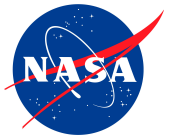
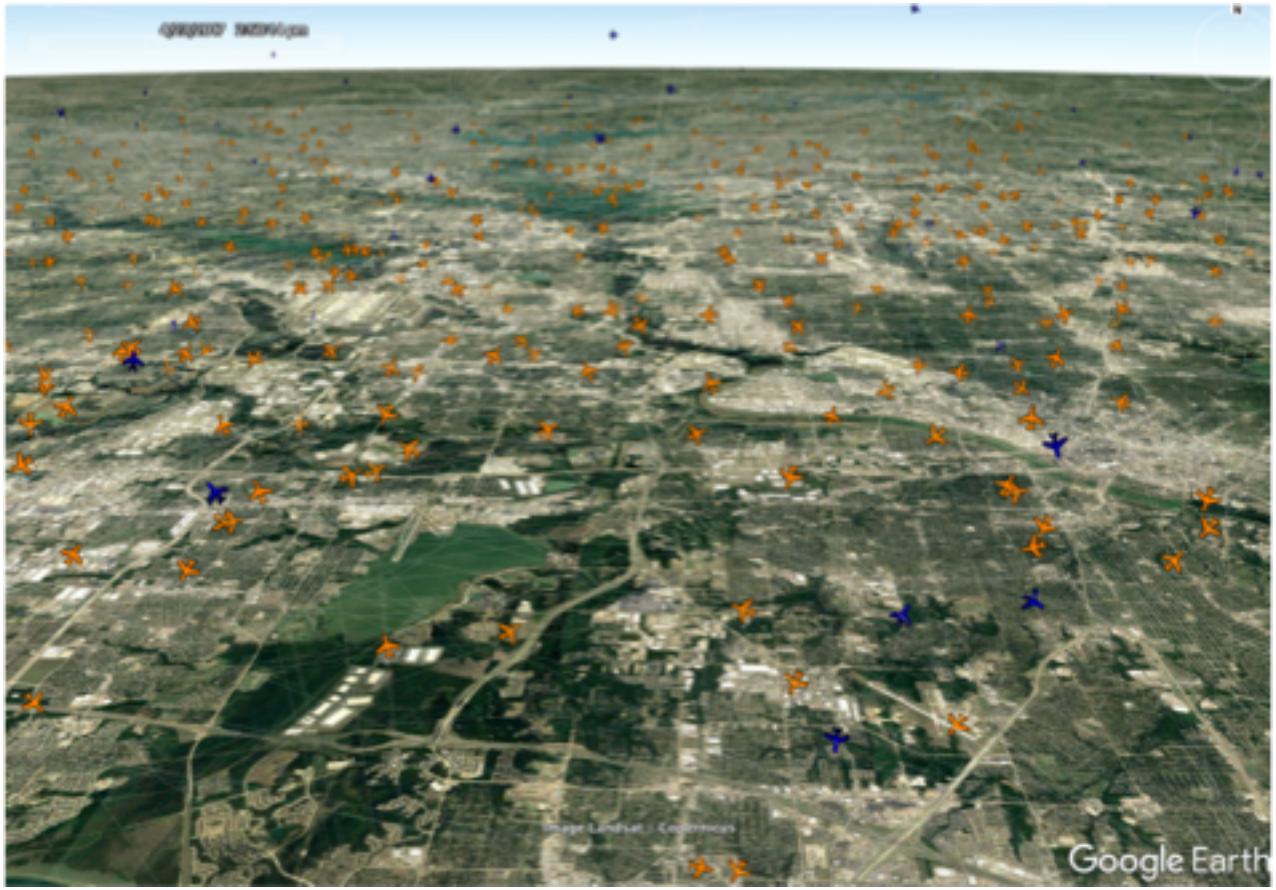


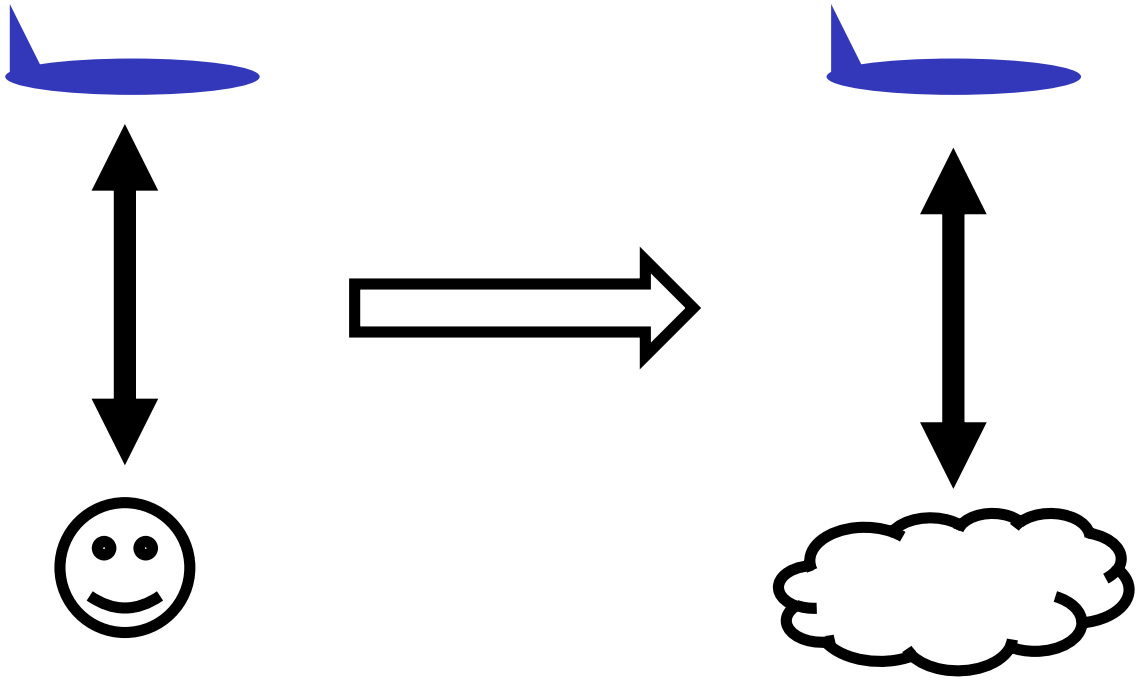
Autonomous Coordinated Airspace Services for Terminal and Enroute Operations with Wind Errors

Todd Lauderdale, Christabelle Bosson,
Yung-Cheng Chu, and Heinz Erzberger
NASA Ames Research Center

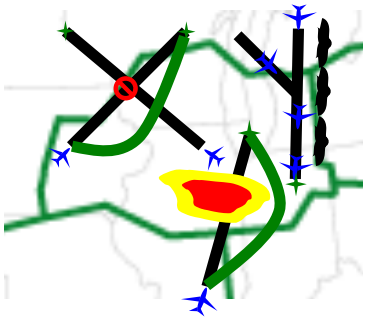
Increasingly Complex Airspace



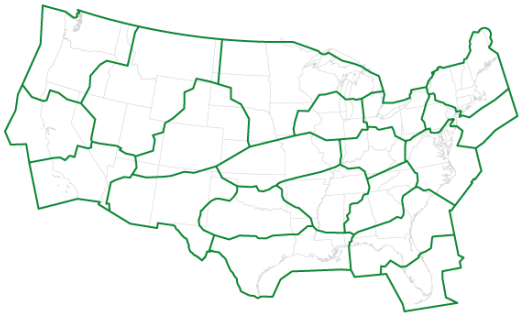
Foundational Autonomy Research



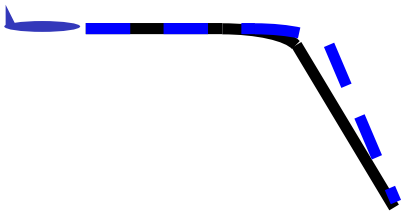
Development of an Autonomous Airspace Service



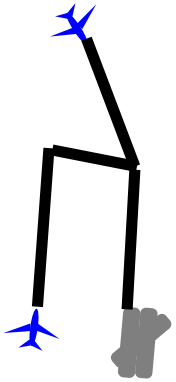
4D separation, arrival management and weather avoidance



