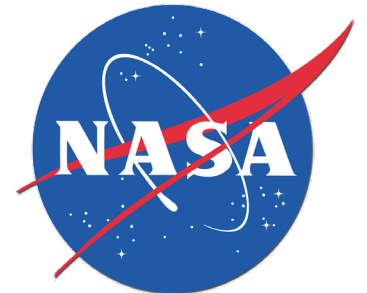


A Ground-Delay-Based Approach to Reduce Impedance-Based Airspace Complexity

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AIAA Aviation (August 2, 2021)

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Aviation Today

Complexity -

MAP – Monitor Alert Parameter

DD – Dynamic Density

Air Traffic Management (ATM) approaches

Airspace Flow Program (AFP), Ground Delay Program (GDP)

Departure Sequencing Program (DSP), Miles-In-Trail (MIT)...



Aviation Future?



Past Research

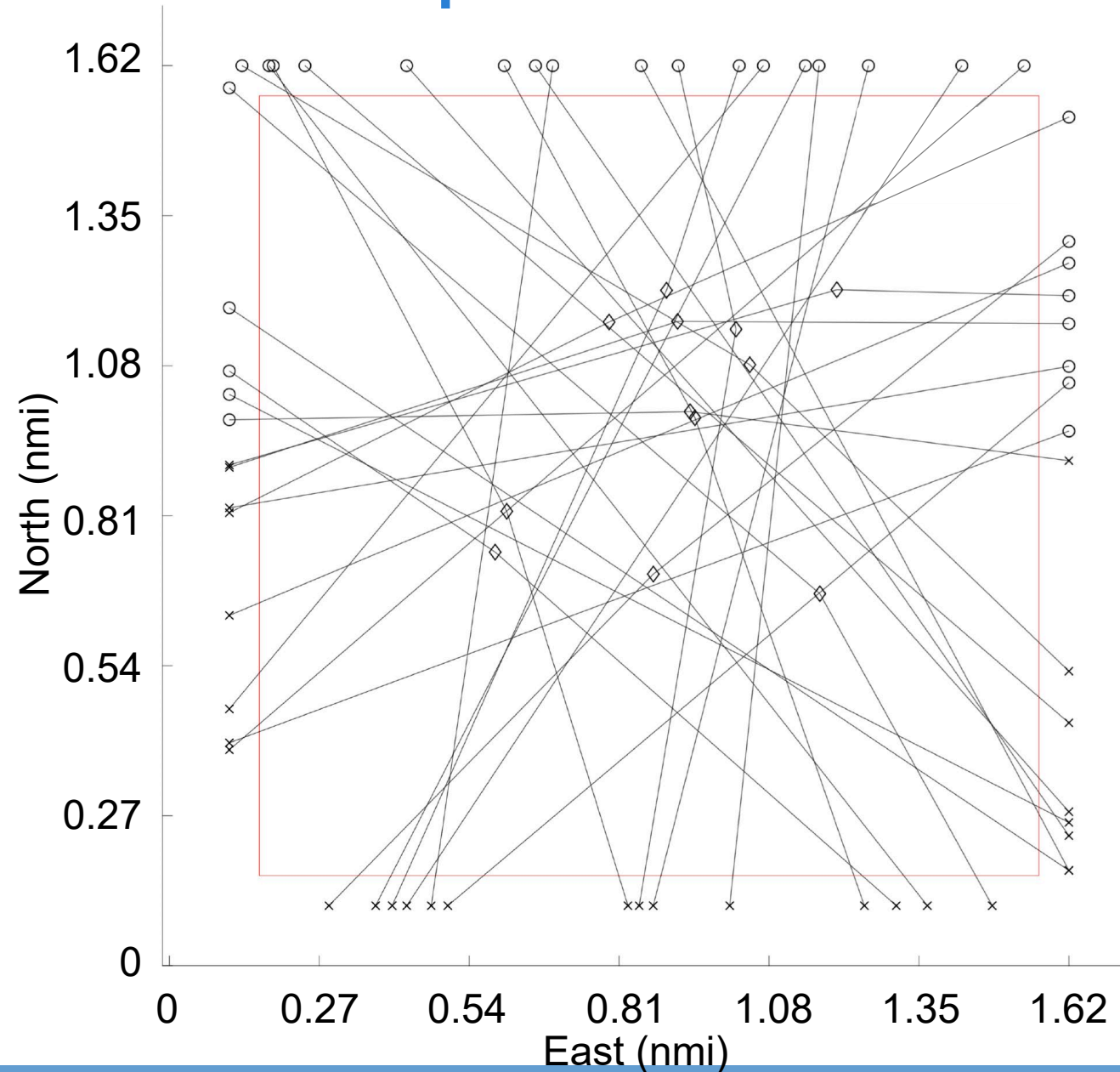
Xue, M., and Do, M., “*Scenario Complexity for Unmanned Aircraft System Traffic*”, AIAA Aviation 2019

