

Simulation Evaluations of an Autonomous Urban Air Mobility Network Management and Separation Service

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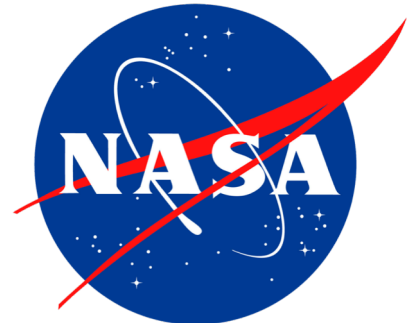
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Motivation

- ✈ Increased interest in Urban Air Mobility (UAM)
- ✈ New aircraft types and missions
- ✈ Extend airspace uses to high-density and mixed operations
- ✈ Paradigm shift towards greater levels of autonomy

Research Objectives

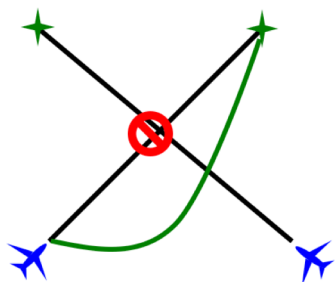
- 1) Develop a research platform to explore far-term UAM operations
- 2) Build and evaluate a prototype of an autonomous network management and separation concept under different operational conditions

Outline

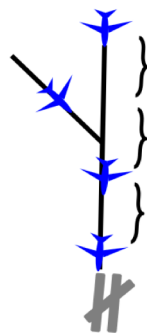
- Prototype Algorithm
- Methodology
- Simulation Results
- Summary
- Future Work

Prototype Algorithm

- Prototype extending NASA's autonomous AutoResolver algorithm
- Trajectory-based algorithm that iteratively performs automated



Conflict detection and resolution



Arrival spacing and metering

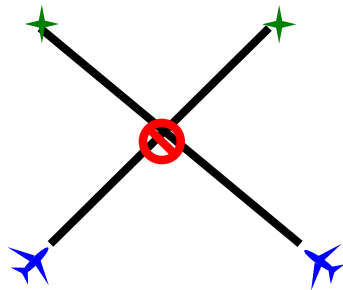


Weather avoidance

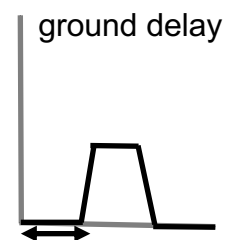
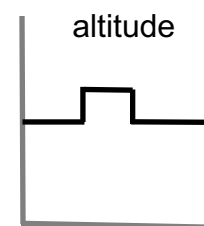
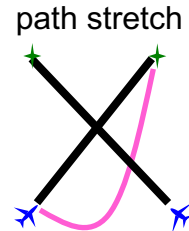
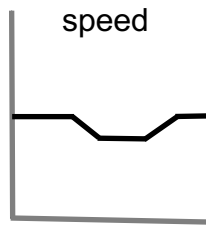
- Uses 4D aircraft projected trajectories
- Applied in past research in the Dallas-Fort Worth metroplex
[Erzberger et al., 2012,2016][Nikoleris et al.,2014,2016][Lauderdale et al.,2011,2018]

Prototype Algorithm

- AutoResolver capabilities for UAM operations
 - Separation assurance to avoid losses of separation (LOS)

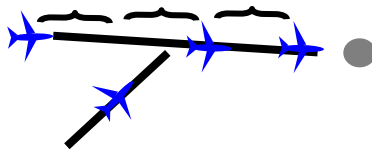


Prediction of a LOS



Resolution types for a LOS

- Arrival management to avoid scheduling/sequencing conflicts (SEQ)



