

# Using an Automated Air Traffic Simulation Capability for a Parametric Study in Traffic Flow Management

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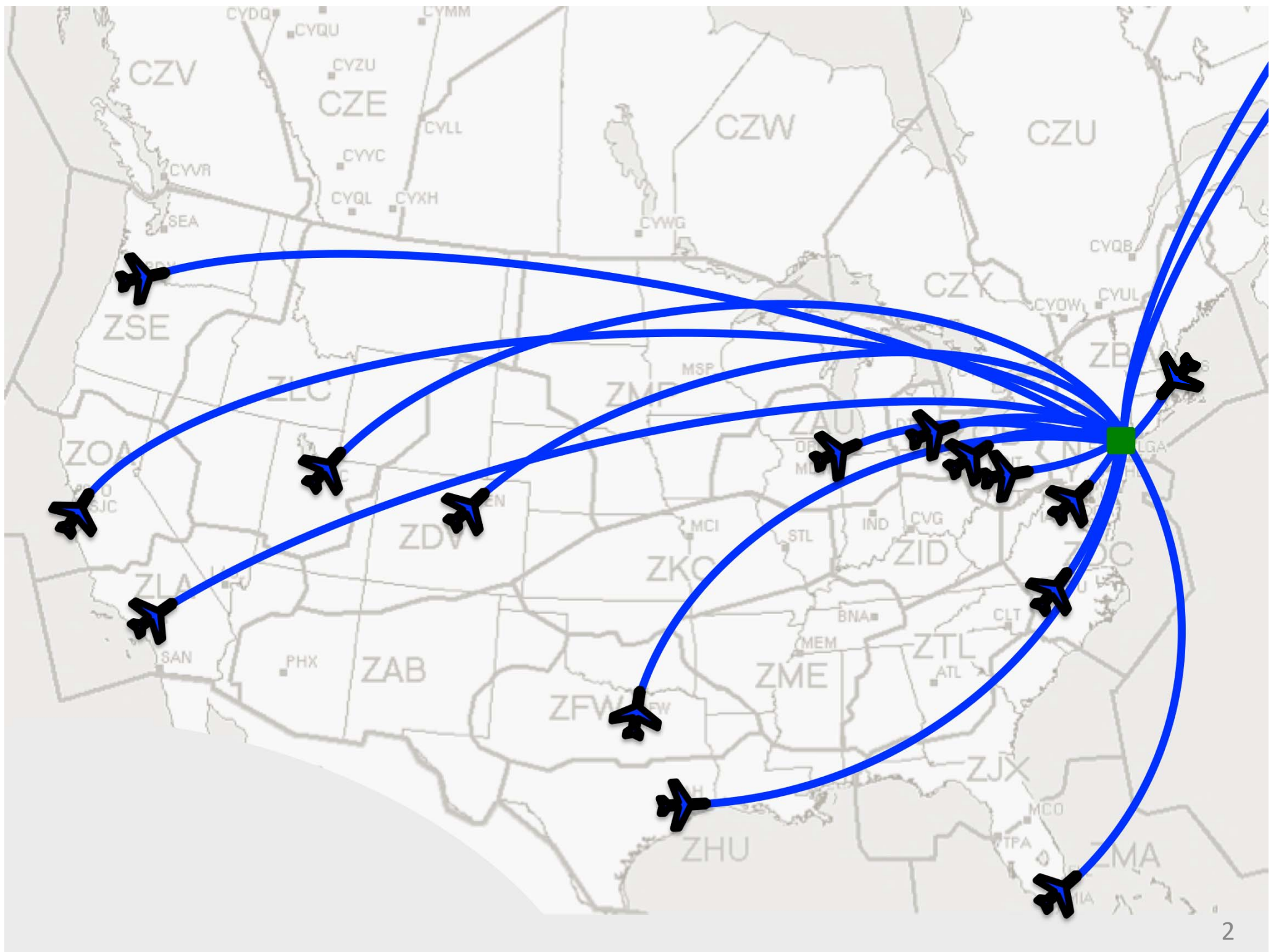
Deepak Kulkarni, Paul Lee, Mei Yueh Wei