- Complexity based on number of conflicts weighted by conflict resolution cost
- Showed a 90% correlation to baseline
- Better than number of flights or number of conflicts

Bulusu, V., Sridhar, B. and Xue, M., “*An Impedance Based Complexity Metric for Unmanned Aircraft System Traffic Scenario Classification*”, AIAA Aviation 2020

- Complexity based on the impedance to conflict resolution by the number of conflicts and proximity to aircraft and other conflicts around.
- Showed a 93% correlation to baseline
- **Impedance Maps** – helpful to identify hot spots: regions with impeded conflict resolution capability

Sample Scenario*



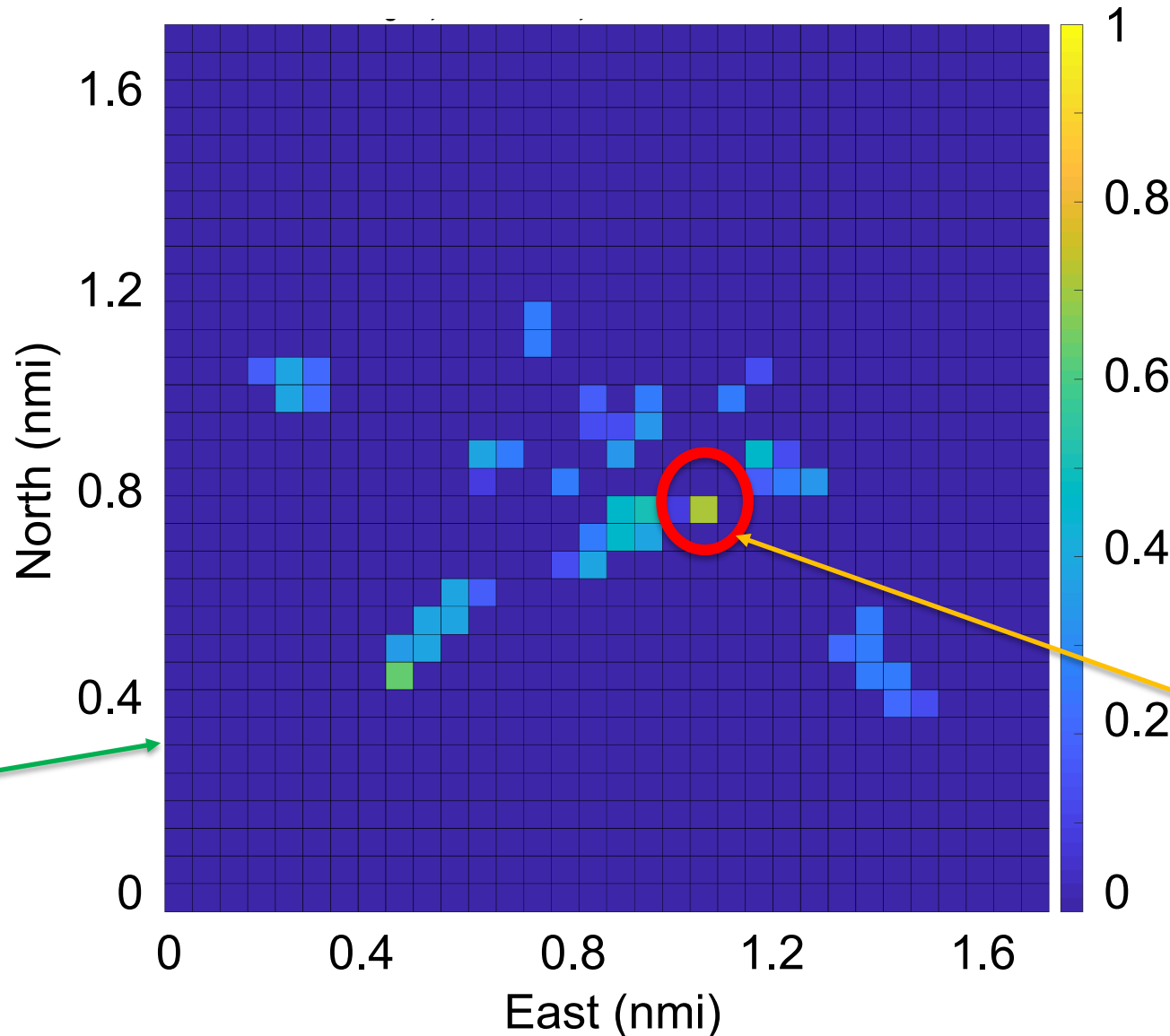
Sample Scenario*

For threshold
P = 0.2,

I = 0.04

I – Overall
Impedance of
Scenario

Impedance Map



Flights = 30

**$h_{sep} = 60.96m$
(200 ft)**

dt = 5 s

Potential Hot Spot

Ground-Delay-Based Approach

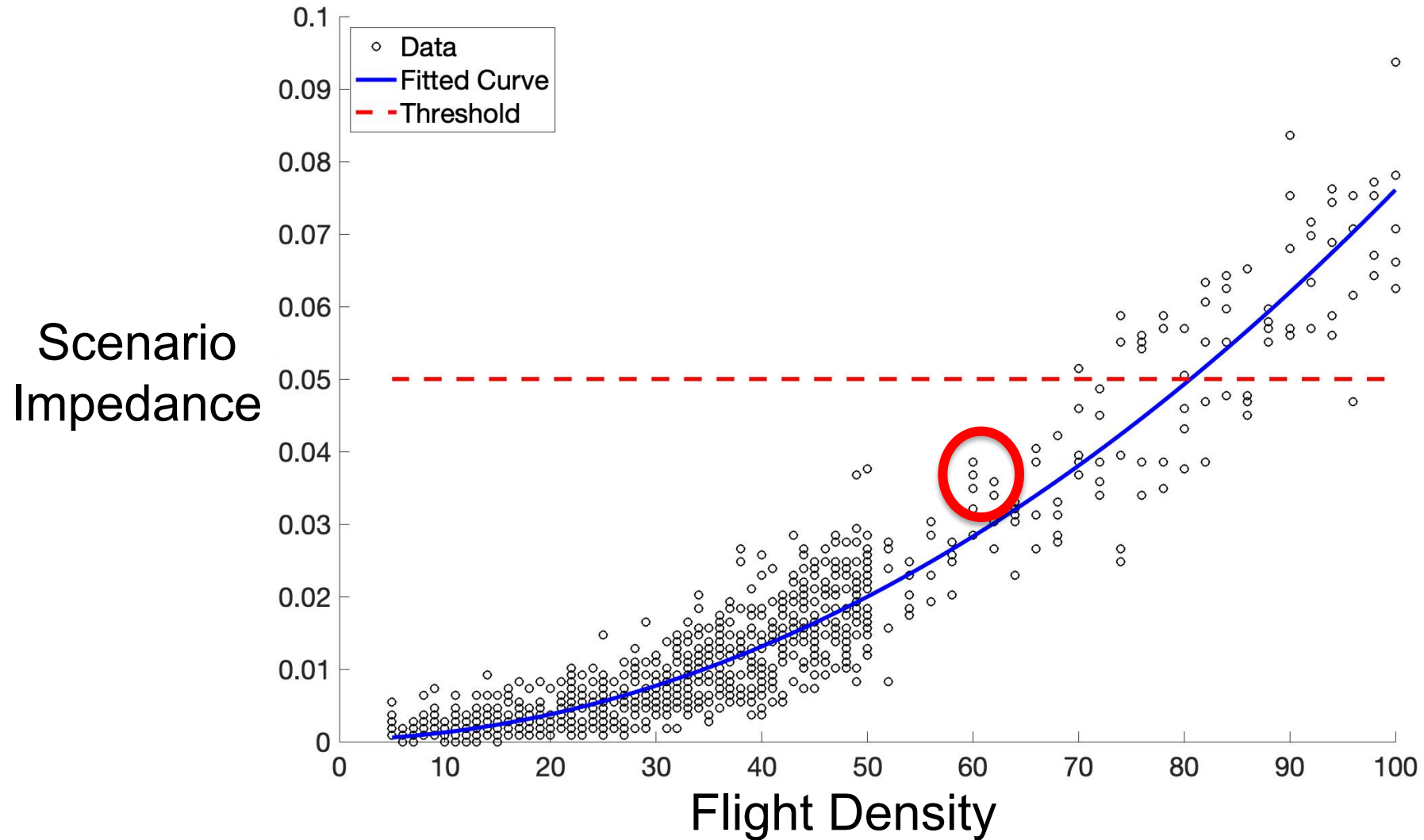
Research Objective -

Develop management strategies to reduce impedance-based complexity.

