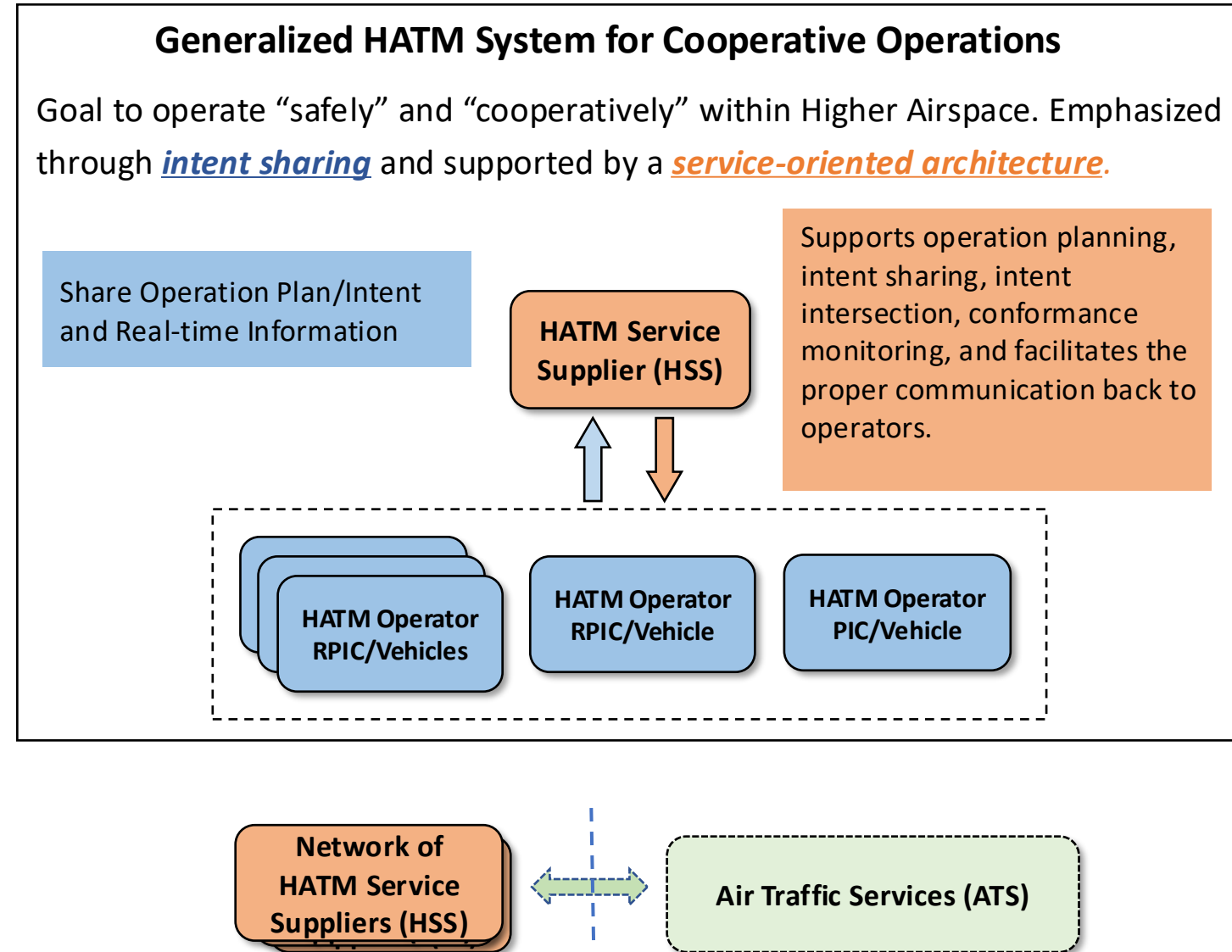
2019/2020	2021/2022	2023	2024	2025/2026
Tabletop #1 April 18–19, 2019 NASA Ames, CA	Workshop July 21–22, 2021 Virtual	Guided Discussion #2 January 10–11, 2023 Virtual	Guided Discussion #4 March 12–13, 2024 NASA Ames, CA	Collaborative Evaluation 1.5 July 29–30, 2025 NASA Ames, CA
<i>Initial Discussions with Industry Stakeholders and FAA on Operational Needs and Principles for a Cooperative Traffic Management Concept</i>	<i>Informational Briefings on ETM Concept Development and Breakout Groups for Operators to Discuss Interactions with Each Other in HATM Environment</i>	<i>Working Session with Industry Stakeholders Focusing on COPs Development for Strategic Conflict Detection</i>	<i>Working Session with Industry Stakeholders Focusing on Operational Intent Sharing</i>	<i>Invite additional HATM community partners to connect to a prototype NASA research HATM System and refine the Operational Intent and Strategic Conflict Negotiation</i>
Tabletop #2 December 12–13, 2019 NASA Ames, CA	Guided Discussion #1 August 10–11, 2022 Washington, DC	Guided Discussion #3 August 9–10, 2023 NASA Ames, CA	Collaborative Evaluation 1.0 June 25–27, 2024 NASA Ames, CA	Concept of Operations V2.0 FAA December 2025
<i>Concept Development Focusing on Upper Class E Operator Interactions with Air Traffic Control</i>	<i>Working Session with Industry Stakeholders to Develop an Initial Set of Cooperative Operating Practices (COPs)</i>	<i>Working Session with Industry Stakeholders to Continue COPs Development</i>	<i>Invite ETM community partners to collaboratively evaluate COPs and connect to a prototype NASA research ETM System</i>	<i>HATM ConOps further matures the operating environments and progression of Cooperative Operating Practices among Operators</i>
Concept of Operations V1.0 FAA May 2020	<i>Ongoing Software System Development and Hardware Design Work for Prototype Higher Airspace Research Evaluation Platform</i>		COPs Review from CE-1 Industry-FAA Sept/Dec 2024	Workshop April 8-9, 2026 NASA Ames, CA
<i>ETM construct must: Scale beyond current NAS infrastructure and promote shared situation awareness among Operators</i>			<i>Series of CE-1 Data output overviews presented to Industry and FAA.</i>	<i>Informational Briefings on HATM Concept Development and additional discussions on next steps in concept progression</i>

* NASA continues to lead quarterly meetings with Industry and FAA to stay connected with latest developments



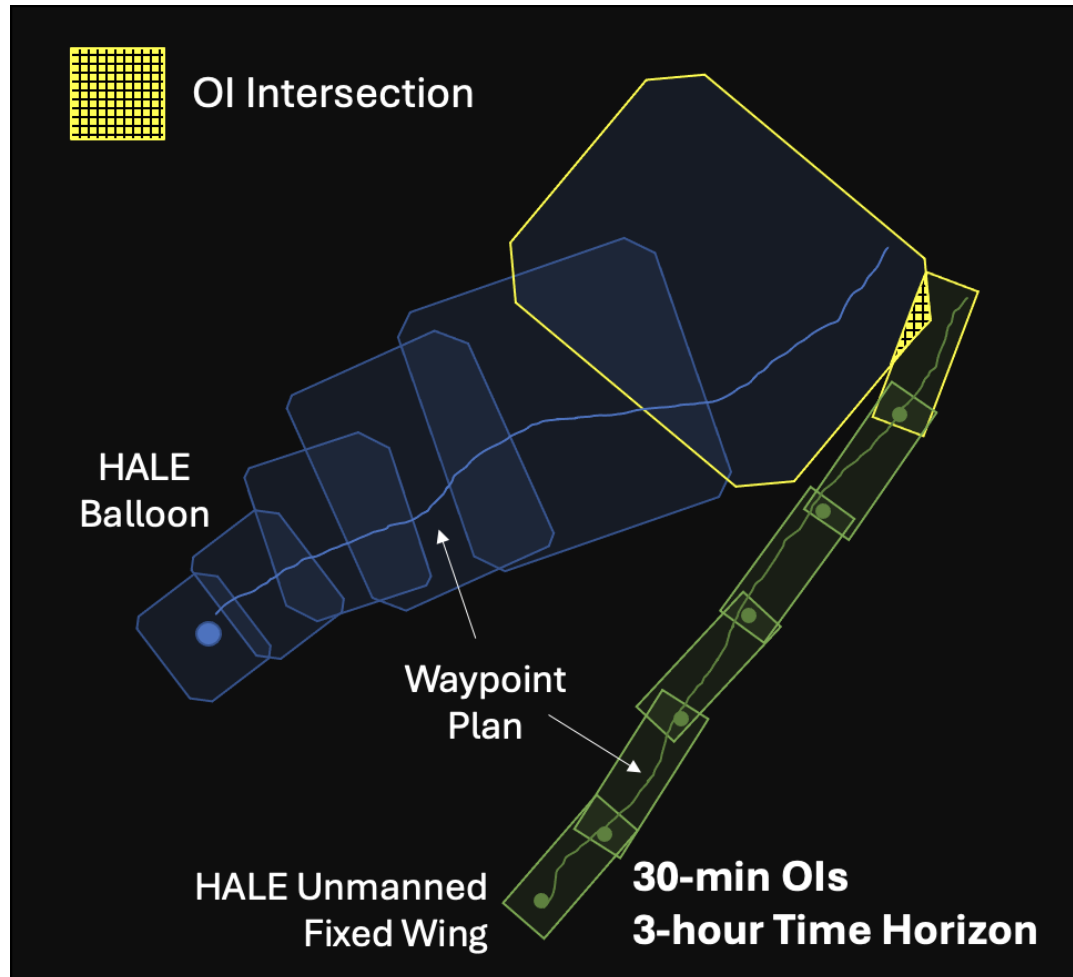
HATM Conceptual Architecture - Simplified

- Automated information exchange infrastructure
 - HATM operators will use a set of tools, automation, and services to support cooperative operations
 - Ensuring cooperative Situation Awareness
 - **HATM Service Supplier (HSS)**
 - An operator tool that supports operations planning, intent sharing, coordinating, monitoring and de-confliction protocols.
- ↕
- Utilizing HSS(s) to share information not only to connect operators but to potentially facilitate information exchange between HATM and ATS.