Coordinated operations across 20 enroute centers

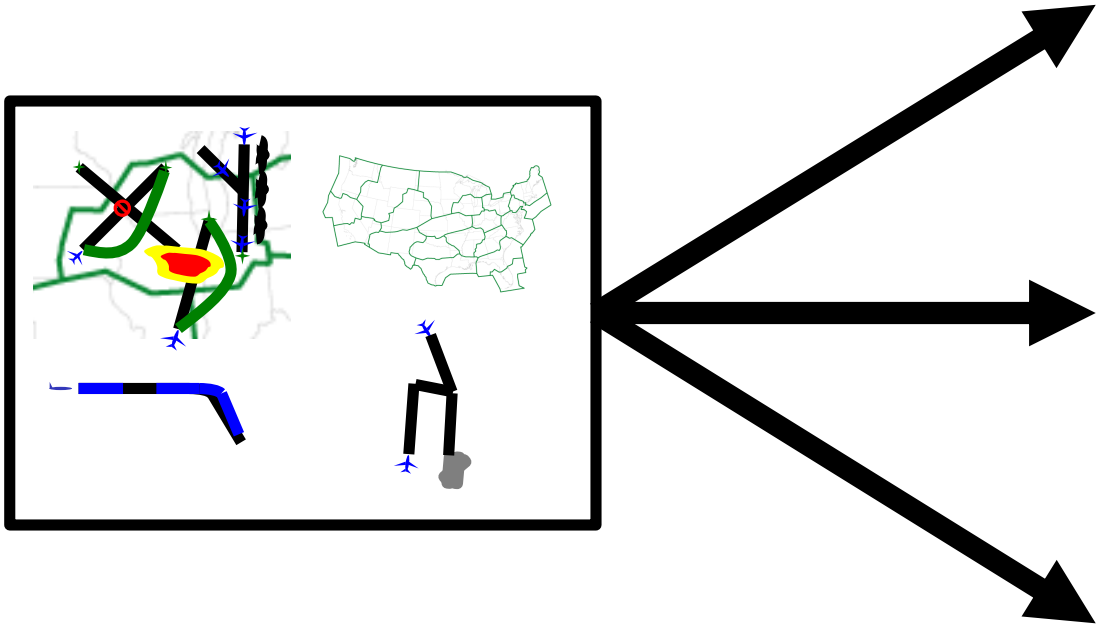


Operations in the presence of uncertainty and errors

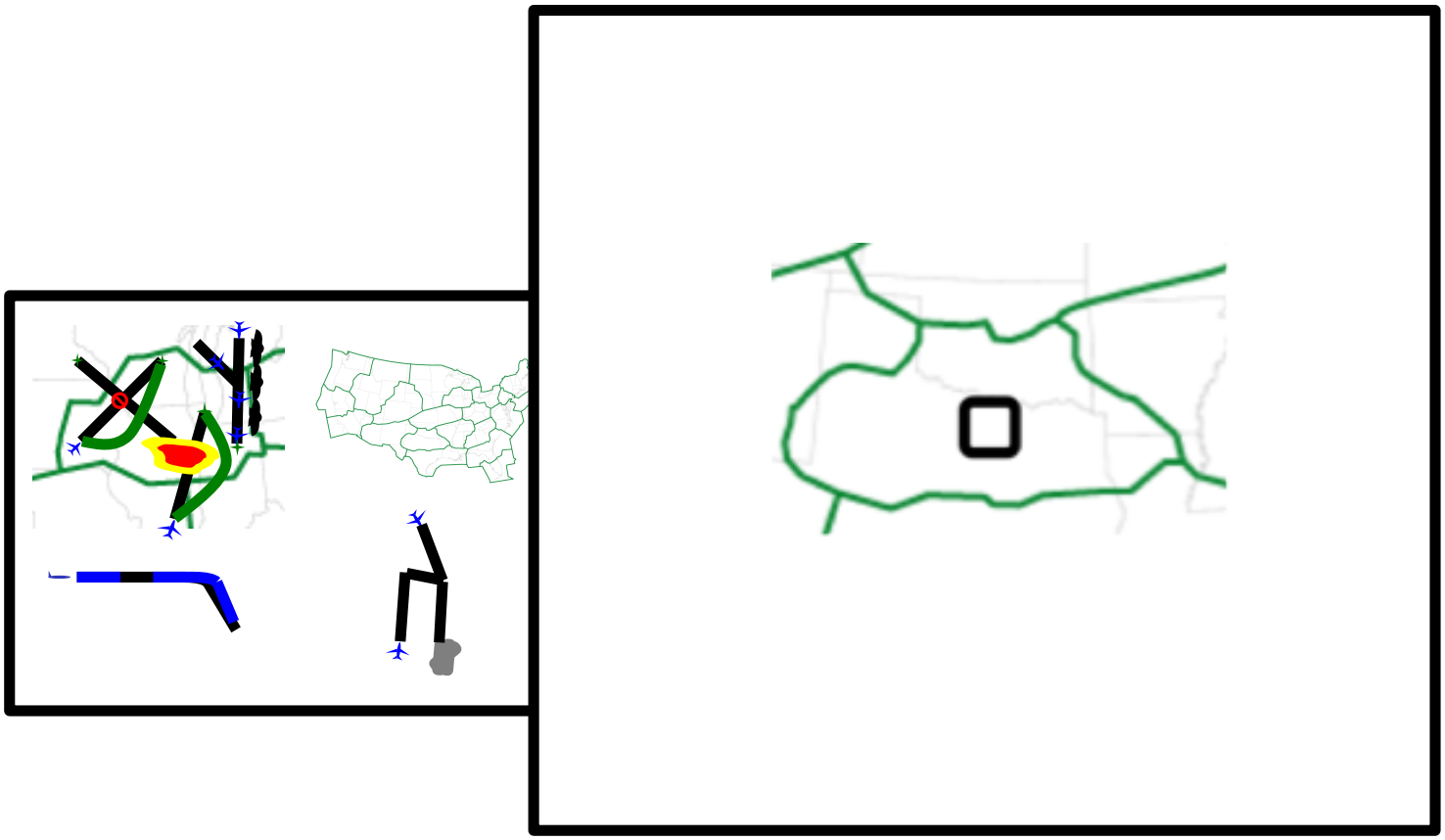


Terminal Area Operations

Current Development

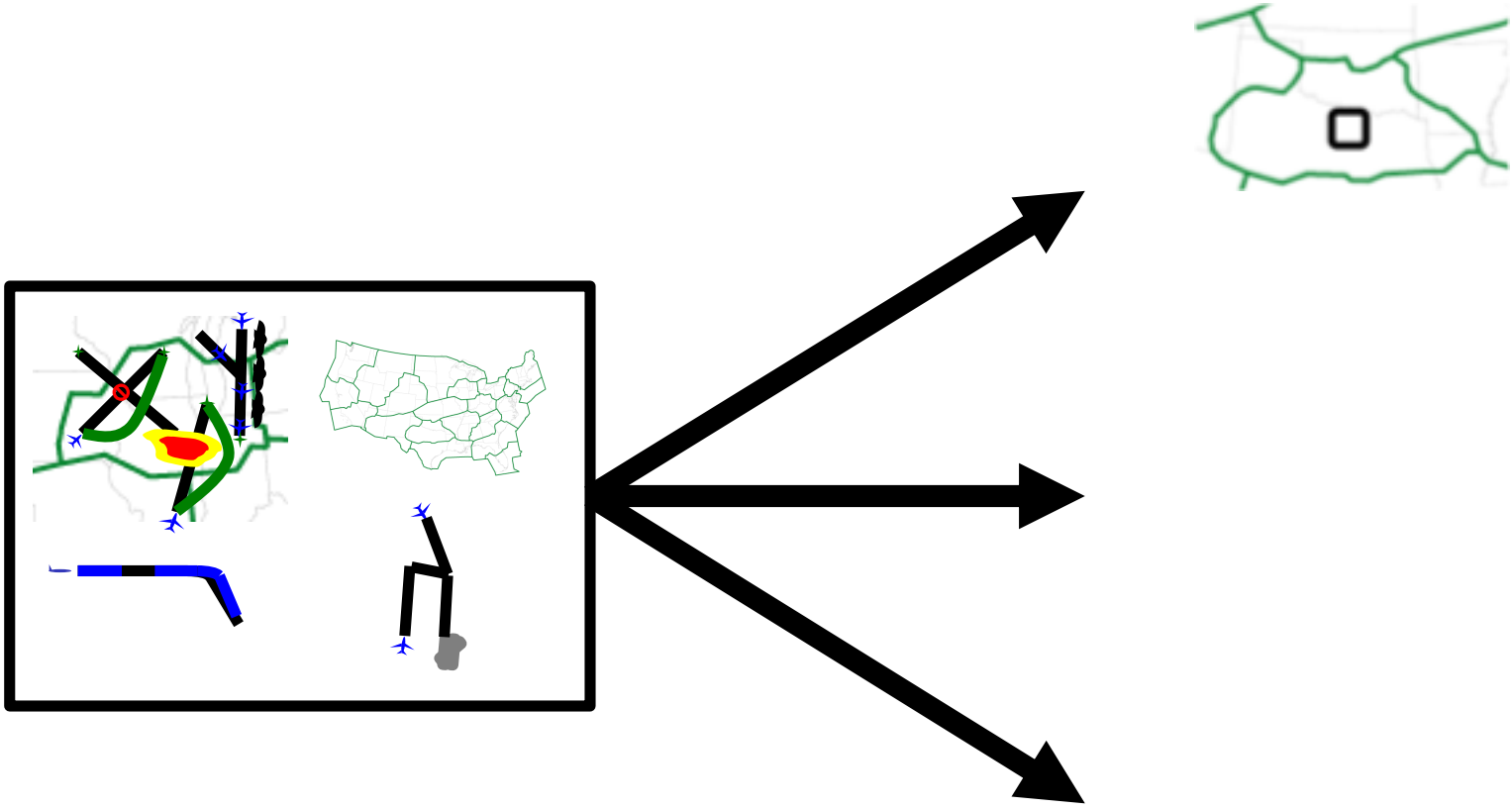


Current Development

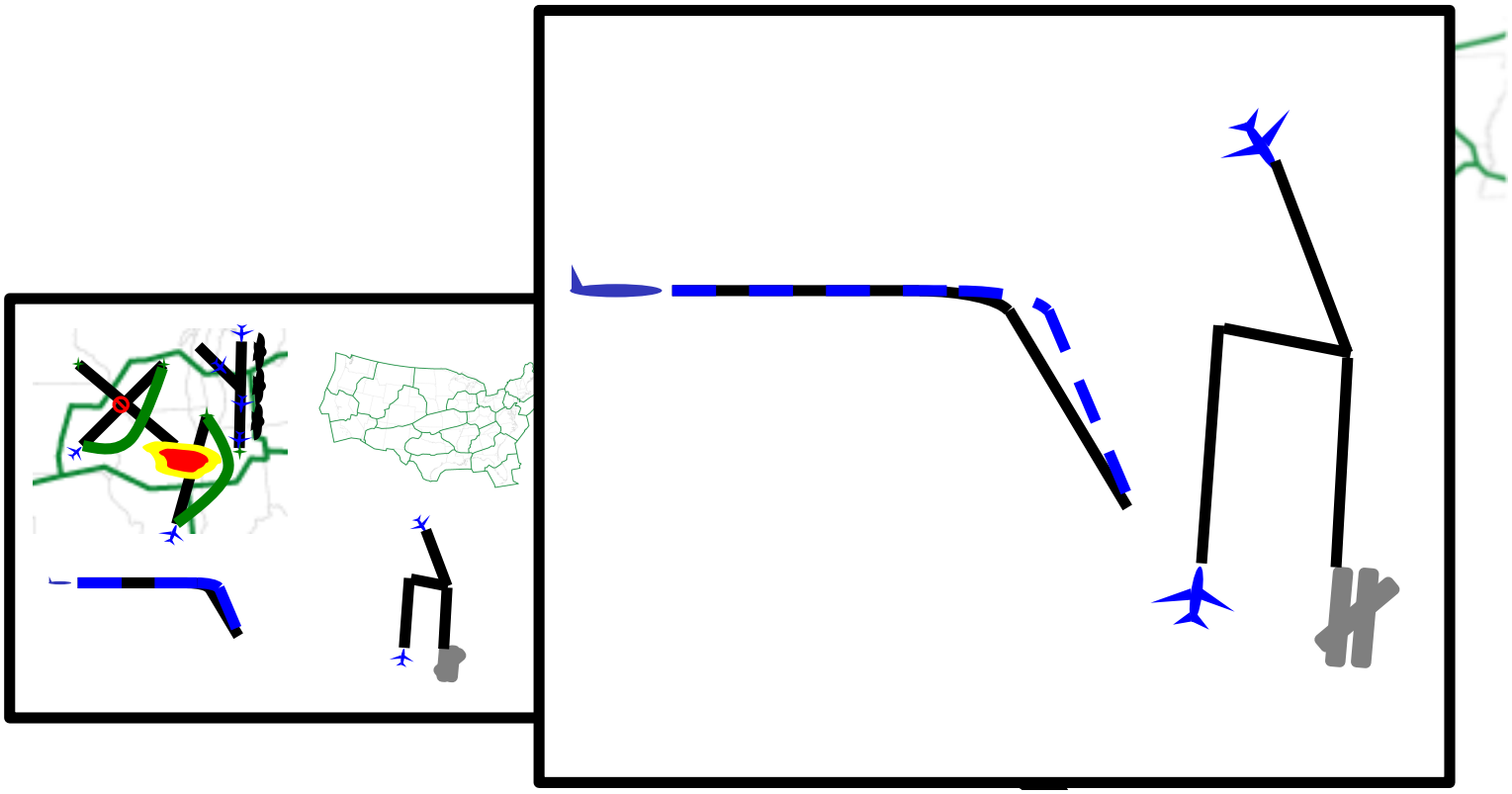


Coordinated Terminal Area and Enroute Operations