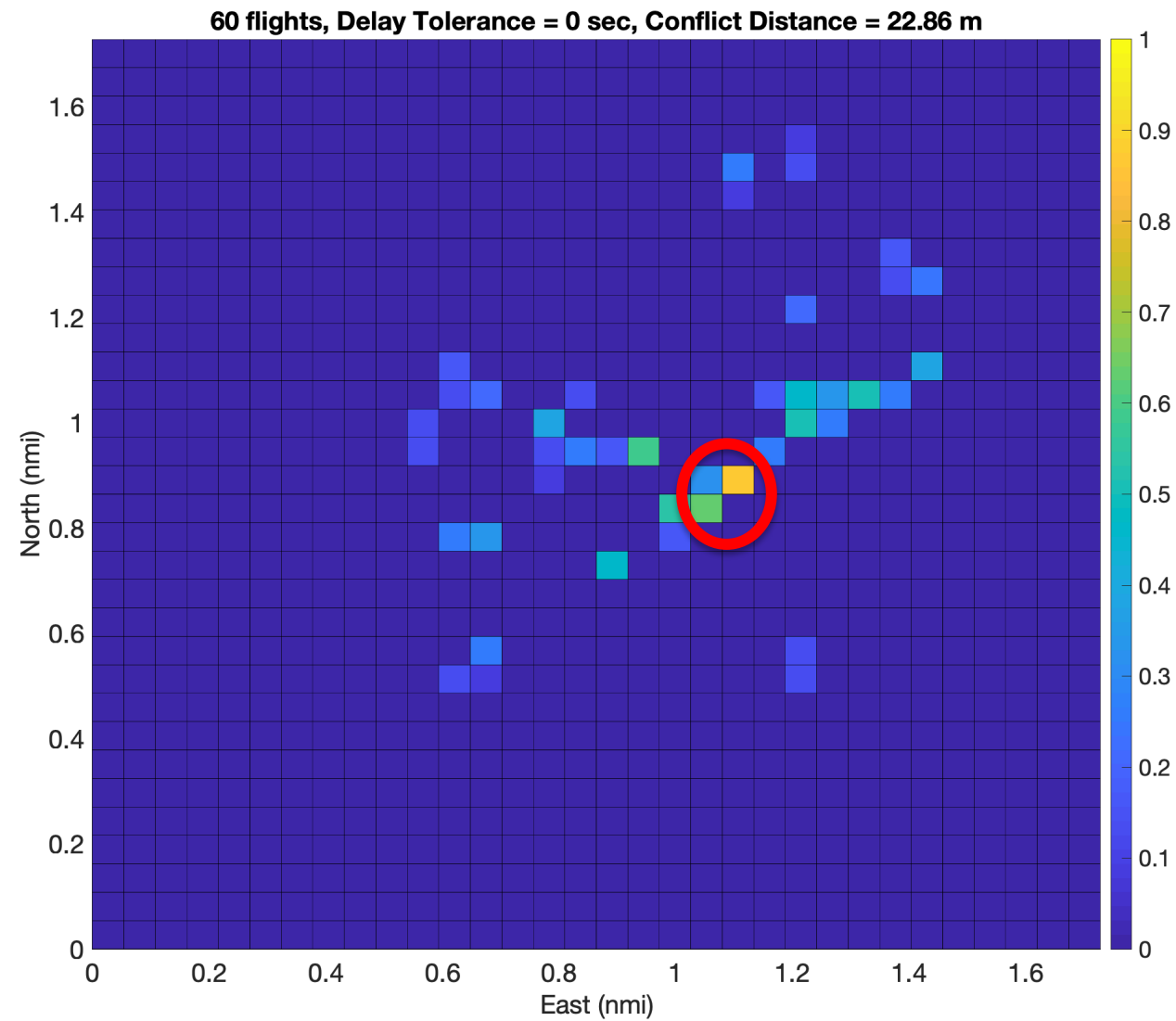
Methodology -

- Declare a scenario as feasible/not feasible.
- For feasible scenarios, mitigate hot spots to the extent possible by delaying flights within a delay tolerance.

