

Evaluation of a Dynamic Weather-Avoidance Rerouting Tool in Adjacent-Center Arrival Metering



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Presentation Sections



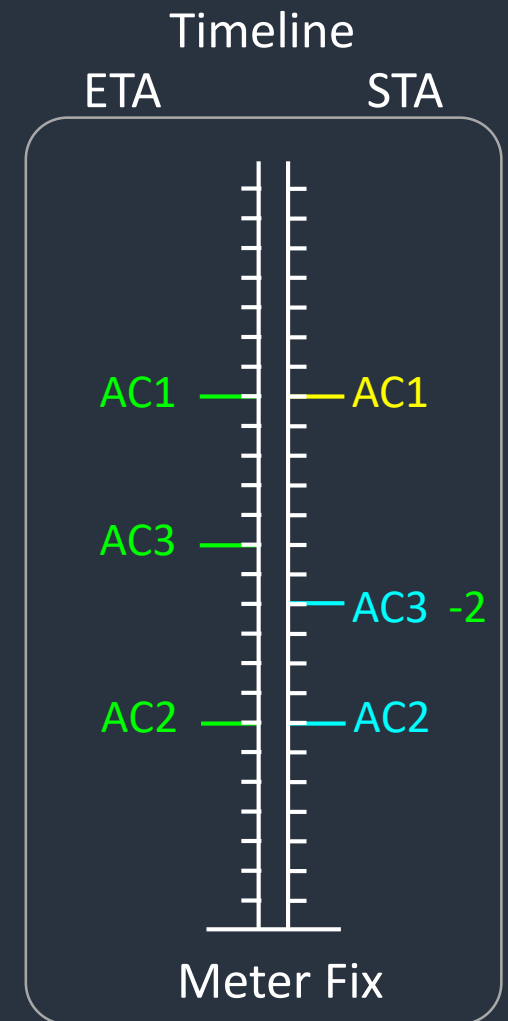
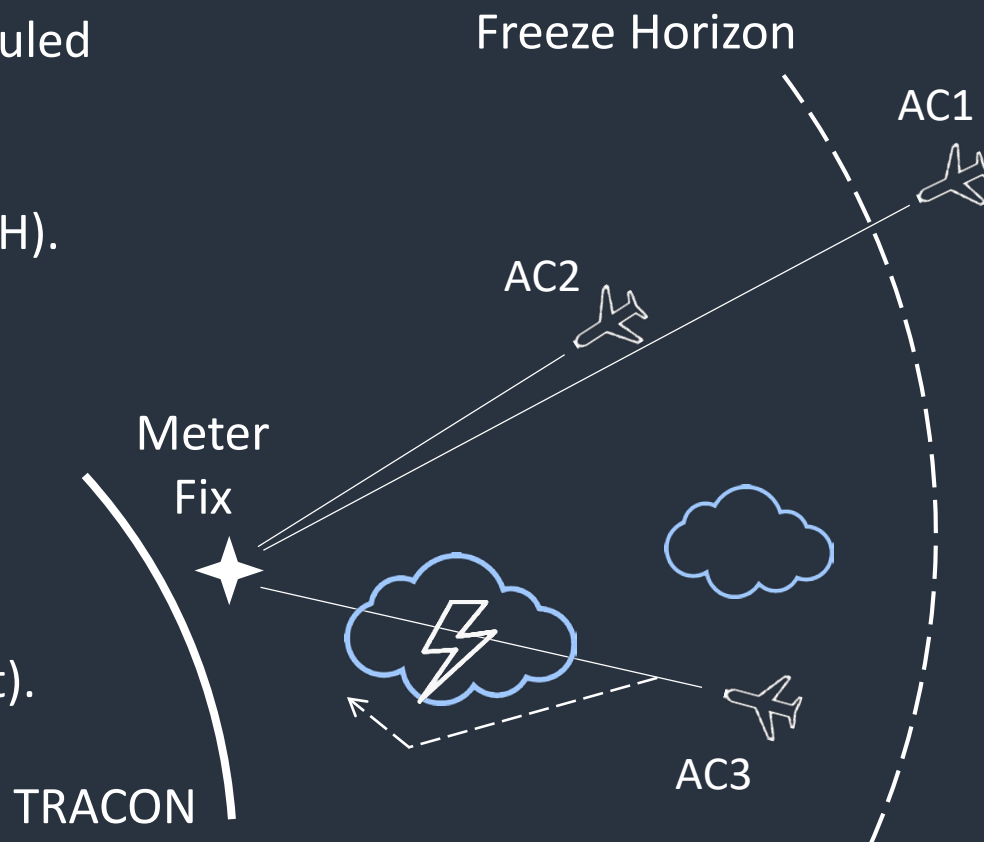
Presentation Sections

- Arrival Metering in Weather
- Dynamic Routing for Arrivals in Weather (DRAW)
- Relevant Past Work
- Objectives of the Study



Arrival Metering in Weather

- Estimated Time of Arrival (ETA) at Meter Fix is used to assign Scheduled Time of Arrival (STA).
- STA is frozen at Freeze Horizon (FH).
- Weather can disturb ETAs.
- When too many flights show bad STA, metering is switched to Miles in Trail (simpler, but reduced throughput).



Dynamic Routes for Arrivals in Weather (DRAW)

- Is a decision-support tool for Traffic Management Coordinators (TMCs) at en-route facilities (“Centers”)
- Utilizes 4D current & forecast weather data:
 - Corridor Integrated Weather System (CIWS) for the current weather depiction
 - Convective Weather Avoidance Model (CWAM) forecast for weather-avoidance reroute computation
- Proposes Flight Plan route amendments that avoid weather:
 - Going around weather
 - Weather-free shortcut
 - Alternate Meter Fix (disabled in this study)
- [Goal] Allows arrival metering to continue under wider range of weather conditions