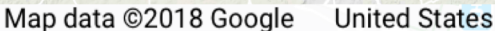
Prediction of a SEQ

Path stretch, speed, ground delay

Resolution types for a SEQ

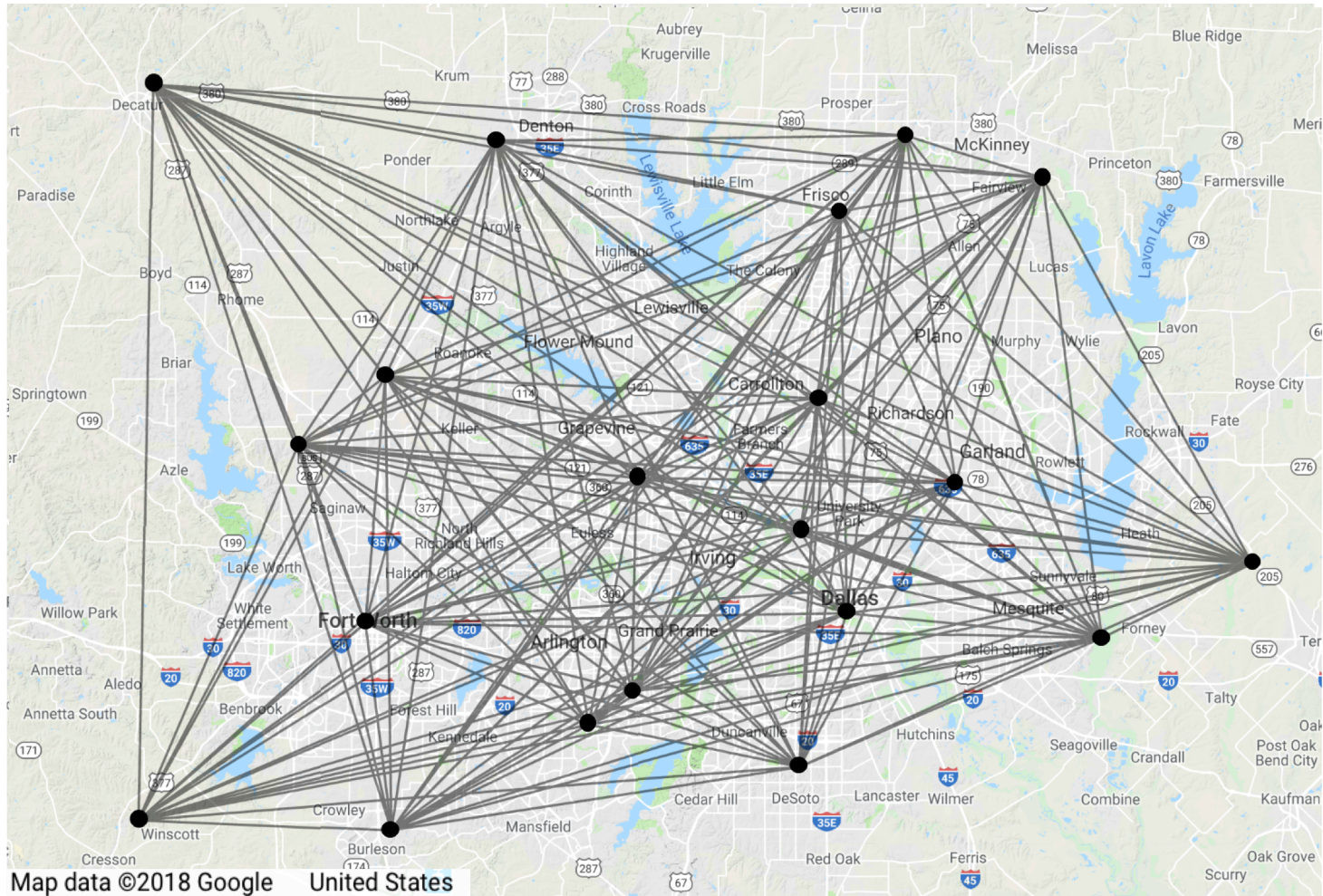
- Generates conflict free and efficient trajectory resolutions
- Picks and issues autonomously best resolutions to aircraft

