

Digital Avionics Systems Conference
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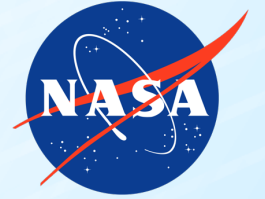
Airspace Performance Observations of Scalable Autonomous Operations in a High Density Vertiplex Simulation

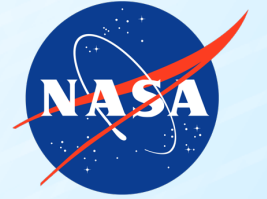
Presented by Madison Goodyear

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Introduction

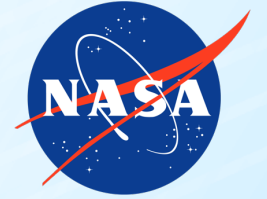
- Madison Goodyear
- Human Factors Researcher & Designer working for San Jose State Research Foundation @ NASA Ames
- M.S. in Human Factors and Ergonomics
- B.A. in Psychology





Outline

- Concept Background
- HDV Client Background
- HDV Airspace
- Research Questions
- Metrics
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- Scenarios
- Results Summary
- Results
- Discussion
- Summary



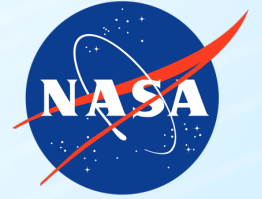
Concept Background

- In the future, there will be air taxis flying in high density urban areas, and that is why NASA's advanced air mobility (AAM) project created the high density vertiplex (HDV) subproject
- The High Density Vertiplex (HDV) subproject is focusing on terminal area management and how arrival/departure management can be scaled to support higher densities
- In a collaborative simulation between NASA Ames and NASA Langley, HDV airspace was tested
- To approximate a representative HDV airspace, airspace structures and vertiports were created around Langley, and were displayed in the traffic management interface
- Automated and human-piloted simulated traffic was used

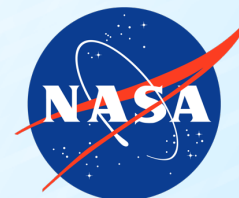


HDV Client Background

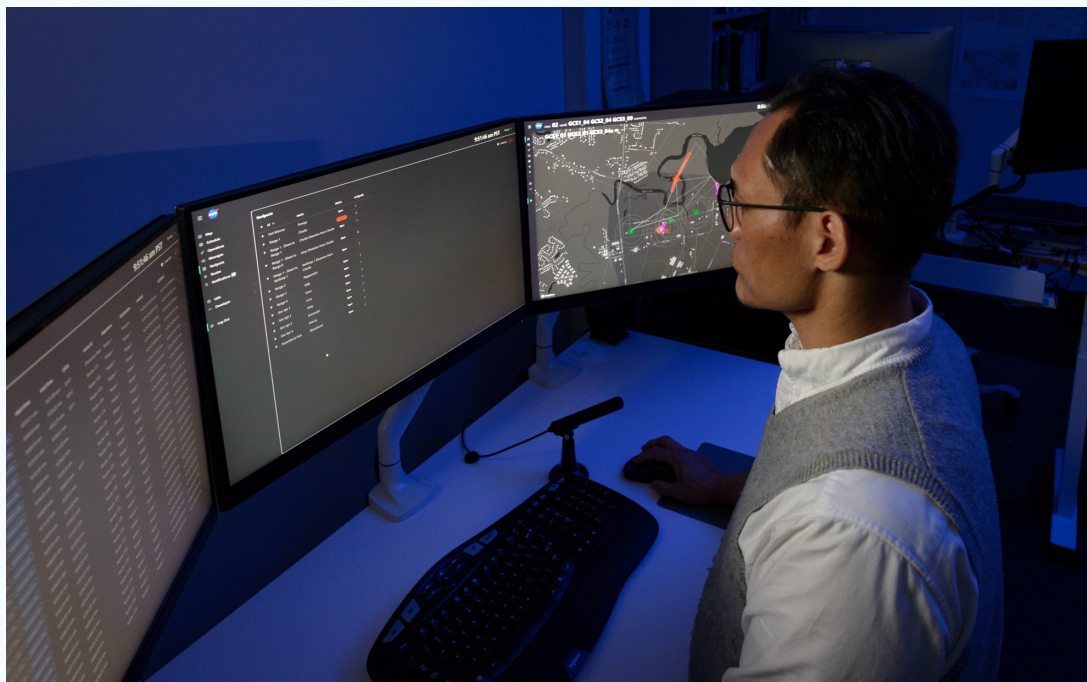
- The traffic management interface used was called the HDV client and its key features include:
 - A 2D display of the airspace, routes, flight plans, and waypoints
 - Operation status changes, such as state changes
 - Critical alert messages for operations
 - Partially automated trial planning to amend routes while airborne
 - Divert
 - Missed Approach
 - This is the fleet manager role that connects with both ground control stations (pilots) and vertiport manager