DRAW User Interface

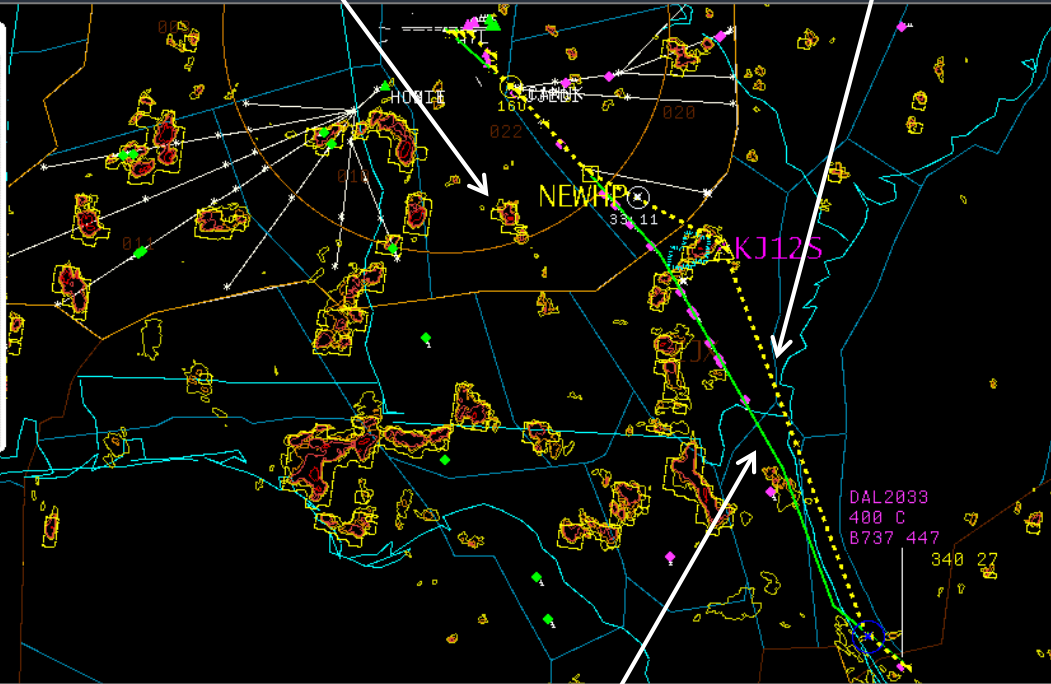
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<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	HOBTT HONIE				<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	CANUK JJEDI				<input type="checkbox"/>
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DRAW Advisory List

Planview GUI (PGUI)

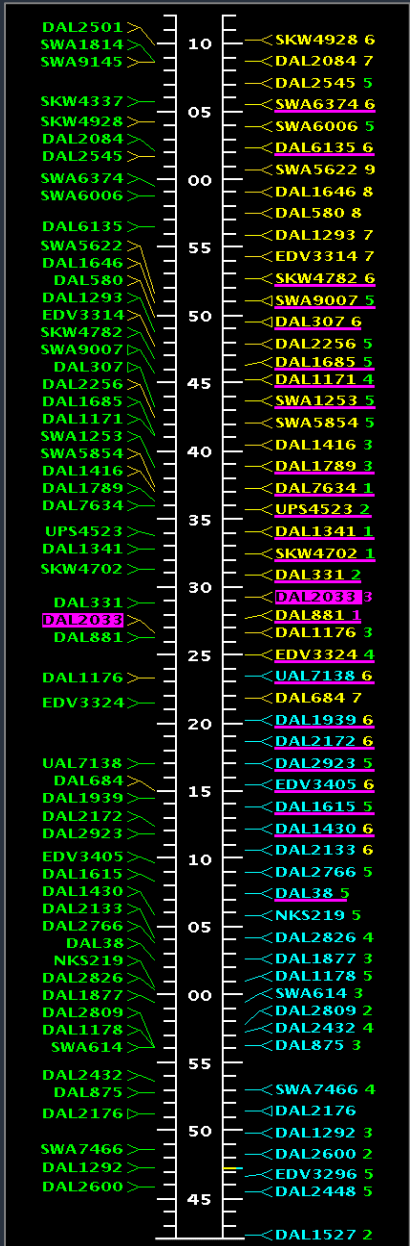
CIWS polygons

DRAW advisory route



Flight Plan route

Timeline GUI (TGUI)

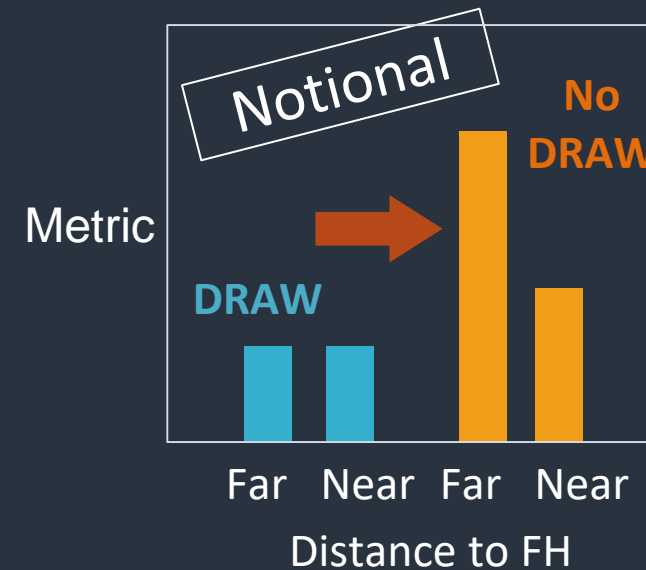


Relevant Past Work

- NASA's Dynamic Weather Routes (DWR) (McNally, et al., 2013/2015)
- Traffic Management Advisor (TMA) (Swenson, 1997)
- MITRE's Advanced Flight-Specific Trajectories (AFST) (DeArmon, et al., 2017)
- On acceptable thresholds for arrival metering delivery accuracy:
 - Human-in-the-loop simulation evaluations: error < 30-40 sec (Robinson, 2015)
 - Numerical simulations: error std dev < 60 sec in Atlanta Center (Shresta, 2009)
- Previous DRAW simulation evaluation (Isaacson, et al., 2018)
 - DRAW use resulted ~16 minutes earlier reroute advisories
 - No evidence was found that DRAW improved arrival metering performance

Objectives of the Study

- Investigate how arrival metering performance in weather was affected by:
 - Use of DRAW
 - Interaction of use of DRAW and the freeze horizon (FH) distance



- Observe inter-Center coordination for weather-avoidance and metering operations.