HATM Concept – Operational Intent (OI) Sharing



- **Operational Intent (OI) Volumes**

- 4D representations of the vehicle's intended flight path
- OI volumes are sized based on the conformance confidence of the vehicle to stay within the OI volumes
- OI volumes are assumed to have taken the wind predictions into account
- OI volumes may grow in size with higher uncertainty in the intent prediction

- OI sharing is the fundamental basis for HATM operations

- Vehicles are expected to share their OIs with others in HATM environment
- Vehicles are expected to stay within their OIs in the shorter time horizon (e.g. 1-2 hours)

- OI intersections can be used as a trigger for strategic conflict detection, negotiation, and resolution, well in advance of potential safety issues

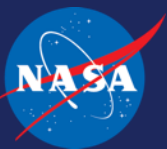


HATM Collaborative Evaluation Overview

NASA, FAA, and Industry Partnership
Pathway to Operational Validation

Initial Collaborative Evaluation (CE-1) 2024
&

Follow-up Collaborative Evaluation (CE-1.5) 2025



FY24 HATM Collaborative Evaluation (CE-1) Study

✓ *Successful demonstration of HATM service connectivity and operational viability*

- Participants from **NASA**, **Aerostar**, and **AeroVironment**
- Demonstrated connectivity between:
 - NASA developed **HATM Service Supplier (HSS)**
 - Industry partners' software development
- Build Cooperative Operating Practices (COPS):
 - Explore **notional procedures**
 - Define **information exchange requirements**



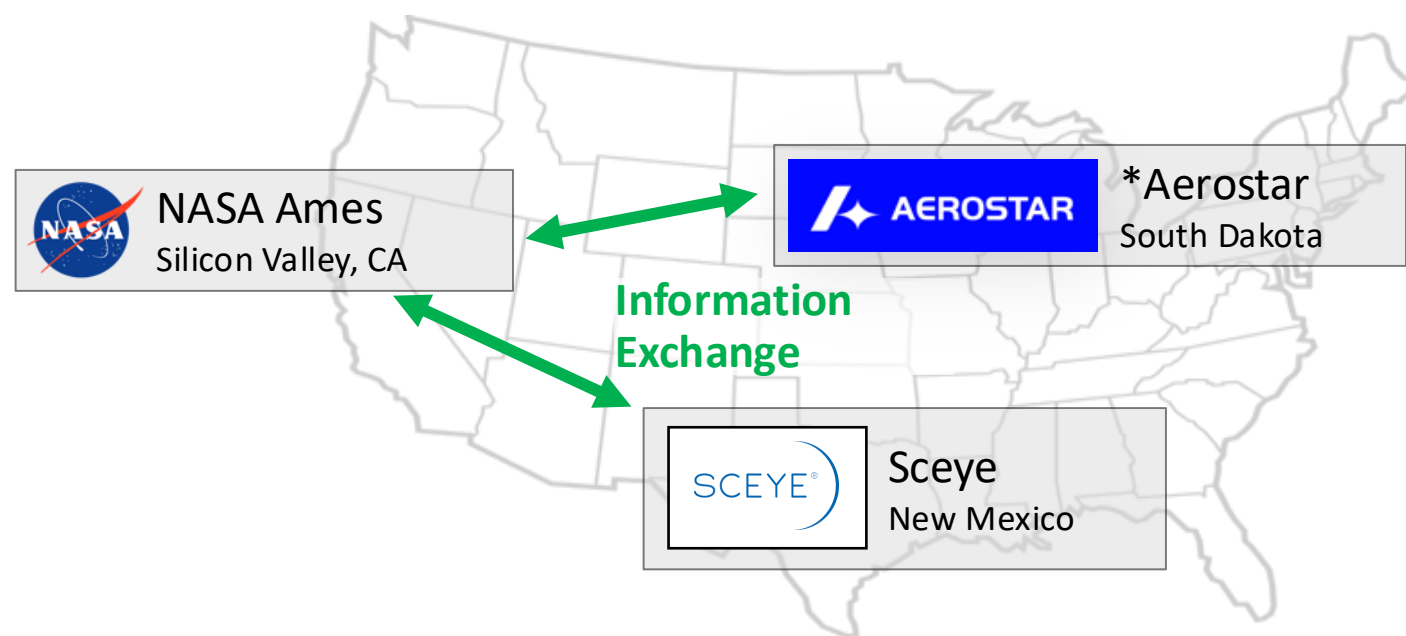
Airspace Operations Laboratory

The simulation was conducted at the Airspace Operations Laboratory at NASA's Ames Research Center in connection with the two partner sites on June 25th – 27th, 2024

Bakowski, D. L., Brasil, C. L., Lee, P. U., Dang-Gabriel, C. V., Garzon Galindo, K.-C., Evans, M., Tiwari, A., & Homola, J. (2025). Advancing the Upper Class E Traffic Management (ETM) Concept: Results of NASA's First ETM Collaborative Evaluation with Industry Partners. Proceedings of the AIAA AVIATION Forum, AIAA-2025-3167, Las Vegas, NV, July 21–25, 2025. <https://doi.org/10.2514/6.2025-3167>



Follow-Up FY25 Collaborative Evaluation (CE 1.5)



- The simulation being conducted at the Airspace Operations Laboratory at NASA's Ames Research Center in connection with the two partner sites on July 29th – 30th, 2025

***First-ever live flight data feed into the HATM environment--sharing OIs and telemetry from 65,000ft**



FY25 CE-1.5: Key Changes from FY24 CE-1

- **CE-1.5 Objectives and Enhancements**

- Onboard a new partner and expand operational diversity
- Address key observations and lessons learned from CE-1

- **Operational Intent (OI) Improvements**

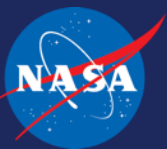
- Partners generated and submitted their own optimally designed OIs
- Improved OI volume sizing and update rates based on CE-1 lessons learned
- Enhanced OI sharing maturity across FY24 CE-1 participants

- **Operational Realism Enhancements**

- Reduced scripted interactions to promote organic coordination
- Utilized specific GFS wind forecast days to introduce realistic environmental variability
- Promoted operator-driven decision-making

- **Cooperative Operating Practices (COPs) Refinement**

- Operational Plan / OI sharing processes
- Strategic conflict negotiation and resolution procedures



Collaborative Evaluation 1.5 – Partners and Vehicle Types

AEROSTAR

March 24, 2025
World record 336 days
in the stratosphere



Stratospheric
Balloon

<https://aerostar.com/products/balloons-airships/thunderhead-balloons>

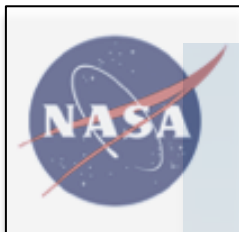


November 6, 2025
Wins NASA SBIR for
Earth Observations



Lighter-Than-Air (LTA)
HAPS

<https://sceye.com/platform/>



<https://www.nasa.gov/aeronautics/global-hawk-uas/>



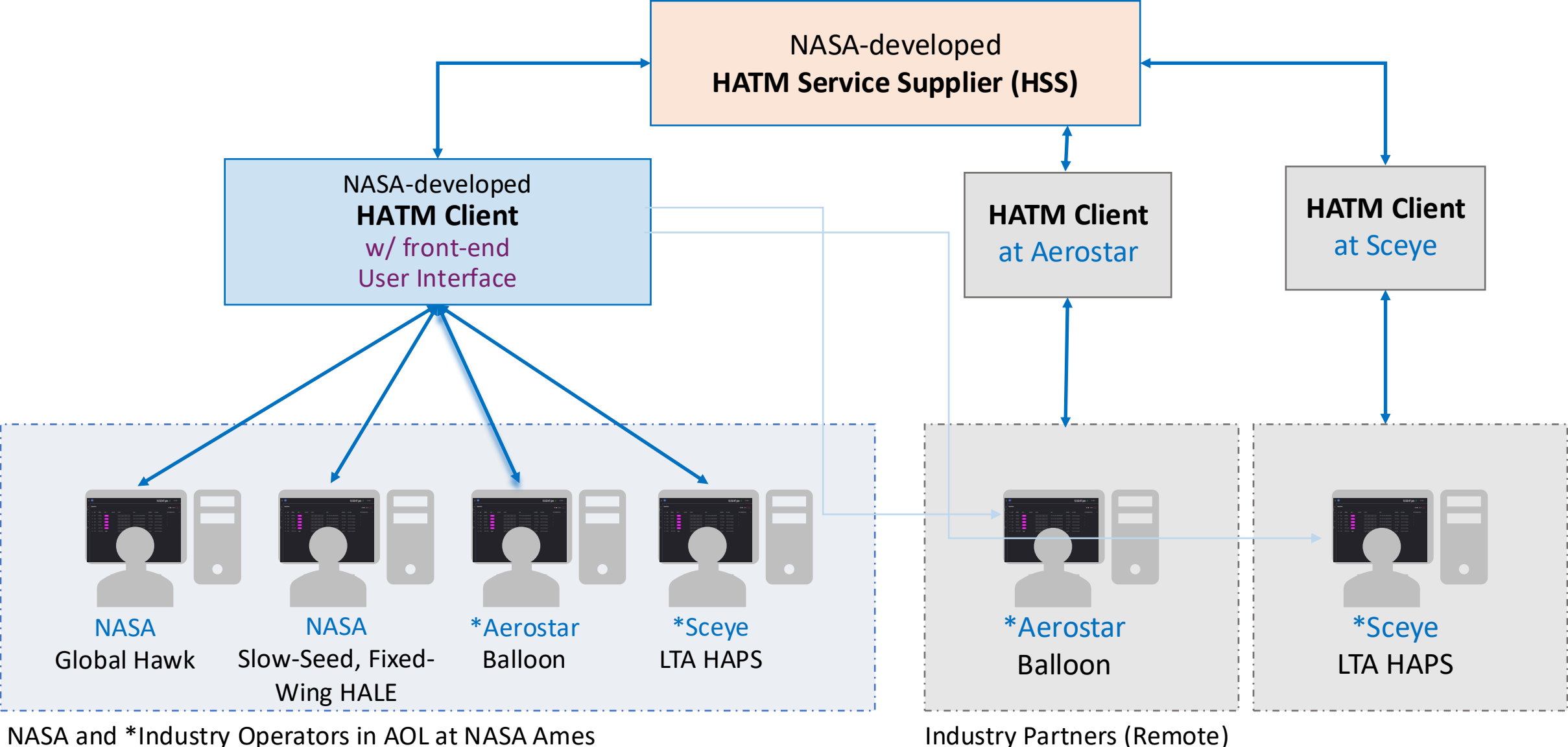
Slow-speed,
Fixed-Wing HALE

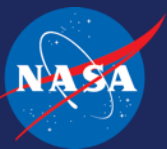


<https://www.avinc.com/macreedy-works/haps>



CE-1.5 Architecture: HATM Developed Software Tools





Visualization of Operational Intents on HATM Client

Global Hawk
(NASA generated)

Lighter-than-Air HAPS
(Sceye)