Fleet Manager Station (Ames)



Other Human Operators In The Loop



Vertiport Manager Station (Ames)



Ground Control Station Operator (Langley)

HDV Airspace

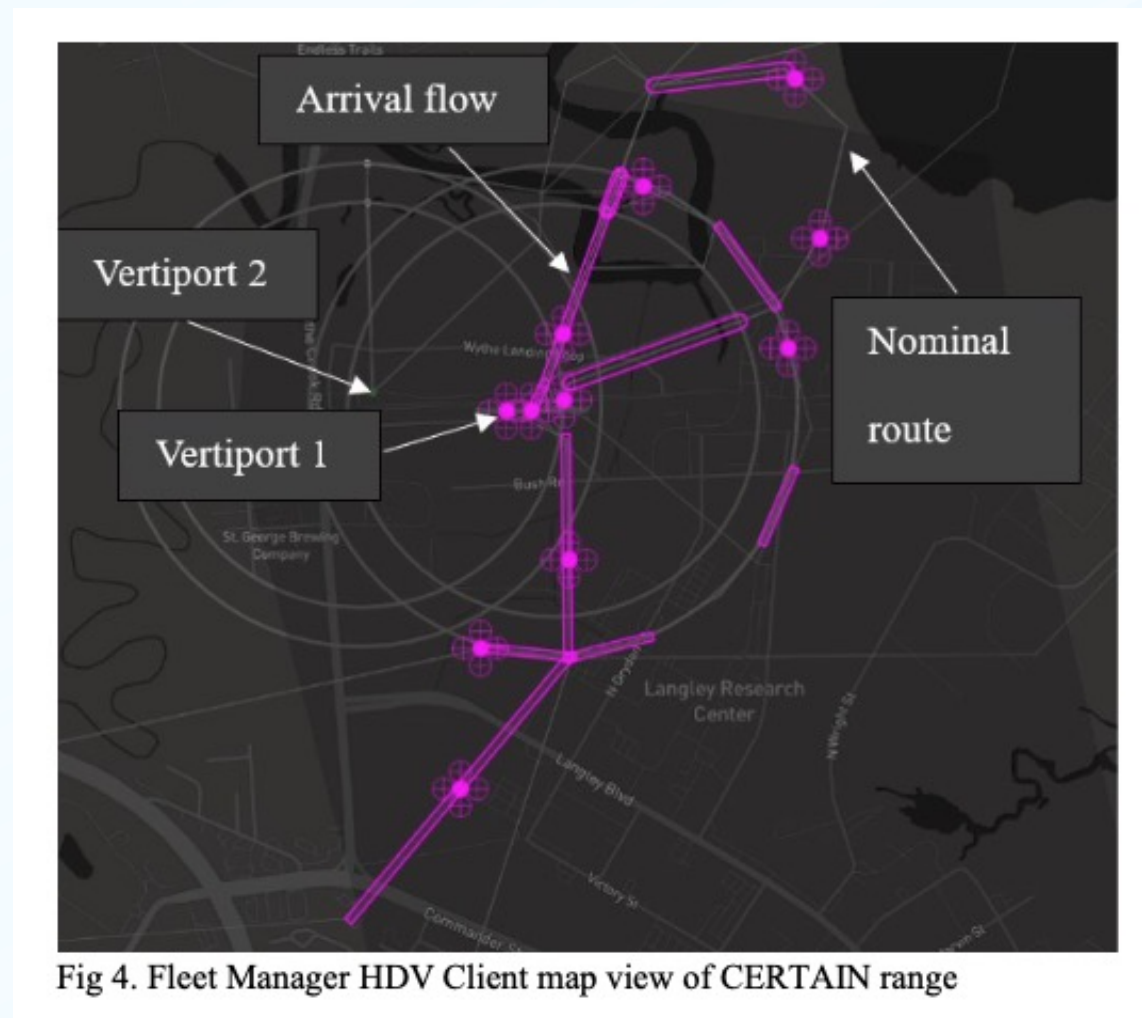
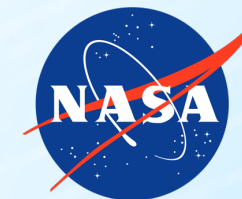