Airspace Details



Methodology

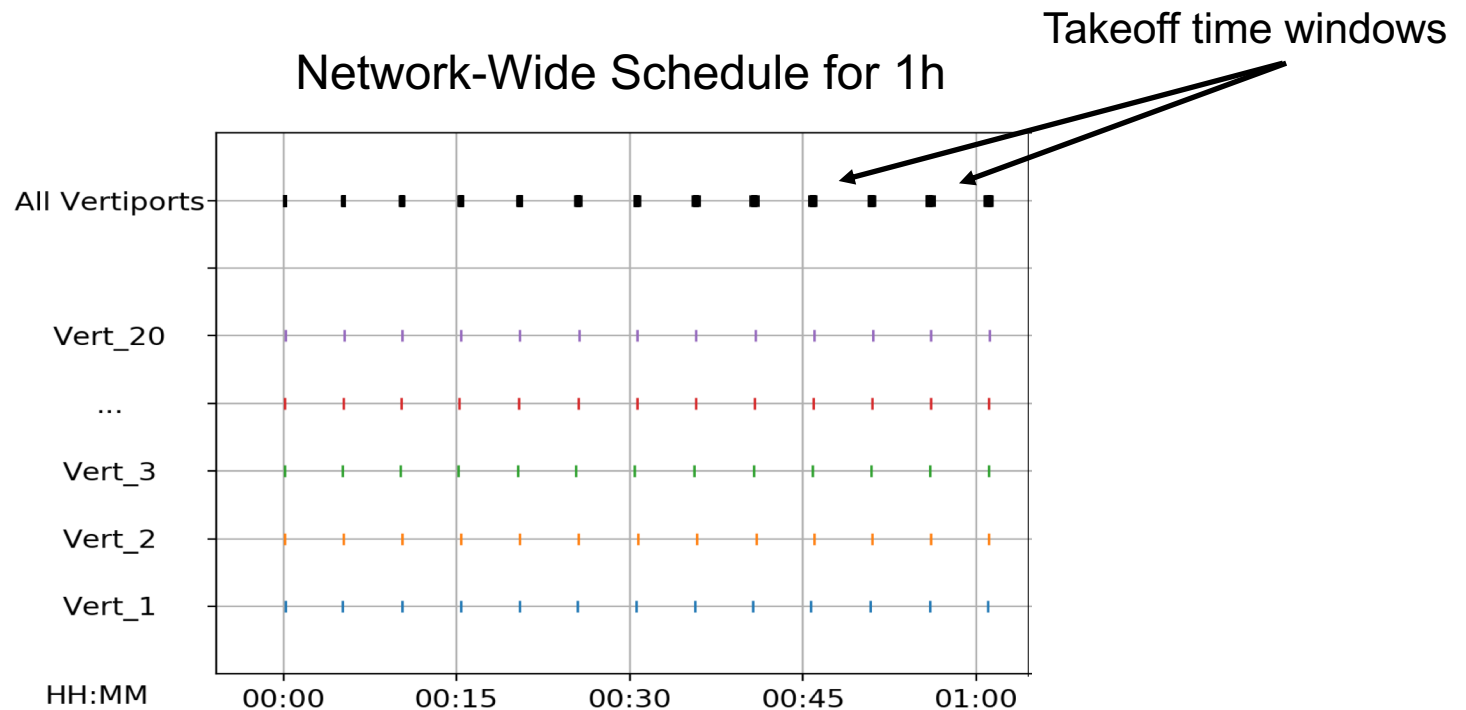
Flight Route Network



Methodology

Network-Wide Traffic Schedule

- 1 takeoff every 5min at all vertiports
- Sample takeoff time uniformly distributed over $[0,10]$ s
- 2h traffic period: 450 flights