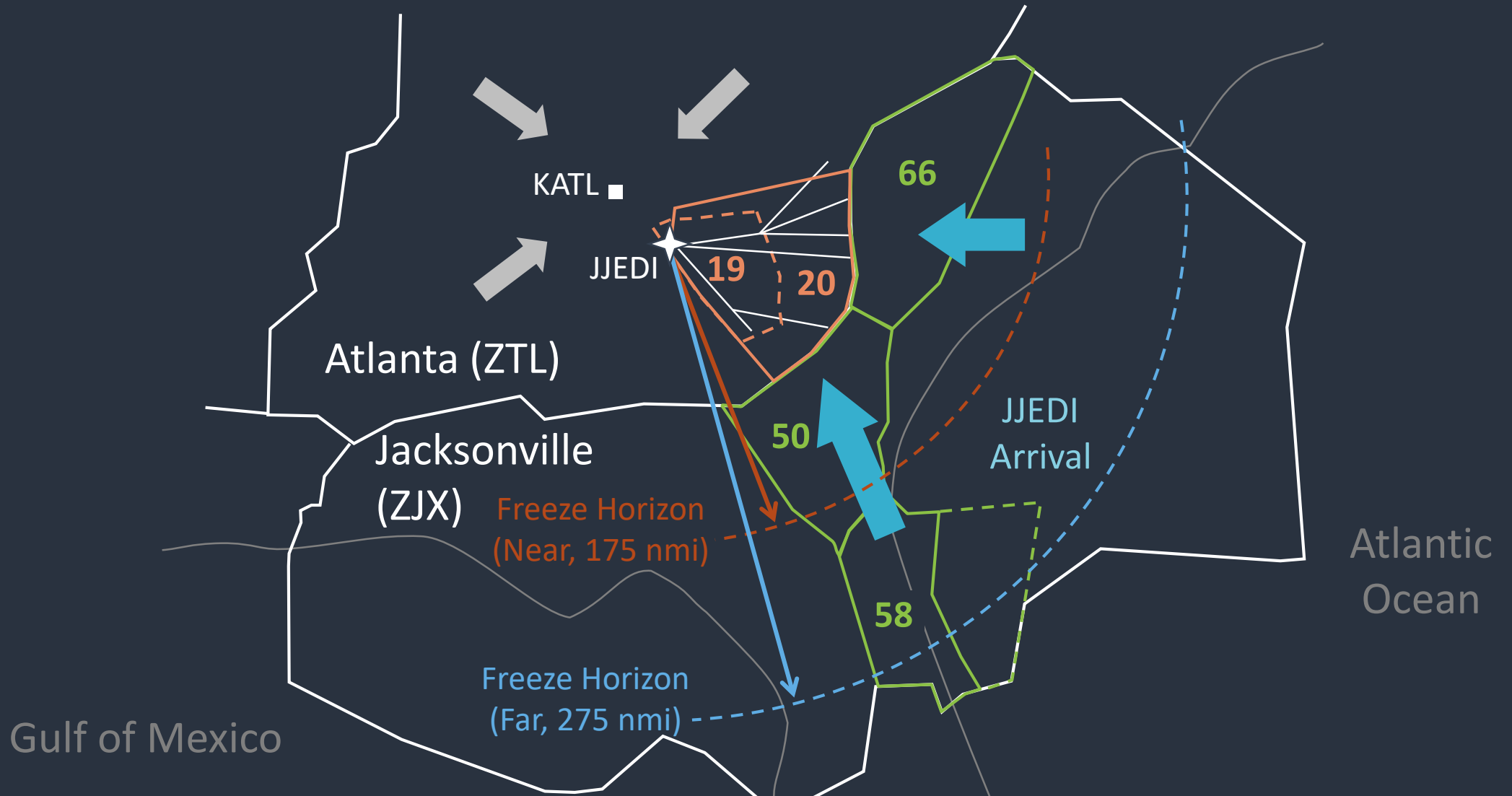
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- Simulated Airspace
- Laboratory Setup
- Experiment Design
- DRAW vs. No-DRAW Condition
- Procedure

Simulated Airspace



Laboratory Setup

Meter List

J JEDI			
DAL331	1810	E00	40
SWA3524	1810	E01	00
DAL2184	1809	E01	10
DAL2359	1807	E00	30
SWA6049	1804	L00	20

DAL2359	240T	240	
	526	438	

Delay Countdown Timer

TMC (1)

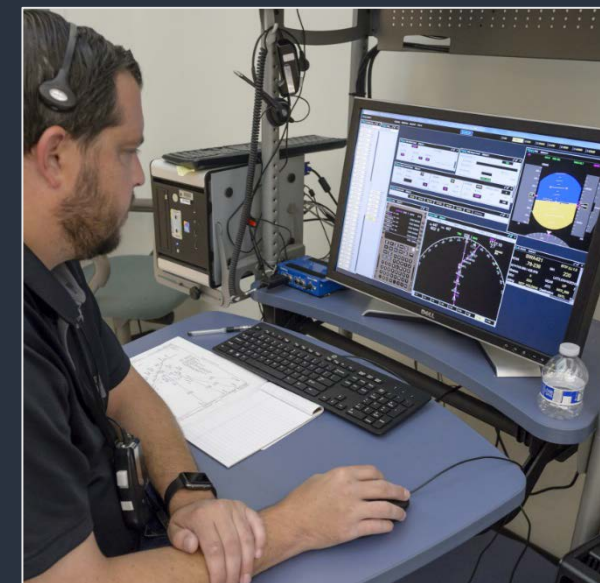


Jacksonville (ZJX) TMC Atlanta (ZTL) TMC

Controller (6)



Pilot (6)



Reroute request

Radio

Experiment Design

- 2-week study, 10/22/2018 – 11/2/2018
- 16 runs for 2x2x2x2 test-matrix design:
 - DRAW Condition (DRAW vs. No-DRAW)
 - Freeze Horizon (FH) Location (Far vs. Near)
 - Weather Scenario (Weather 1 vs. Weather 2)
 - TMC & Controller Team (Week 1 vs. Week 2)
- 1 Baseline run (clear weather) in each week

DRAW vs. No-DRAW Condition

Functions Available in DRAW Condition

Function	DRAW	No-DRAW
DRAW Advisory	X	
Current CIWS weather on PGUI	X	X
Trial Planning: Drag and drop to reroute	X	X
Forecast CWAM conflicts	X	
Metering impact on TGUI	X	

Procedure

- 2-hour runs, 9 runs per week (8 test-matrix runs + 1 Baseline)
- TMCs performed in 0-110 minutes, controllers & pilots in 15-120 minutes
- Manual adjustment of frozen STA was allowed at the TMC or controller's discretion, via any of the 3 methods:
 1. Controller swaps two flights' STAs
 2. TMC adjusts an STA along a TGUI timeline
 3. TMC reschedules the Meter List (ripples the list)

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- ATA Error w.r.t. STA at FH
- ATA Error w.r.t. STA at Meter Fix
- Manual Adjustments of STA
- Discussions



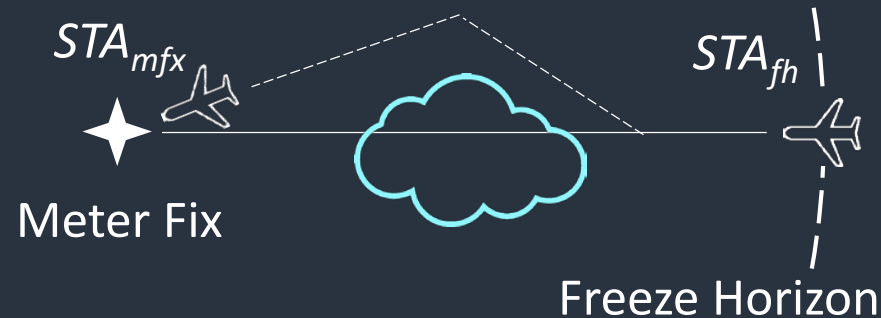
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Actual Time of Arrival (ATA) Error

