

The background of the slide is an aerial view of a city skyline, likely New York City, with the Empire State Building prominently visible. The sky is a mix of blue and orange, suggesting a sunset or sunrise. Several aircraft are shown in flight, including a large white commercial jet, a smaller white jet, a red and white propeller plane, a black and white helicopter, and a small drone. The text "EXPLORE FLIGHT" is overlaid in the center, with "EXPLORE" in white and "FLIGHT" in blue. Below it, the tagline "WE'RE WITH YOU WHEN YOU FLY" is written in blue.

EXPLORE FLIGHT

WE'RE WITH YOU WHEN YOU FLY

Initial Analysis of Digitally Enabled Cooperative
Operations in Class D Terminal Airspace
David Thipphavong and Todd Lauderdale
NASA Ames Research Center

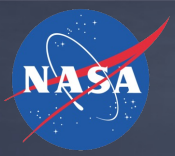
2024 Aviation Forum

ATS-07: NAS Safety and Air Traffic Control
07/31/2024, 0930-1130 PDT (UTC-7)



Presentation Roadmap

- Introduction
- Methodology
- Test Apparatus
- Results
- Concluding Remarks

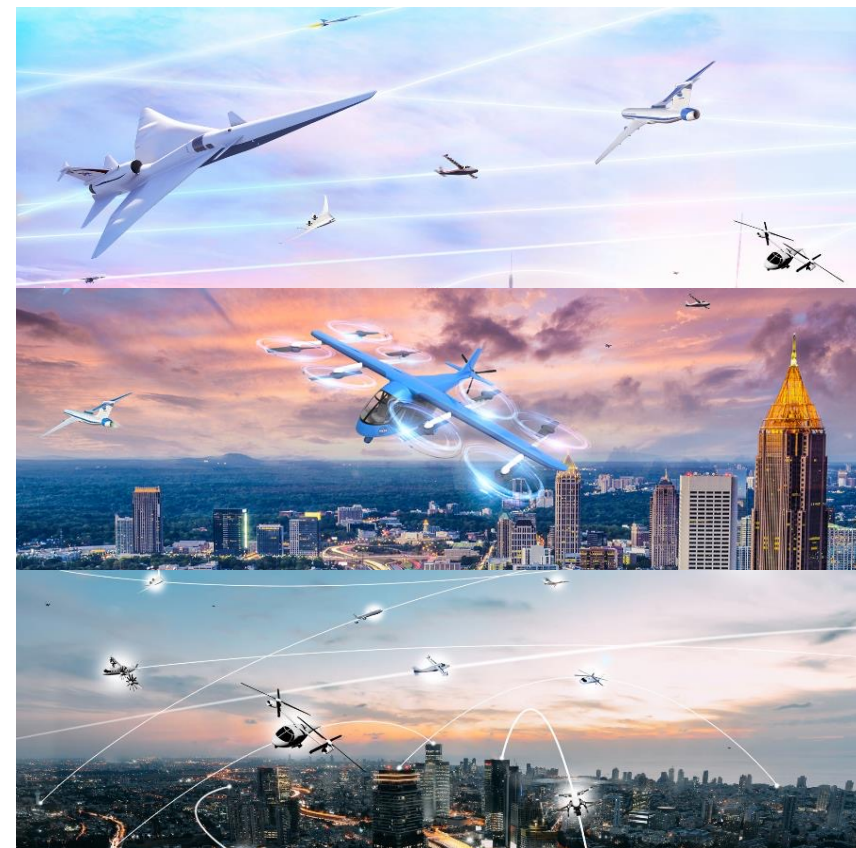


Introduction



Background

- Increasing diversity of aircraft and operations
 - New missions, business models, flight locations
 - New capabilities, including increasingly autonomous
 - Unknown future innovations
- **“New and adapted flight rules and procedures will be required...”** Airbus and Boeing (2020)
- Flight operators are seeking to conduct higher-tempo, higher-density operations in a more collaborative environment



Pursue a routine operating mode founded on digital technologies
See Wing, Lacher, et al., “Digital Flight ...,” NASA/TM–20220013225, Sep. 2022.



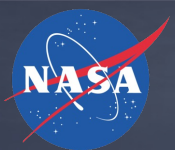
Research Goal and Objectives

Research Goal

Analyze the integration of digitally enabled cooperative operations (referred to as digital operations) with IFR and VFR operations in Class D airspace

Research Objectives

- Identify conflict management challenges for different paradigms of the digital operations concept
 - Centralized
 - Federated
 - Fully Distributed
- Characterize the scope and magnitude of these challenges
- Propose potential mitigations



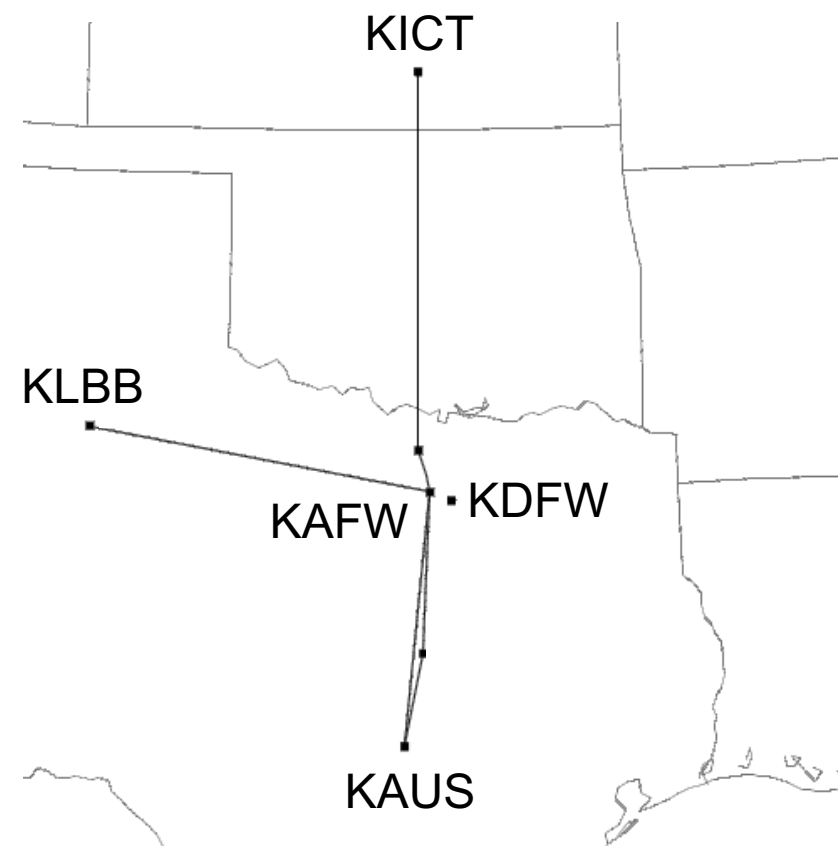
Methodology

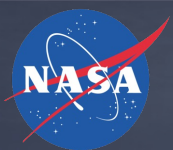


Baseline Scenario for Simulated Digital Operations

- Simulated five digital operations into Fort Worth Alliance airport (KAFW) during 2.5 hours of the morning rush on January 18, 2022 (no weather impacts)
 - Three flights from Austin (KAUS), followed by
 - One flight from Lubbock (KLBB), followed by
 - One flight from Wichita (KICT)
- Based on Cessna 208 flights on that day (same aircraft currently being utilized in autonomous flight testing)
- Time shifted to nominally arrive at KAFW at intervals of 20 minutes
 - Baseline conflict situations for digital operations with each other and VFR and IFR operations
 - Ample airspace for conflict-free resolution maneuvers