Current Development

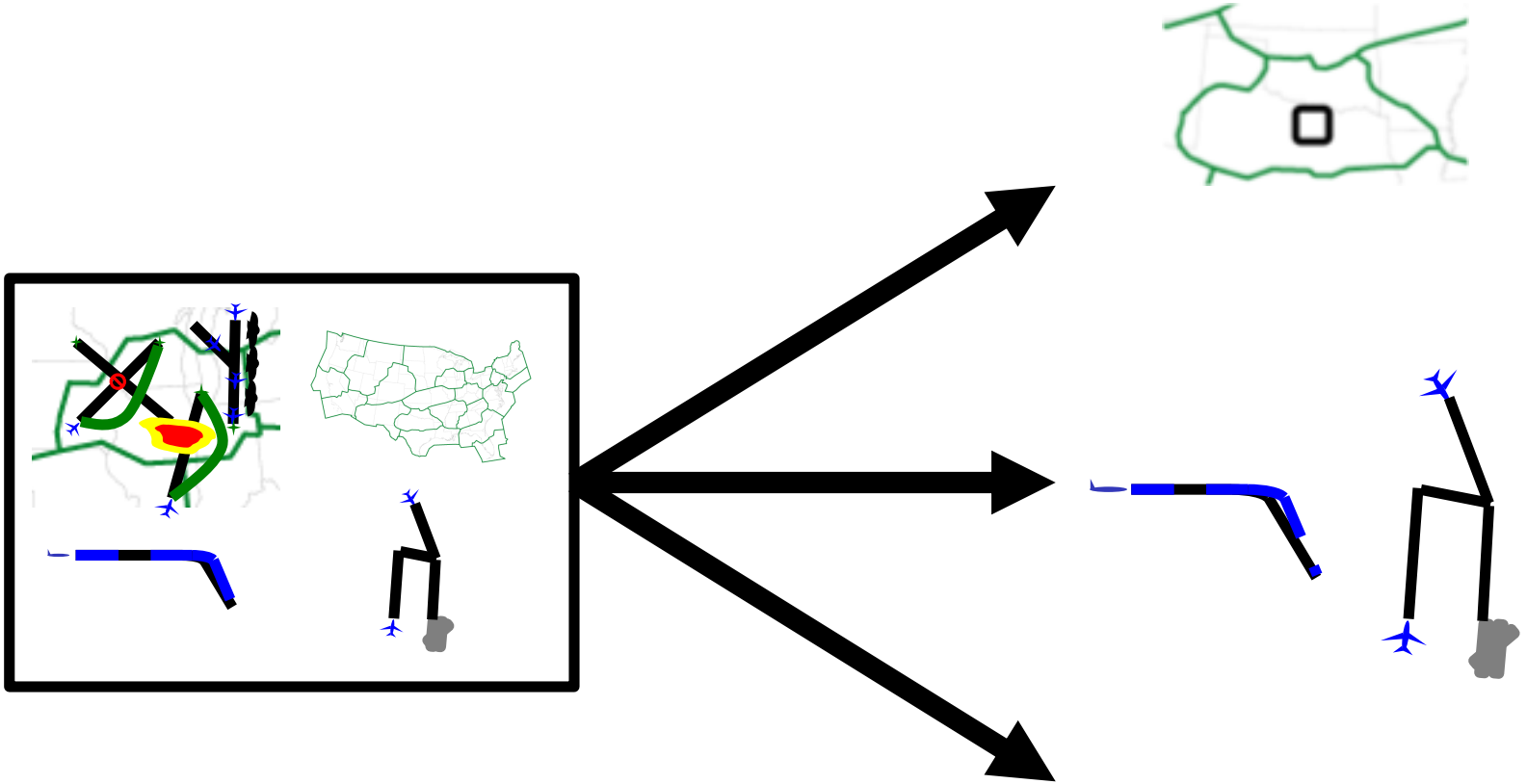


Current Development

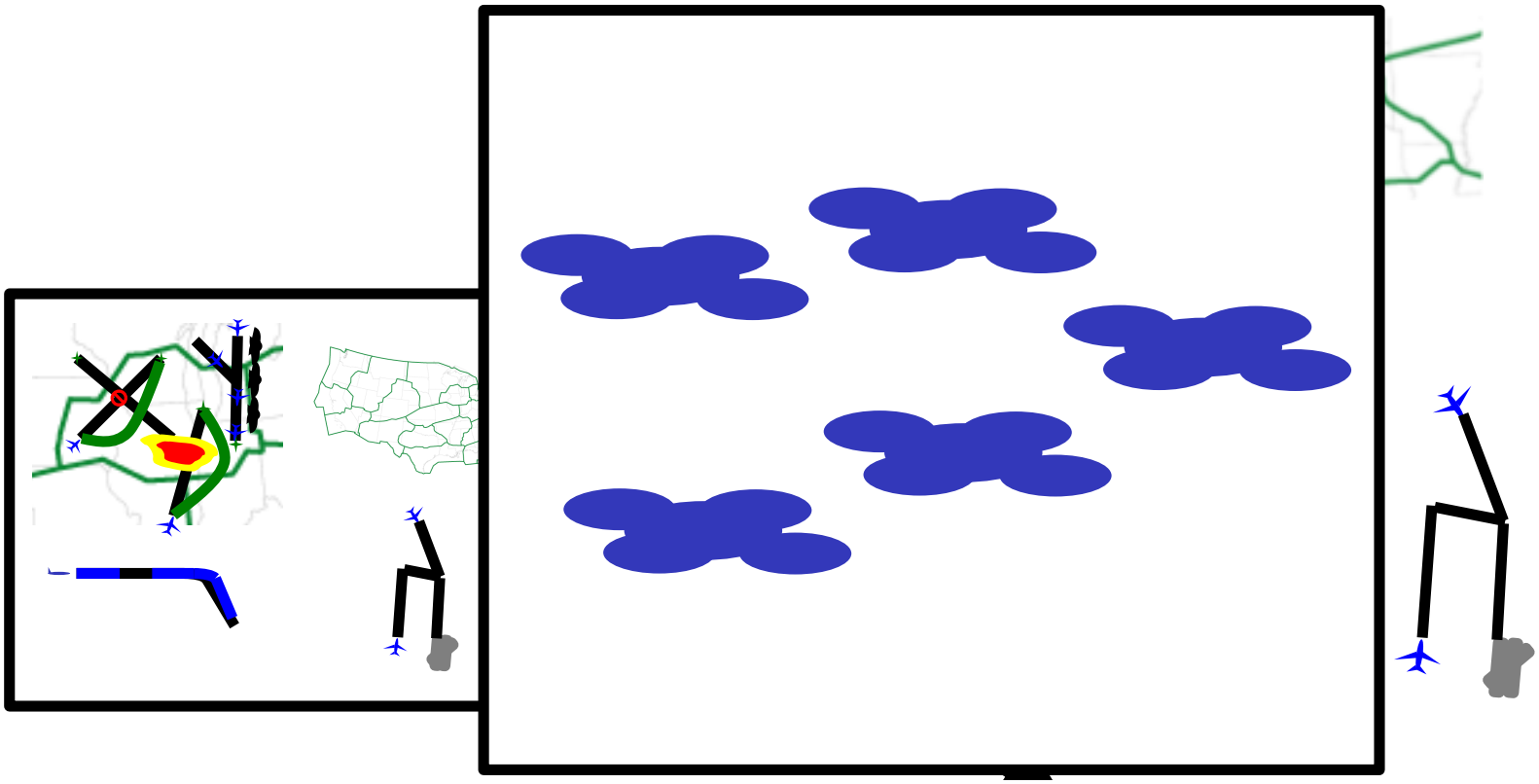


Trajectory Prediction Errors in the Terminal Area

Current Development

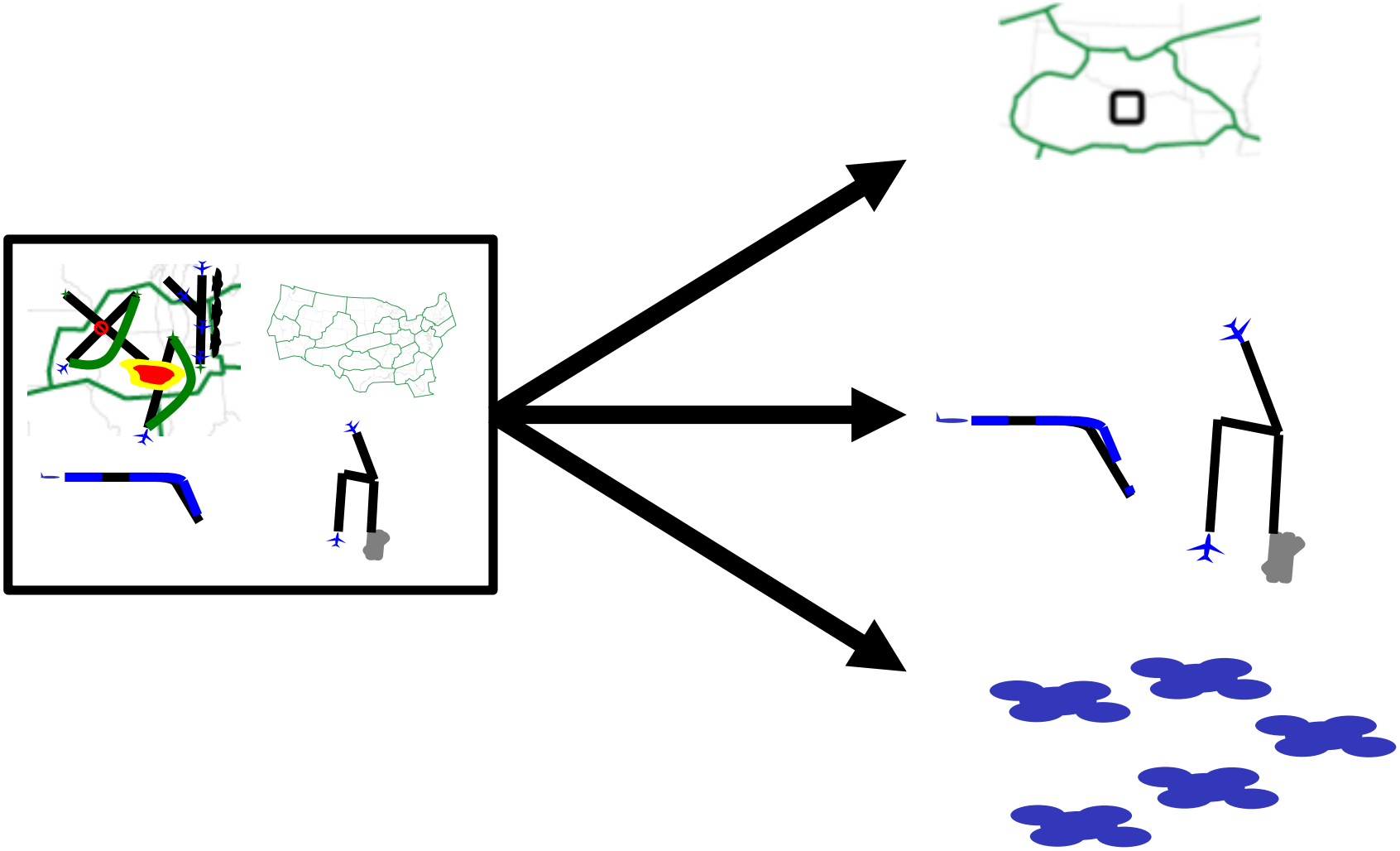


Current Development

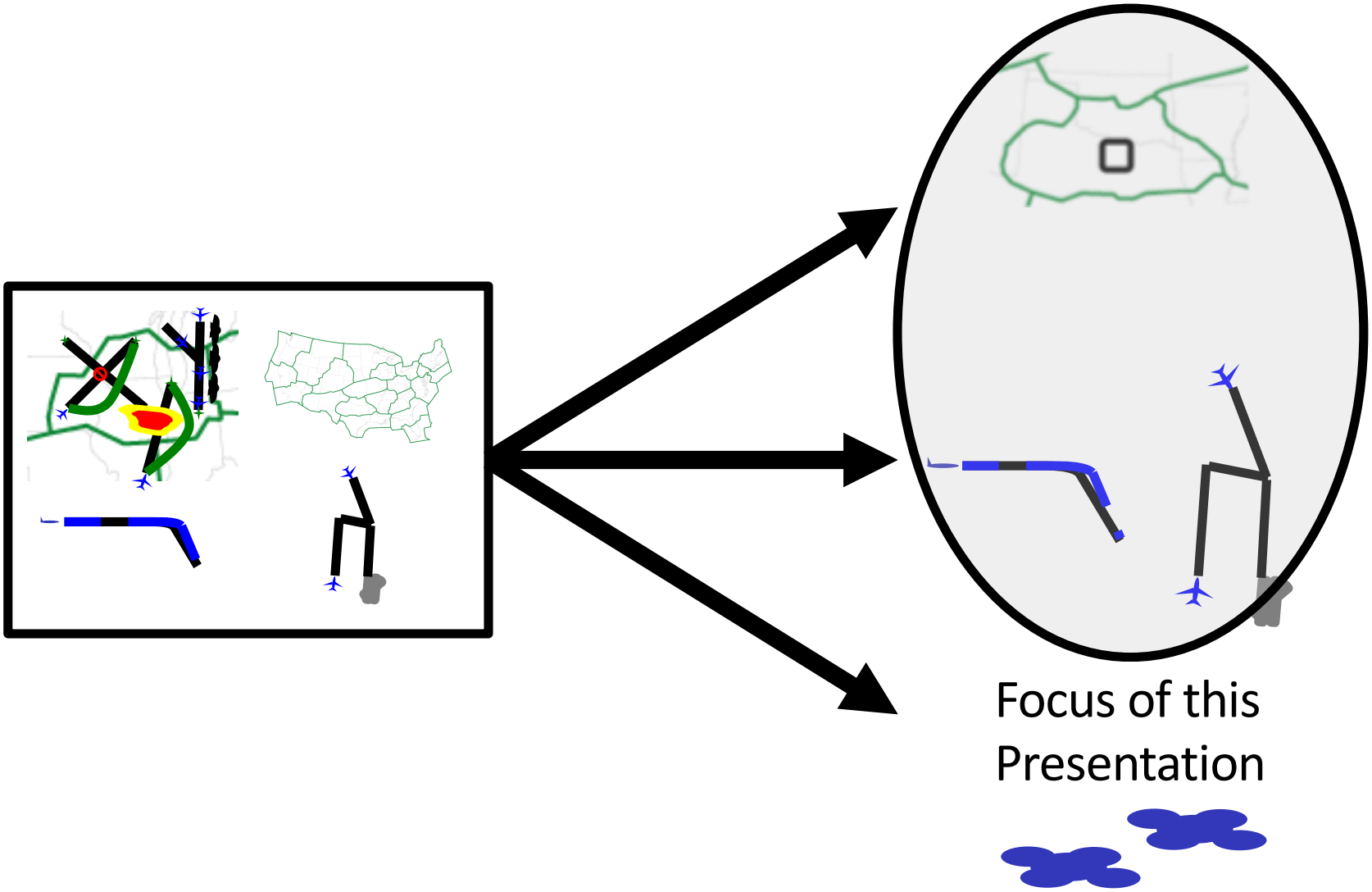


Handling Novel Operations
(Aviation 2018 Talk by Bosson)