Feasibility Check



Ground Delay



Ground-Delay-Based Approach

Algorithm -

- Identify flights going through hot spots
- Starting with earliest, for each flight try all delays up to its tolerance
- Select the delay that reduces the highest observed impedance the most
- Repeat for each flight through hot spot.

Until

- All possible delay combinations are tested and best for each flight is kept; OR
- A combination is found such that the highest impedance observed is below chosen local impedance threshold

Assumptions

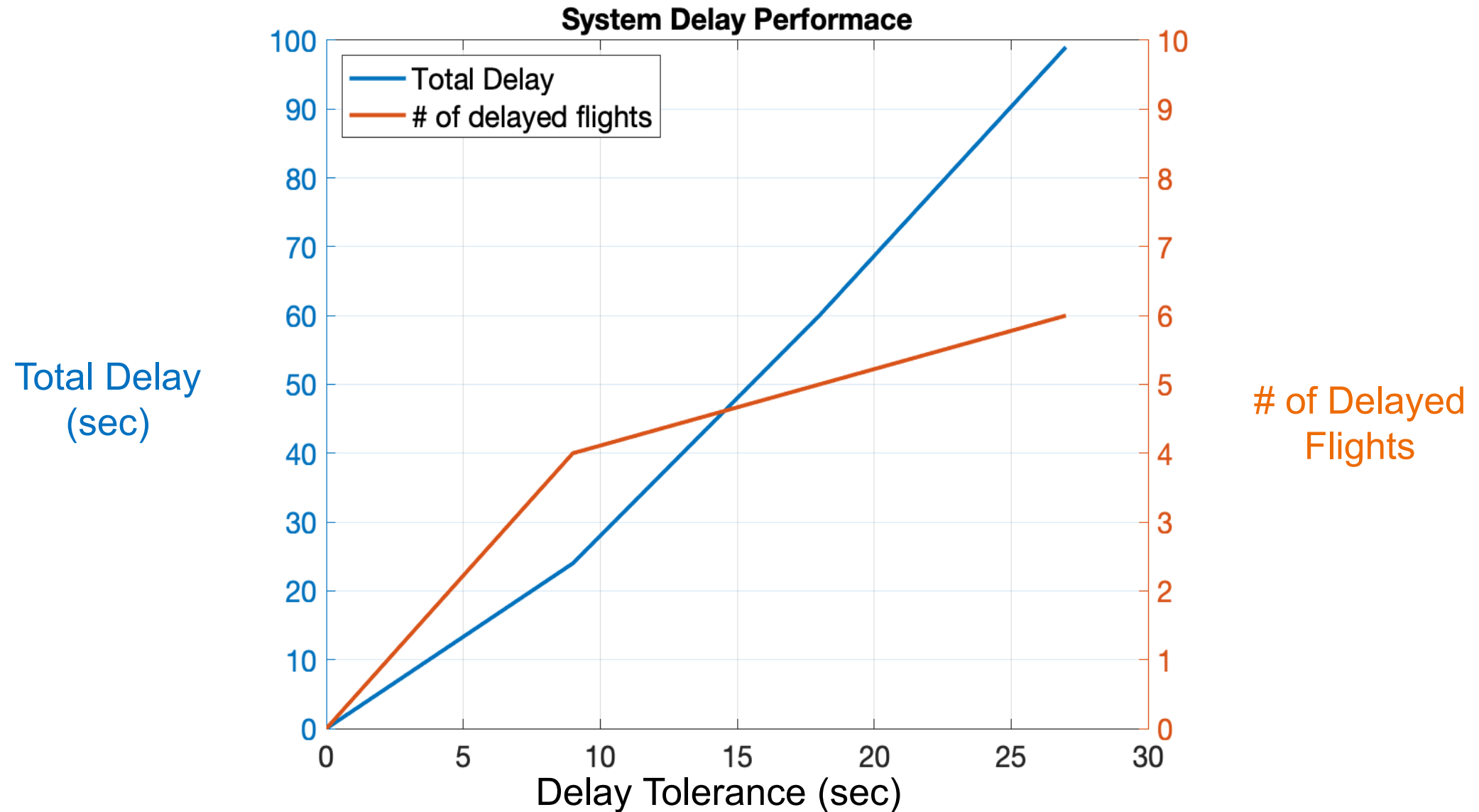
- Traffic density: 5 - 100 flights (1045 scenarios)
- Aircraft speed: 5 - 20 m/s (~ 10-40 knots small drones)
- Cell edge length: 100 m (0.054 nmi)
- For given delay tolerance, delay increment = 3 sec.
- High local impedance limit = 0.6
- **Delay tolerance**: 9 s, 18 s, and 27 s
- No wind, communication, navigation, or surveillance uncertainties