Simulated Digital Operations Flight Routes



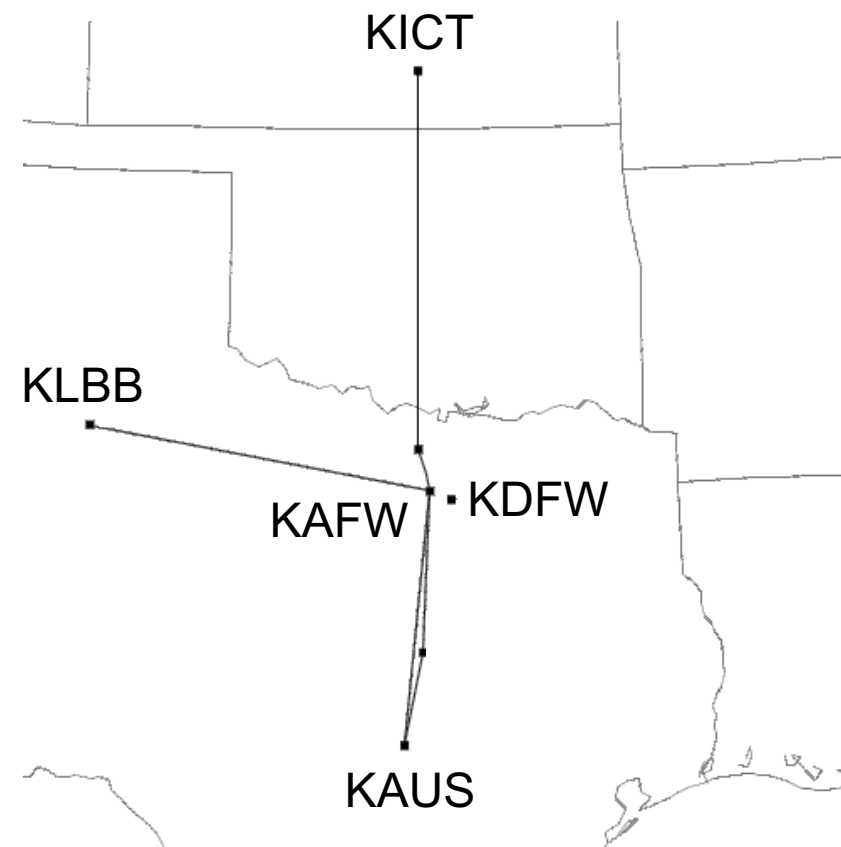


Higher-Tempo Scenarios for Simulated Digital Operations

- Replicated and time shifted digital operations within the same period
- Nominally arrive at KAFW at intervals of
 - 10 minutes (10 digital operations)
 - 5 minutes (20 digital operations)

Increasingly more dense airspace and more complex conflict situations for digital operations and conflict management

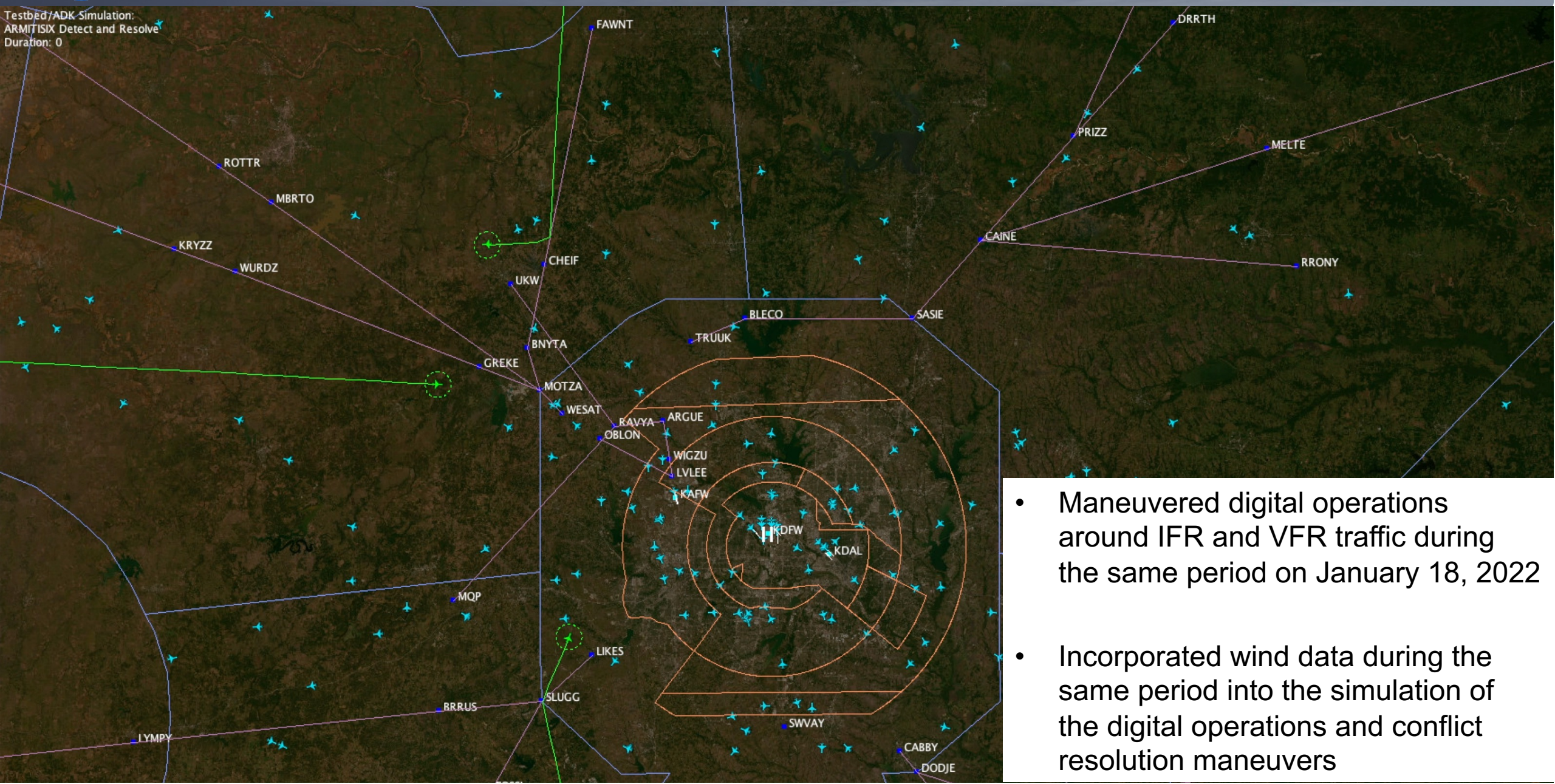
Simulated Digital Operations Flight Routes