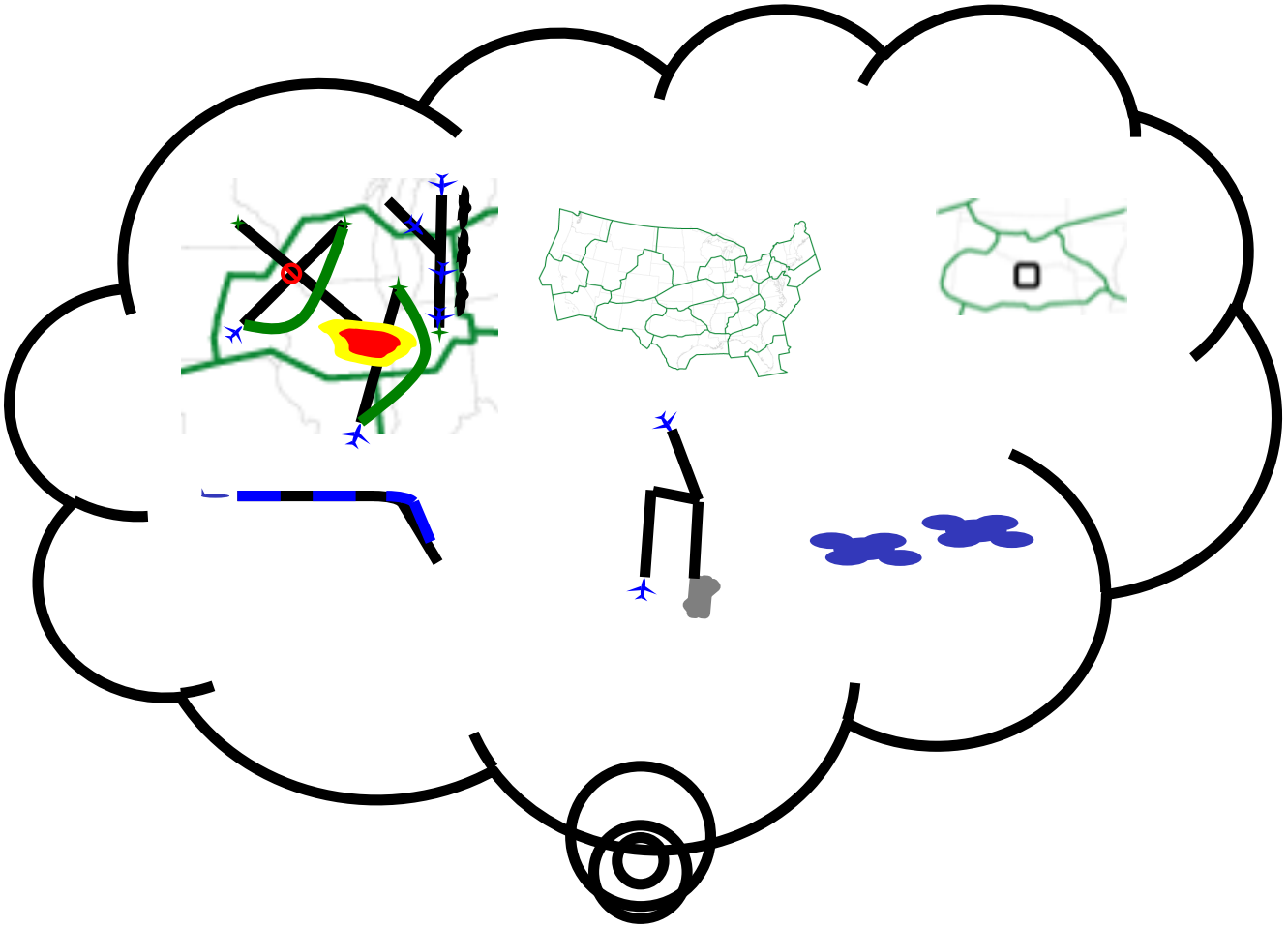
Current Development



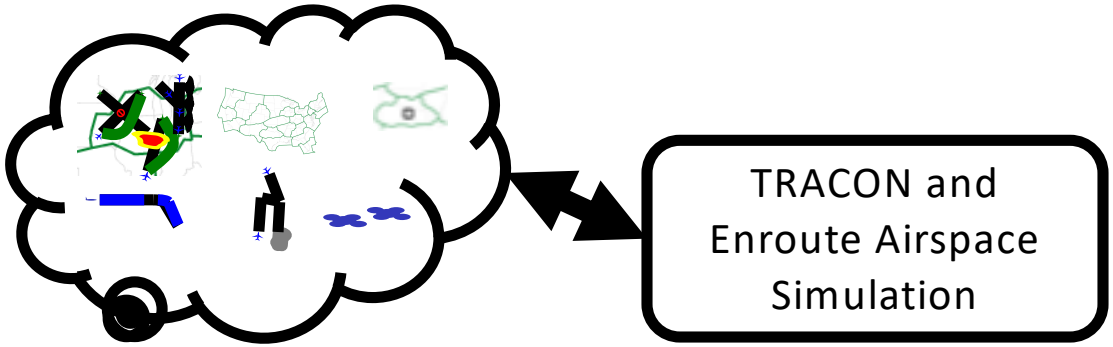
Current Development



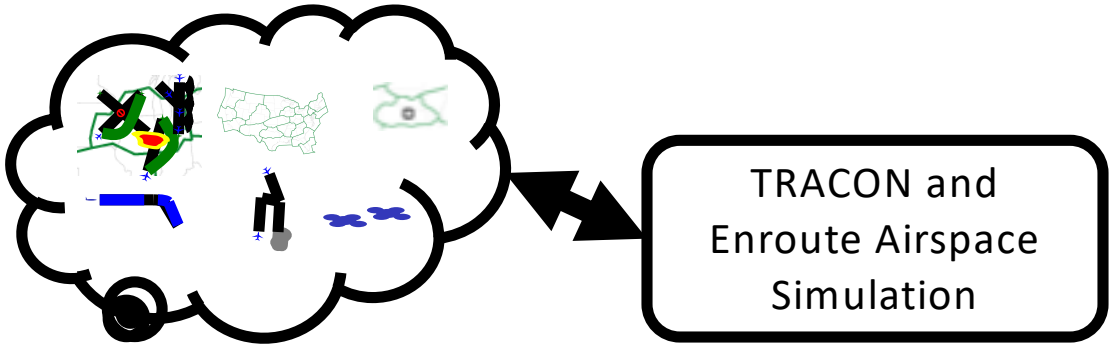
Cloud-Based Service



Exercising New Capabilities

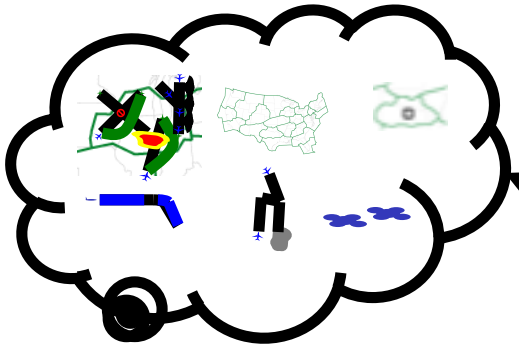


Exercising New Capabilities

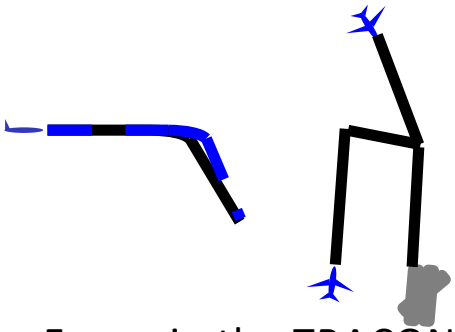


Coordination Rules

Exercising New Capabilities



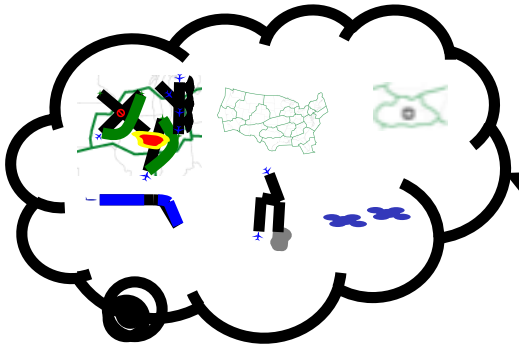
TRACON and
Enroute Airspace
Simulation



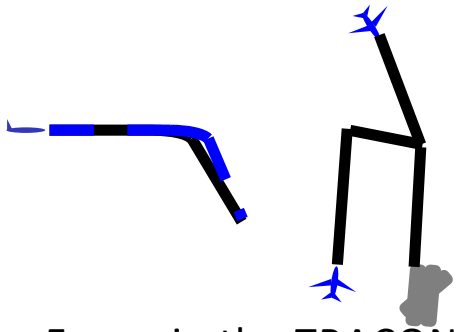
Errors in the TRACON

Coordination Rules

Exercising New Capabilities

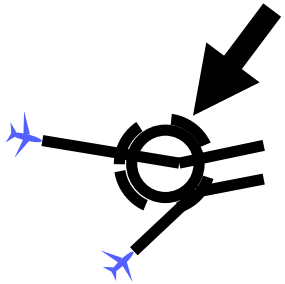


TRACON and
Enroute Airspace
Simulation



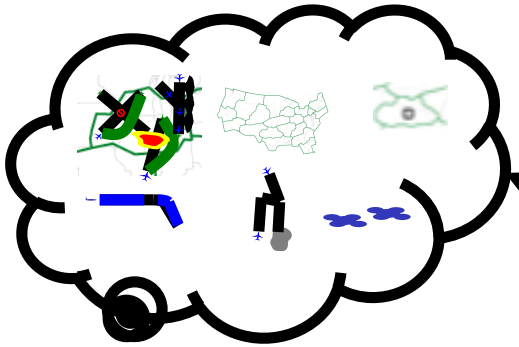
Errors in the TRACON

Coordination Rules