- 2 types of errors in the ATA at the Meter Fix:

1) ATA Error with Respect to STA assigned at FH: $E_{fh} = STA_{fh} - ATA$

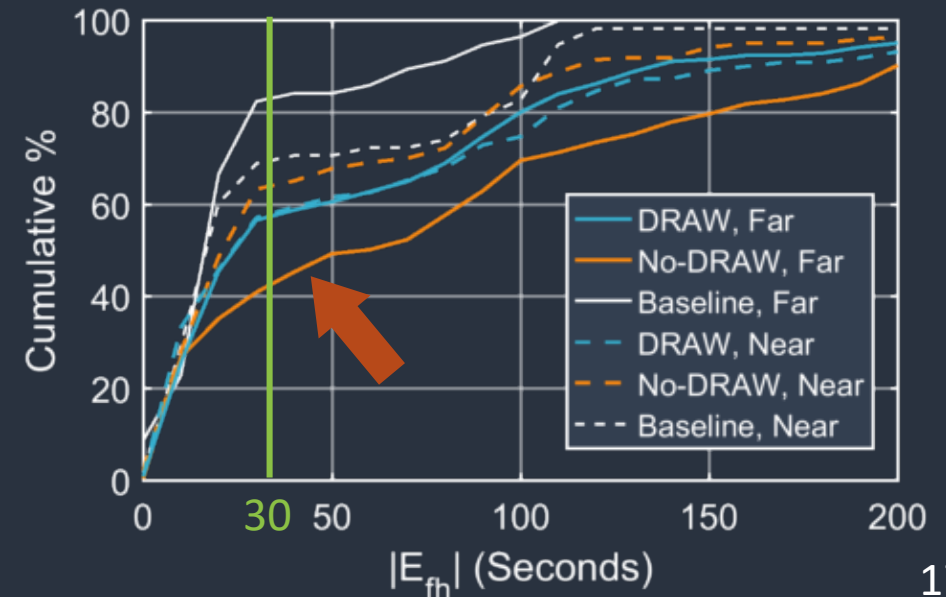
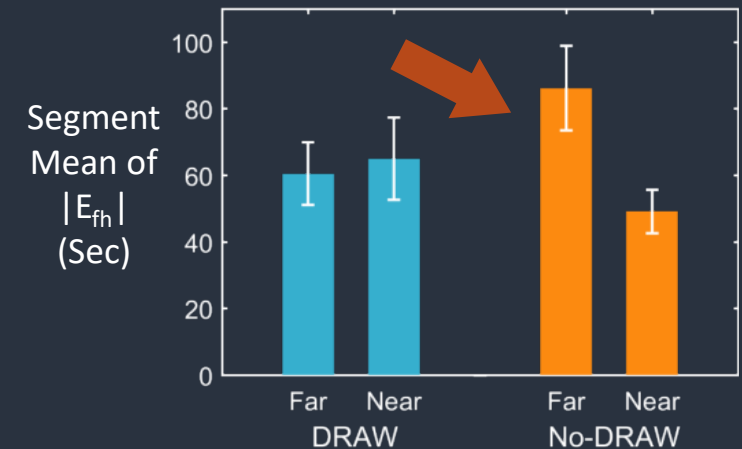
2) ATA Error with Respect to STA indicated at Meter Fix: $E_{mfx} = STA_{mfx} - ATA$



- Smaller E_{mfx} (#2) helps the TRACON work
- Smaller E_{fh} (#1) may suggest lower Center workload

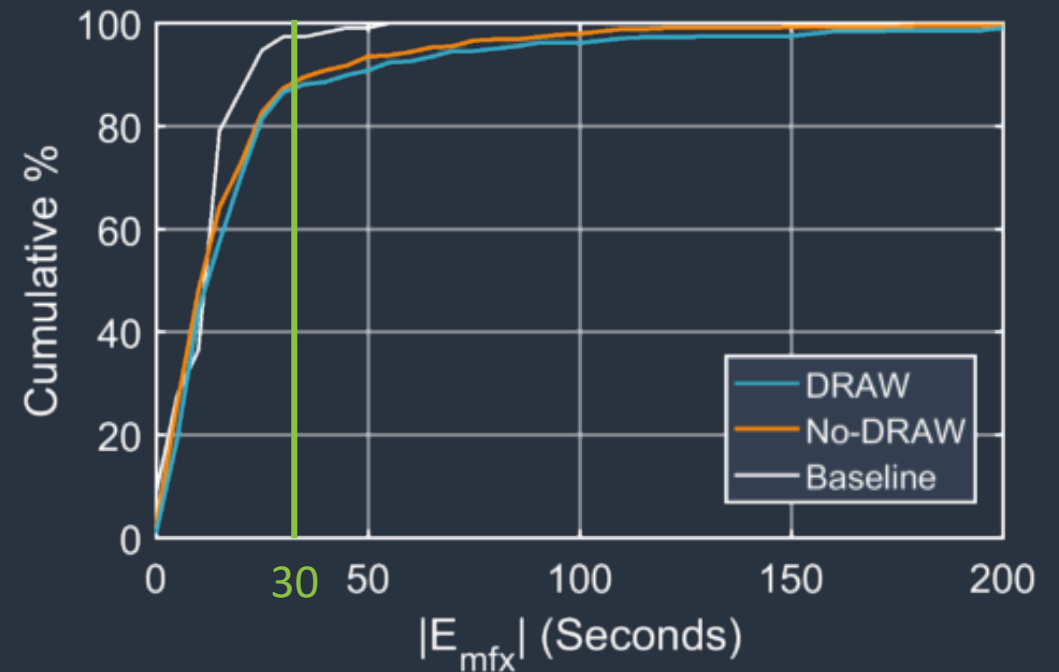
1) ATA Error with Respect to STA at FH, $|E_{fh}|$

- The means of $|E_{fh}|$ over 30-minute segments (30-60, 60-90, and 90-120 min) were computed.
- Regression found the segment means were significantly larger in No-DRAW, Far FH ($p = 0.023$).
- Cumulative percentage of the ATA errors shows poor accuracy overall, but especially in No-DRAW, Far FH.
- The estimated std devs of the ATA errors were also large, 91 sec (DRAW) and 95 sec (No-DRAW).