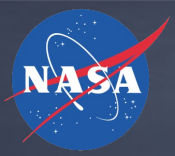


IFR and VFR Traffic

Testbed/ADK Simulation:
ARMITISIX Detect and Resolve
Duration: 0



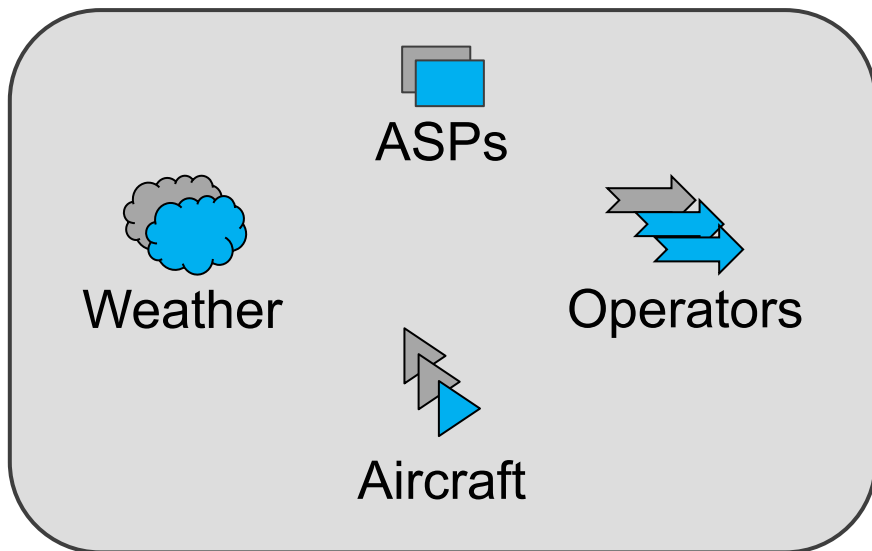
- Maneuvered digital operations around IFR and VFR traffic during the same period on January 18, 2022
- Incorporated wind data during the same period into the simulation of the digital operations and conflict resolution maneuvers



Test Apparatus



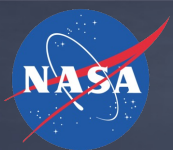
National Airspace System Digital Twin (NDT) Simulation Environment



NAS Digital Twin

- Combines real and simulated air (navigation) service providers (ASPs), operators, aircraft, and weather
- Uncovers unintended consequences and risks of introducing new concepts and technologies to the NAS

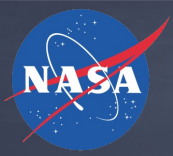
See Lauderdale, et al., “Overview of the National Airspace System (NAS) Digital Twin Simulation Environment,” 2024 Aviation Forum.



Autoresolver (AR) Conflict Management Service

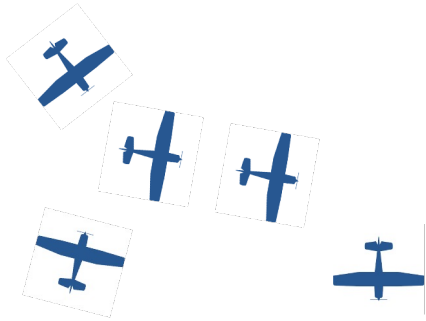
- Detects conflicts
- Develops coordinated and comprehensive trajectory-based solutions
 - Horizontal
 - Vertical
 - Speed
 - Pre-departure ground holding
 - Arrival merging and spacing

See Erzberger, H., Lauderdale, T. A., Chu, Y., “Automated Conflict Resolution, Arrival Management and Weather Avoidance for ATM,” Journal of Aerospace Engineering, Volume 226, Issue 8.

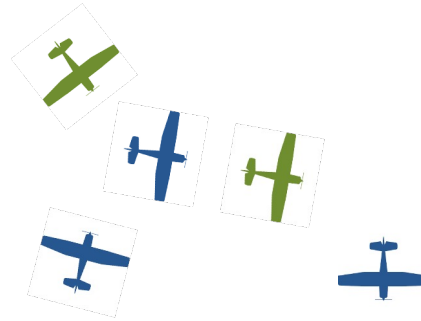


Conflict Management Configurations

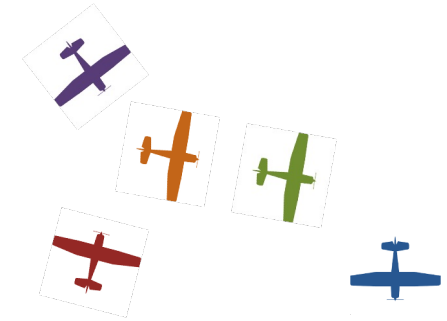
Centralized



Federated

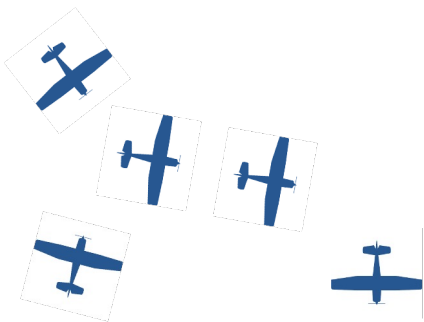


Fully Distributed



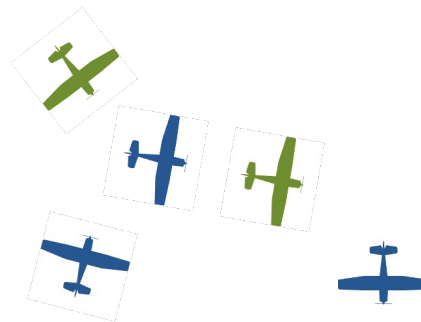
Conflict Management Configurations

Centralized



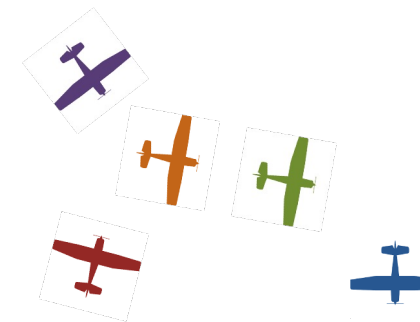
- Models one fleet operator of digital operations; or, all utilizing the same conflict management service

Federated

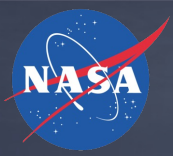


- Models two fleet operators utilizing different conflict management services running at different times