Slow-speed, fixed-wing HALE
(NASA generated)

40x40 nmi test area
approximates a
current-day, single
vehicle ALTRV

40 nmi

40 nmi

Balloon
(Aerostar)

Conflict Management Volumes

- 30-min volumes for 2 hours

Informational Volumes

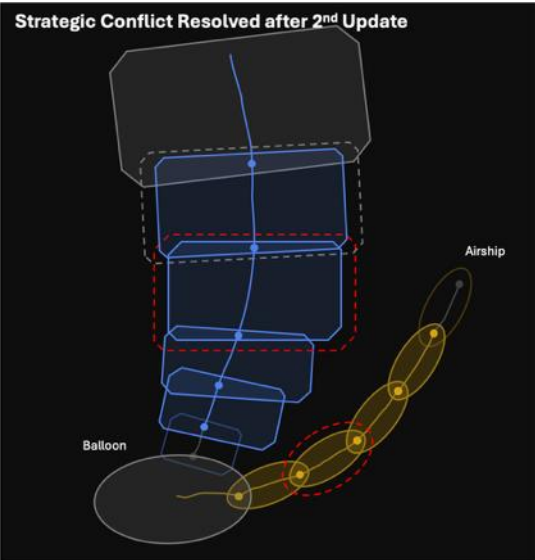
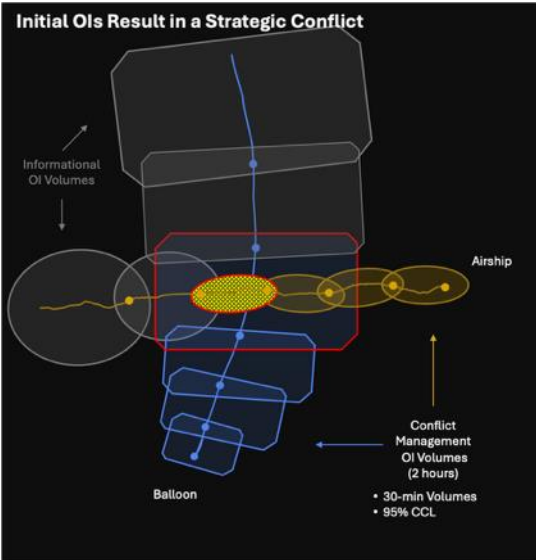
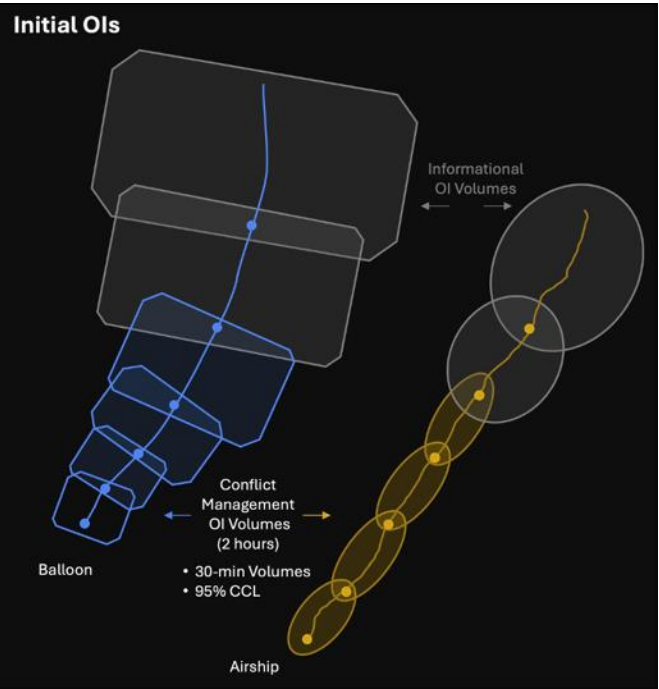
- Beyond 2 hours



CE-1.5 Scenarios

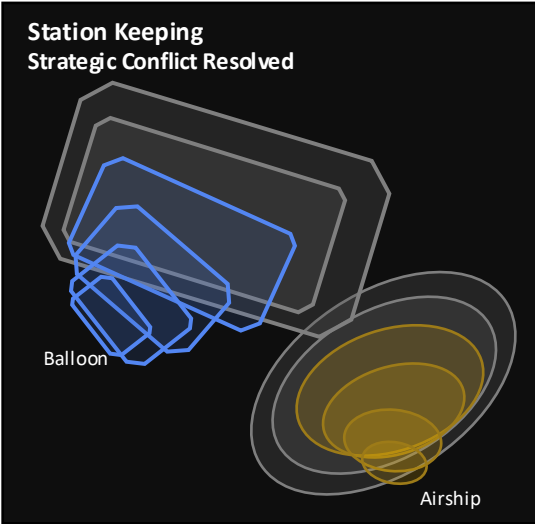
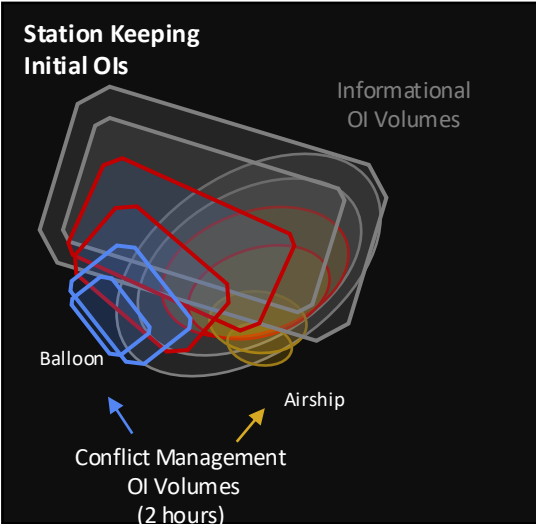
Scenario 1

OI Submission



Scenario 2A

***Strategic Conflict and Resolution:
Vehicles in Transit from A to B***

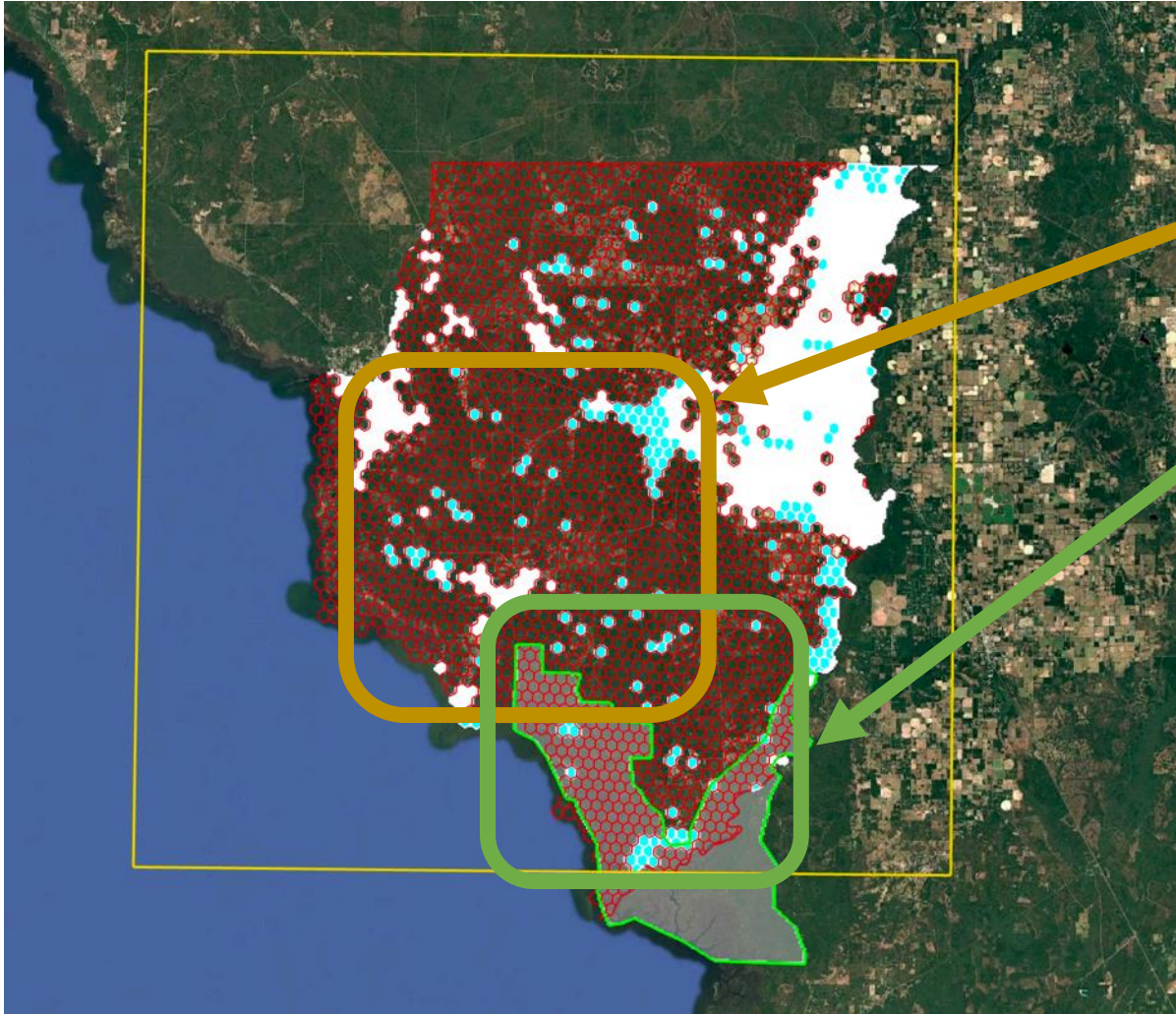


Scenario 2B

***Strategic Conflict and Resolution:
Station-Keeping Vehicles***



Mission Goals for Station Keeping Scenario



- Mission Goals
 - Provide internet in under-covered, remote areas
 - Provide aerial images of fire-risk areas
- Strategic deconfliction for station keeping scenario requires operators to consider their mission goals in defining their negotiation strategies.