*NASA Ames Research Center*

Jinhua Li

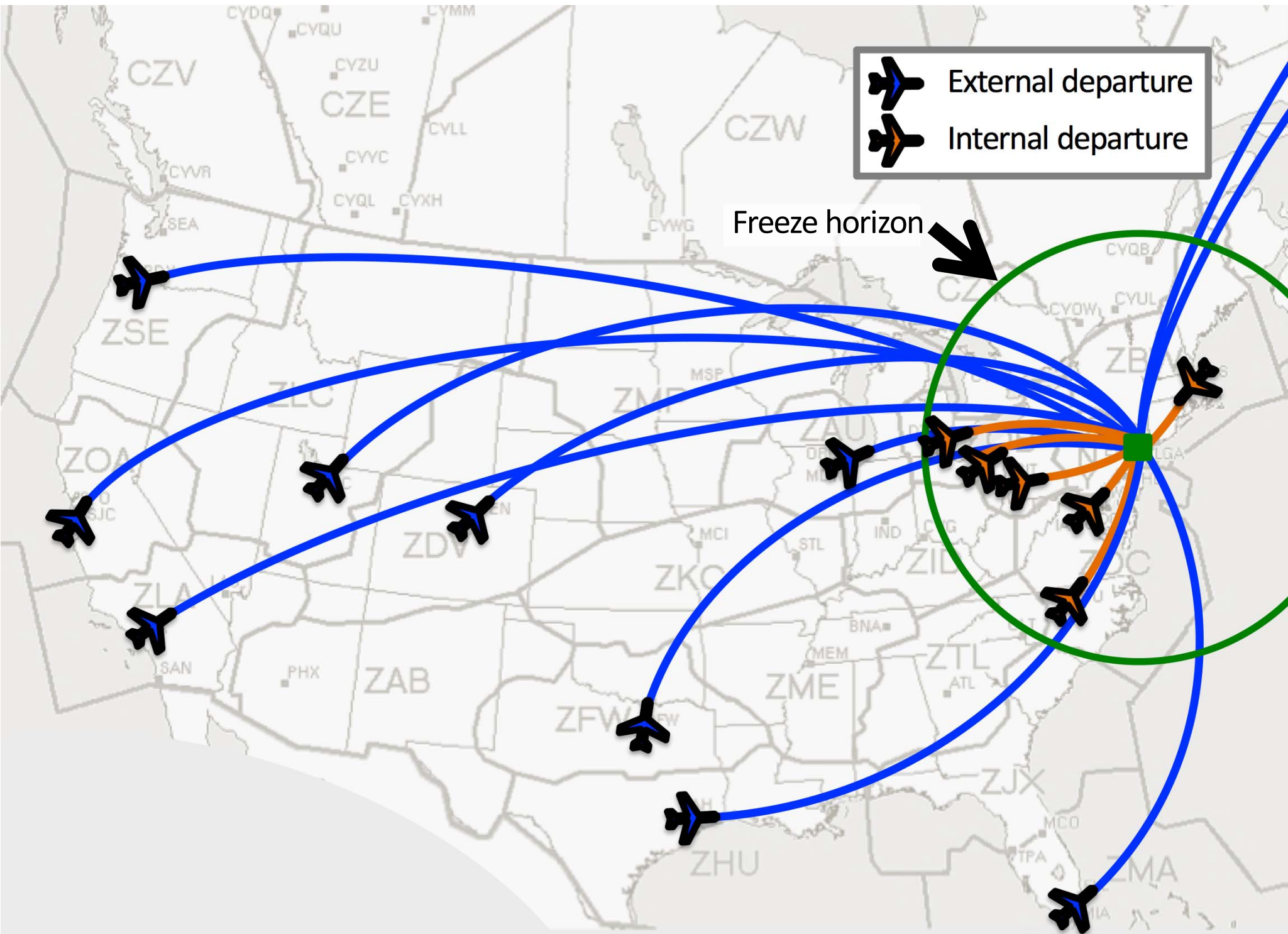
*Universities Space Research Association, NASA Ames Research Center*











## Strategic planner: e.g. Ground Delay Program (GDP)

- Pre-departure ground delay
- Adjust demand to roughly meet arrival rate constraint

## Tactical planner: Time-Based Flow Management (TBFM)

- Airborne delay near arrival airport
- Pre-departure ground delay for internal departures
- Deliver demand to actual arrival rate constraint

## Interaction between strategic and tactical planners

- High demand → tactical delay to meet arrival rate
- Low demand → underutilized airport

## Trade-off between airborne and ground delay

- Some amount of delay can be absorbed in the air
- As airborne delay becomes impractical, internal departures delayed on ground
- “Practical delay” is situationally dependent
  - Distance from freeze horizon to airport
  - Number of flights given airborne delay

- Identify trends in airborne delay due to
- Variance in departure time conformance
  - Bias towards late departures

- Overview of tactical planner
- Experiment setup
- Tactical airborne delay results
  - Departure error variance
  - Departure error bias
- Summary
- Future work



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# Overview of tactical planner

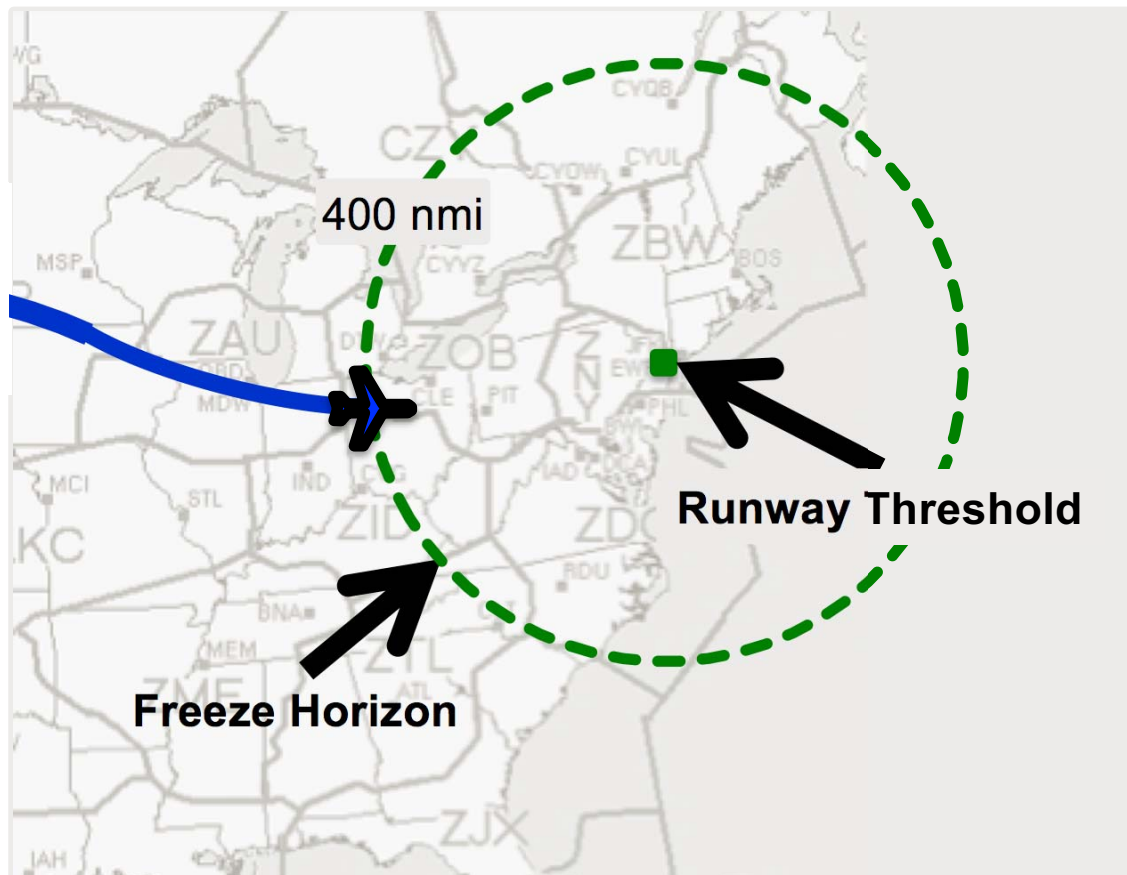
## Tactical scheduling paradigms:

- Priority given to internal departures
- Priority given to airborne flights



# Tactical planning

External departure arrives at freeze horizon

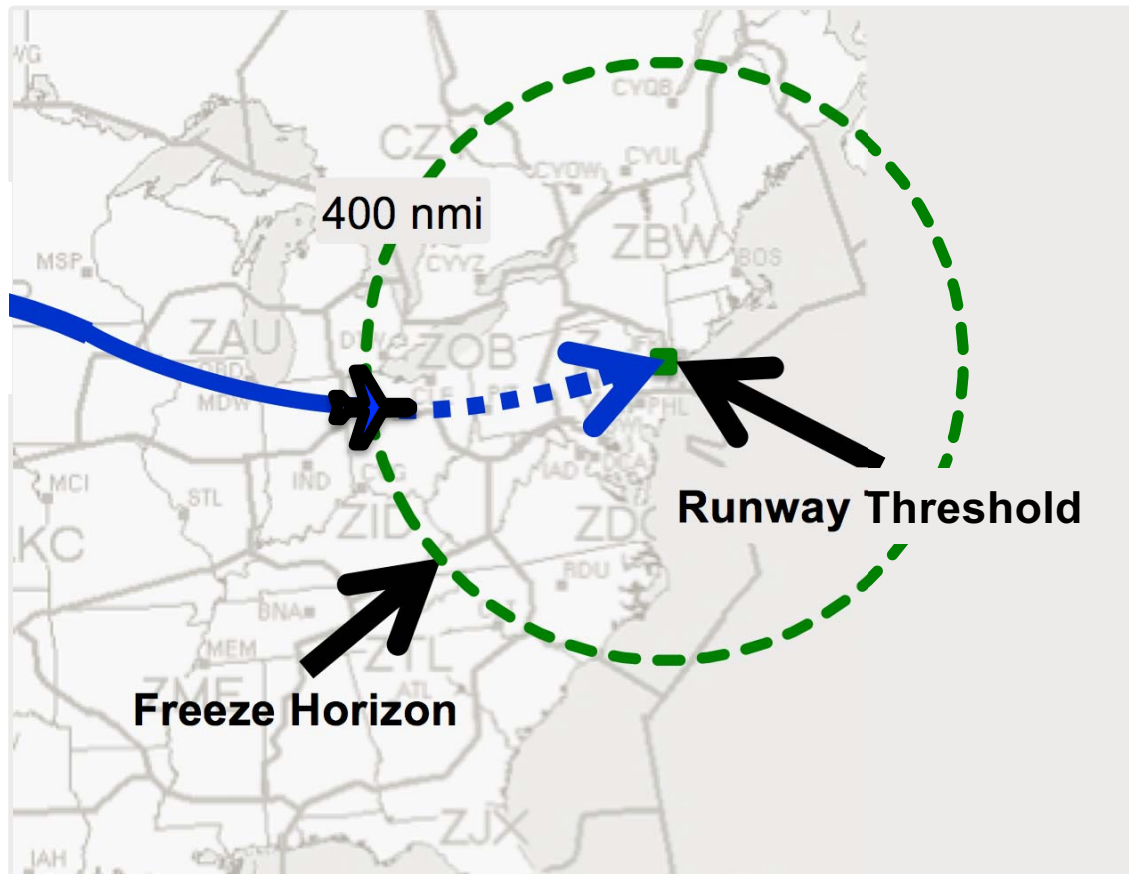