Fully Distributed

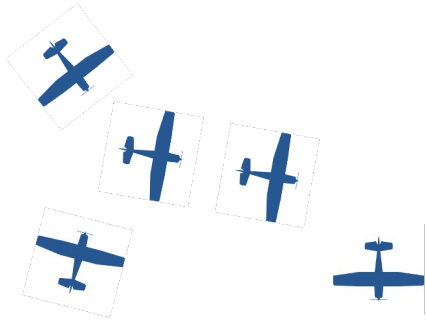


- Models X operators of one digital operation each; or, on-board conflict management



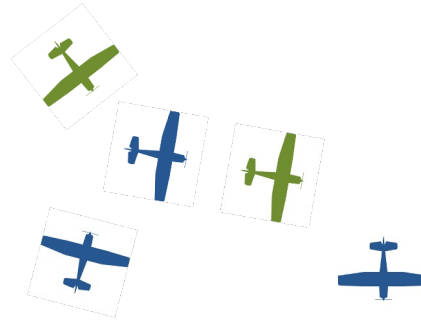
Conflict Management Configurations

Centralized



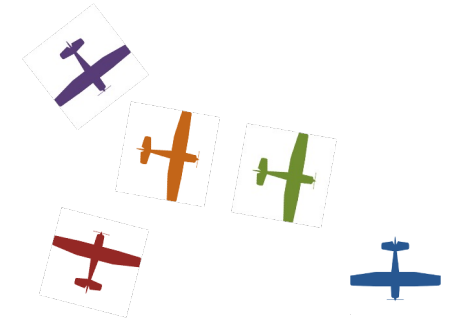
- Models one fleet operator of digital operations; or, all utilizing the same conflict management service
- One instance of the conflict management service for all digital operations

Federated



- Models two fleet operators utilizing different conflict management services running at different times
- Two instances for different subsets of digital operations (can be more)

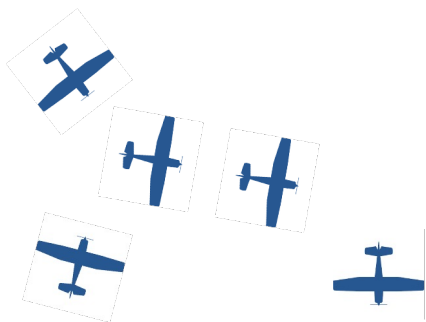
Fully Distributed



- Models X operators of one digital operation each; or, on-board conflict management
- Separate instance for each digital operation

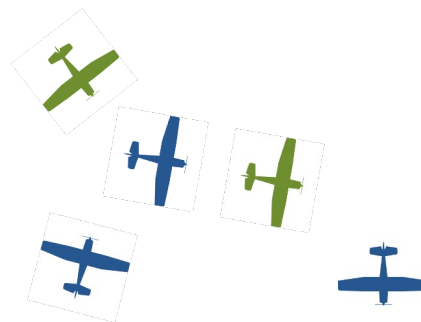
Conflict Management Configurations

Centralized



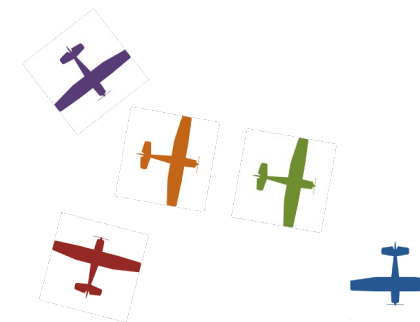
- Models one fleet operator of digital operations; or, all utilizing the same conflict management service
- One instance of the conflict management service for all digital operations
- Ran once during conflict management cycle (60 sec)

Federated



- Models two fleet operators utilizing different conflict management services running at different times
- Two instances for different subsets of digital operations (can be more)
- Ran at two different times during conflict management cycle

Fully Distributed



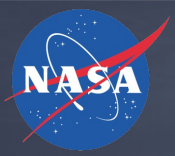
- Models X operators of one digital operation each; or, on-board conflict management
- Separate instance for each digital operation
- Ran at X different times during conflict management cycle (where X is # of digital ops)



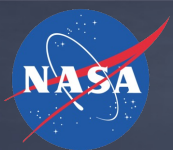
Test Matrix

		Conflict Management Configuration for Digital Operations		
		Centralized	Federated	Fully Distributed
Nominal Time between Simulated Digital Operations Arriving at KAFW	20 minutes			
	10 minutes			
	5 minutes			

- Increasingly higher-tempo, higher-complexity conflict management paradigms of the digital operations concept
- All zero-uncertainty simulations, which
 - Modeled ideal conditions
 - Reduced analytical complexity in this initial analysis