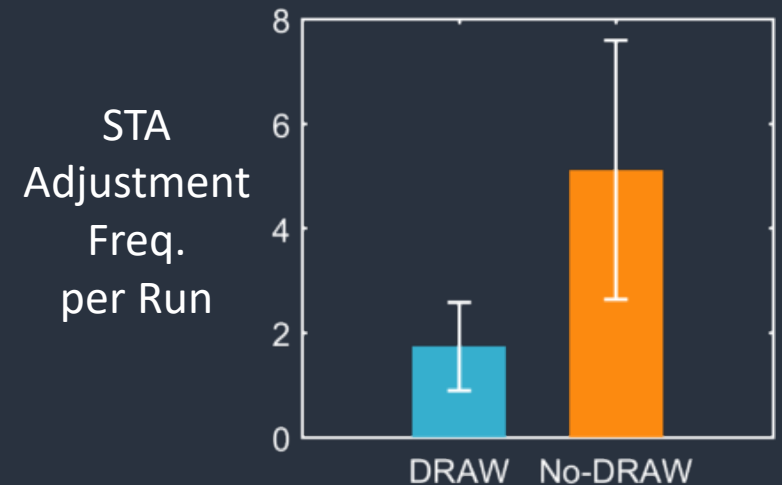
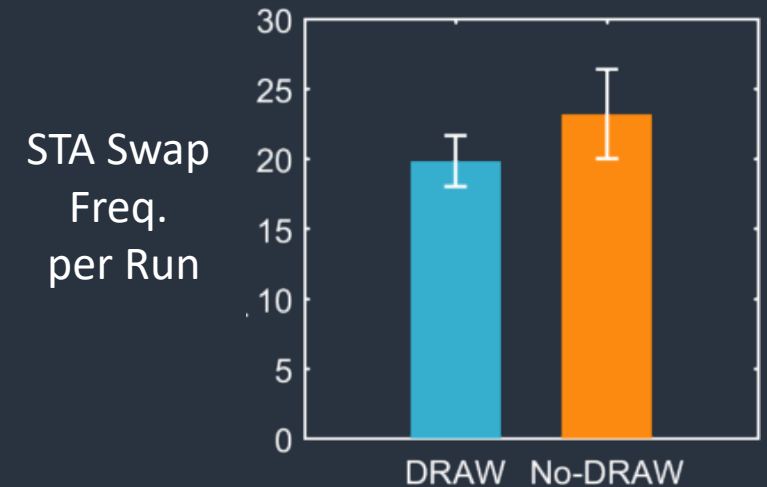
2) ATA Error with Respect to STA at MFx, $|E_{mfx}|$

- Regression did not find any significant effect.
- Cumulative percentage of the ATA errors showed both DRAW and No-DRAW runs achieved similarly good metering accuracy performance.
- The estimated std devs of the ATA errors were 29 sec (DRAW) and 42 sec (No-DRAW).



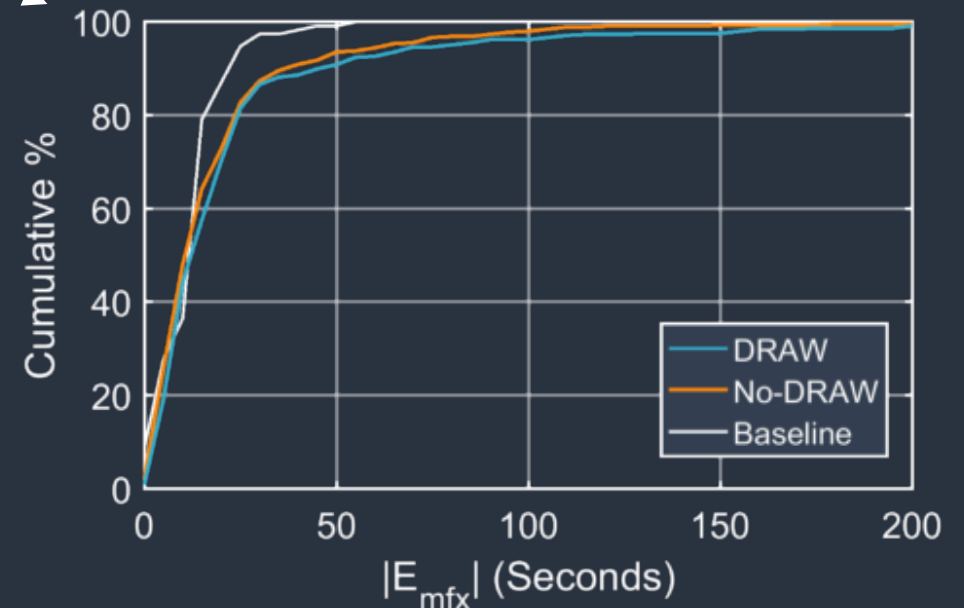
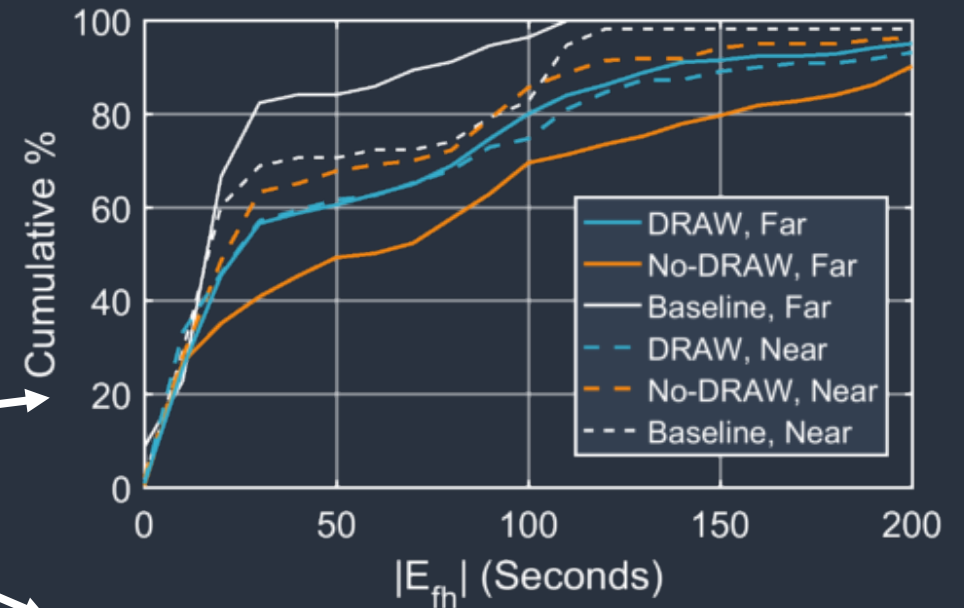
Manual Adjustments of STA

- Increased STA swaps by controllers in No-DRAW runs was found ($p = 0.044$).
- Increased STA adjustments by TMC in No-DRAW runs was found ($p = 0.069$, marginal significance).