Fig 4. Fleet Manager HDV Client map view of CERTAIN range

HDV Airspace

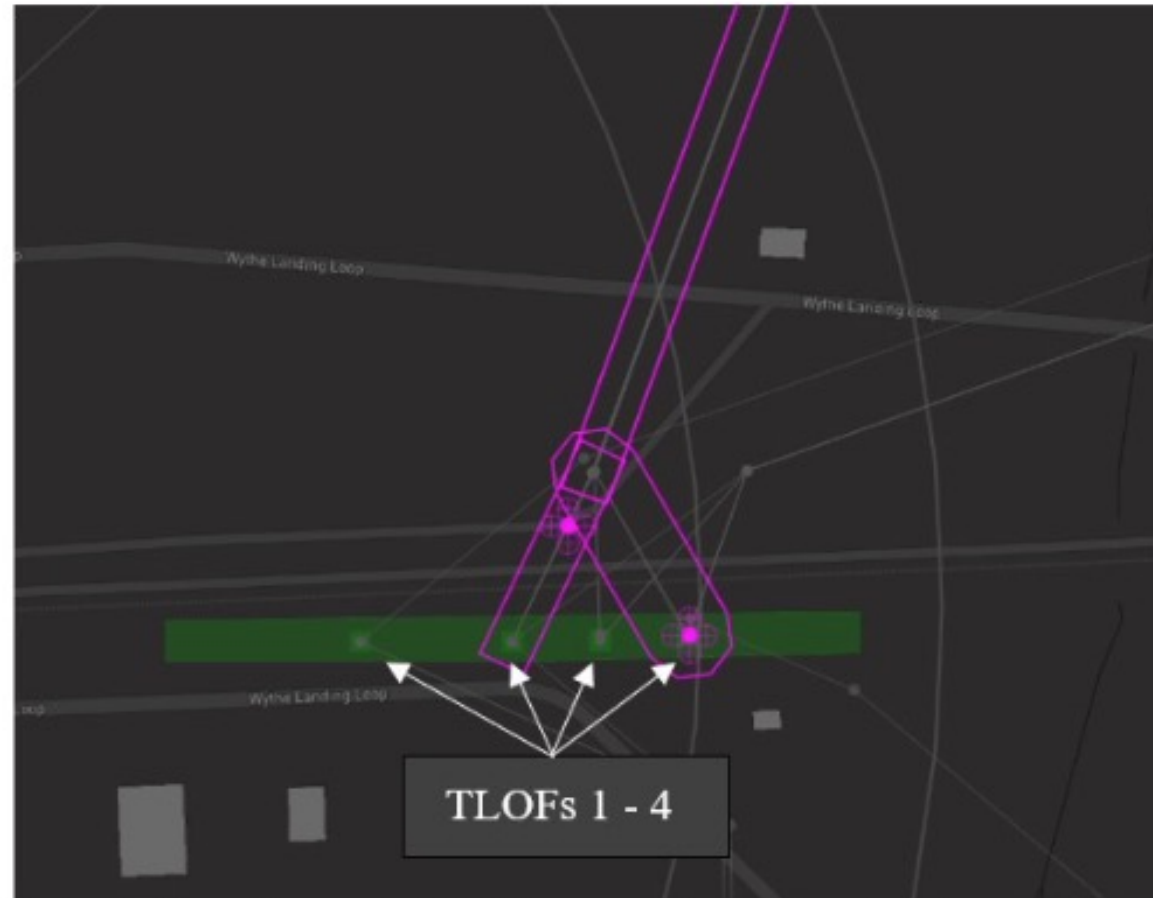
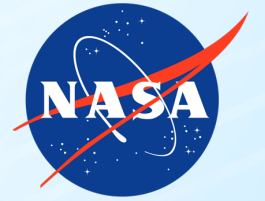
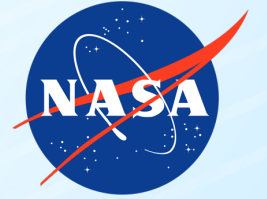
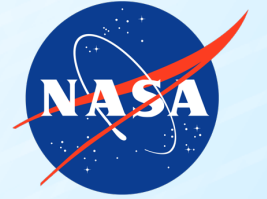