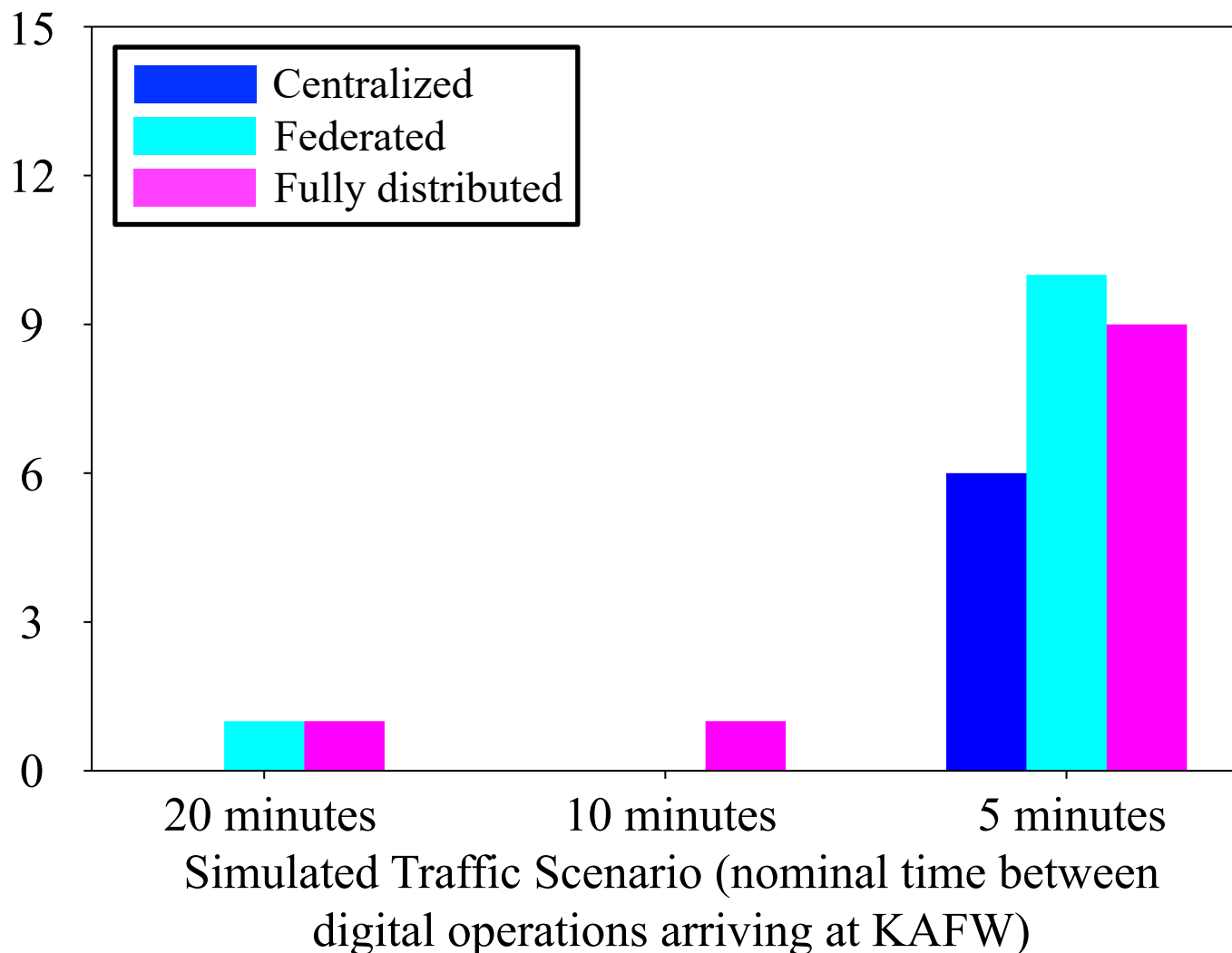


Results



Number of LOS (Loss of Separation)

Number of LOS



- LOS* that involved one or more simulated digital operations
- Excludes LOS involving historical IFR or VFR operation with digital operation on final approach
- Reasonable to expect ATC to clear the final approach path

See paper for example involving VFR operation that was performing touch-and-go maneuvers around KAFW

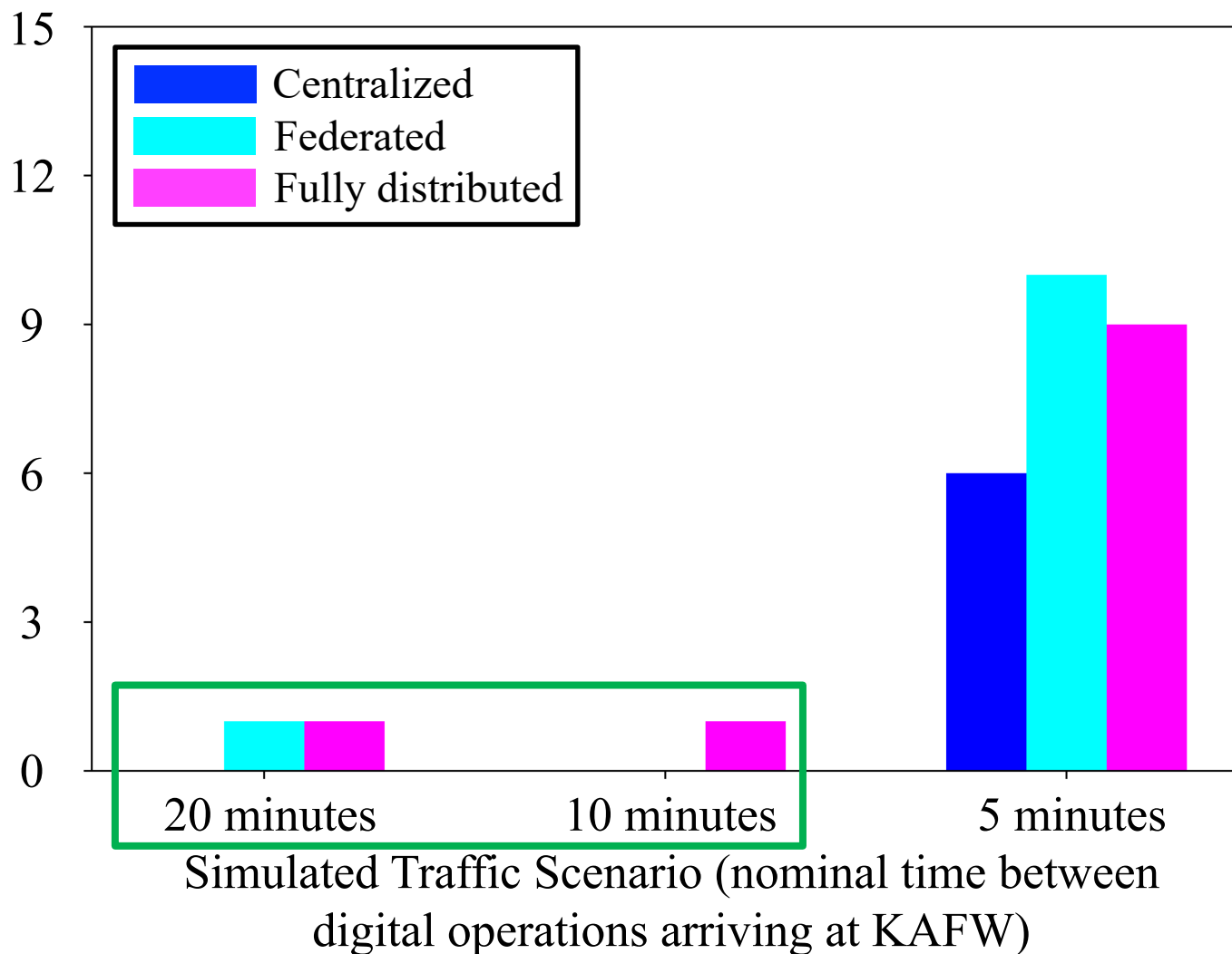
*(Terminal) Less than 3.0 nmi of horizontal separation and less than 1000 ft of vertical separation

*(Center) Less than 5.0 nmi of horizontal separation and less than 1000 ft of vertical separation