Discussions – ATA Error

- The 2 types of ATA errors showed very different pictures.
 - 1) ATA Error w.r.t. STA at FH (E_{fh}):
 - 2) ATA Error w.r.t. STA at Meter Fix (E_{mfx}):
- E_{fh} (#1) was reduced to E_{mfx} (#2) in No-DRAW runs by more manual STA adjustments.
- The STAs assigned at the FH are coordinated and optimized by the scheduler.
- Both ATA errors have to be small for successful metering.



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Introduction

Simulation

ATA Error

Reroutes

Human Factors

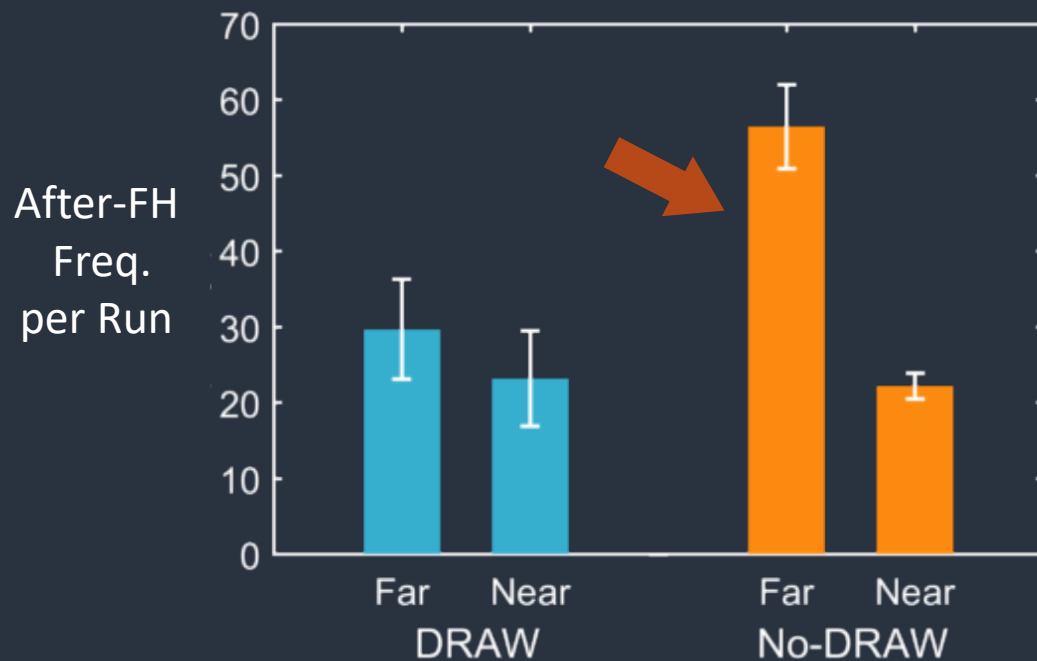
Conclusion

- Simulated Airspace
- Laboratory Setup
- Experiment Design
- DRAW vs. No-DRAW Condition
- Procedure

- Flight Plan Amendment Locations
- Discussions

Route Amendment Locations

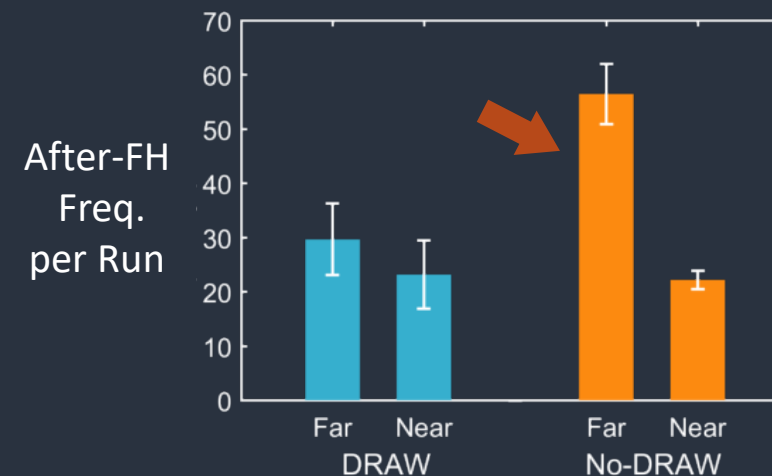
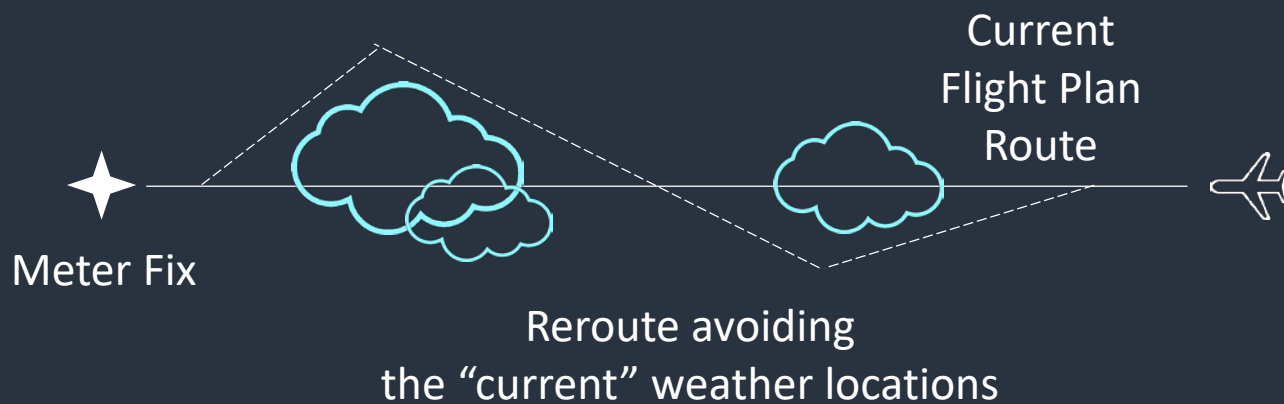
- The frequencies of the Flight Plan route amendments before and after the FH in each run were counted.