HATM Collaborative Evaluation 1.5 Results

Evaluation Results and Operator Feedback



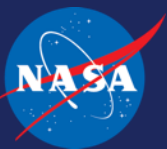
Collaborative Evaluation Research Metrics

- **Capacity / Efficiency**
 - Compared to current-day methods for handling uncrewed, high-altitude traffic (i.e., ALTRVs), can HATM *Cooperative Traffic Management* increase efficiency?
- **Airspace Access and Operational Safety**
 - Can *multiple* vehicles operate *safely* in the target airspace with no strategic conflicts?
 - Can *multiple* vehicles operate *safely* in the target airspace negotiating and resolving strategic conflicts?
- **Operations Plan and Operational Intent Sharing:**
 - Are the *OP/OI parameters* proposed in CE feasible and acceptable to the operators?
 - Are the *COPs procedures* identified for *OP/OI sharing* feasible and acceptable to the operators?
- **Strategic Conflict Negotiation and Resolution:**
 - Can the strategic conflict be *detected* with timeliness and confidence?
 - Can the strategic conflict be *communicated* and *negotiated* effectively with timeliness and confidence?
 - Can the strategic conflict be *resolved* safely, with timeliness and confidence?
 - What are the *maneuvers* or options to resolve strategic conflicts?

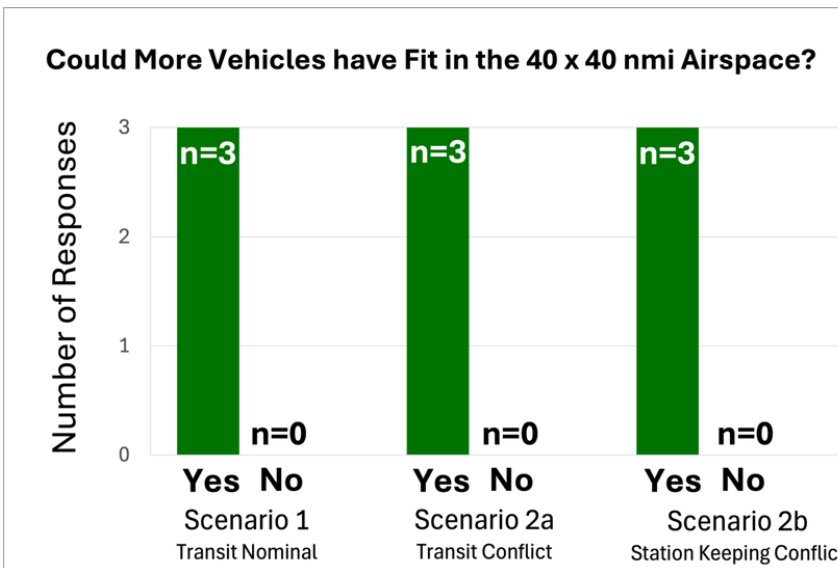
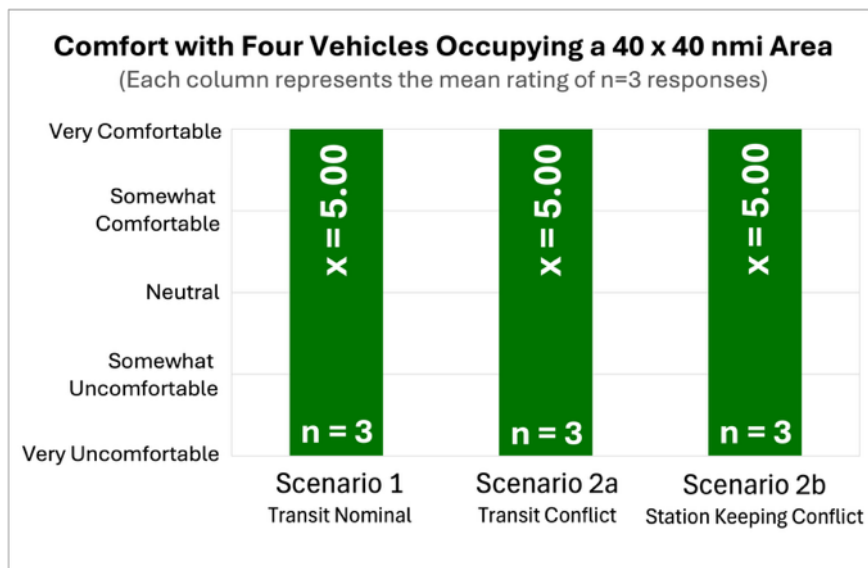
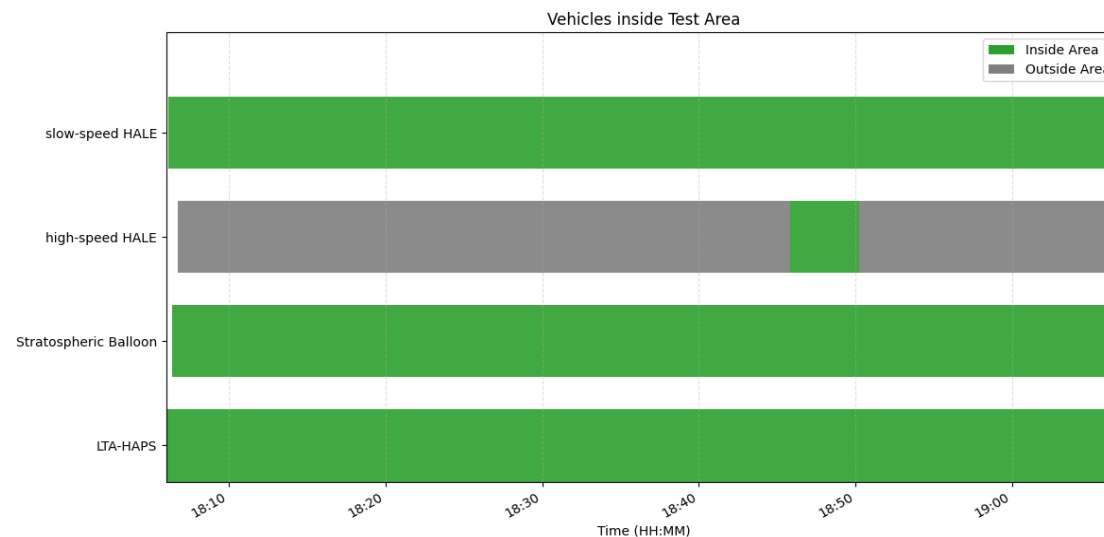
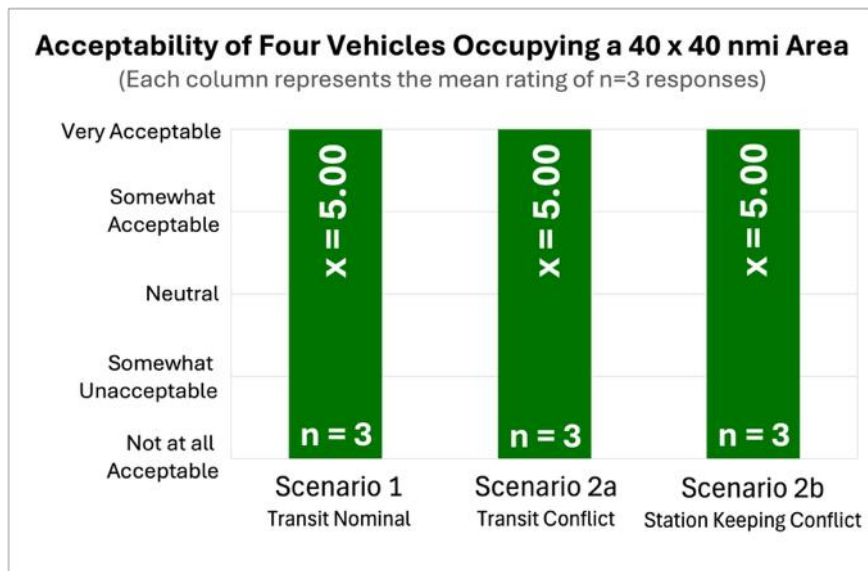


Results: Airspace Capacity / Access and Operational Safety

- **Multiple vehicles can safely co-exist within the target airspace.**
 - A greater number of vehicles is possible for balloons, LTA HAPS, and other slow-speed, low-closure-rate vehicle types with similar operating characteristics.
 - Vehicles can safely operate in close-proximity if they maintain relative spacing and update their positions frequently.
- **Airspace access during climb, descent, or transit from point A to B is not a concern** due to low traffic density during early HATM implementation.
- **Airspace access becomes challenging in station-keeping scenarios**, where multiple operators may compete for the same airspace and need mechanisms that allow extended co-location.
- **Enforcement and performance-monitoring mechanisms are needed** to ensure vehicles entering the HATM Cooperative Area meet required equipage and performance standards.