Number of LOS

Number of LOS

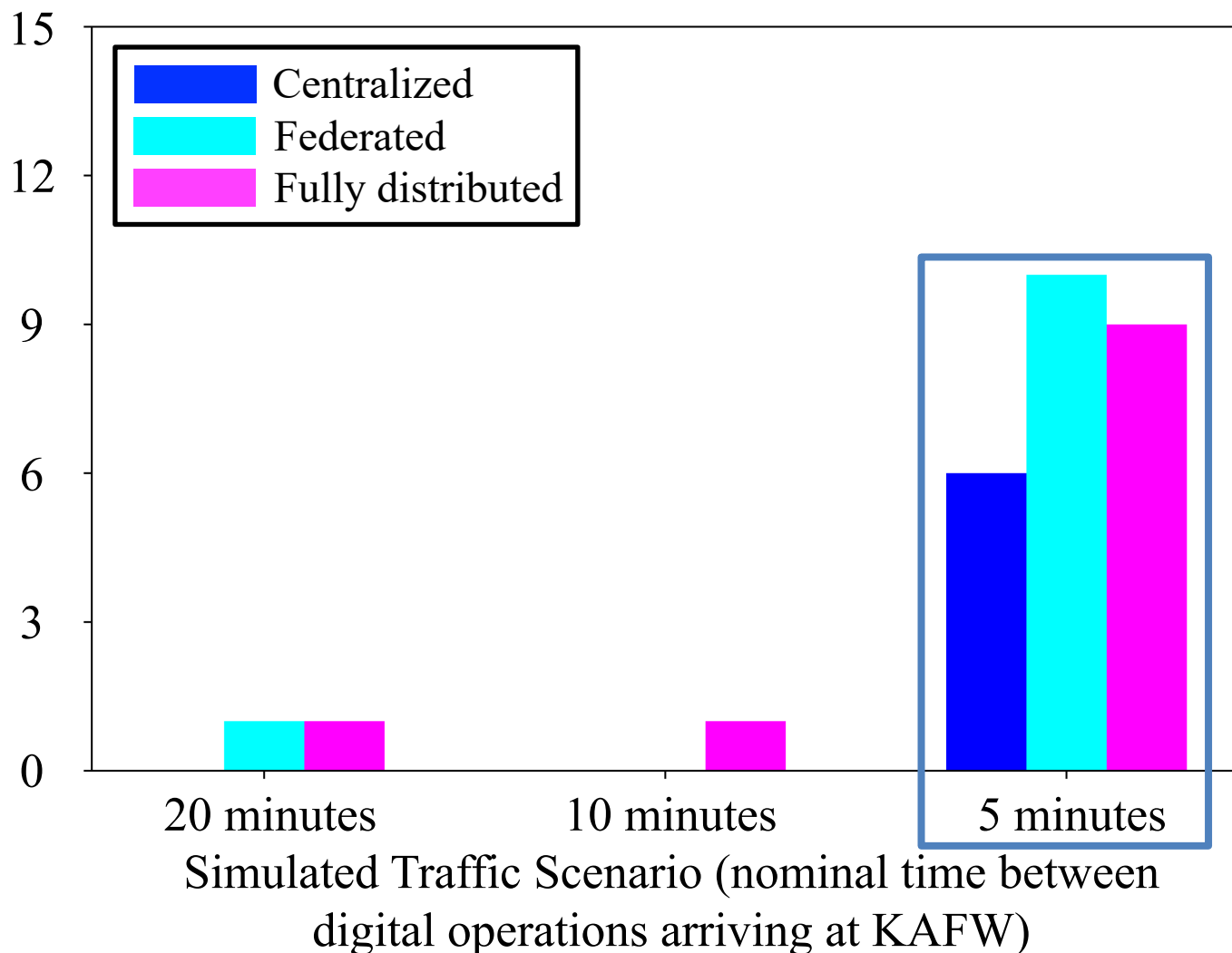


- One or fewer LOS for all conflict management configurations in lower-tempo simulations



Number of LOS

Number of LOS



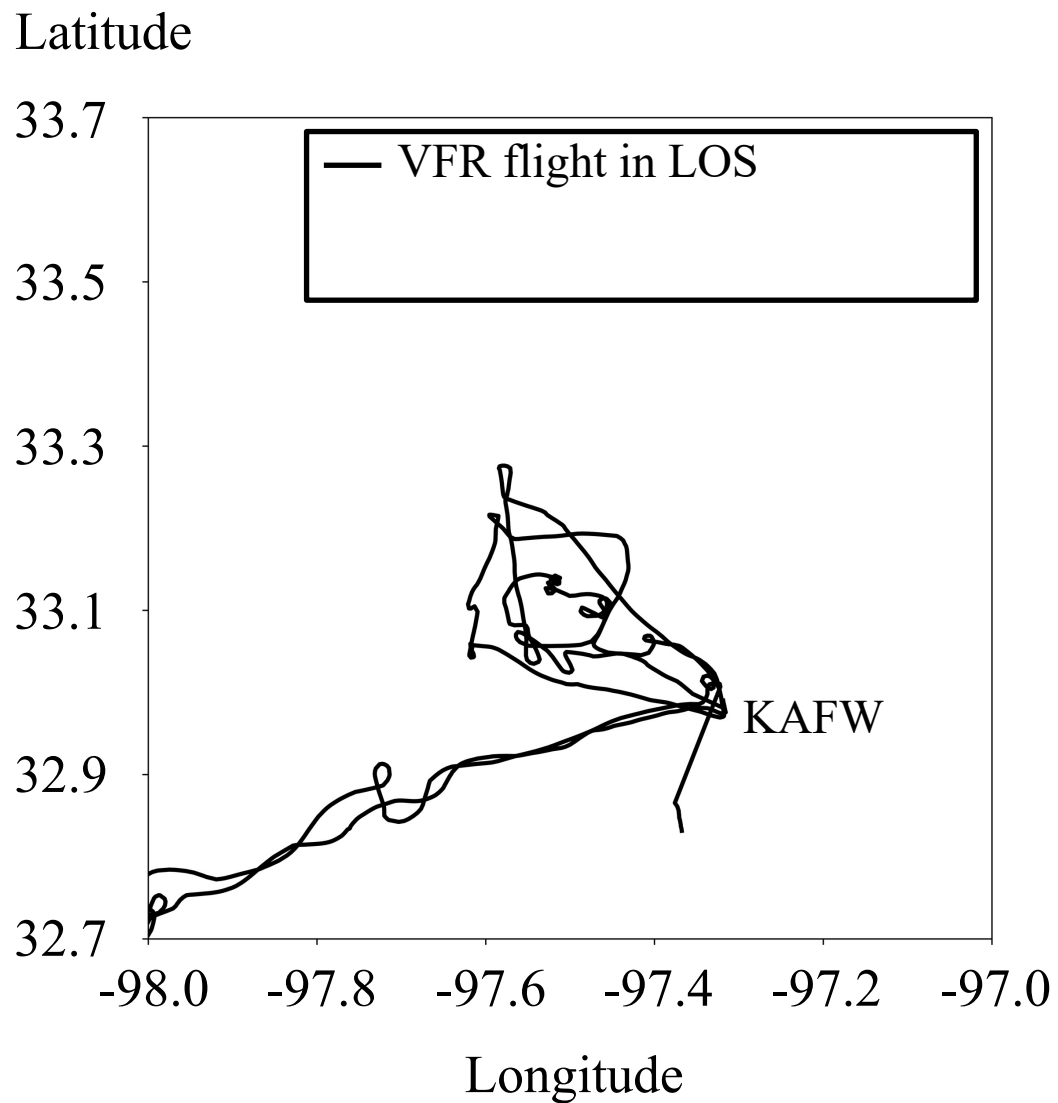
- One or fewer LOS for all conflict management configurations in lower-tempo simulations

- Between six and ten LOS in highest-tempo simulations (inflection point)
 - Variation resulted from collective ripple effect of different instances of the conflict management service operating at different times
 - Federated and fully distributed simulations had clusters of LOS that occurred around the same area and time