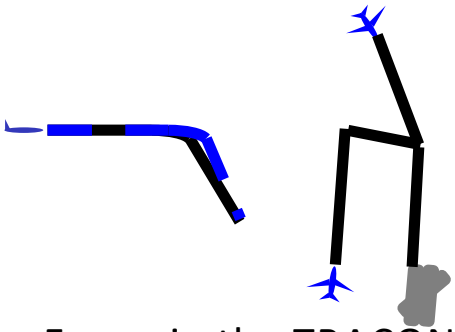


Detection Only

Exercising New Capabilities

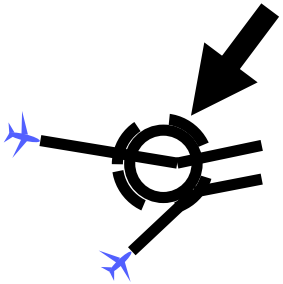


TRACON and
Enroute Airspace
Simulation

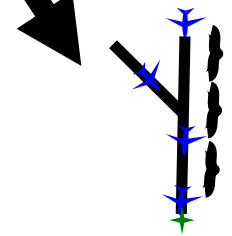


Errors in the TRACON

Coordination Rules

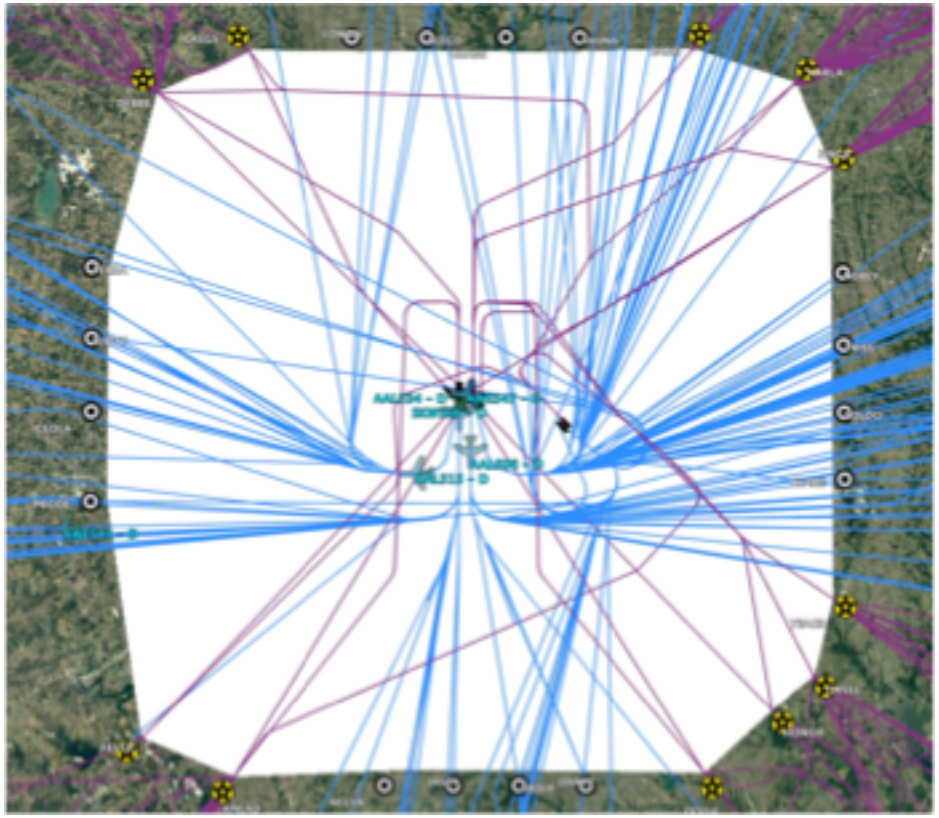


Detection Only



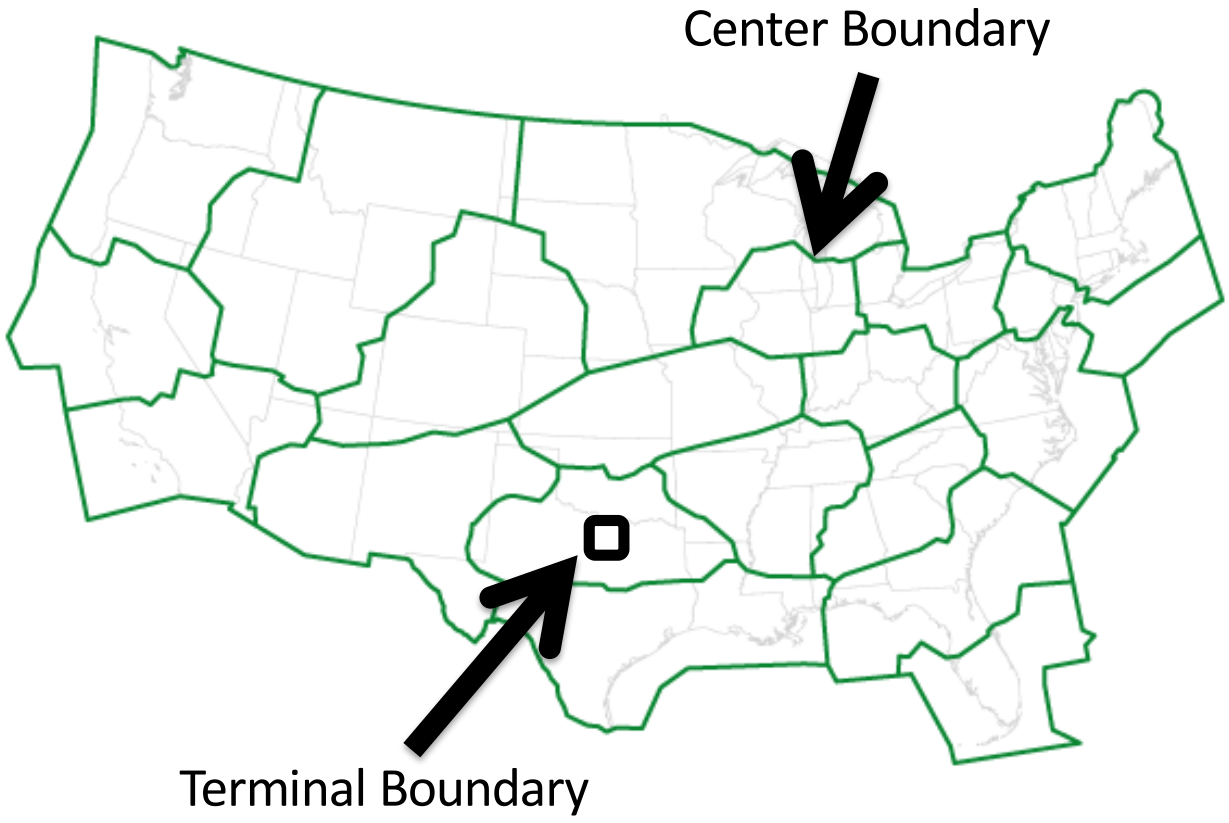
Arrival Conformance

Dallas (D10) TRACON

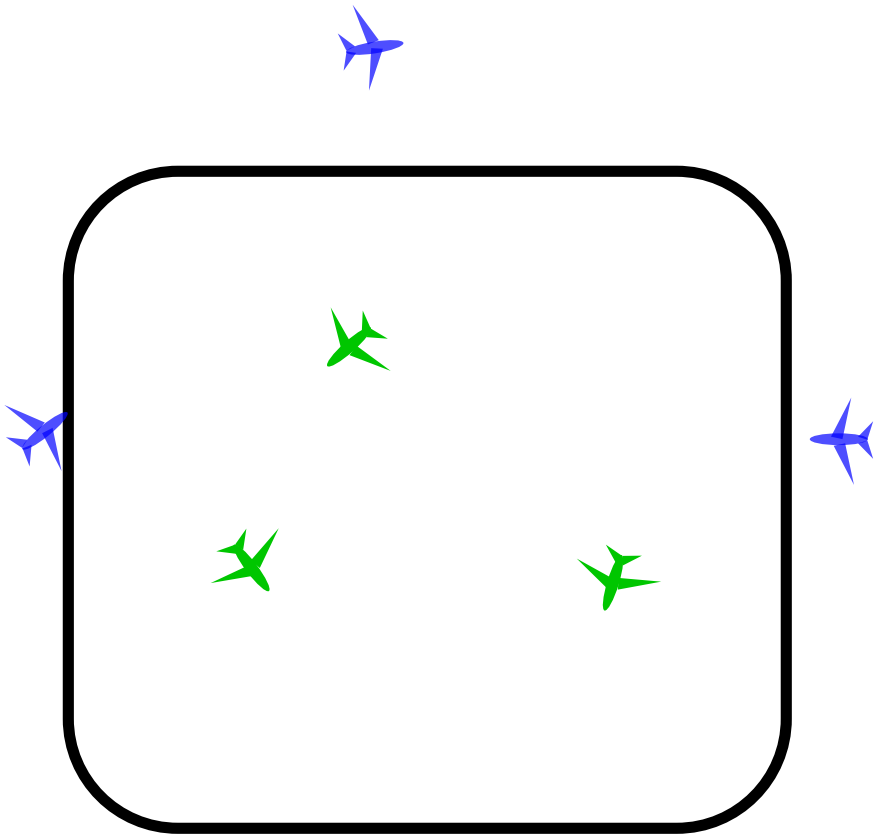


Simulated Traffic in D10;
350 Flights at Present Day
Demand Levels

Coordinated Enroute and Terminal Operations

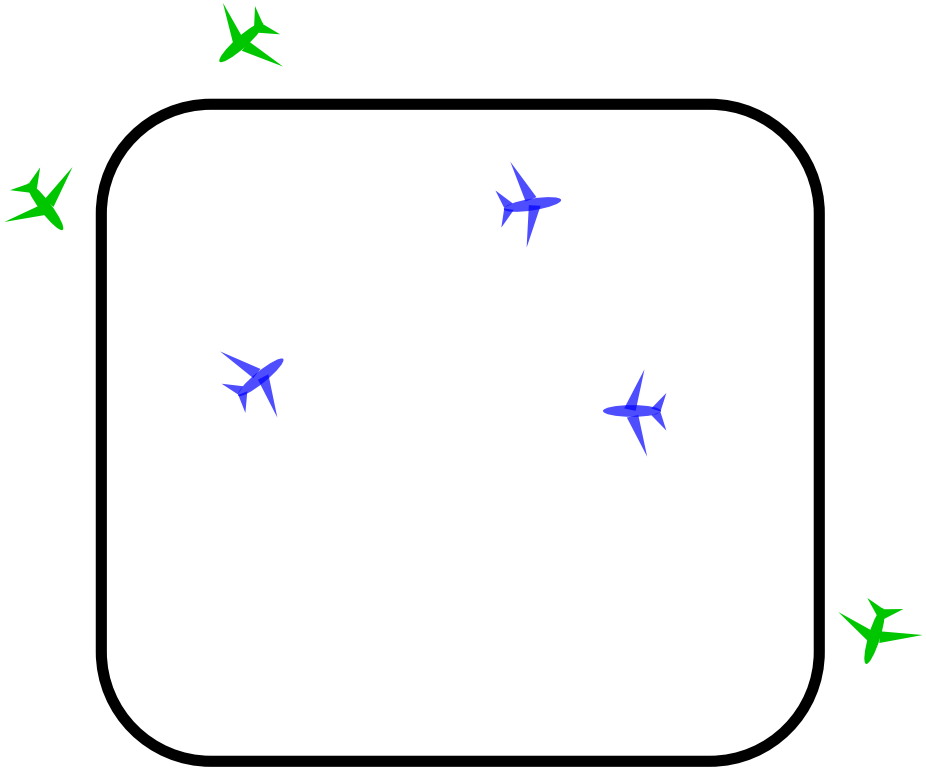


TRACON Visibility and Control



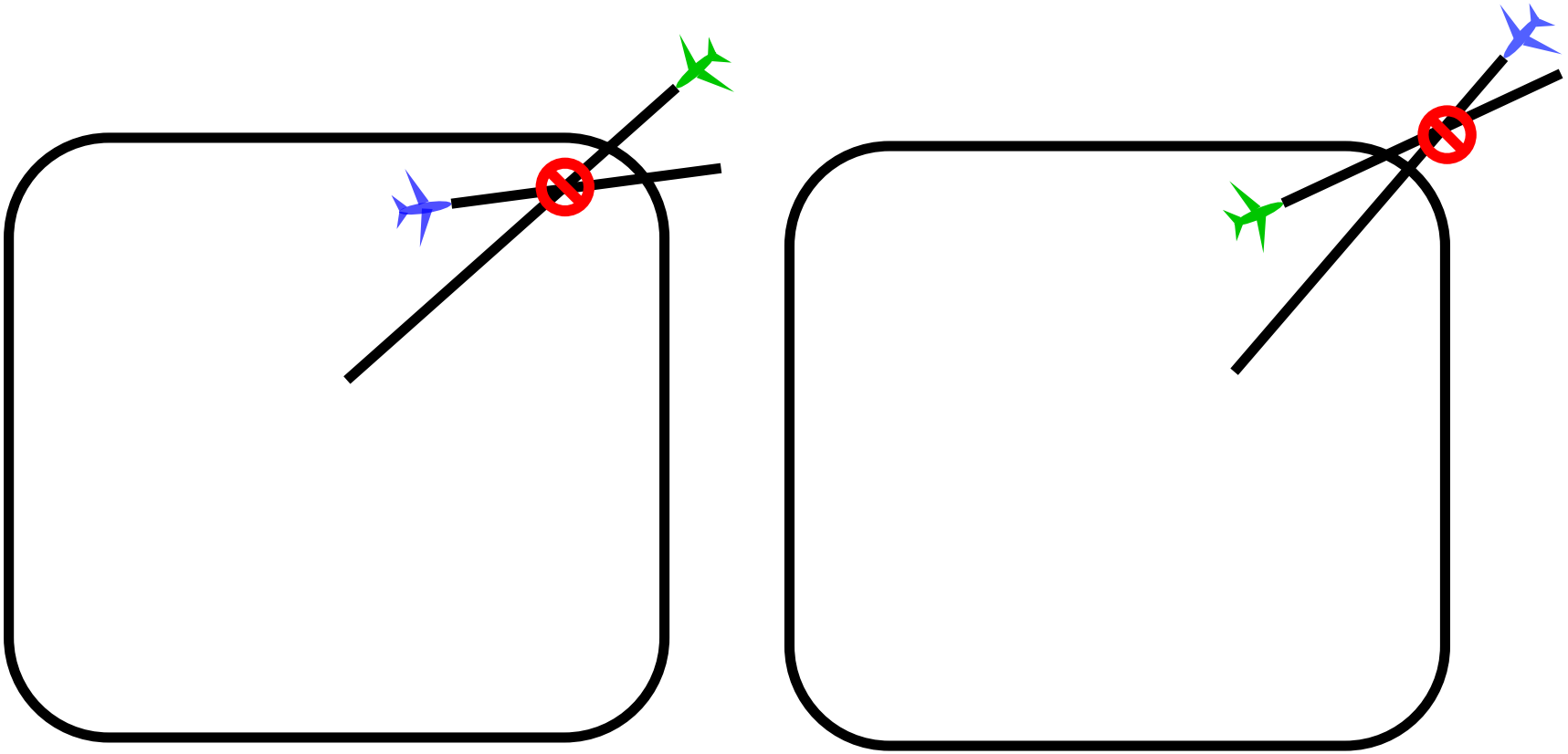
Green = Controlled
Blue = Visible

Enroute Visibility and Control