Metrics

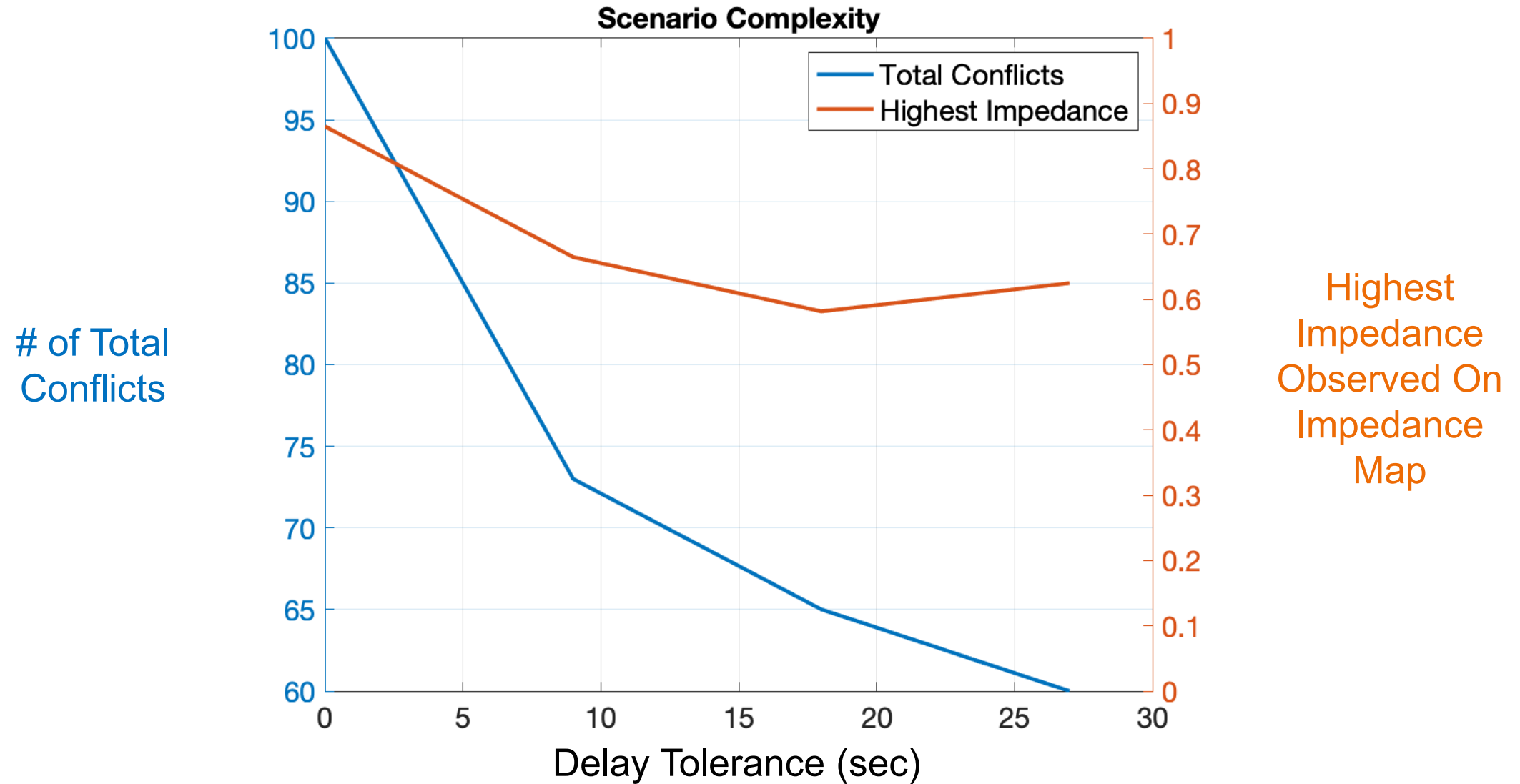
- Total delay in the system
- Number of delayed flights
- Number of total conflicts
- Highest local impedance observed on impedance map