Results: Airspace Capacity / Access and Operational Safety



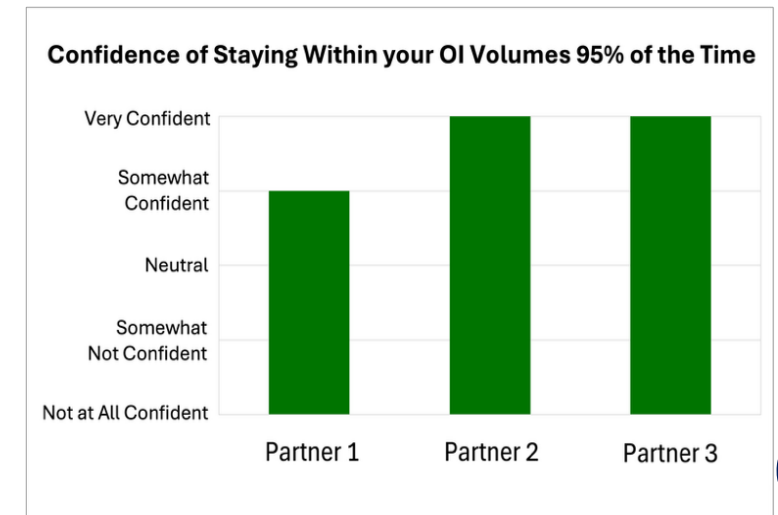
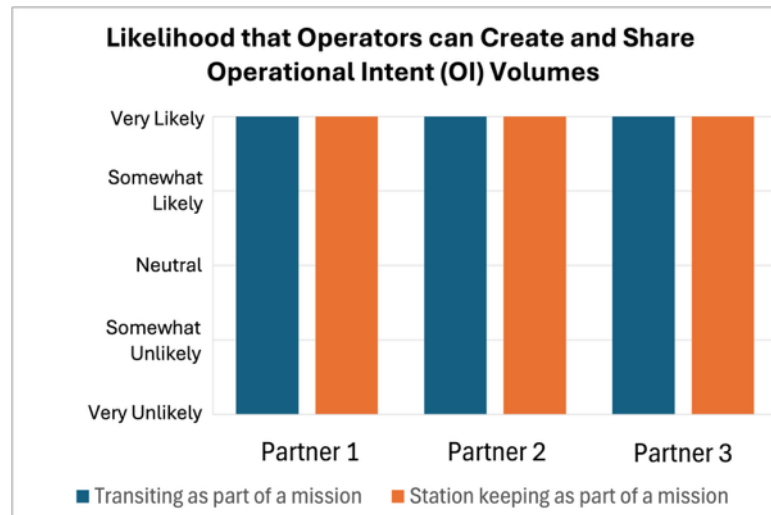
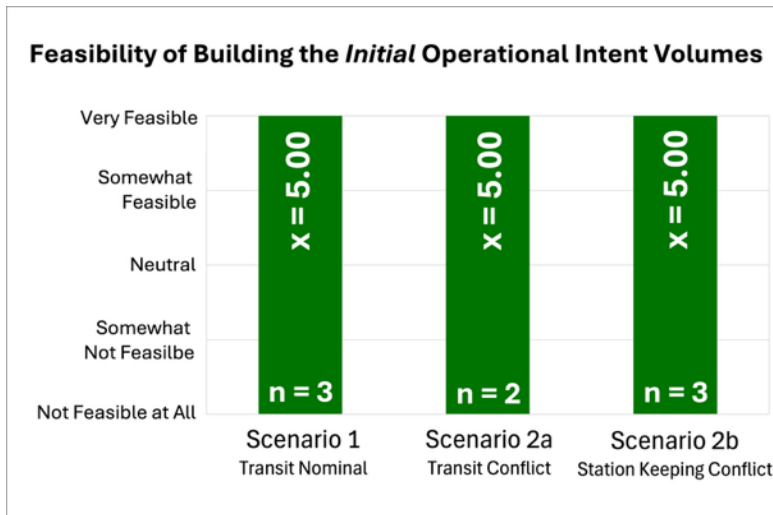
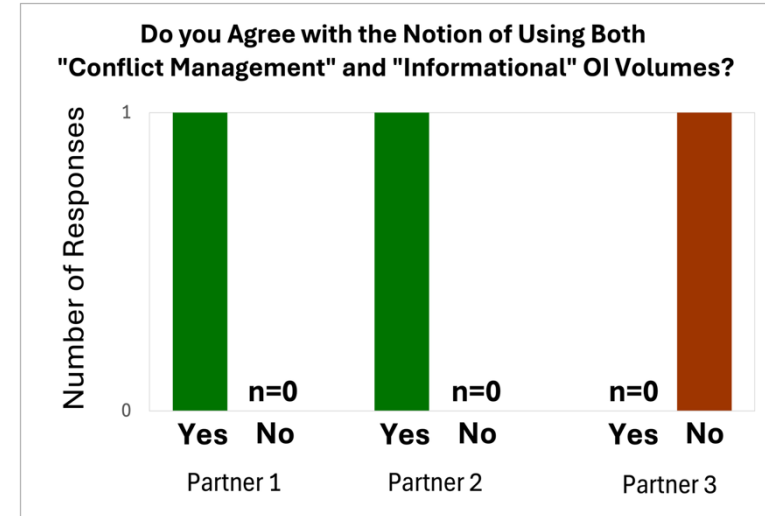
In simpler scenario, 4 or more vehicles could have fit (n=7).

In more complex scenario, 1-3 more vehicles could have fit (n=2)



Results: Operational Intent (OI) Volumes

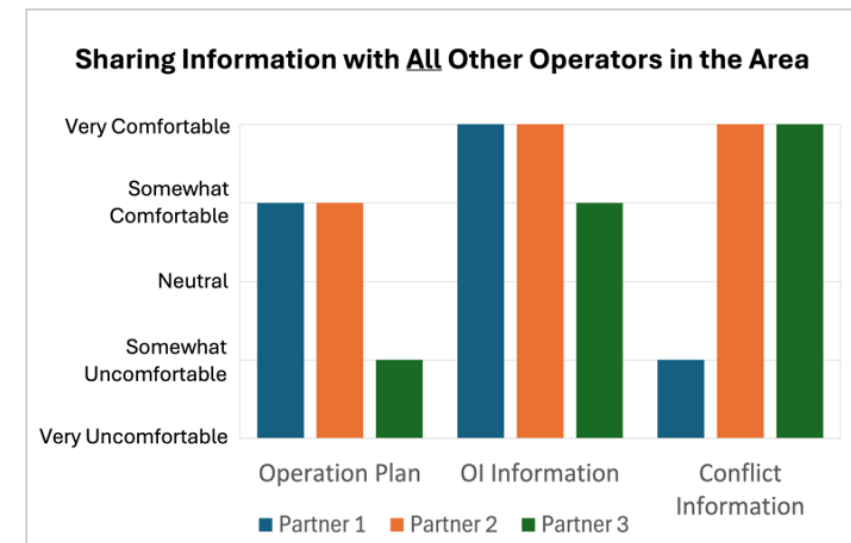
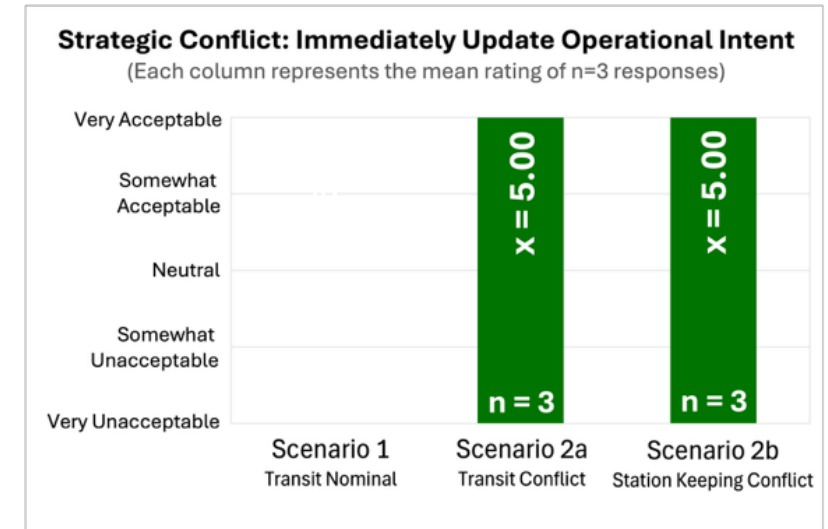
- Conflict Management and Informational OI concept was accepted by 2 of 3 partners
 - Dissenting participant thought that since the strategic conflict negotiation occurred within the Conflict Management OI timeframe, additional OI information beyond that was unnecessary.
 - Participants noted that the large OI volumes created visual clutter and simpler representation could convey the same information with less clutter (e.g. waypoint plan)
- Partners agreed that building the OI volumes was **Feasible**.
- They reported that they were **Very Likely** to be able to create and share OI volumes.
- They were also **Confident** that they could stay within their OI volumes.





Results: Strategic Conflict Detection and Initial Coordination

- Participants agreed that once a strategic conflict is detected, it should automatically trigger an immediate OI update.
- OI update should consist of more precise and accurate OI volumes to help eliminate the conflict.
- Information Sharing
 - There was concern that that providing highly detailed information could make some companies more exposed.
 - Noted the need to consider the "cost" (e.g., proprietary) vs. benefit of sharing information with other operators.





Results: Strategic Conflict Negotiation

- General consensus that the conflict negotiation should be done in two stages:
 - **Mission-Based**
 - The early stage should be very strategic, taking each company's business case into account and finding ways to accommodate one another to reach the fair resolution possible.
 - The strategic negotiation should rely less on detailed OIs and more on each operator's overall mission intent.
 - Negotiation should occur well in advance, i.e., 24 hours in advance.
 - Mission-based negotiation will be discussed further in next slide.
 - **OI Intersection-Based**
 - In response to OI intersections that trigger a strategic conflict alert, negotiation should determine when the action should be taken and how to share the responsibilities for the deconfliction maneuver.



Station Keeping Mission: Characteristics and Procedures

- **Mission-Based Negotiation Goals**

- OI-based negotiation can create inequities due to differences in maneuverability and prediction uncertainty.
- Mission-based negotiation allows flexibility by considering each operator's business case and customer needs.

- **Submission Timing**

- Should occur well in advance to support strategic planning (e.g., 24 hours).

- **Exchange Information Characteristics**

- Operators share the Area of Interest (AOI) for the mission time window.
- Overlapping AOIs form the basis for negotiating a fair resolution.
- Operators may adjust and resubmit missions to avoid overlap.

- *Mission-based negotiation needs further exploration*

FAA ConOps Cooperative Area (CA) practices may align with this negotiation approach



HATM Collaborative Evaluation 1.5 Conclusions

Summary and Key Takeaways
Next Steps



Summary and Key Takeaways

- **Cooperative operations increase safety, scalability, and airspace access**
 - HATM enables multiple high-altitude vehicles to safely co-exist through shared Operational Intent and community-based coordination over current-day ALTRV models.
- **Operational Intent (OI) sharing is foundational**
 - Conflict Management and Informational OIs support early conflict awareness, improved predictability, and operator-to-operator coordination.
- **CE-1 and CE-1.5 validated key HATM concepts**
 - Successful demonstrations showed real-time connectivity, OI exchange maturity, strategic conflict detection, and effective negotiation frameworks.
- **Strategic conflict resolution is feasible and practical**
 - Two-stage negotiation—mission-based and OI-intersection-based—supports both transit and station-keeping missions with diverse vehicle types.
- **HATM shows strong potential for future NAS integration**
 - Results highlight improved capacity, operational safety, and industry readiness for maturing Cooperative Operating Practices (COPs).



Next Steps Toward CE-2.0

- **Updated FAA HATM ConOps 2.0 released Dec 2025**
 - Introduced greater details on the role of Cooperative Area (CA) in flexibly providing higher airspace access to HATM vehicles
- **Future research needed for CE-2.0 (and beyond)**
 - Shift the research focus from strategic conflict negotiation within a CA using OI volumes, to Cooperative Operating airspace access negotiation between conflicting CAs
 - Need development of concept details, procedures, and tools, related to CA initiation, modification, termination, and negotiation, etc.

NASA /FAA / Industry **Guided Discussion #5** - Late Summer, 2026

*~Working Session with Industry Stakeholders Focusing on ConOps 2.0 –
Cooperative Area Operating Environment Applications*



Questions?