Methodology

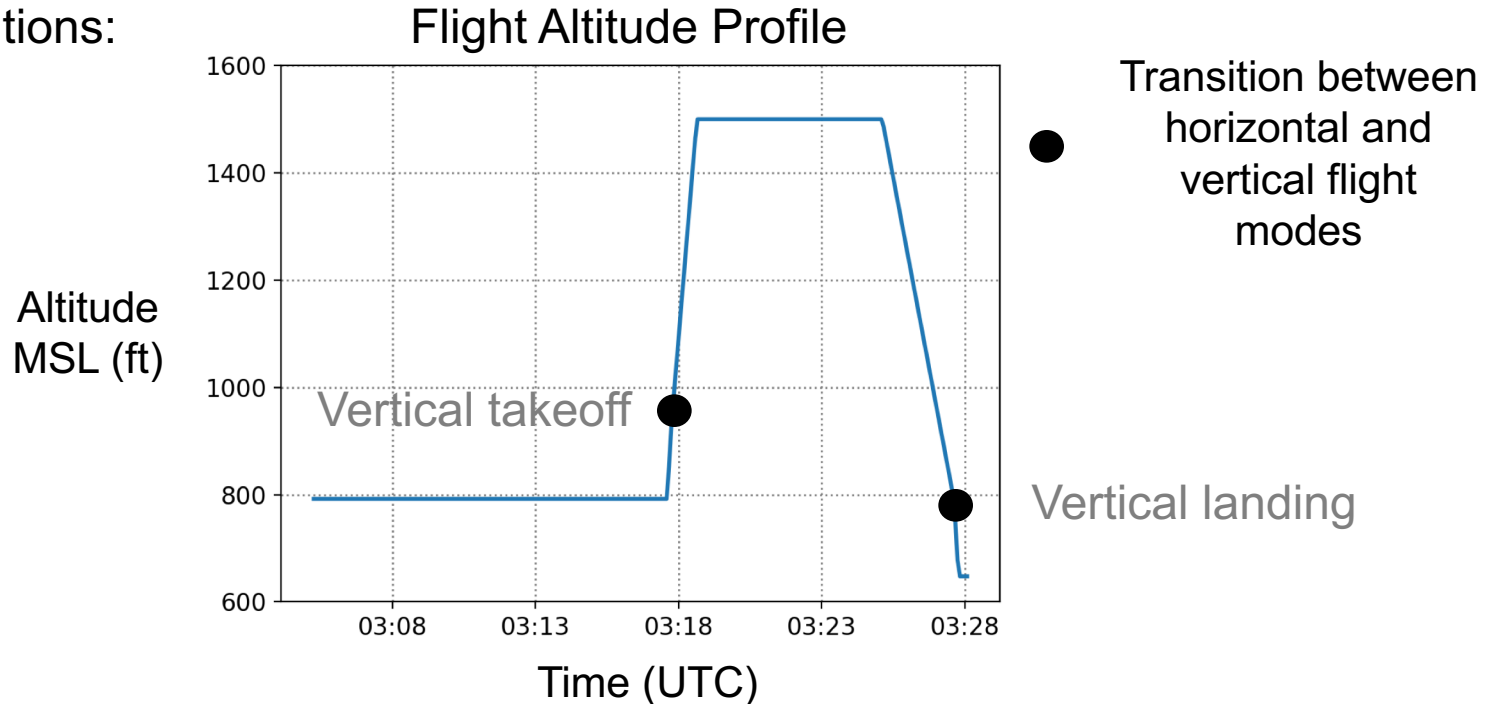
Aircraft Characteristics and Trajectory Generation

- e-VToL aircraft type
- Kinematic linear interpolation-based trajectory generator

Cruise conditions:

170kts

1500ft MSL



Methodology

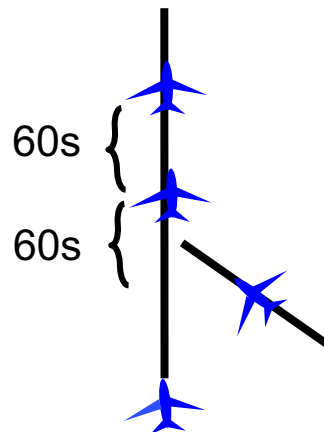
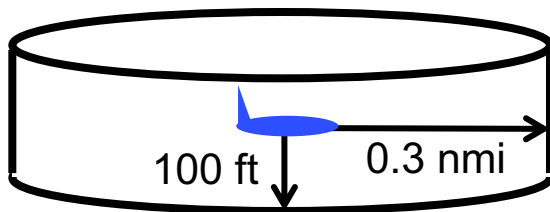
Assumptions

- No uncertainty considered in the simulations
- No trajectory prediction errors
- Simplified kinematic-based aircraft model
- Segregated airspace
- Only UAM-type aircraft considered
- One vertipad modeled per vertiport
- Can immediately use vertipad once aircraft lands/departs
- No vertiport capacity and operations modeled