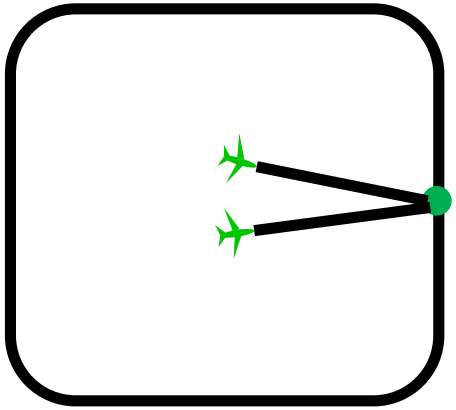


Green = Controlled
Blue = Visible

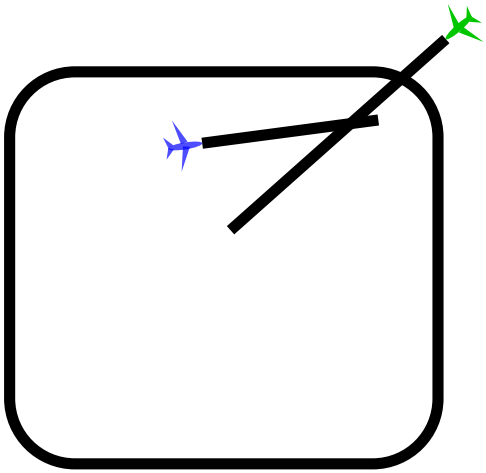
Losses of Separation Near Boundaries



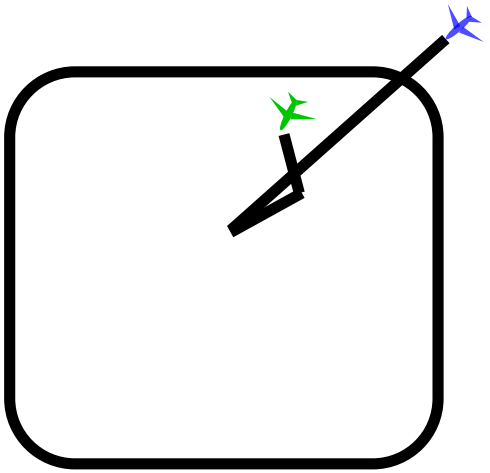
Coordination Rules



Use Enroute Separation

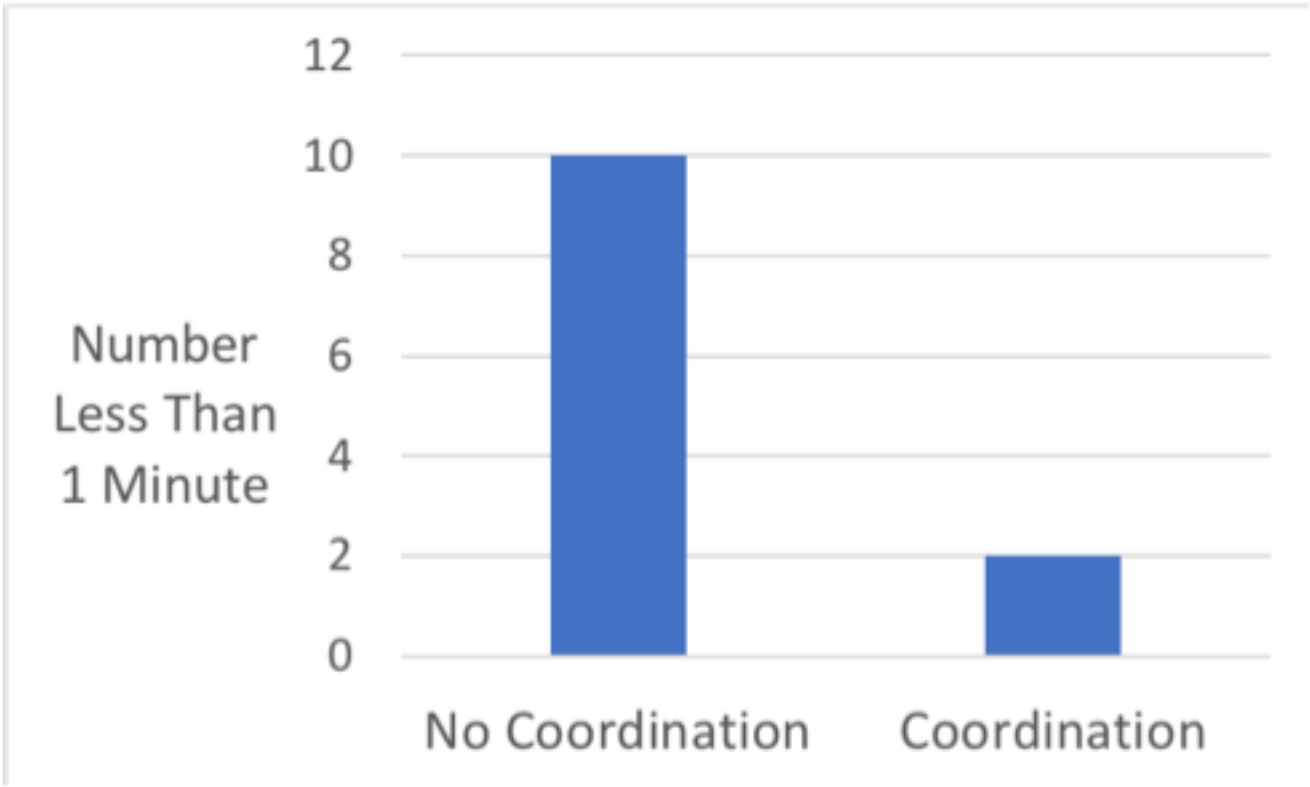


Enroute Ensure Conflict Free Across Boundary

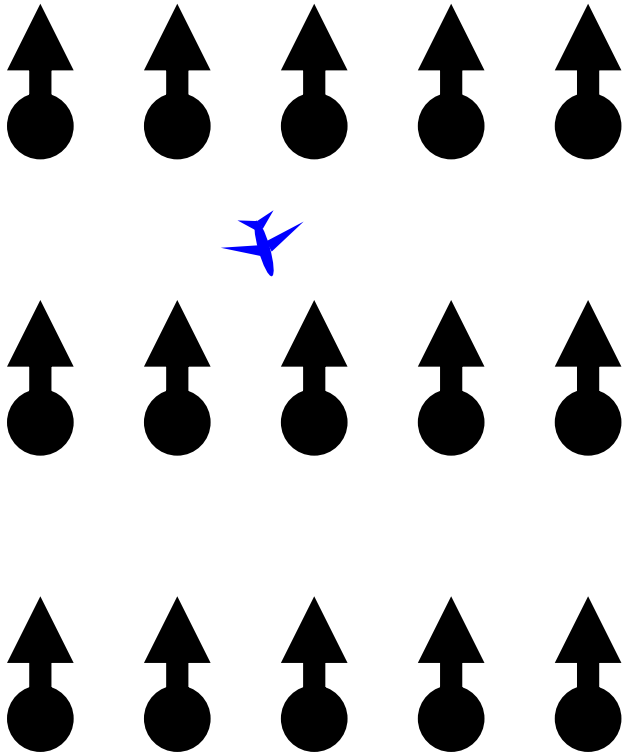


Terminal Assumes “Frozen” Enroute Trajectories

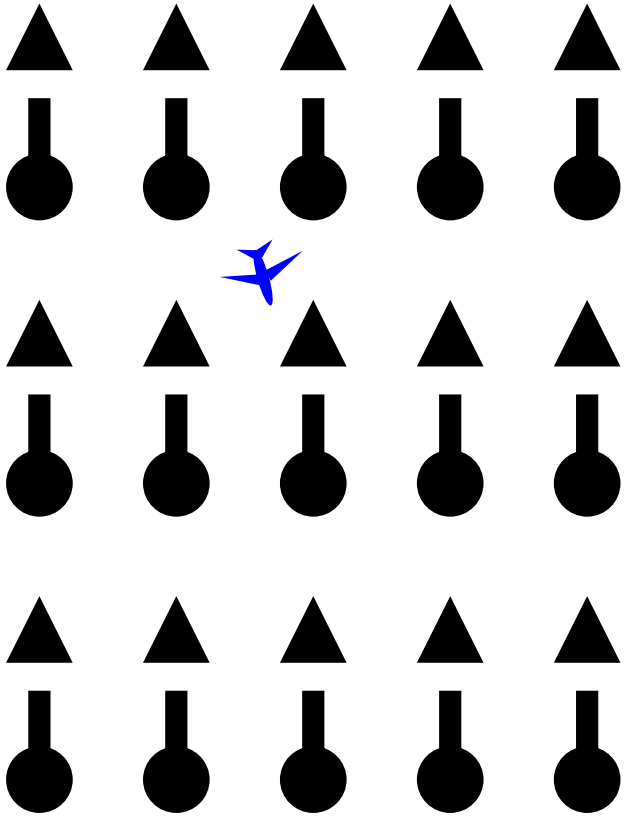
Conflicts Detected with Less than 1 Minute to Loss of Separation



Wind Field Errors

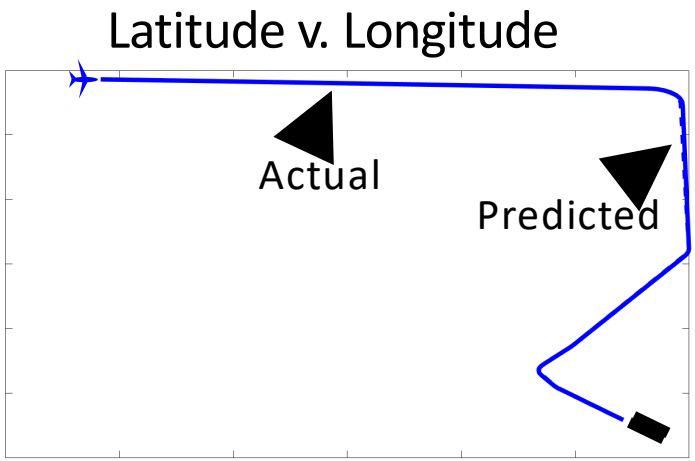


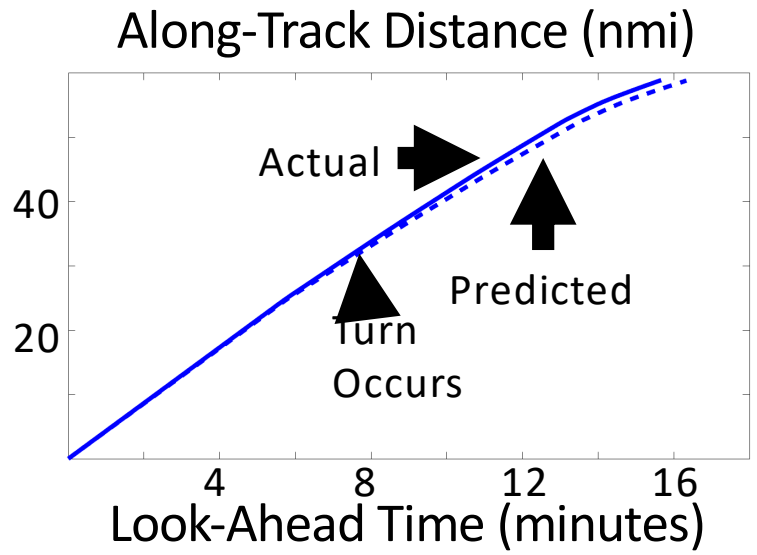
Actual Winds
(Constant 25 knots from the South)

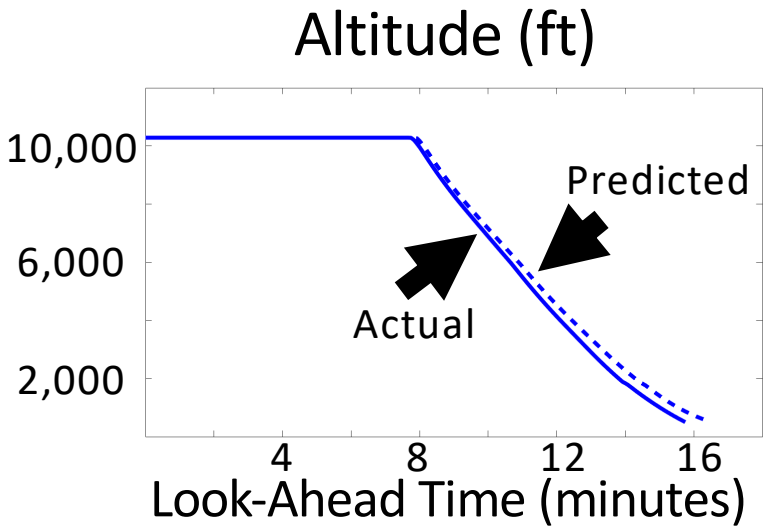


Predicted Winds
(150% Actual Magnitude)