Thank you, from the award winning
HATM Team!! 🎉

CANSO Seamless Skies Awards, presented at Airspace World 2026

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NASA Wins "Seamless Skies for All"

Recognized for Pioneering Higher Airspace Traffic Management Work

~helping shape the rules of the road for an entirely new class of airspace operations



EXTRA SLIDES



CE-1 Demonstration / Evaluation – Key Outcomes

Successful demonstration of HATM service connectivity and operational viability

- **Capacity**

- Enabled increased vehicle density within 40 × 40-mile target airspace
- Demonstrated potential scalability beyond what is achievable under current procedures (i.e., ALTRVs)

- **Safety**

- Safe co-occupancy under nominal operations and strategic conflict scenarios
- Initiated a structured conflict management negotiation framework

- **Operational Intent (OI)**

- Both **Conflict Management** and **Informational OI** types were operationally acceptable
- Short-duration and frequently updated Conflict Management OIs (≈10 minutes) reduce conflict probability

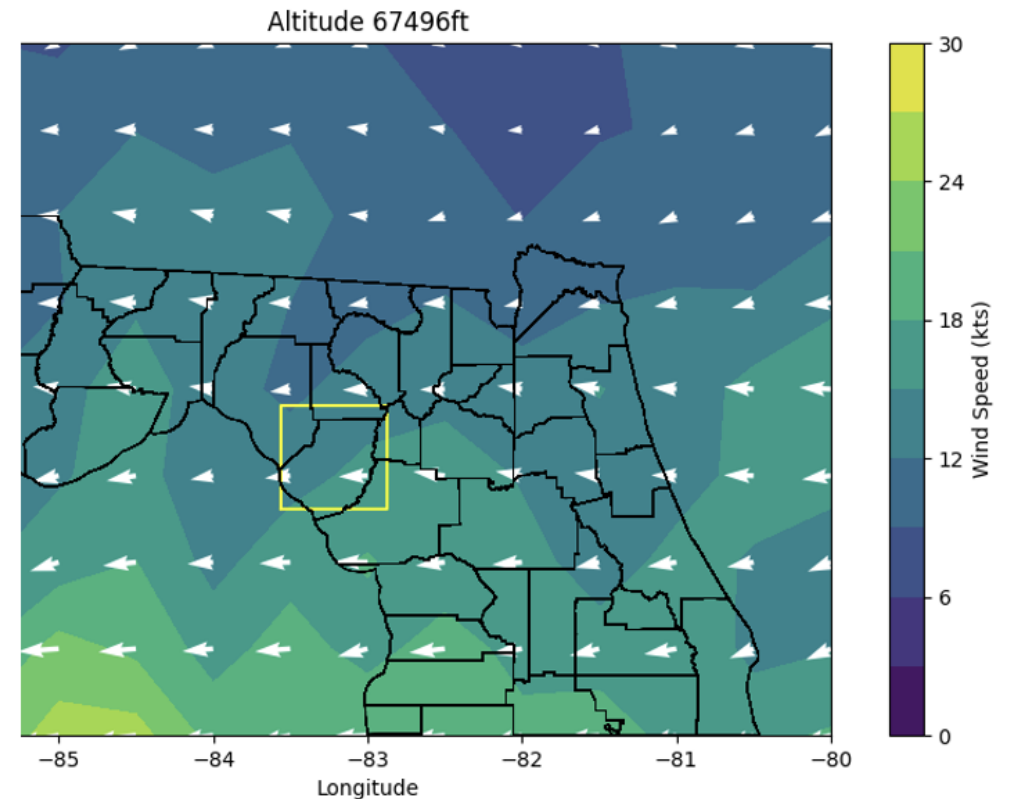
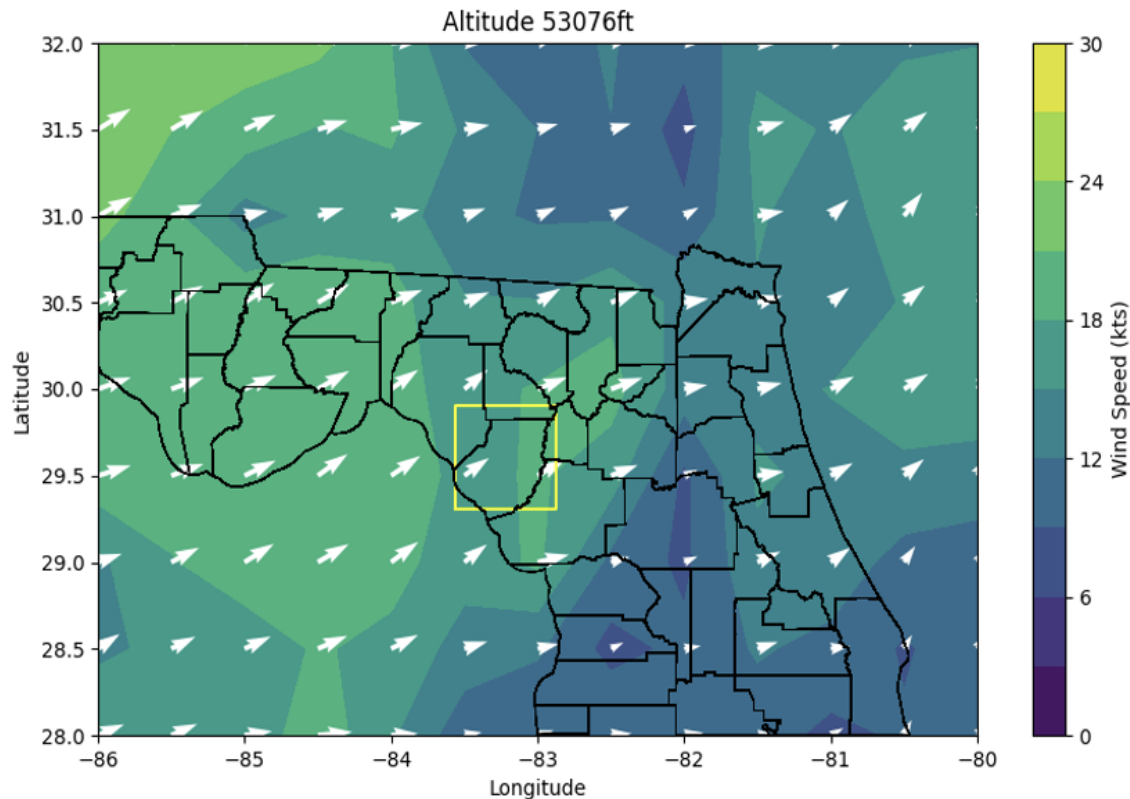
- **Conflict Detection, Negotiation & Resolution**

- Two-step negotiation approach recommended:
 - Early coordination between operators
 - Delay resolution execution until safely necessary



Wind Profiles for Station Keeping Scenario 2B

- All vehicles reference the same date/time for the wind profile (GFS, June 11, 2025).
- A mild wind profile at the target altitude (70-hPa ~60K feet) was selected for the station-keeping mission.
- Other altitudes exhibit stronger wind profiles, which would affect loitering capability and available conflict-management maneuvers.





NASA Wins "Seamless Skies for All"

NASA Wins "Seamless Skies for All" for Pioneering Higher Airspace Traffic Management Work

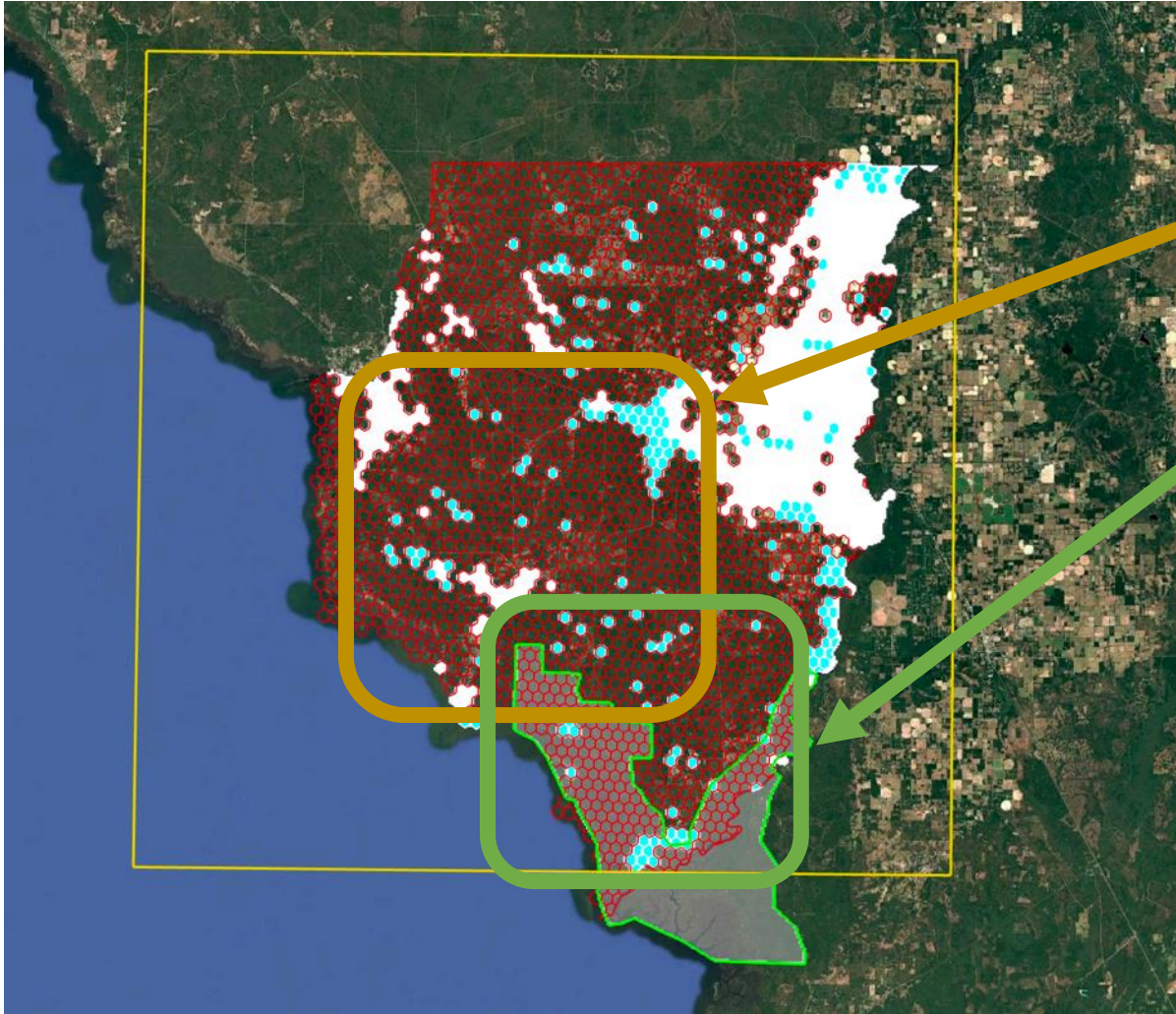
A July 2025 collaborative simulation — the first to incorporate live telemetry from a stratospheric vehicle in flight — helped shape the rules of the road for an entirely new class of airspace operations.