Methodology

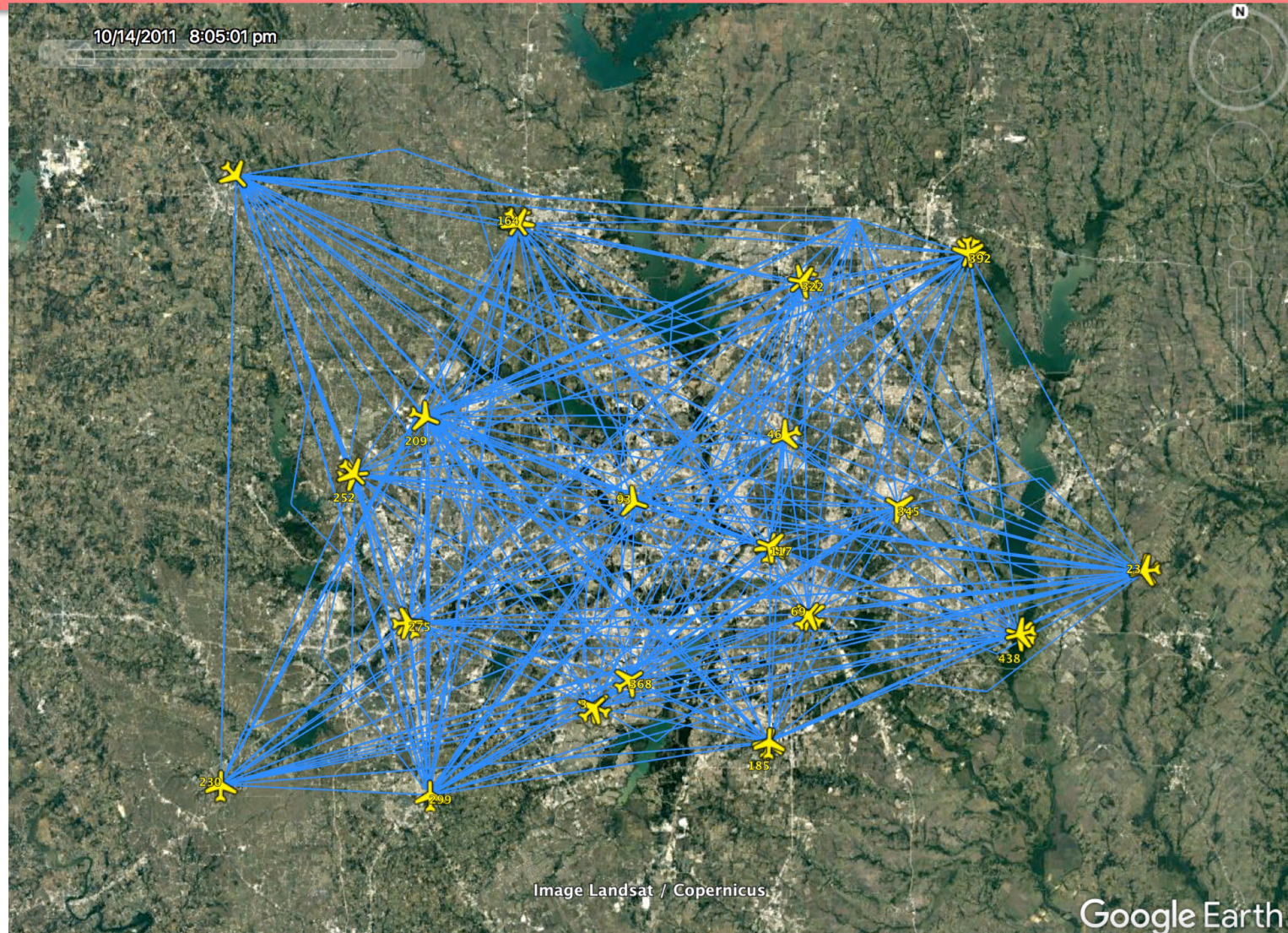
Evaluation Conditions

| Test Case | Separation Standards | Sequencing Specification | Arrival Scheduling Horizon |
|---------------------------------------|-------------------------|--------------------------|----------------------------|
| 1. Baseline | 0.3nmi H 100ft V | 60s | 50min |
| 2. Reduced lateral spacing | 0.1nmi H 100ft V | 60s | 50min |
| 3. Reduced temporal spacing | 0.3nmi H 100ft V | 45s | 50min |
| 4. Reduced arrival scheduling horizon | 0.3nmi H 100ft V | 60s | 8min |