RESULTS

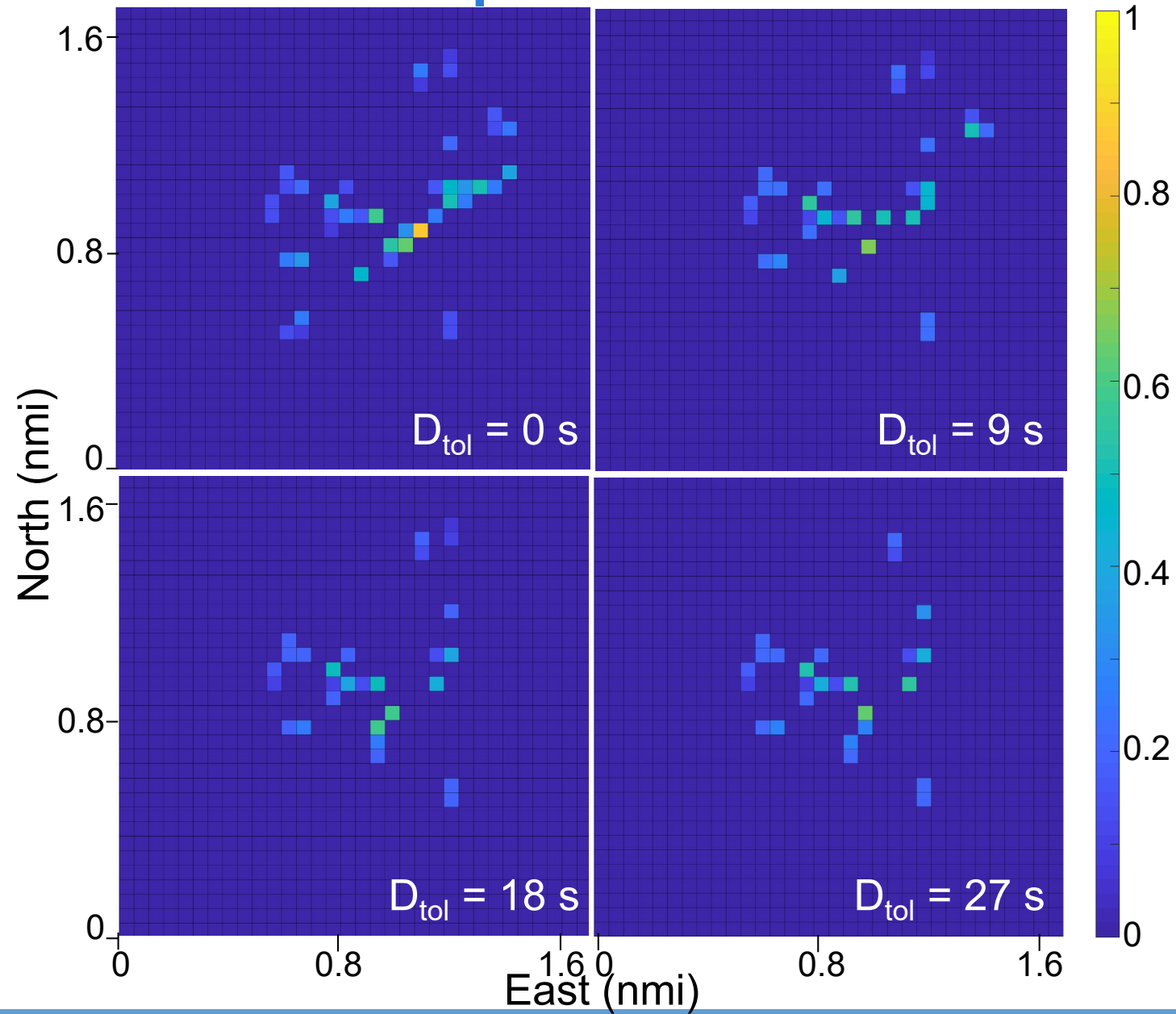
Delay



Complexity



Hot Spot Dissolution



Applications

Insight - Delay on ground preferable to delay in air.

- System delay vs individual delay tradeoffs
- Generalizable to non direct traffic
- Also applicable to UAM scenarios



Questions/Comments/Suggestions?
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