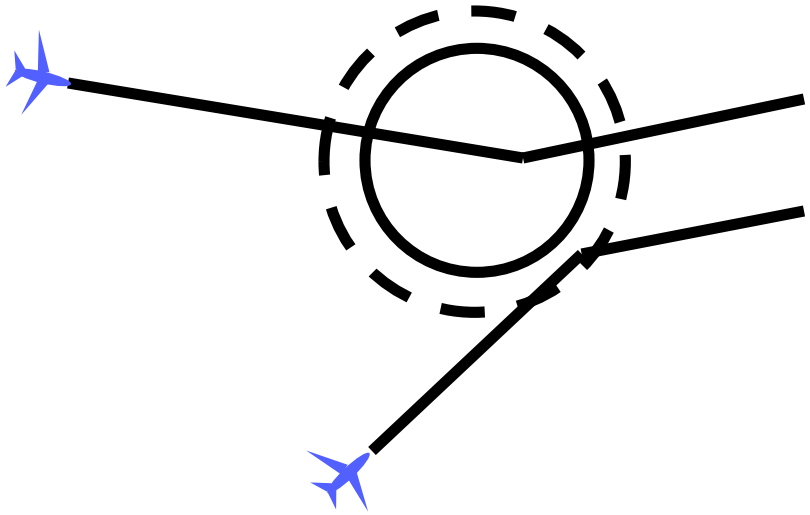
Example Trajectories



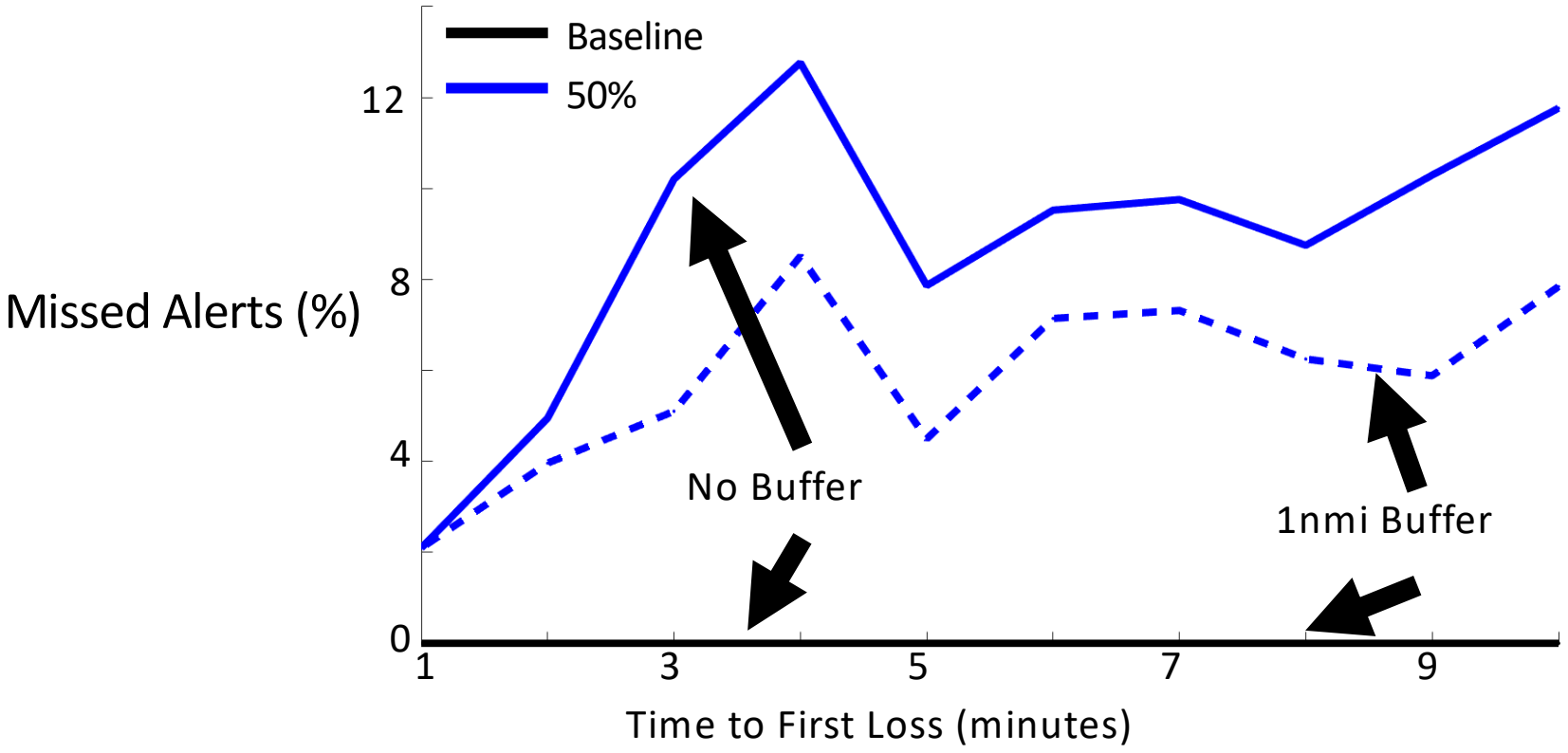




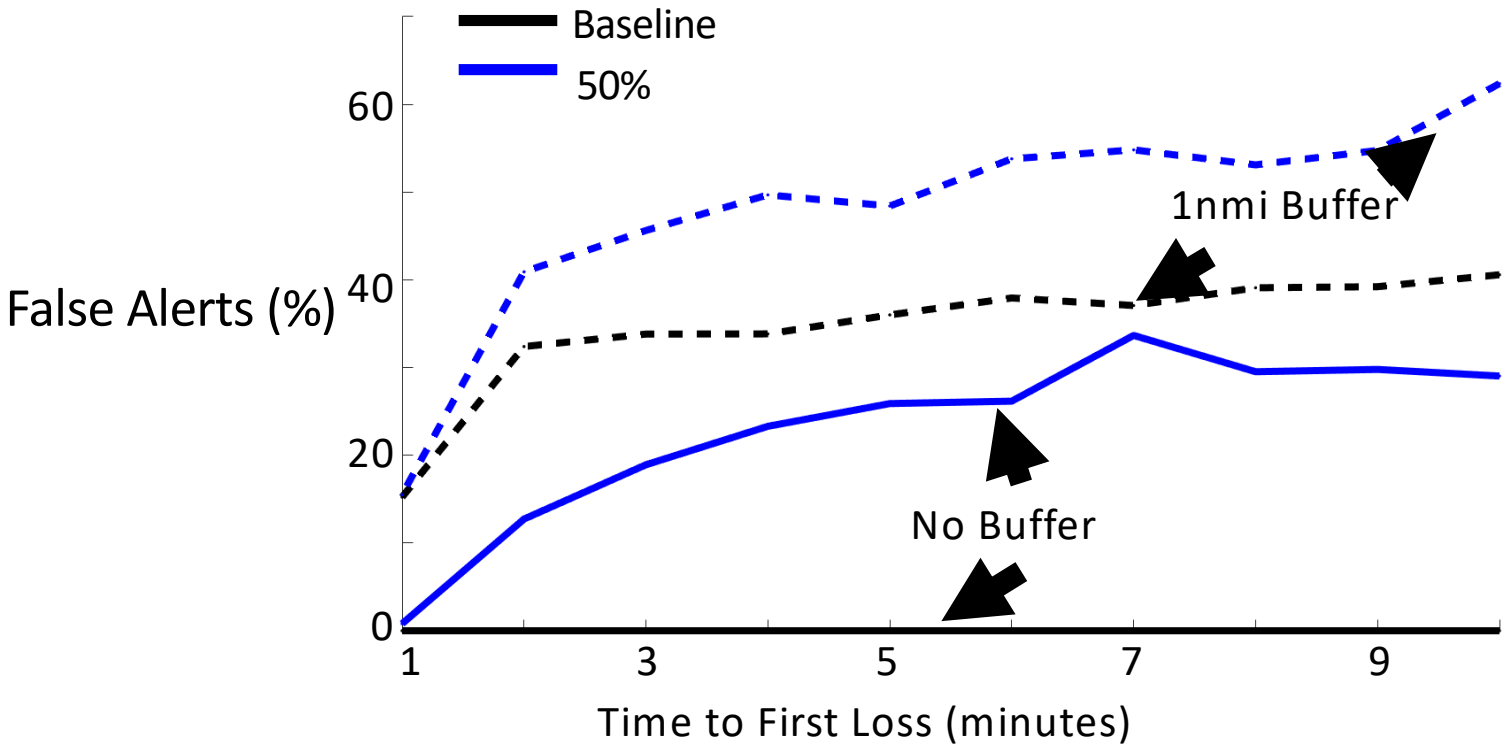
Detection Buffer



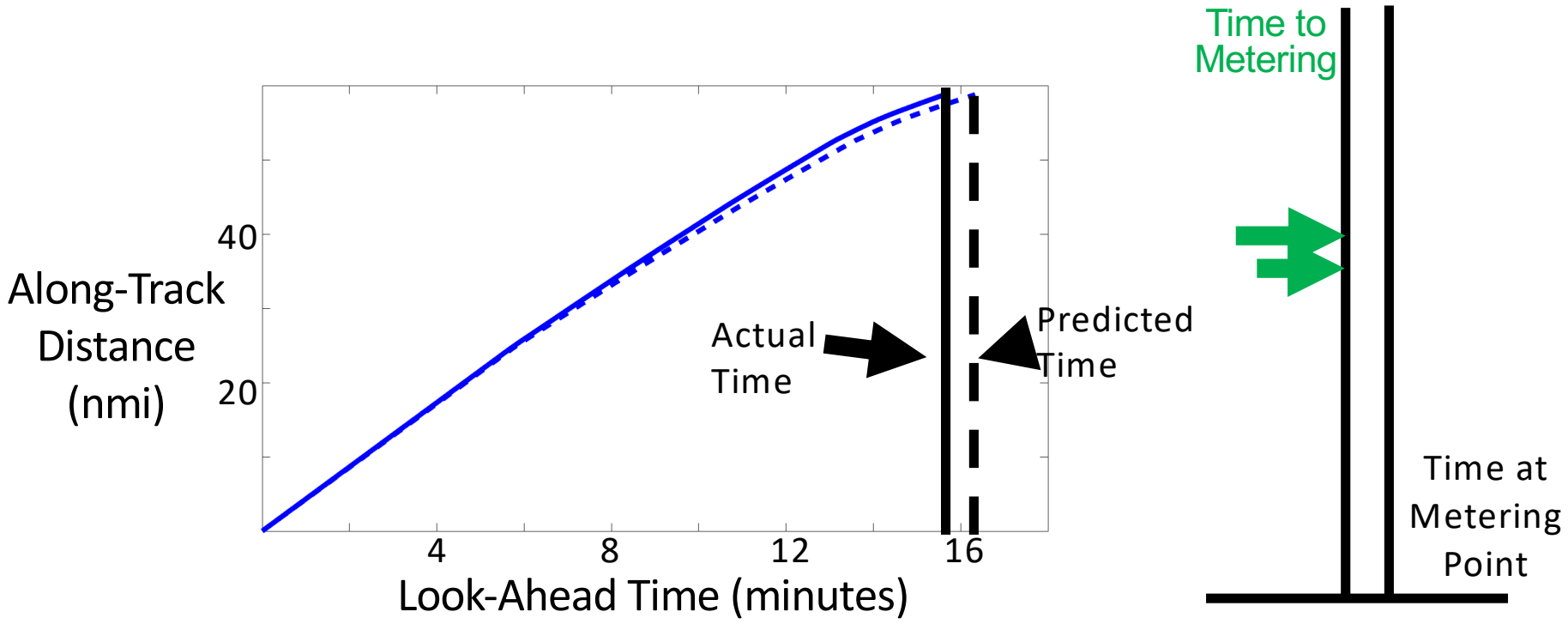
Missed Alerts



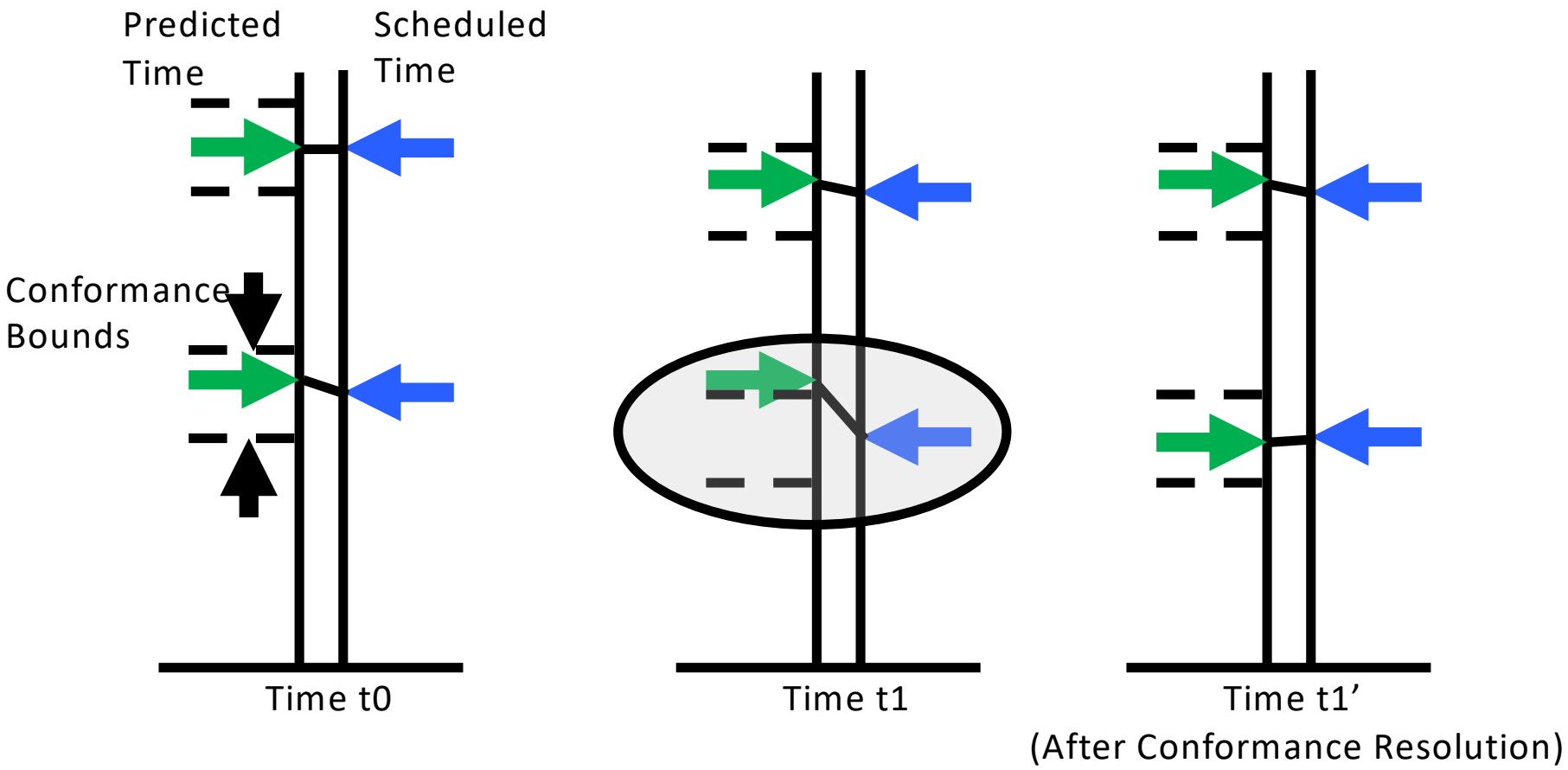
False Alerts



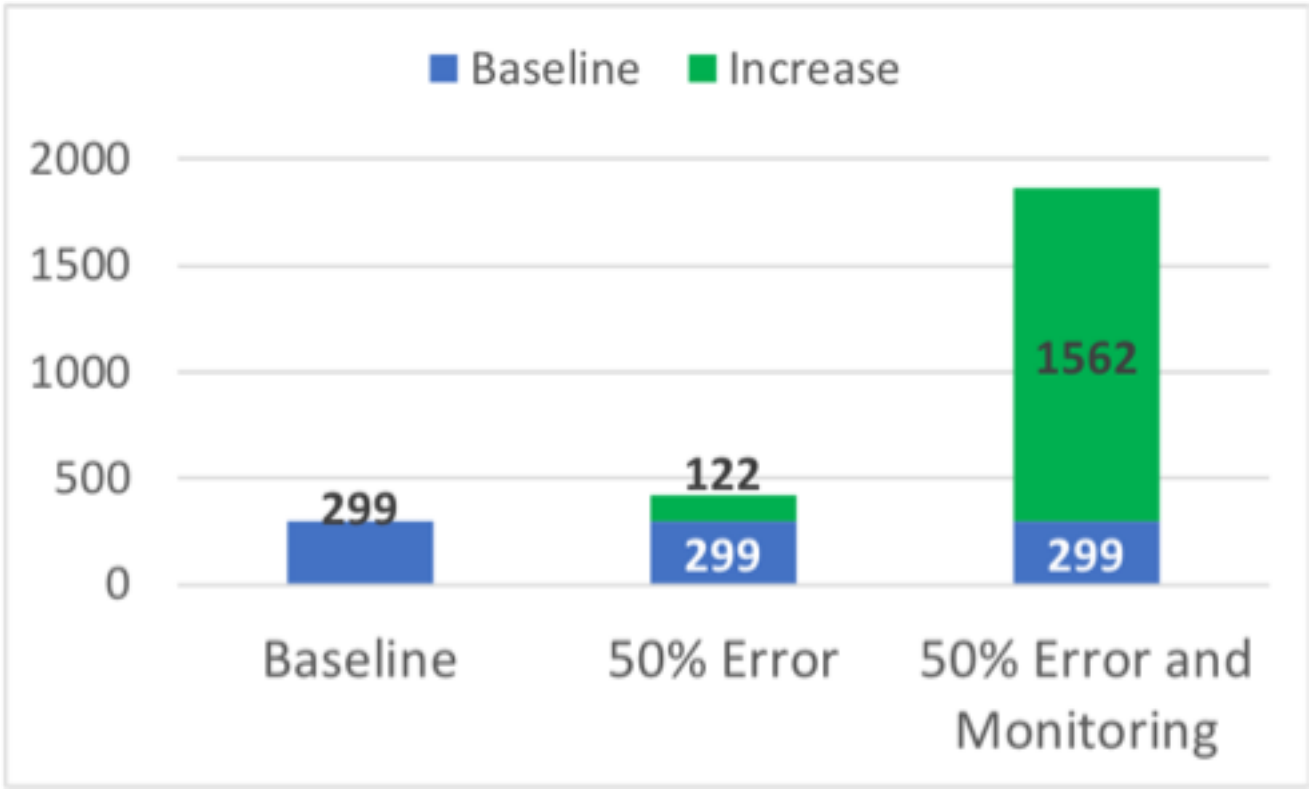
Errors and Arrival Scheduling



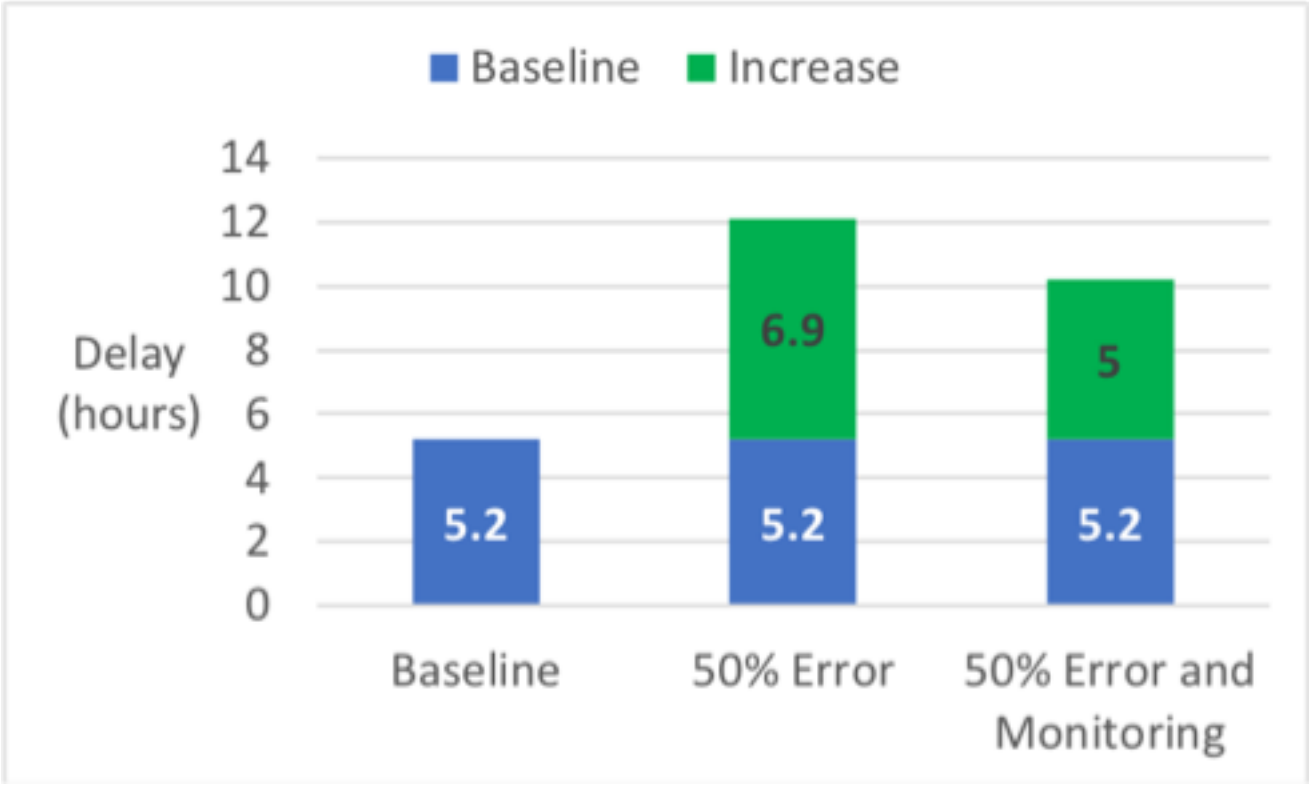
Arrival Schedule Conformance Monitoring



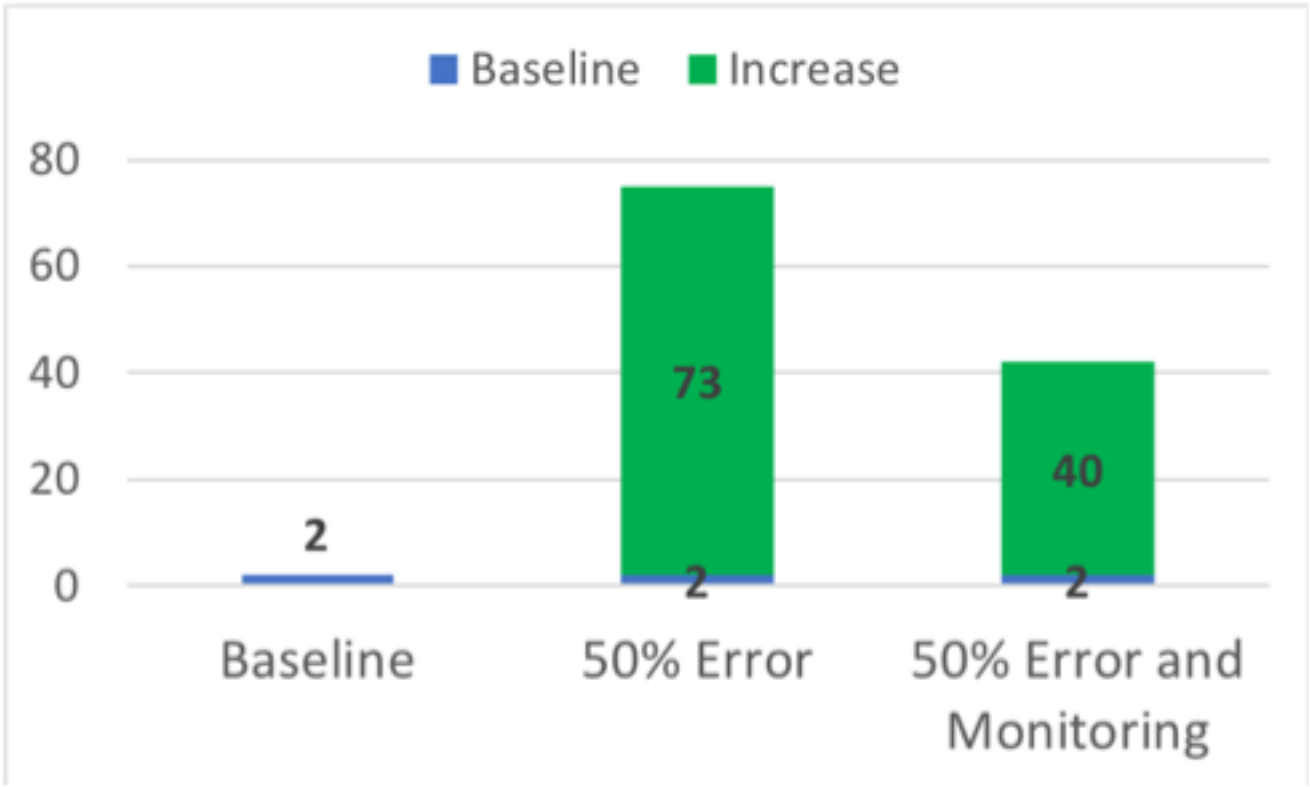
Number of Resolutions