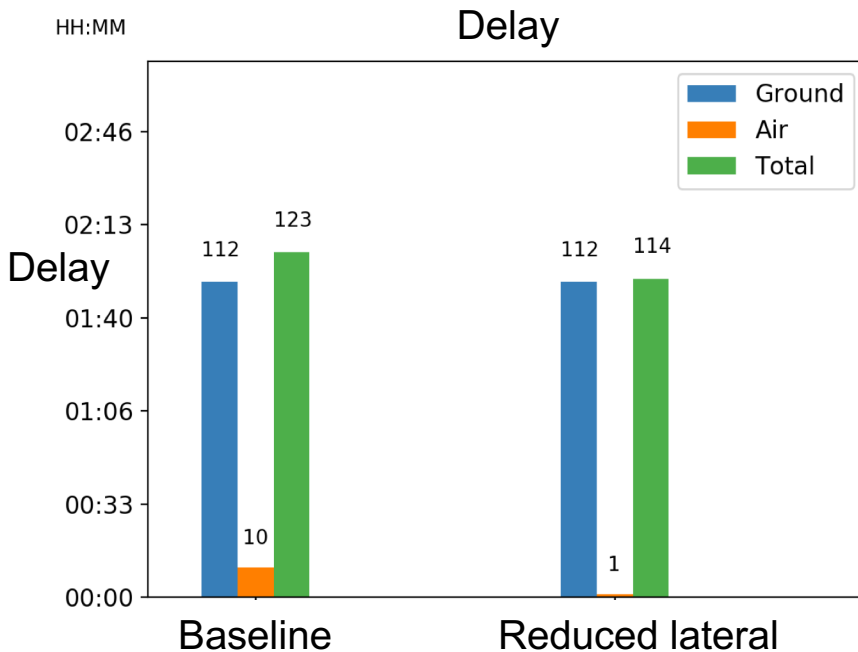
Time at which the ETA at the arrival vertiport is computed and frozen