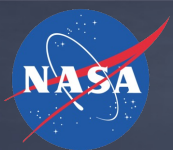
Need to investigate the potential need for additional capabilities for digital operations, such as complexity management and/or flow organization



Cluster of LOS (Highest-Tempo; Fully Distributed Conflict Management)

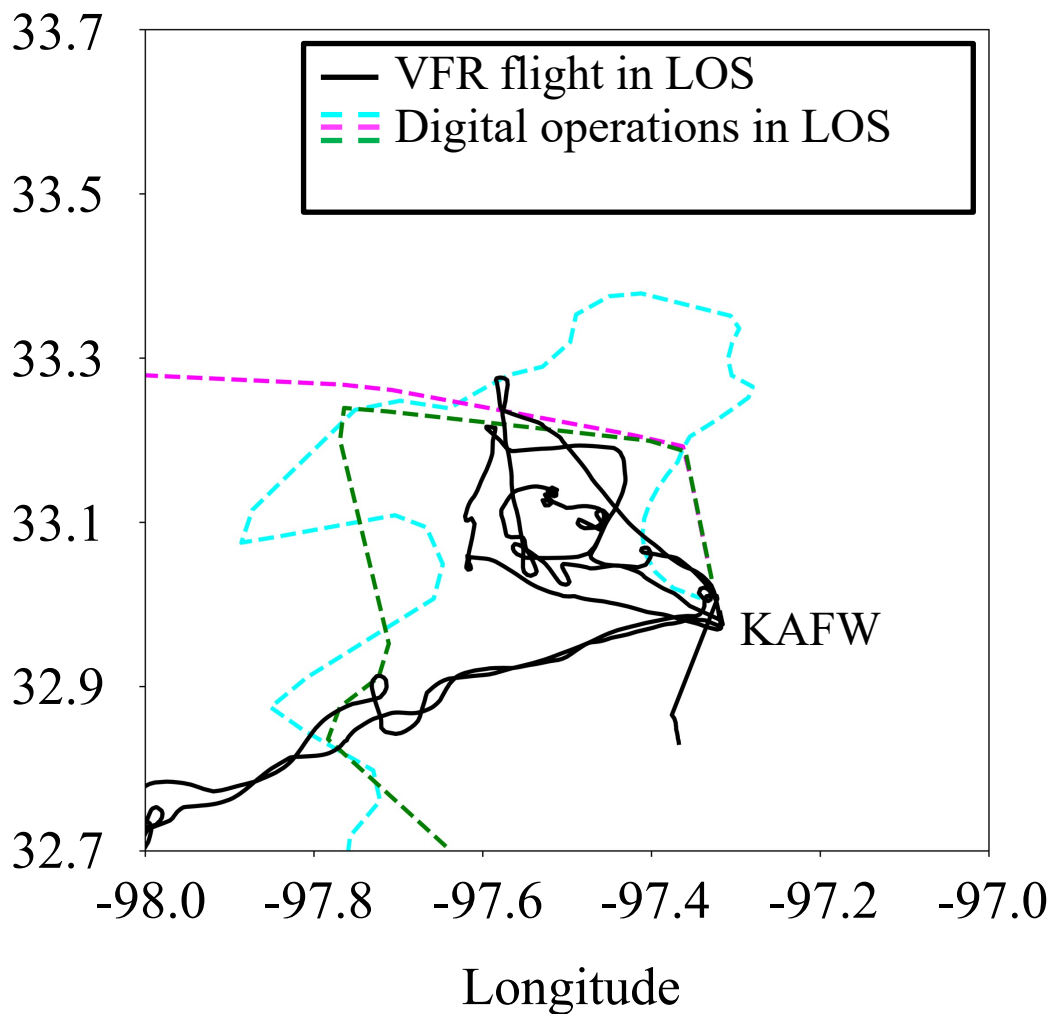


- Meandering historical VFR flight around KAFW occupied substantial airspace around arrival route



Cluster of LOS (Highest-Tempo; Fully Distributed Conflict Management)

Latitude

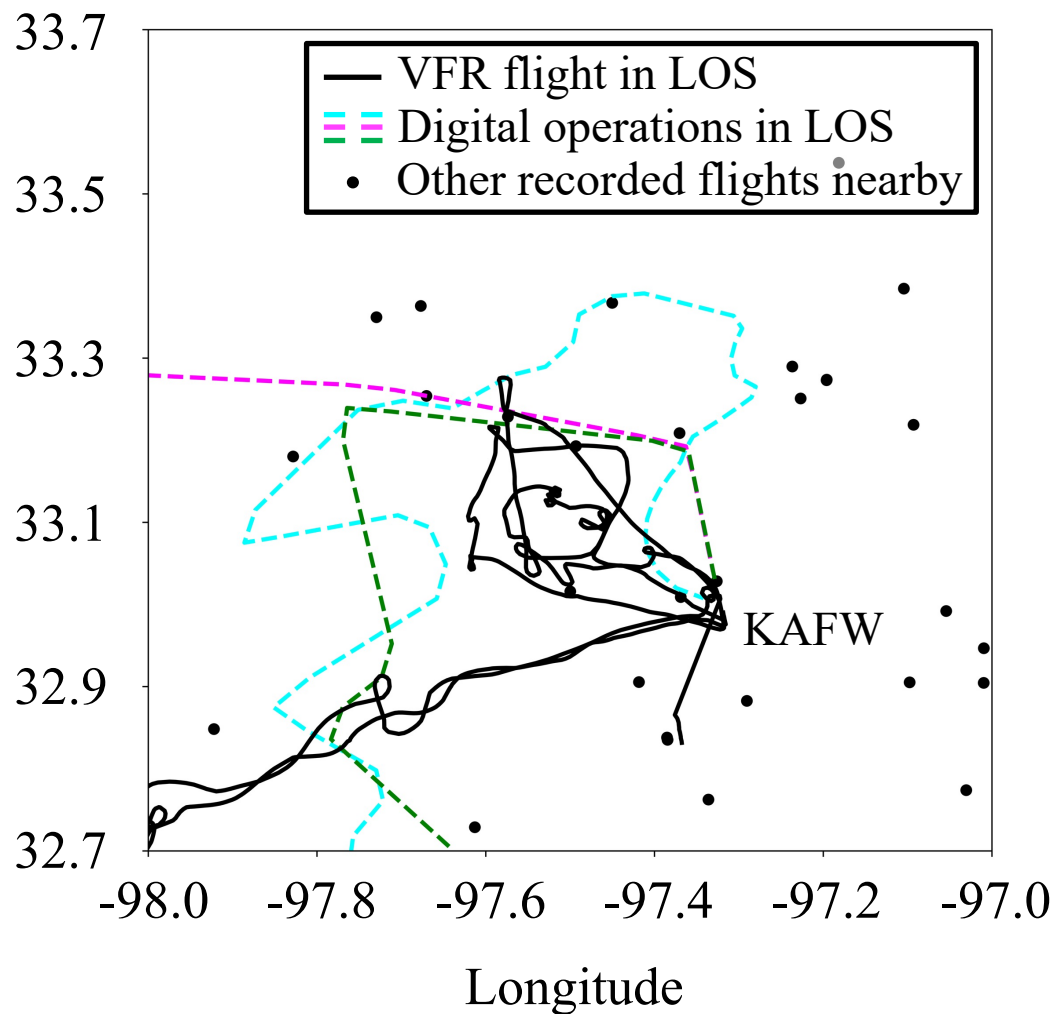


- Meandering historical VFR flight around KAFW occupied substantial airspace around arrival route
- Several digital operations arriving at KAFW had limited maneuver options due to this and
 - Being in the same area going to the same destination at the same time