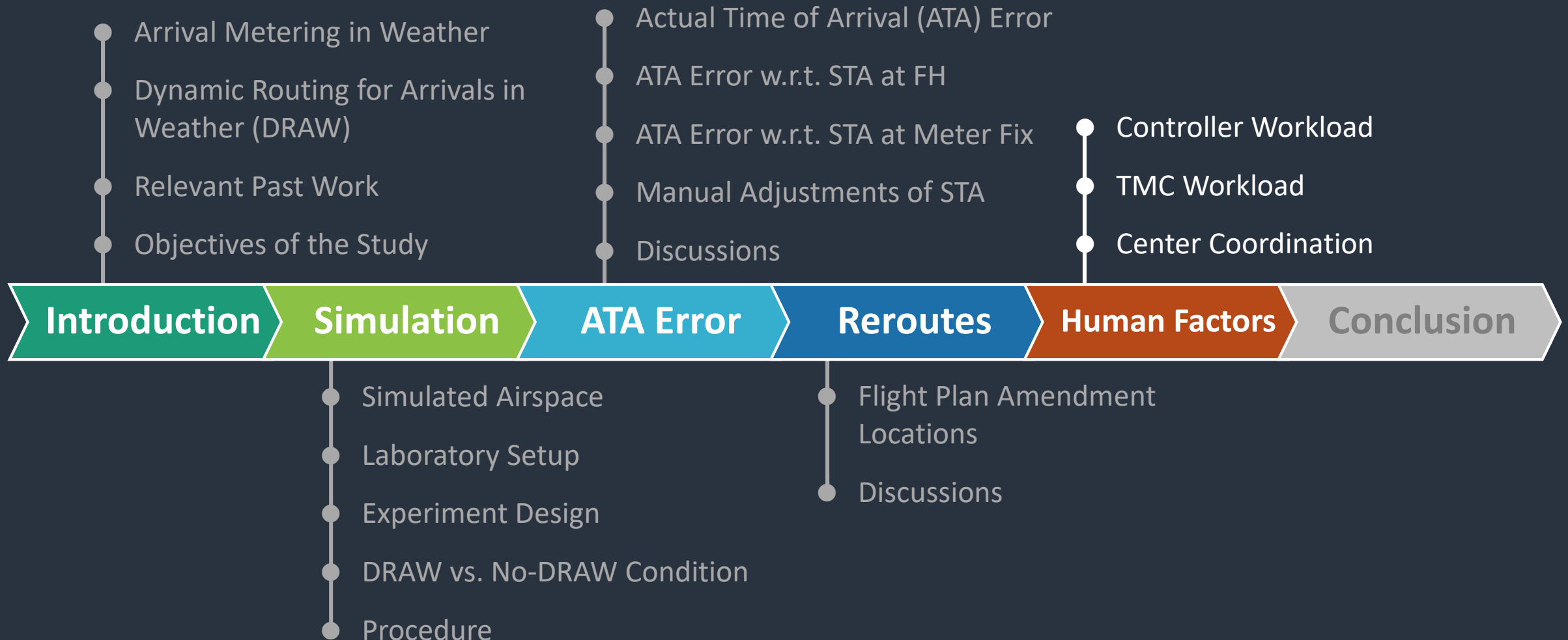
- The frequency of route amendments after the FH was significantly higher in No-DRAW, Far FH ($p = 0.014$).

Discussions – Weather Forecast Quality

- The quality of weather forecast is critical:
 - TMC liked having the anticipated weather locations on the PGUI map.
- Potential TMC mistake during high workload periods:

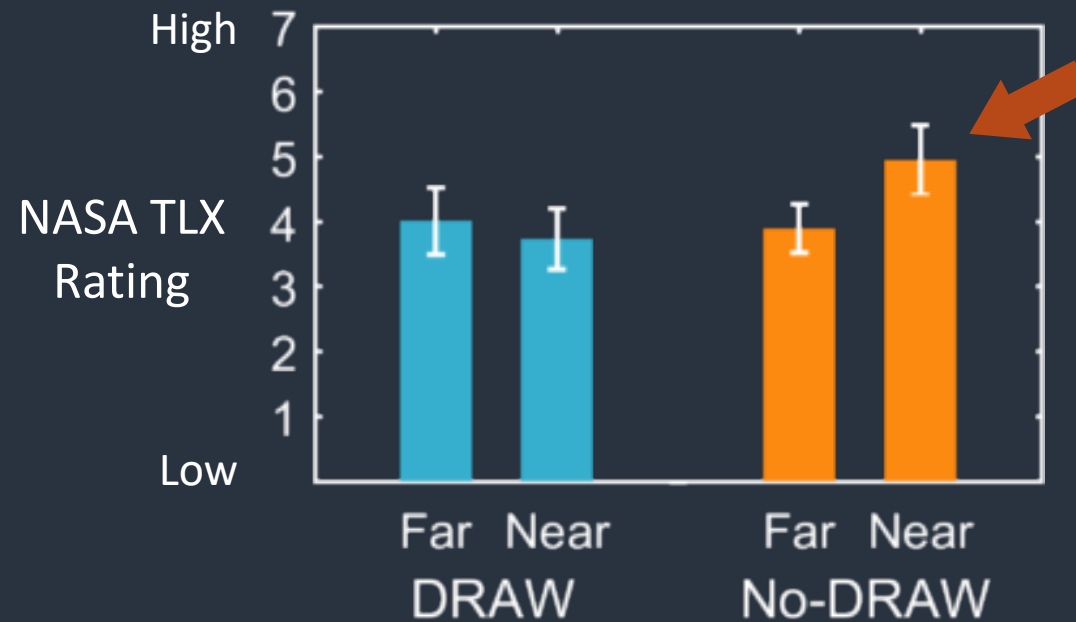


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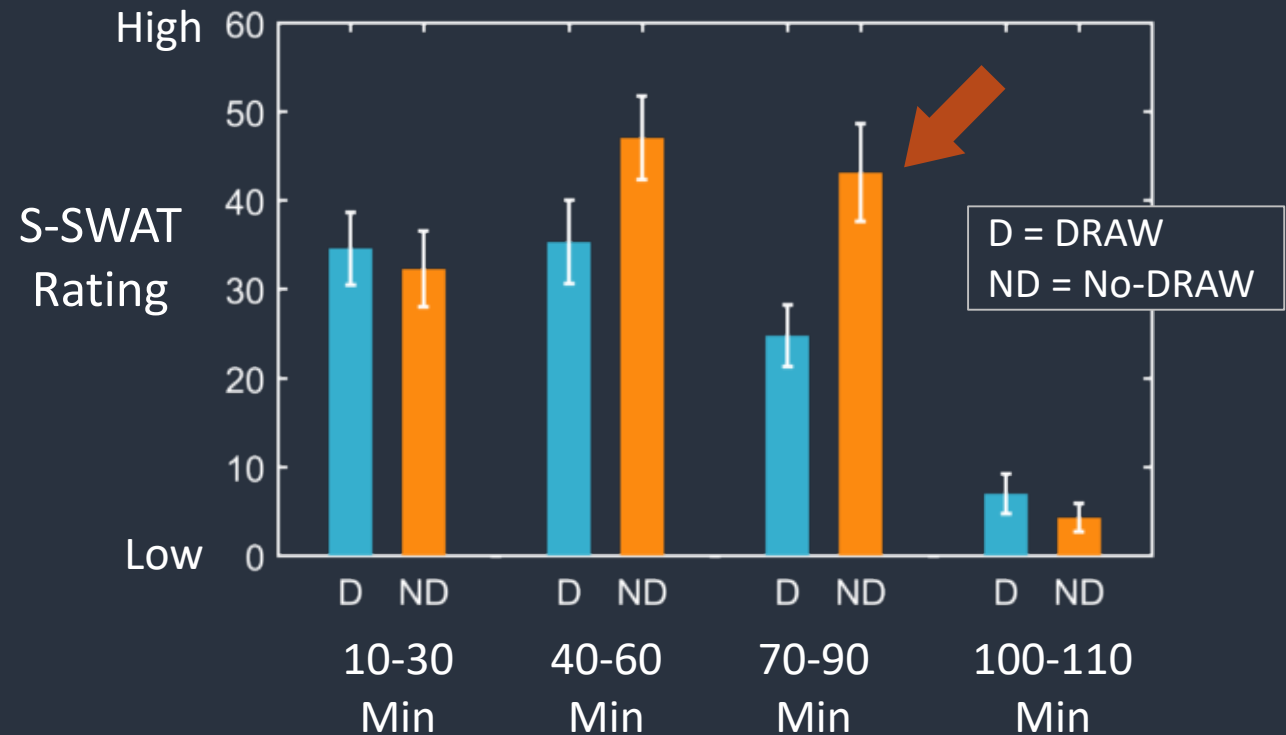
Controller Workload