CANSO's Seamless Skies Awards, presented at Airspace World 2026

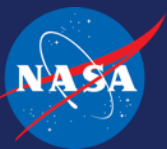
Recognized NASA's Air Traffic Management – eXploration (ATM-X) project, together with industry partners Aerostar and Sceye, with the award for Seamless Skies for All — honoring work that has delivered a measurable improvement to the optimization of airspace management performance.



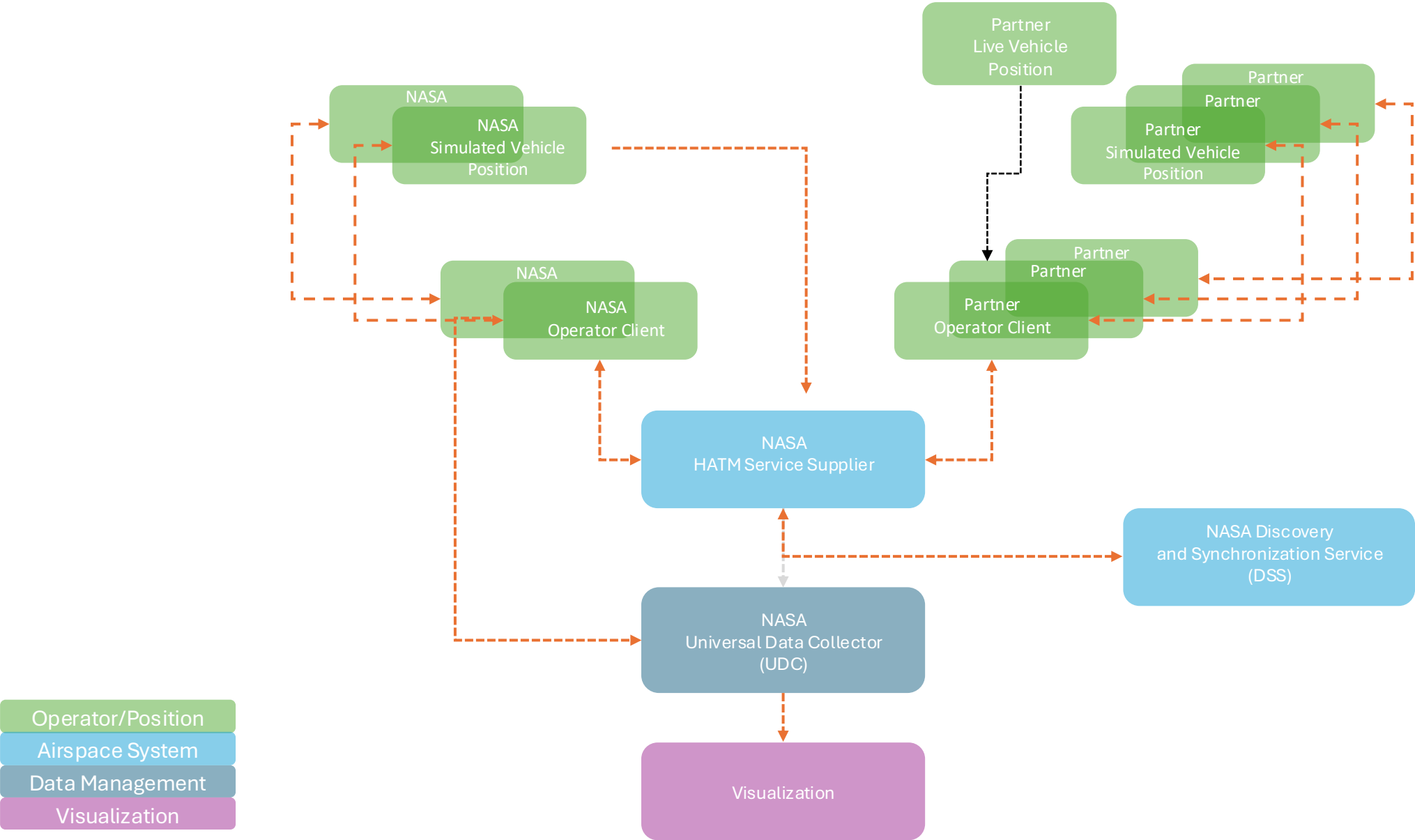
Next Steps: Example Scenario for CA Negotiations



- Mission Goals
 - Operator A – Solar Glider
 - Provide internet in under-covered, remote areas
 - Operator B – LTA HAPS
 - Provide aerial images of fire-risk areas
- Research Topics
 - How and when do Operations A and B declare their Operational / Cooperative Areas?
 - How and how often are they updated?
 - What happens when two CAs overlap?
 - How are they alerted and how do they negotiate and resolve the overlap?



HATM CE-1.5 System Architecture



Conflict Management and Informational OI Volumes

Operational Intent Volumes

COP

Conflict Management OI: To support prompt and accurate **Strategic Conflict Detection**, OI Volumes *within* the Minimum Lookahead Time Window are required to be:

- **Accurate**
- **Regularly** updated
- **95% or greater** Containment Confidence Level (CCL)
- Not be longer than **1-hour duration**, **10-30 min for CE1.5**
- Must assess Strategic Conflict and resolve if needed

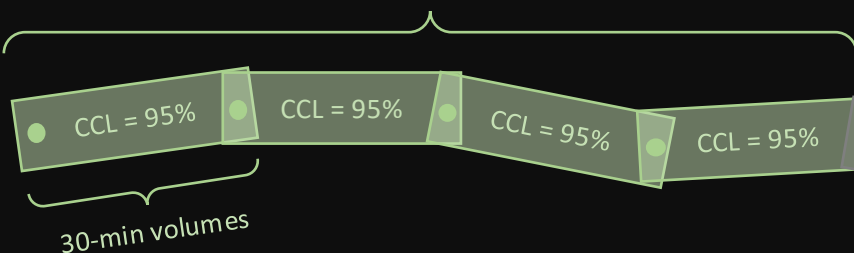
COP

Informational OI: Operational Intent Volumes *beyond* the Minimum Lookahead Time Window:

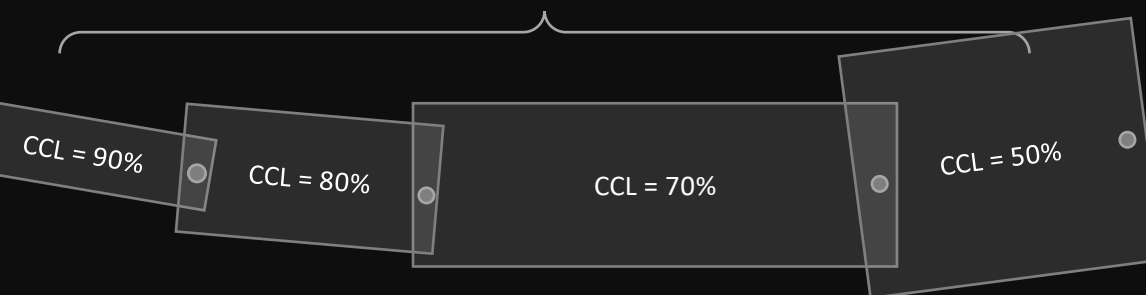
- Can be **larger in size**
- Can be **longer duration**
- Can be **less than 95%** Containment Confidence Level (CCL)
- No Strategic Conflict Resolution required

Minimum Lookahead Time Window

Conflict Management OI Volumes (in this example, *within* 2 hours)



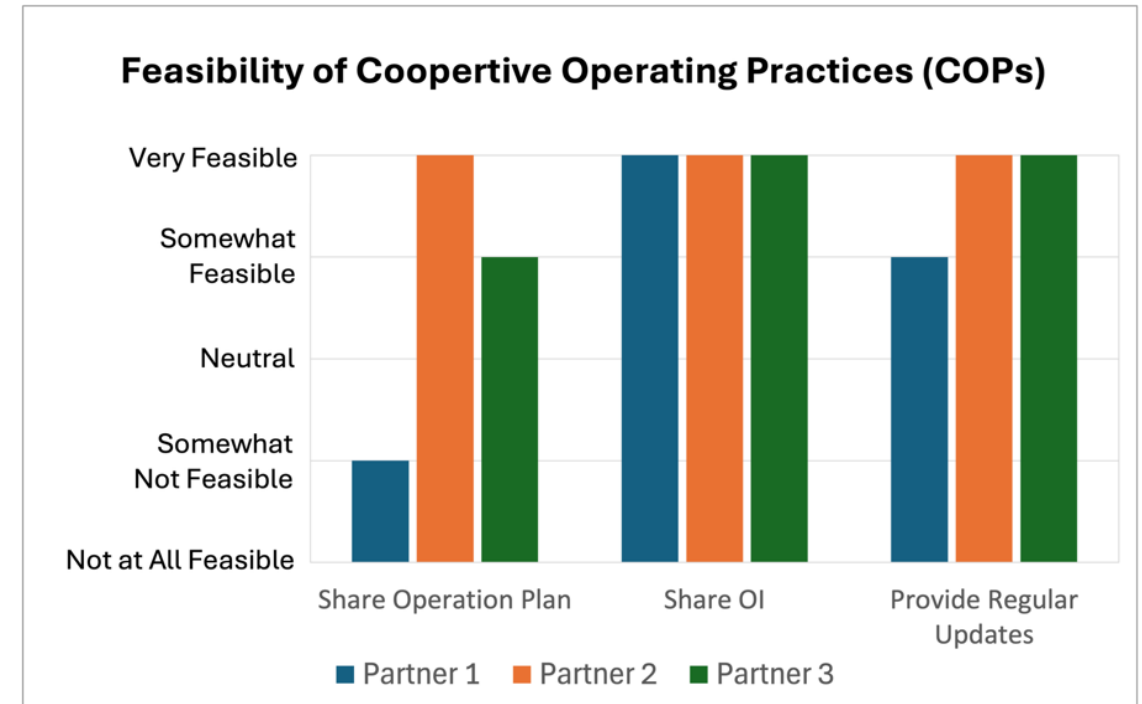
Informational OI Volumes (in this example, *beyond* 2 hours)



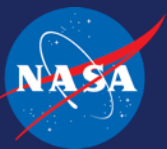


Results: Cooperative Operating Practices (COPs)