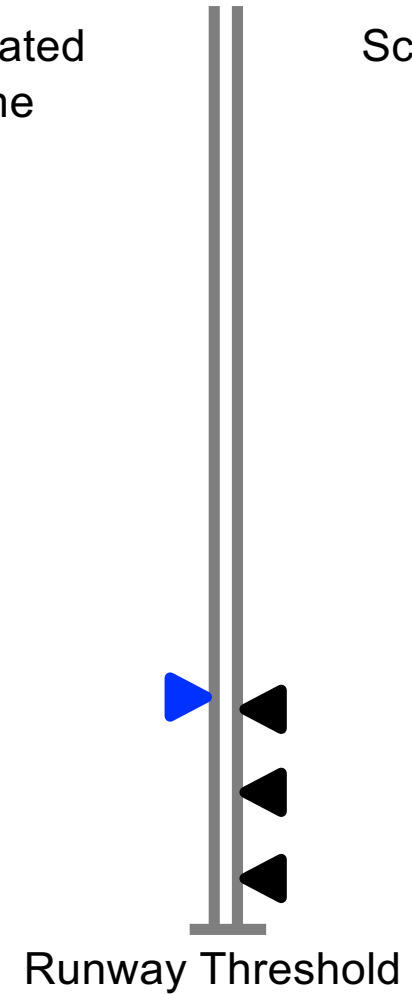
# Tactical planning

Compare to scheduled arrivals



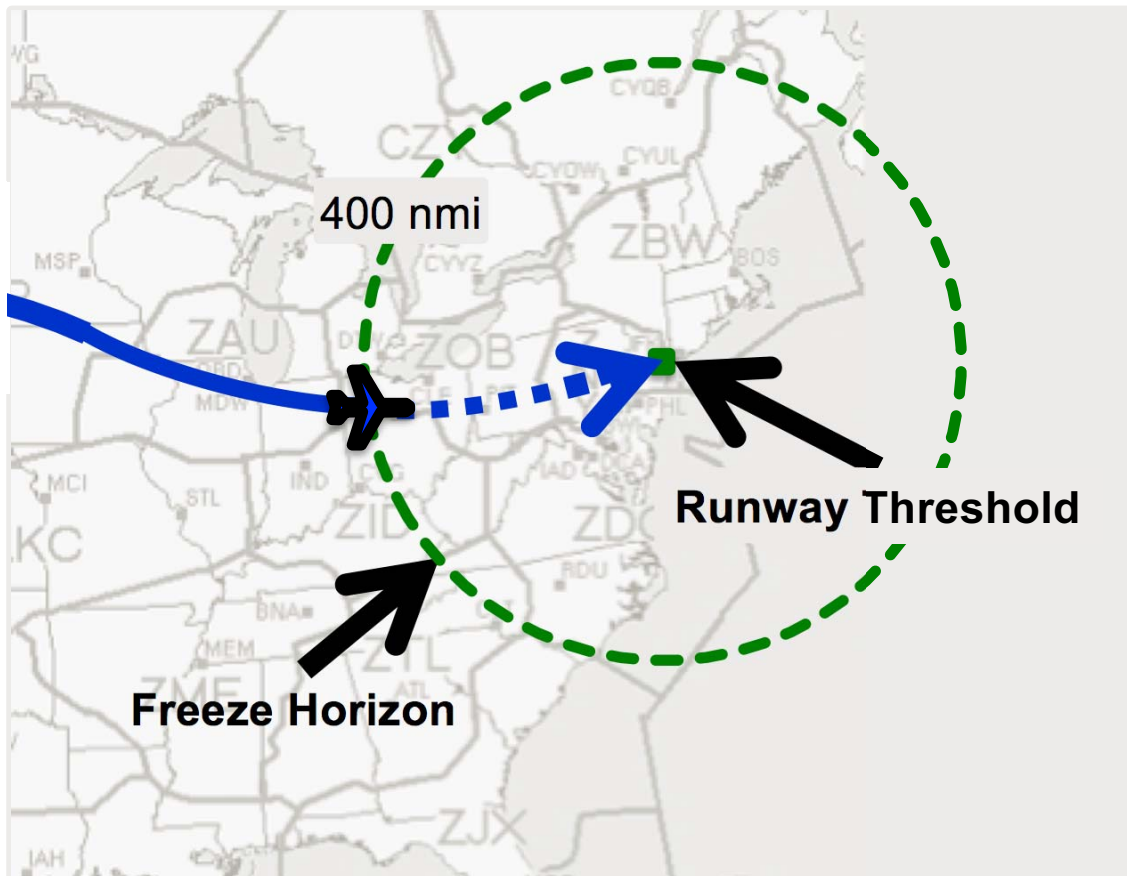
Estimated  
Time

Scheduled  
Time



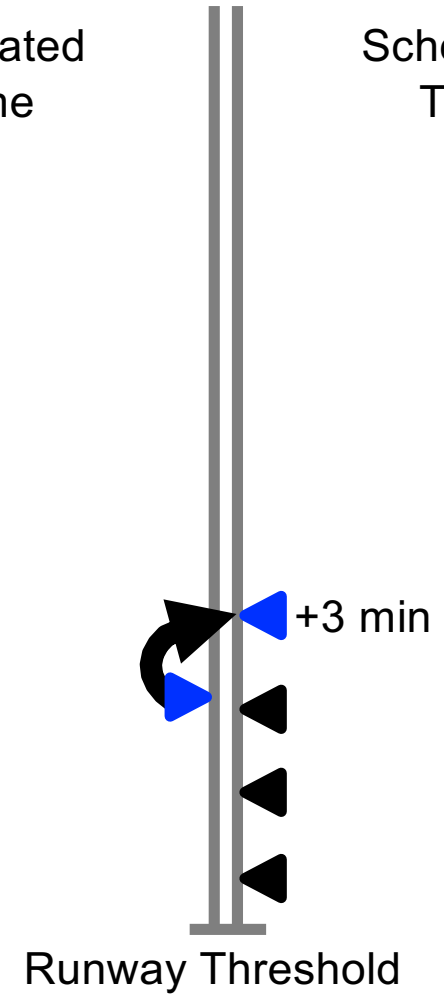