Simulation Results

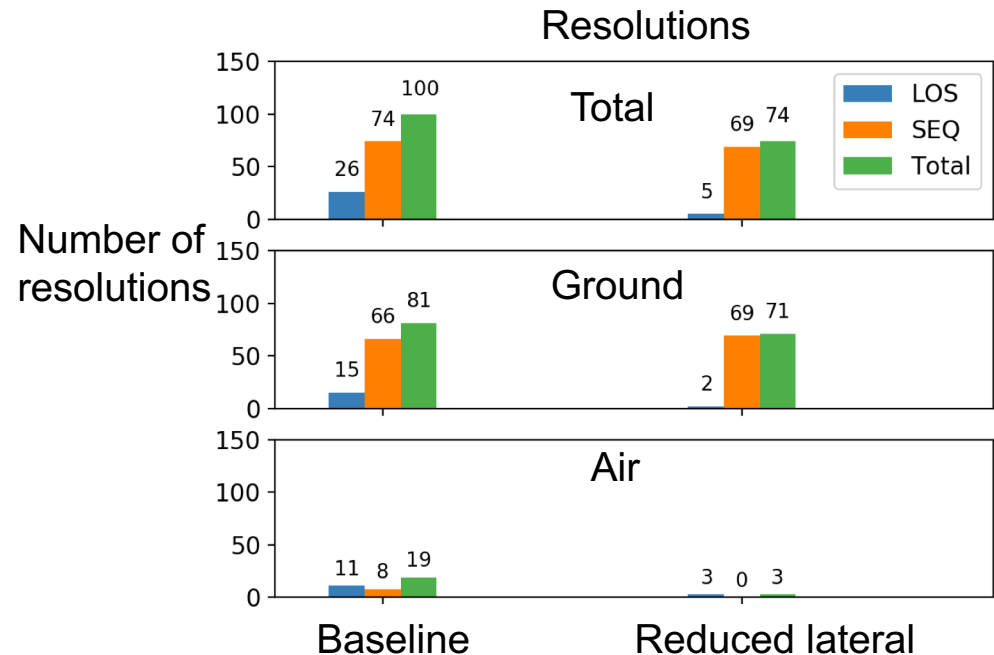


Simulation Results

Separation standards comparison: 0.3nmi vs 0.1nmi



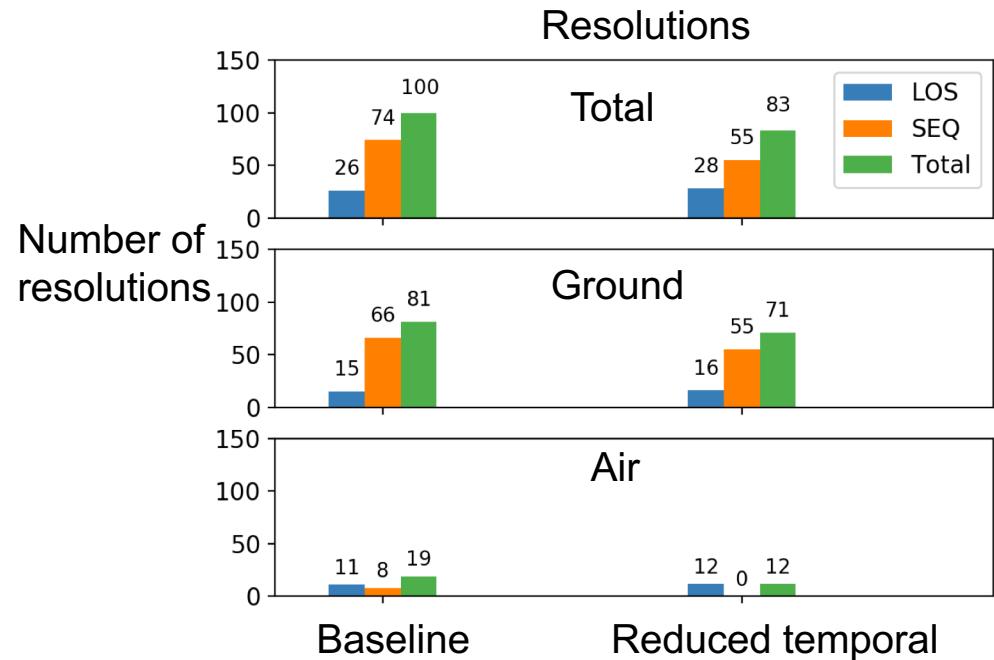
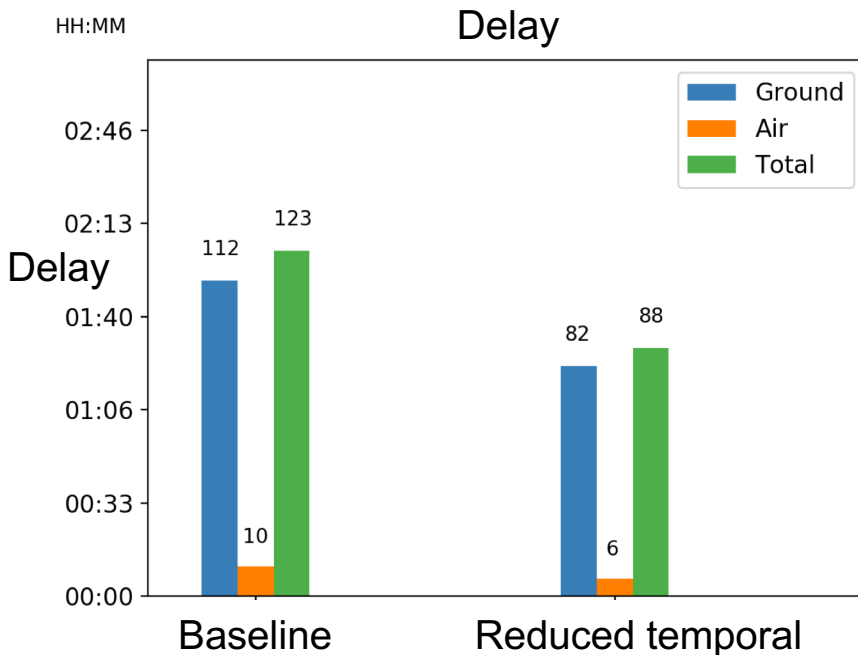
- Constant ground delay
- Less air delay
- Total delay decreased by 7.3%



- Fewer resolutions
- Total resolution number decreased by 26%
- More impact in air than on ground