- Operators agree to share their **Operation Plan (OP)** (e.g., operator info, vehicle info, mission info, waypoint plan)
- Operators agree to share their **Operational Intent (OI)** by defining:
 - 1) "**Conflict Management**" OI Volumes, and
 - 2) "**Informational**" OI Volumes
- Operators agree to provide **regular OI updates**

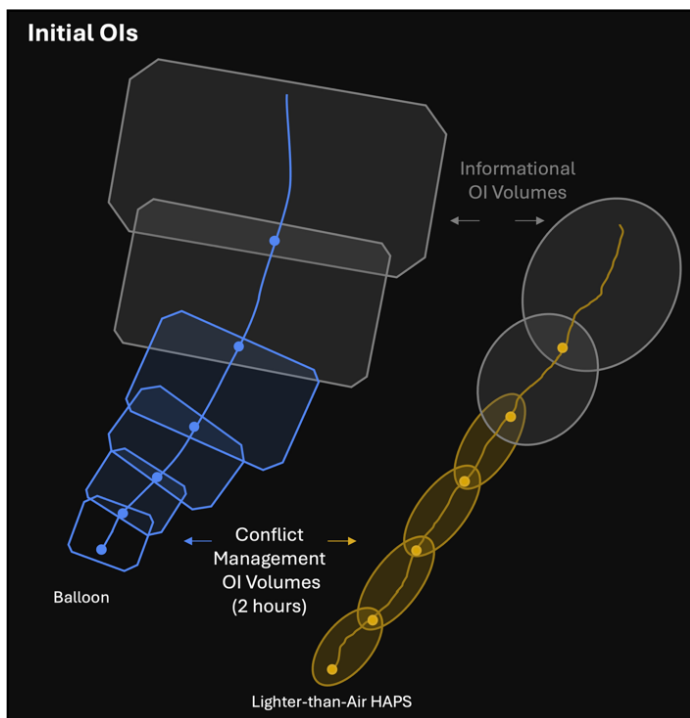


- Lower ratings due to a concern about sharing too much detailed information may make some companies more exposed than others.



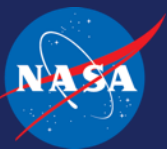
Scenario 1: Operation Plan/Operation Intent Submission

Research Question: Utilizing Cooperative Operating Practices (COPS), what information, capabilities, and procedures are needed to safely improve airspace access for high-altitude operations?



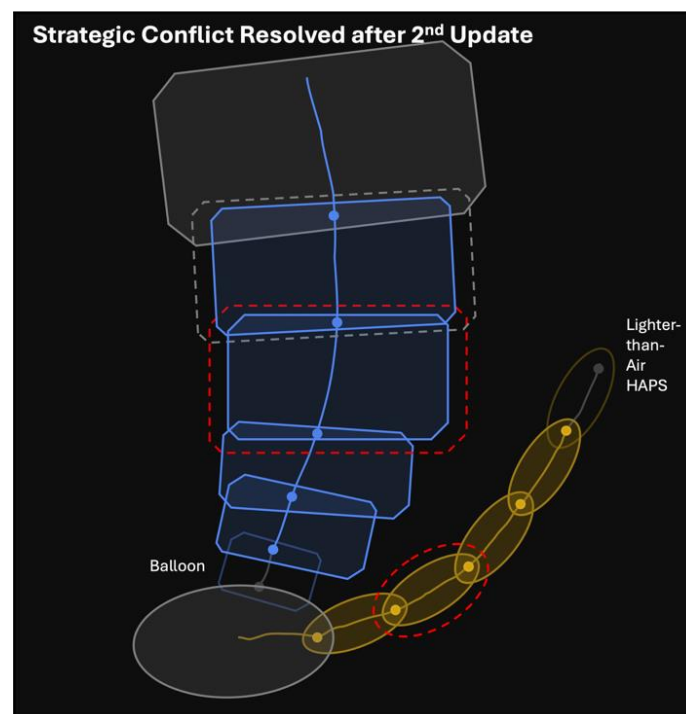
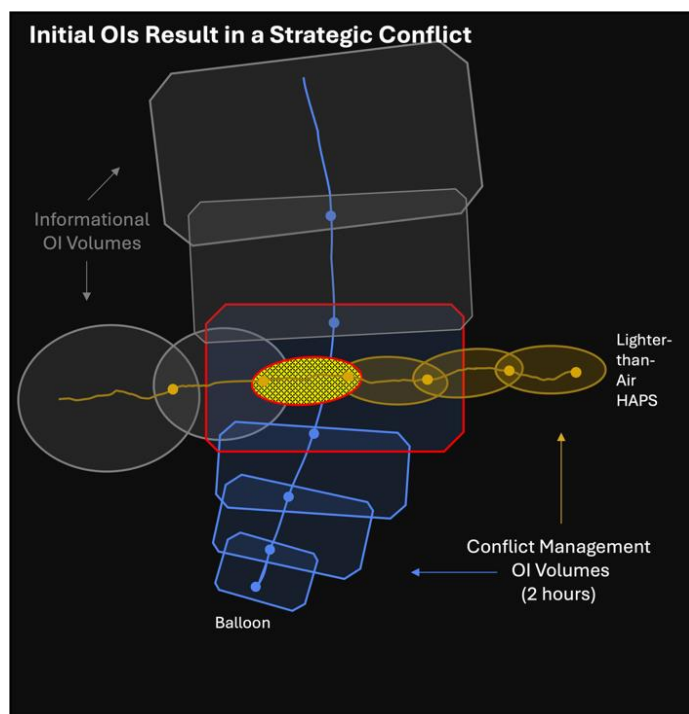
Scenario 1 *OP/OI Submission*

- What is the most efficient way to share operational intent (OI) volumes for various types of vehicles?
- Can the operators share OIs with high confidence- confidence containment level (CCL)?
- Can they gain sufficient common situational awareness using HATM Service oriented architecture?



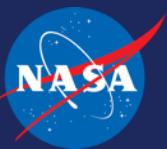
Scenario 2A: Strategic Conflict during Transit

Research Question: Utilizing Cooperative Operating Practices (COPS), what information, capabilities, and procedures are needed for strategic conflict identification and resolution for transiting operations?



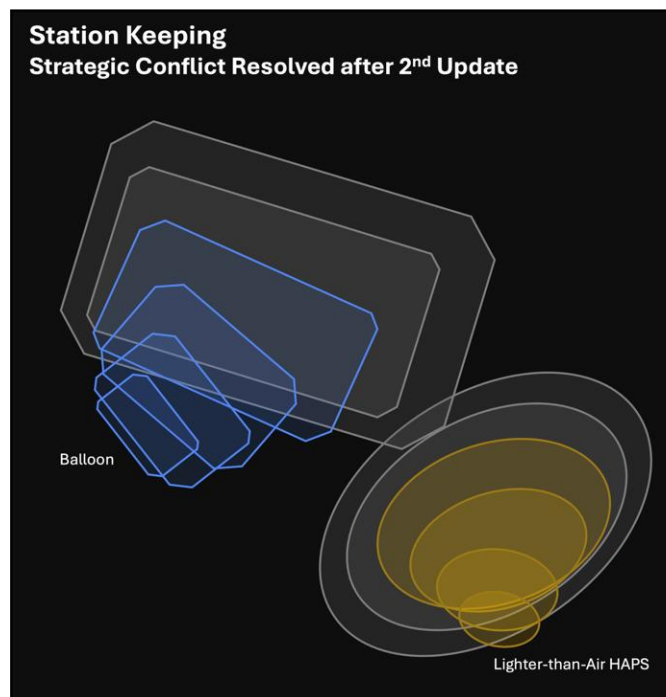
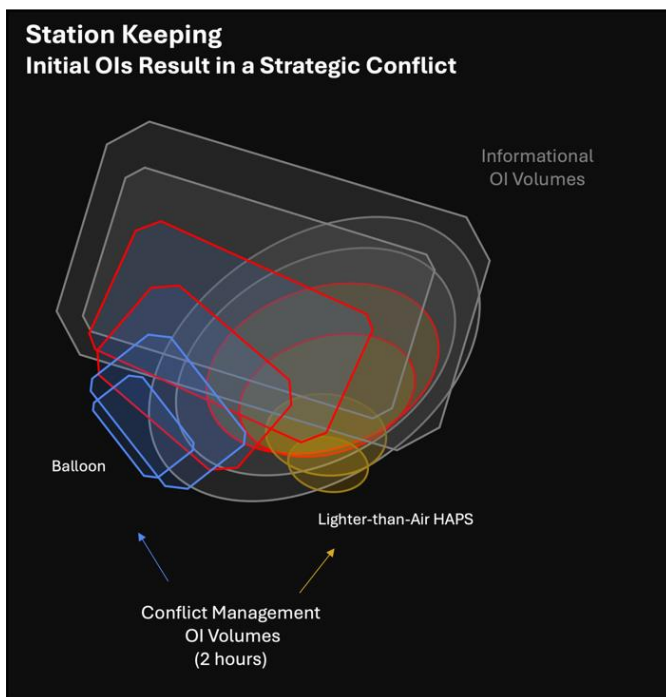
Scenario 2A *Strategic Conflict and Resolution: Vehicles in Transit from A to B*

- What is the effective way to identify strategic conflict for various types of vehicles (e.g., using OI intersections)?
- What are the proper parameters for conflict detection and notification?
- What are the effective procedures to cooperatively negotiate and resolve potential conflict?

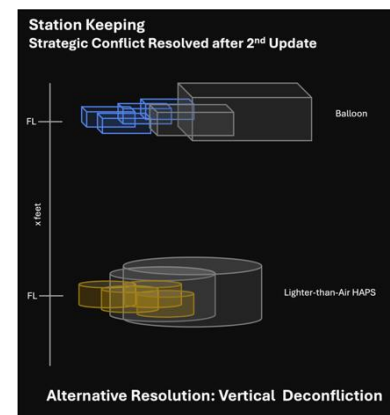


Scenario 2B: Strategic Conflict for Vehicles on Mission

Research Question: Utilizing Cooperative Operating Practices (COPS), what information, capabilities, and procedures are needed for strategic conflict identification and resolution for specific mission operations?



Scenario 2B *Strategic Conflict and Resolution: Station-Keeping Vehicles*



- What are the proper parameters for conflict detection and notification? Are they the same based on vehicle telemetry (*Transit vs Station-keeping*)?
- What are the effective procedures to cooperatively negotiate and resolve potential conflicts while *station-keeping for mission*?
- What are the information needs for cooperative negotiation?
- What are the maneuvers or options to resolve mission oriented strategic conflicts?