# Tactical planning

Airborne delay to get proper spacing



Estimated Time

Scheduled Time

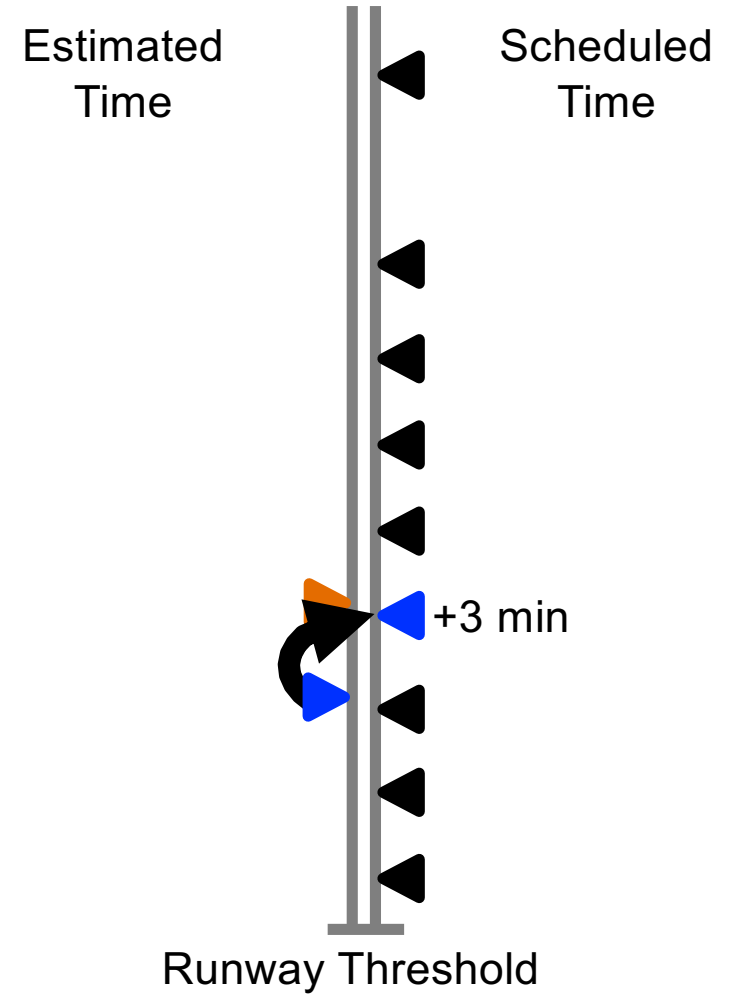
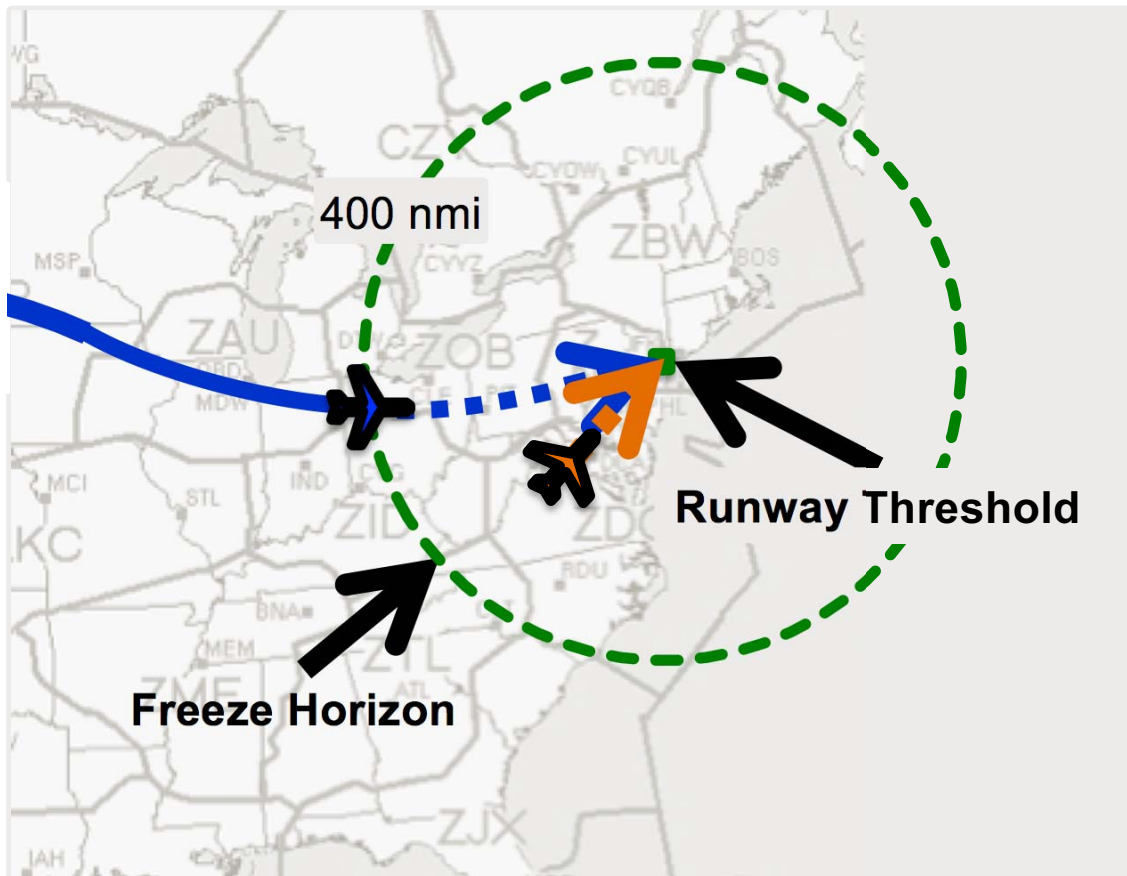