Fig 3. Vertiport Manager HDV Client map view of Vertiport 1



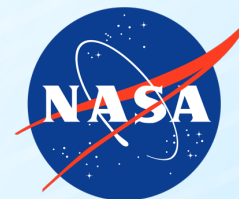
Research Questions

- What are the effects of potential airspace disruptions that could cause impacts to other vehicles?
- What can be done to resolve the gaps in capabilities and procedures of the HDV airspace?



Metrics

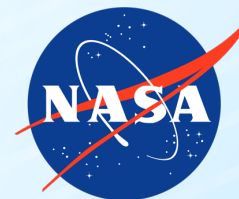
- Throughput
- Spacing violations
 - Closest point of approach
 - Vehicle deletions
- Vehicle delay
- Interface delay



Procedure

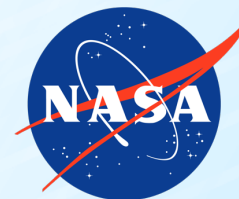
- 3 Fleet Managers
- 3 Vertiport Managers
- 9 Ground Control Station Operators
- Traffic density of 60 ops per hour
 - 60 ops simulation traffic
 - 3 ops live traffic
- Ran 5 unique scenarios
 - FM scheduled and revised operations as needed
 - Researcher on standby to delete any vehicles that interfered with GCSOs





Results Summary

- Throughput
 - HDV defined 60 operations per hour as high density, and we met this benchmark for all scenarios
- Spacing violations
 - Closest point of approach
 - Detected multiple vehicles within well-clear boundaries of each other throughout the simulation
 - Vehicle deletions
 - Vehicles were deleted to resolve conflicts that could not be handled by the fleet manager



Results Summary (cont.)

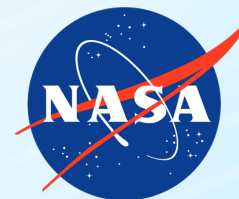
- Vehicle Delay

- Average delay from procedures like missed approach and divert were recorded

- Interface Delay

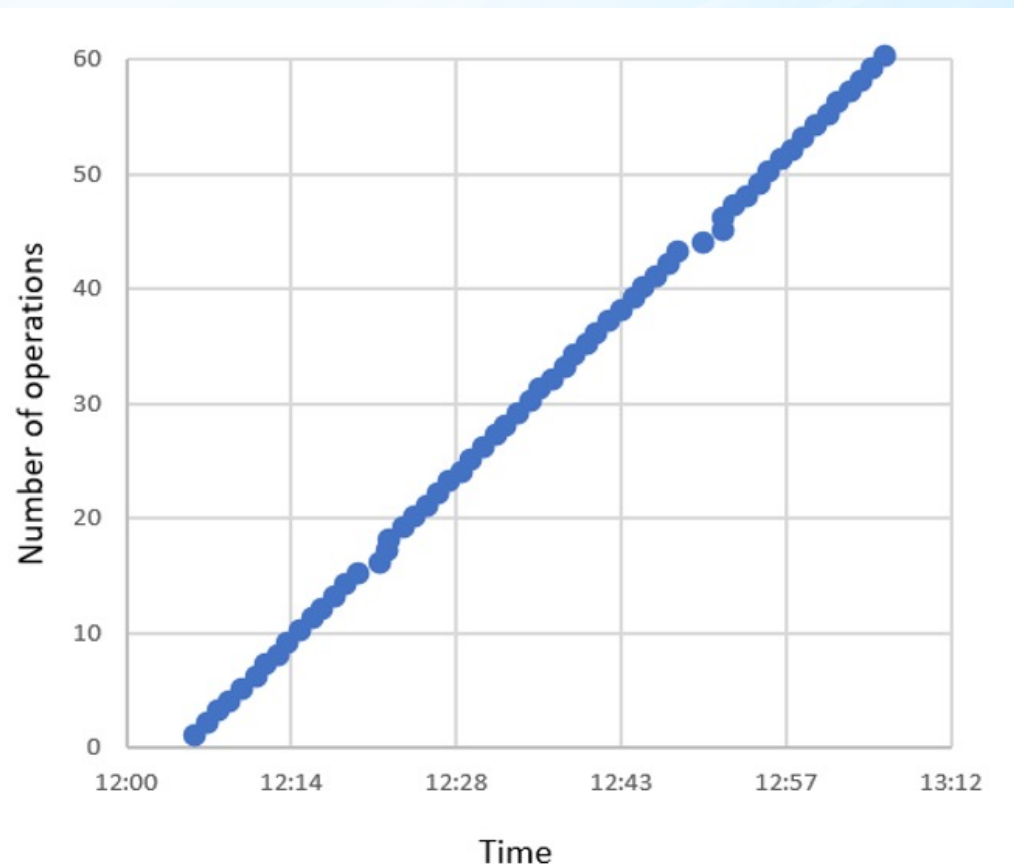
- We observed that the fleet manager was occasionally unable to generate a landing time for the vehicle that had gone on missed approach