- The sector controllers' post-run NASA TLX workload ratings (unweighted average of the subscale ratings) were higher in No-DRAW, Near FH ($p = 0.005$).



TMC Workload

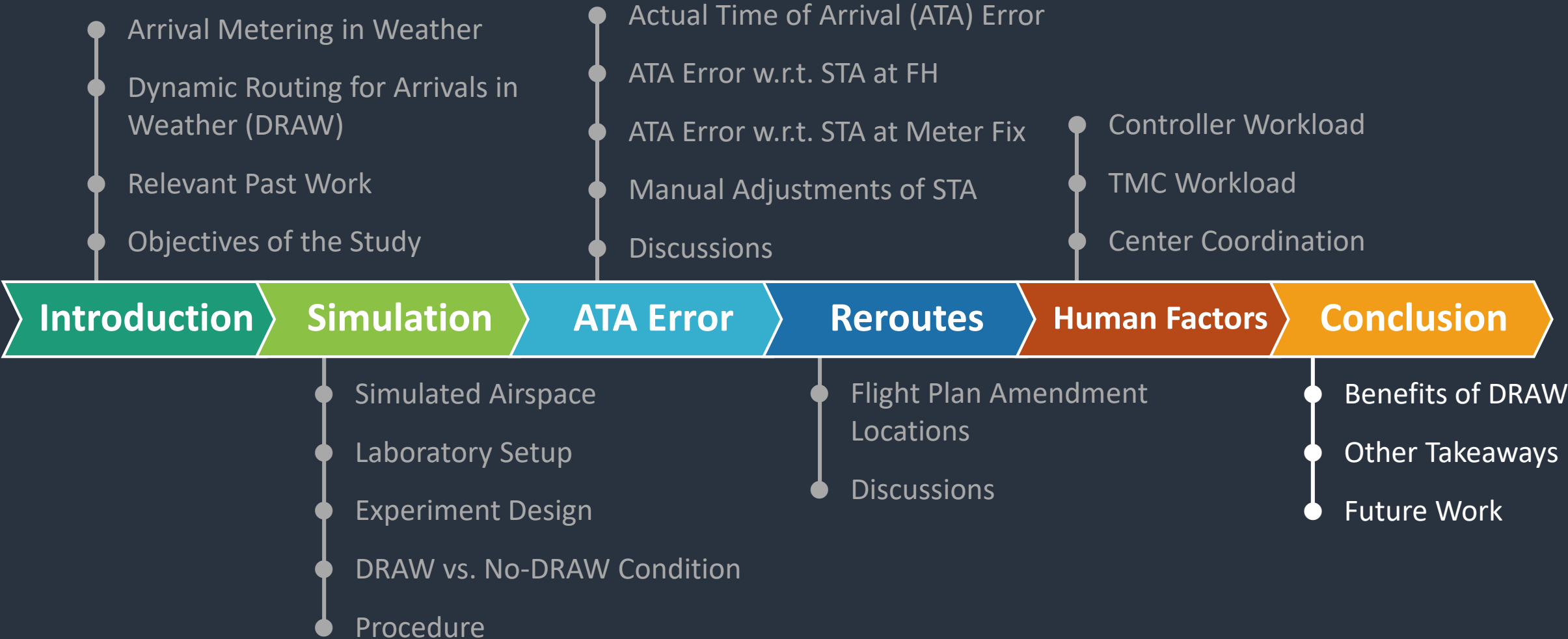
- The Atlanta TMCs' real-time workload ratings were recorded every 10 minutes.
- Simplified Subjective Workload Assessment Technique (S-SWAT) scale was used.
- In 70-90 scenario-elapsed min segment (heavy traffic), the TMC workload was significantly higher when DRAW was not provided ($p = 0.008$).



Center Coordination

- In this study:
 - Atlanta (ZTL) TMC was the user of the DRAW.
 - Jacksonville (ZJX) TMC provided consultation.
- In field operation, however, ZJX should be the DRAW user.
 - Most weather-avoidance reroutes occurred in the ZJX airspace.
- Coordination when the responsibilities for weather avoidance and arrival metering fall into 2 different Centers?
 - A technological solution to enable the relevant Centers and the Command Center to view, discuss, and modify the reroute may be needed.

Presentation Sections



Benefits of DRAW Use

- Some DRAW benefits were observed regardless of the FH locations:
 - Reduced number of manual STA swaps
 - Reduced TMC workload (when the traffic volume was high)
- Some DRAW benefits were robustness to the FH locations:
 - ATA errors w.r.t. the STA at the FH ($|E_{fh}|$)
 - The number of reroutes after the FH
 - Controller workload
- The robustness benefits in advanced metering (e.g., Extended Metering).
 - E.g., fewer FHs further apart

Other Takeaways

- For successful arrival metering operation, ATA errors w.r.t. both the STA at FH and the STA at Meter Fix must be small.
- The DRAW benefits rely on good weather forecast.
- Clear strategy for inter-facility communication and coordination is needed.

Future Work

- Human-in-the-loop simulation demonstration of the DRAW software on the FAA's Time-Based Flow Management (TBFM) system (July, 2019)
- Technology Transfer to the FAA (September, 2019)

Thank You



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