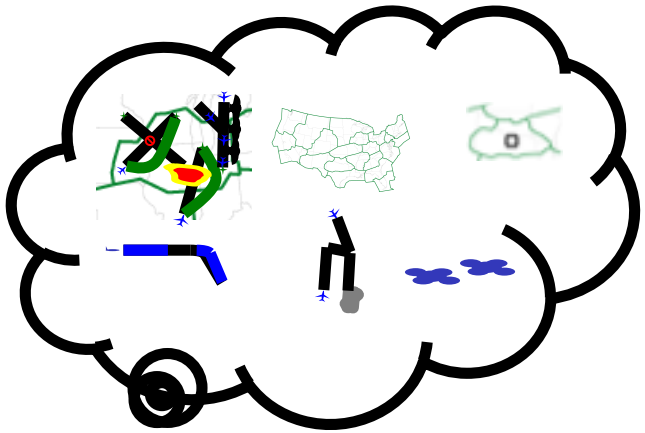
Total Delay


Baseline
Increase
14
12
10
8
6
4
2
0
Delay (hours)
6.9
5
5.2
5.2
5.2
Baseline
50% Error
50% Error and Monitoring

Number of Schedule Changes



Conclusions



- Coordinated operations in multiple types of airspace were demonstrated in the presence of trajectory prediction errors
- Simple rules were demonstrated that enabled coordination across control boundaries
- Arrival schedule conformance monitoring reduced delay significantly at the cost of significantly more resolutions