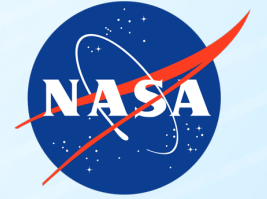
Results



Results

- Throughput
 - Calculated over 30 minutes
 - Data confirmed a rate of 60 operations per hour, meaning a rate of 1 operation every minute
 - Confirms capacity met original criteria



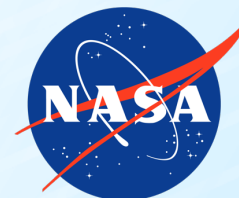


Results (cont.)

- Spacing violations: Closest point of approach
 - Sim vehicles were automated and uncontrolled, and had all of their closest point of approaches (CPAs) accounted for
 - Well-clear boundaries were defined as 500 feet horizontal and 100 feet vertical by Flarm, the onboard detect and avoid automation

Table 2. Closest Point of Approach less than 100 feet vertical and 500 feet horizontal

Descriptive	Number
Average number of CPAs	14.4
Average horizontal distance	110.23
Max	300.20
Min	42.33
Average vertical distance	57.64
Max	61.54
Min	40.42

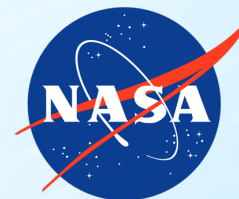


Results (cont.)

- Spacing violations: Closest point of approach (cont.)
 - Many instances of vehicles exceeding the well-clear boundaries, and no way for the system to alert the operators to this
 - The airspace management automation was able to deconflict departure and arrival times, but not segments of the operation enroute
 - The HDV client also did not alert for vehicle conflicts

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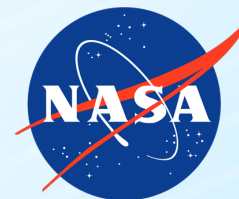


Results (cont.)

- Spacing violations: Vehicle deletions
 - The amount of deleted aircraft were recorded to serve as an indicator of how many times operators would have potentially reacted to vehicle conflicts
 - Vehicles were deleted to resolve conflicts not able to be handled by the fleet manager

Table 1. Descriptive of deleted aircraft per run

Descriptive	Number
Average	1.6
Mode	2
Max	6
Min	0

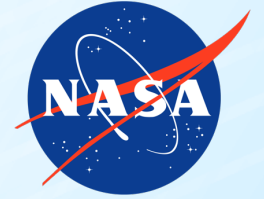


Results (cont.)

- Spacing violations: Vehicle delay
 - The additional flight time added to vehicles who performed a missed approach or divert procedure was recorded
 - Missed approaches or divers did not contribute to overall airspace system delay because any potential vehicle conflicts were deleted

Table 3. Airborne delay (minutes) by condition

Descriptive	Missed Approach	Divert
Average	2.5	1.3
Max	4	4
Min	1	0
SD	1.2	1.1

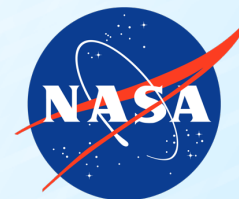


Results (cont.)