Simulation Results

Sequencing specification comparison: 60s vs 45s

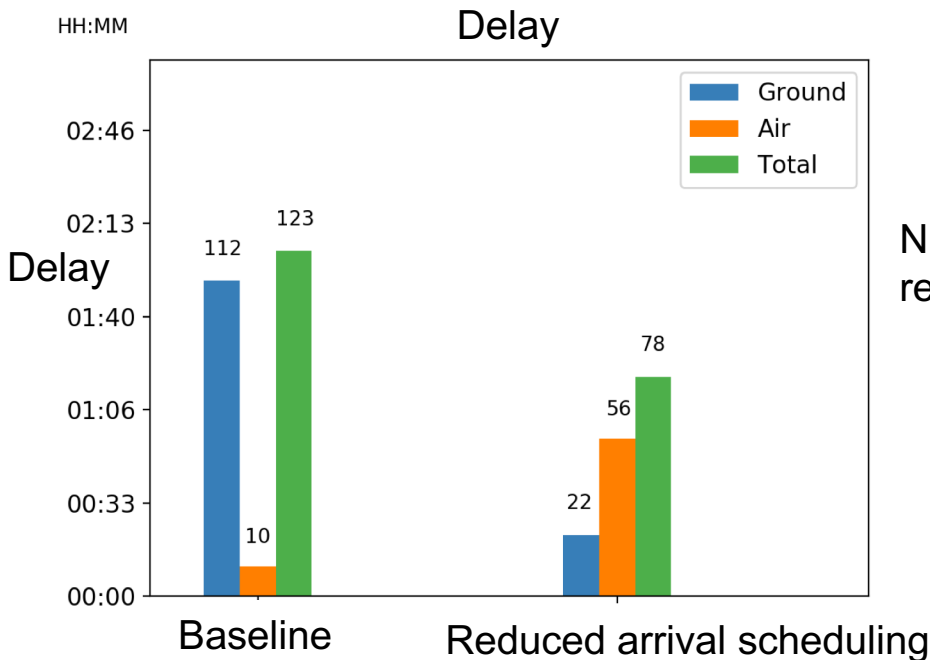


- Decrease of all delays
- Total delay decreased by 28.4%

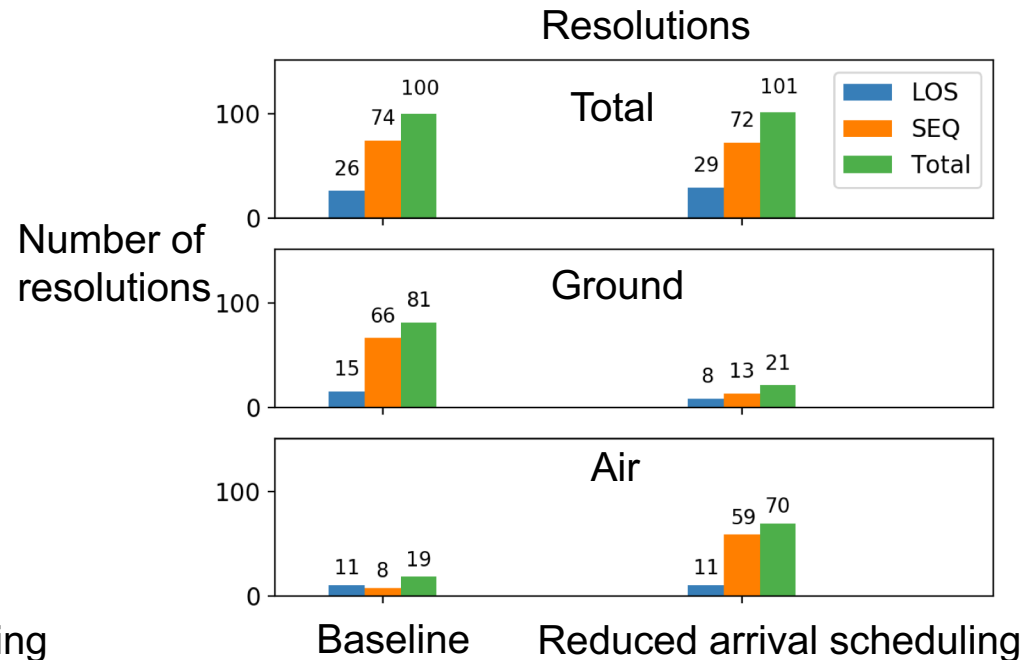
- Fewer resolutions
- Total resolution number decreased by 17%
- More impact on ground than in air

Simulation Results

Arrival scheduling horizon comparison: 50min vs 8min



- Decrease of total delay
- Shift of ground to air delay
- Total delay decreased by 36.6%



- Similar aggregate resolution numbers
- Impacts on both ground and air

Summary

- Developed an initial implementation of a research platform to explore far-term UAM operations
- Evaluated a research prototype of an autonomous network management and separation concept under different operational conditions
- Demonstrated that AutoResolver's capabilities were effective at solving the designed scenario, under all three operational conditions and for the selected density, without creating any losses of separation
 - Delay and conflict resolution trends were as expected
 - Showed that allowing aircraft to takeoff prior to being scheduled can offer reduced delay values for the network

Future Work

Future work is required to

- Expand further the AutoResolver algorithm capabilities
- Evaluate more complex scenarios looking at
 - Interactions with non-UAM-aircraft in non-segregated airspace
 - Uncertainties
 - Different vertiport and vertipad configurations
 - Model aircraft battery usage

Thank you!

Questions?

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