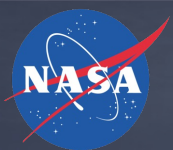


Cluster of LOS (Highest-Tempo; Fully Distributed Conflict Management)

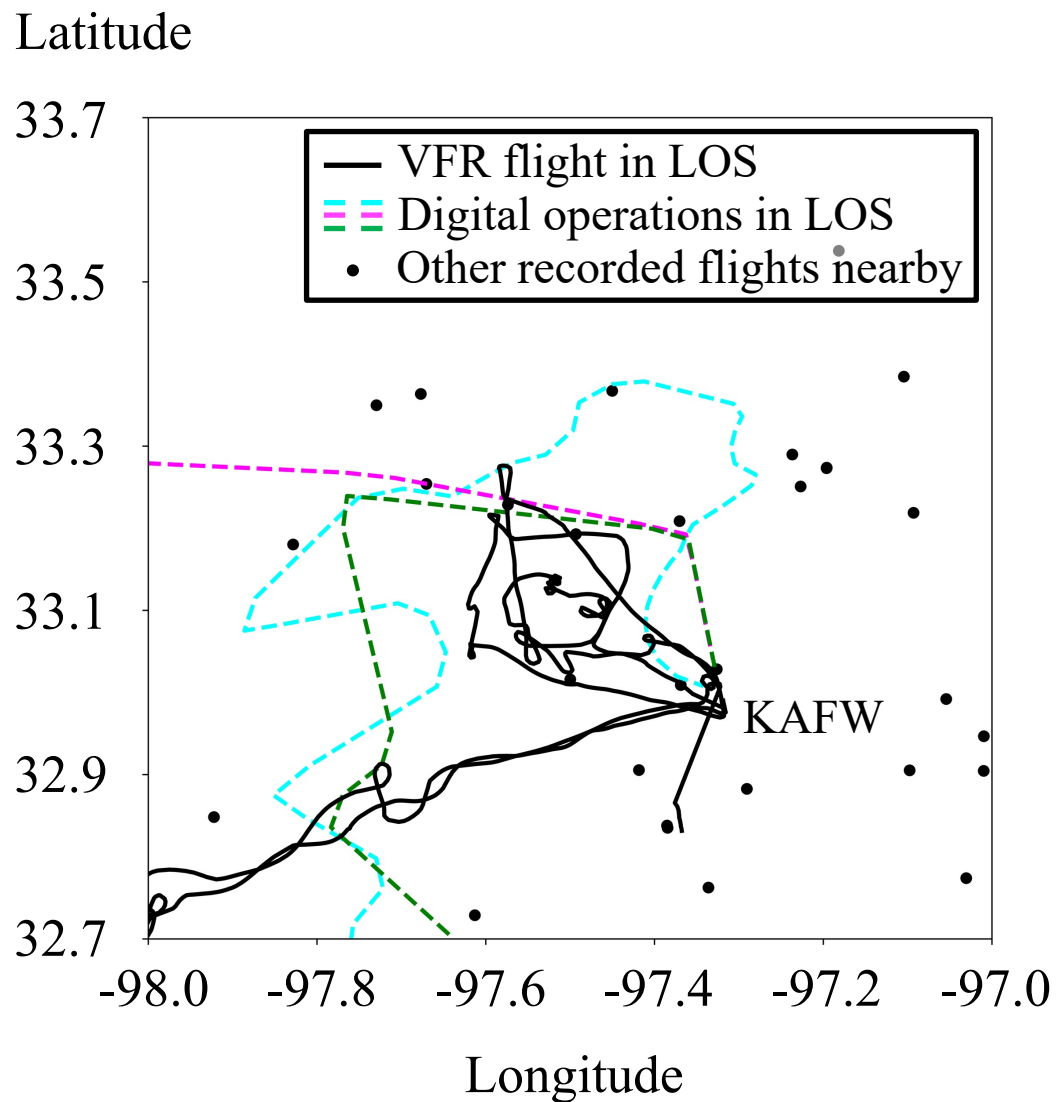
Latitude



- Meandering historical VFR flight around KAFW occupied substantial airspace around arrival route
- Several digital operations arriving at KAFW had limited maneuver options due to this and
 - Being in the same area going to the same destination at the same time
 - Presence of many other recorded flights in the same area at the same time



Cluster of LOS (Highest-Tempo; Fully Distributed Conflict Management)



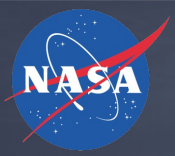
- Meandering historical VFR flight around KAFW occupied substantial airspace around arrival route
- Several digital operations arriving at KAFW had limited maneuver options due to this and
 - Being in the same area going to the same destination at the same time
 - Presence of many other recorded flights in the same area at the same time

Each digital operation maneuvered multiple times to maintain separation as much as possible but did not have enough available airspace

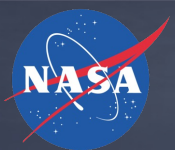


Ideas for Follow-on Work

- Extend this study to broaden characterization and deepen understanding of conflict management challenges for digital operations, including analyzing additional
 - Conflict management coordination schemes and parameters
 - Traffic scenarios (airspace, flight phases, aircraft types)
 - Uncertainties
- Investigate potential need for additional capabilities beyond conflict management for digital operations
 - Complexity management
 - Flow organization

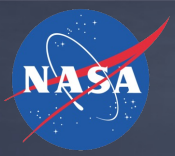


Concluding Remarks



Takeaway Messages

- Conducted initial investigation on the integration of digital operations with VFR and IFR operations in Class D airspace
- Ran test matrix of nine simulations of different paradigms of the digital operations concept
 - Three conflict management configurations (centralized, federated, fully distributed)
 - Three traffic scenarios (increasing tempo)
- Identified and characterized the scope and magnitude of challenging situations for digital operations
- Need to broaden characterization and deepen understanding of conflict management challenges for digital operations and explore solutions beyond conflict management



Questions, Comments, Feedback?

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Sources

- Slide 9: The map data is from https://services.arcgisonline.com/ArcGIS/rest/services/World_Imagery/MapServer and is used with permission according to the ESRI terms of service: <https://www.esri.com/en-us/legal/copyright-trademarks>