- Spacing violations: Vehicle delay (cont.)
 - Proper detection and resolution of these conflicts using classic traffic management methods (i.e. speed changes, vectoring, ground delay, etc.) was not possible because these capabilities don't exist yet for the fleet manager. However, if a traffic manager could have resolved the conflicts, it would have resulted in more congestion and delays throughout the system

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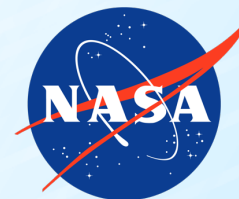


Results (cont.)

- Interface delay
 - There were also cases of the fleet manager taking longer than expected to generate an approach route for a vehicle that had gone on missed approach
 - If the vehicle couldn't be cleared to land, then the scenario was considered failed
 - The missed approach procedure was run a total of 11 times, and failed 3 times

Table 4. Frequency and duration of interface delay on successful and failed Missed Approach procedures

Descriptive	Number
Number of successful Missed Approaches	8
Number of failed Missed Approaches	3
	<i>(minute:seconds)</i>
Average time to generate route (success)	0:40
Min	0
Max	3:05
Average time out (fail)	1:48
Min	0:15
Max	3:40

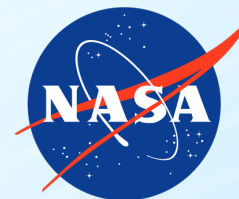


Results (cont.)

- Interface delay (cont.)
 - The higher the traffic density, the harder it was to find an open arrival slot

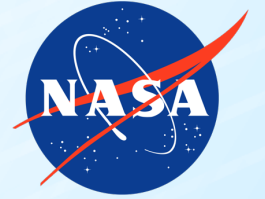
Table 5. Missed approach at different traffic levels

Traffic Level	Original STA	Invoke Missed Approach		New STA	Interface Delay (mins)
		<i>First attempt</i>	<i>Final attempt</i>		
20	12:26	12:25	--	12:29	0:00
40	10:31	10:24	10:27	10:31	3:05
60	11:16	11:16	11:19	--	3:16



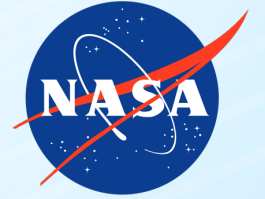
Discussion

- It is important to understand how different airspace resources will impact a vertiport's capacity to handle demand
 - In the future, capacity limits on vertiport resources need to be derived from research, and demand and capacity balancing will need to be addressed
- Will be important to measure how the ripple effect of airborne delay will affect airspace performance
 - Current HDV capabilities would not be able to effectively manage suboptimal airspace conditions



Discussion (cont.)

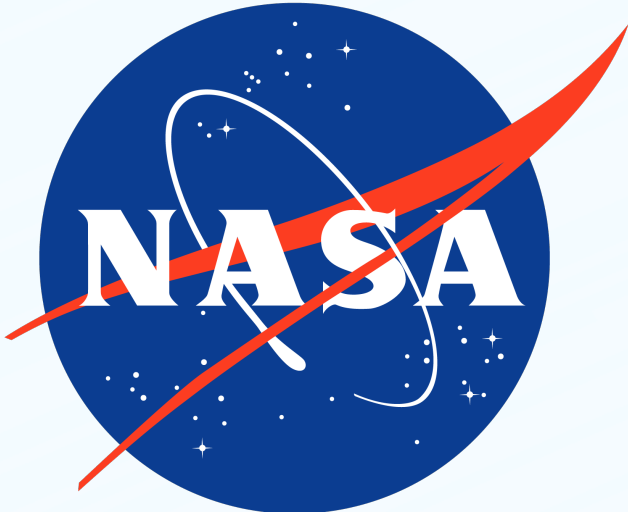
- Conflict detection should be improved and responsibility should be allocated
 - Onboard vehicle automation ICAROUS was integrated into the HDV toolset in 2021 and had acceptable results and performance when handling conflicts and automatically rerouting
 - ICAROUS is not integrated with HDV client, which limits the shared situational awareness between multiple operators



Recommendations

- Procedures and more advanced systems need to be developed to handle higher demand situations
- Responsibility for traffic conditioning needs to be determined
- Conflict detection needs to be improved

Thank You!



HDV Airspace