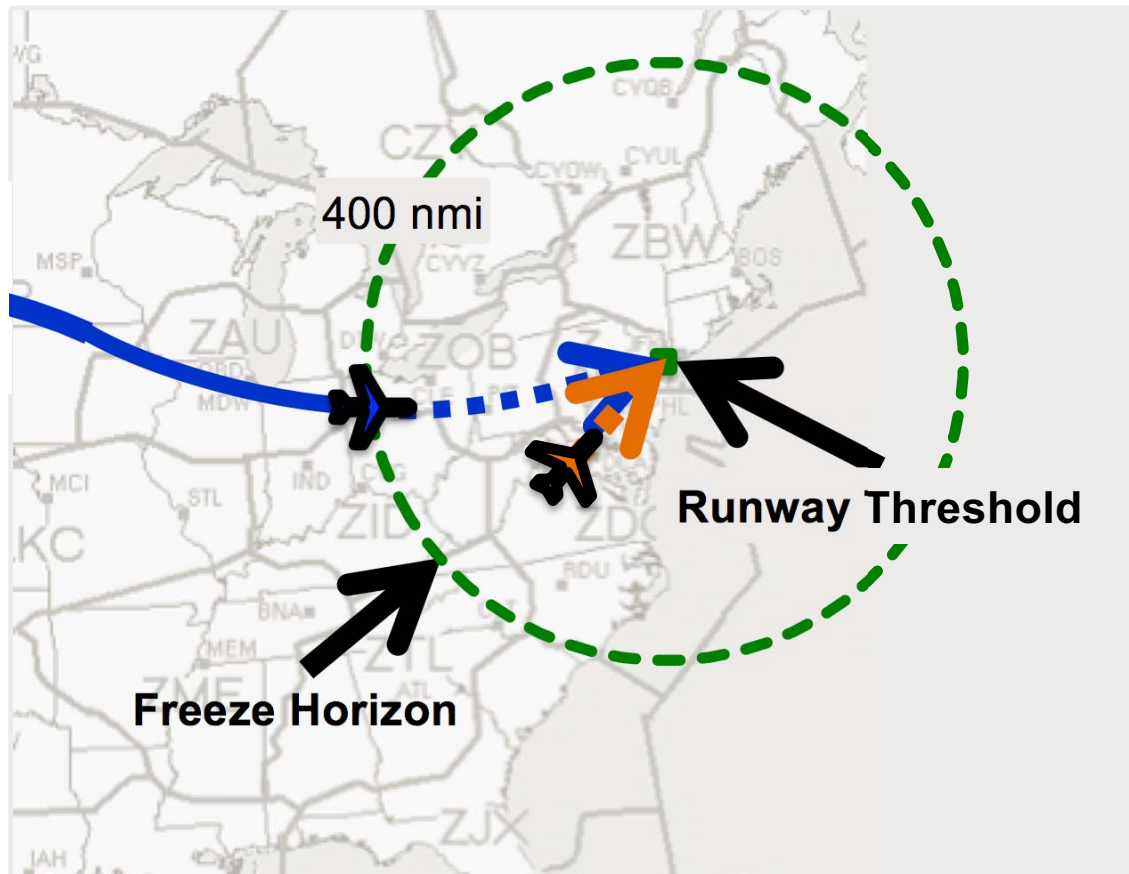
# Tactical planning

Compare to scheduled arrivals

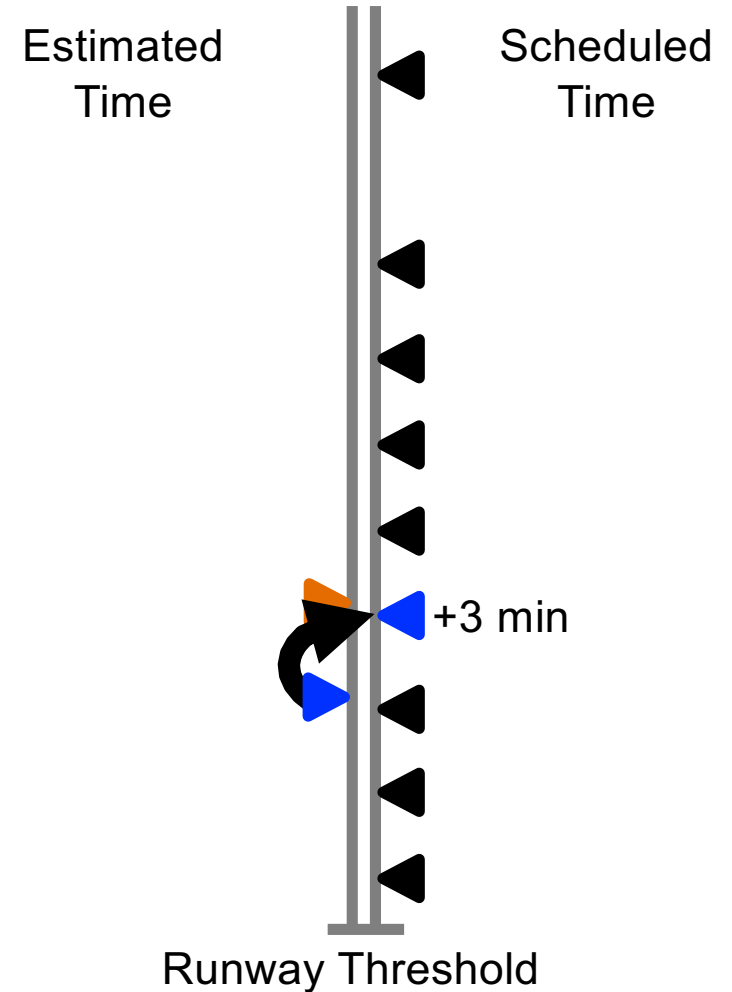




# Tactical planning



## Priority to internal departures



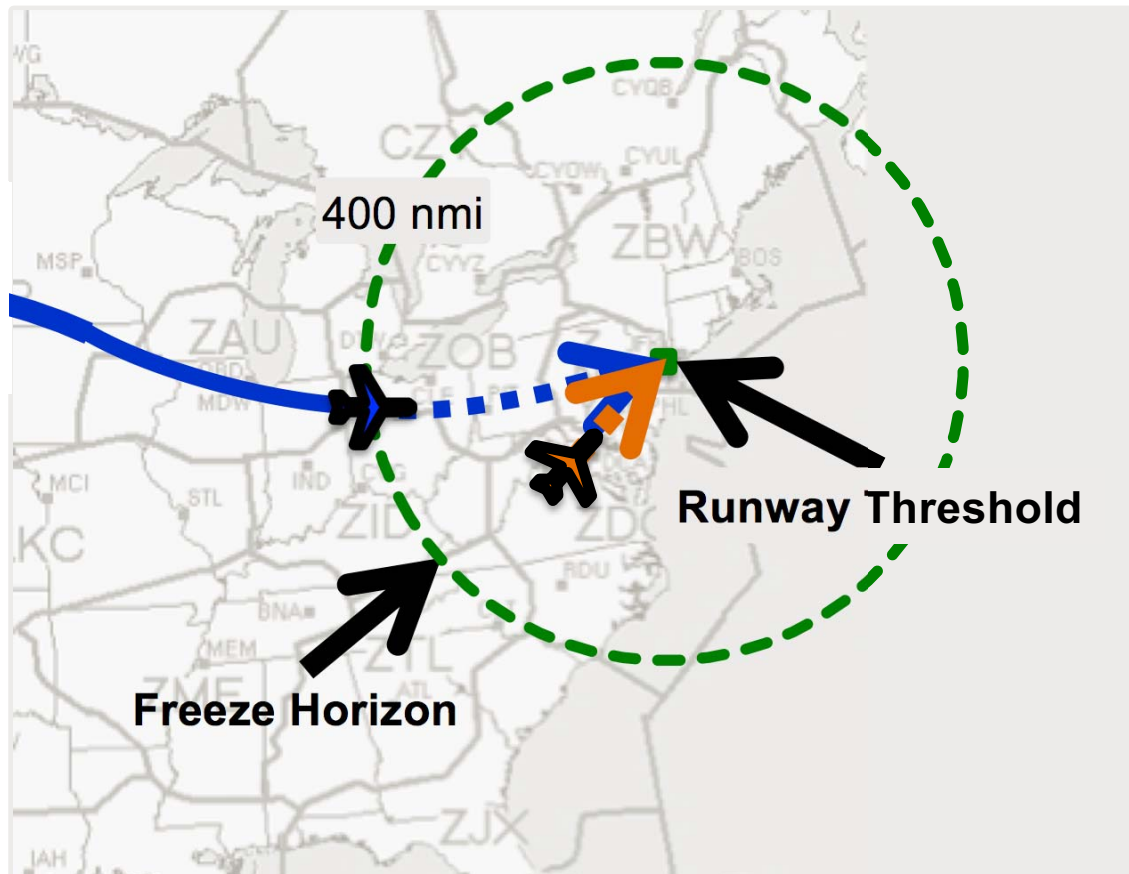




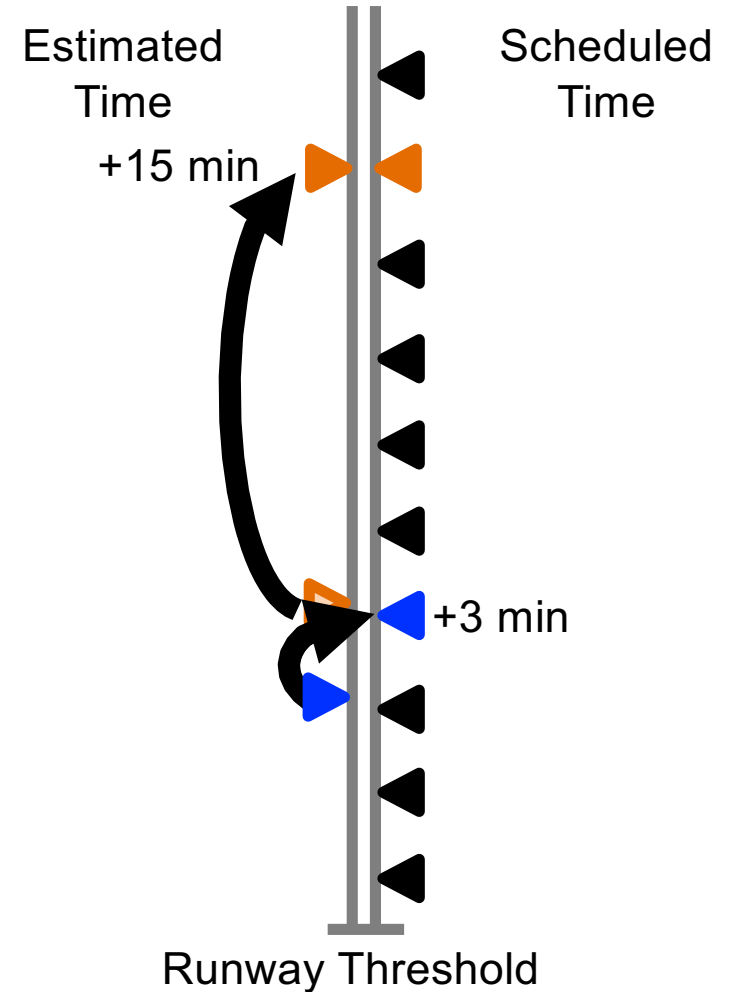


# Tactical planning

Delay internal until gap in scheduled arrivals



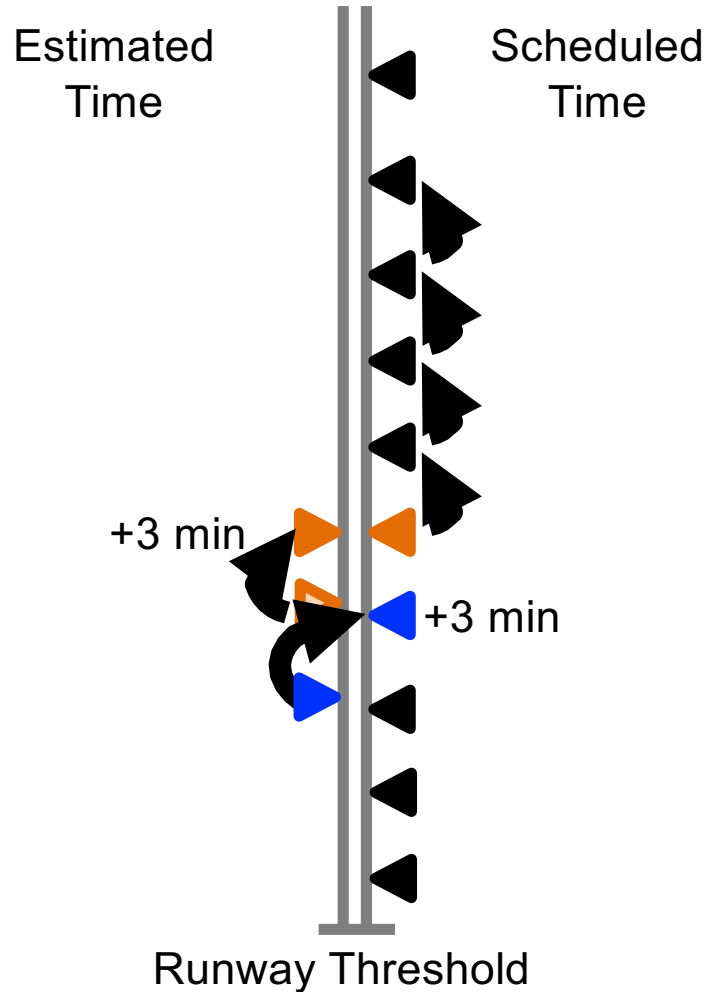
Priority to airborne flights



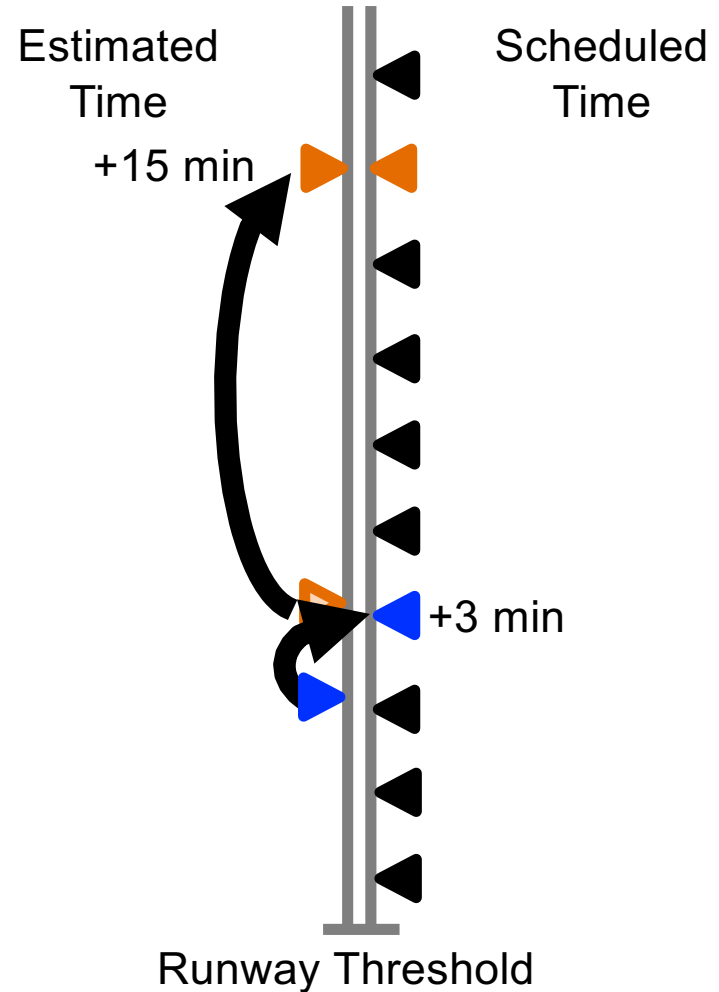


# Tactical planning

## Priority to internal departures



## Priority to airborne flights



# Tactical scheduling method pro/con

- **Priority given to internal departures**
  - Pro** – internal flights have relatively low delay
  - Con** – airborne delay can become impractical
- **Priority given to airborne flights**
  - Pro** – airborne delay remains practical
  - Con** – internal departures given relatively high delay

# Research question

When is tactical airborne delay too high?

- Acceptable: below 7 minutes
- Marginal: between 7 and 14 minutes
- Unacceptable: greater than 14 minutes

## Objective

Identify trends in airborne delay due to

- Variance in departure time conformance
- Bias towards late departures

- Overview of tactical planner
- **Experiment setup**
- Tactical airborne delay results
  - Departure error variance
  - Departure error bias
- Summary
- Future work

# Experiment setup

Fixed parameters		
Flight information	Arrivals into	Newark Liberty International Airport
	Total	194
	Start airborne	42
	External departures	128
	Internal departures	66
	Flight plans	fixed
	Scheduled departure times	fixed



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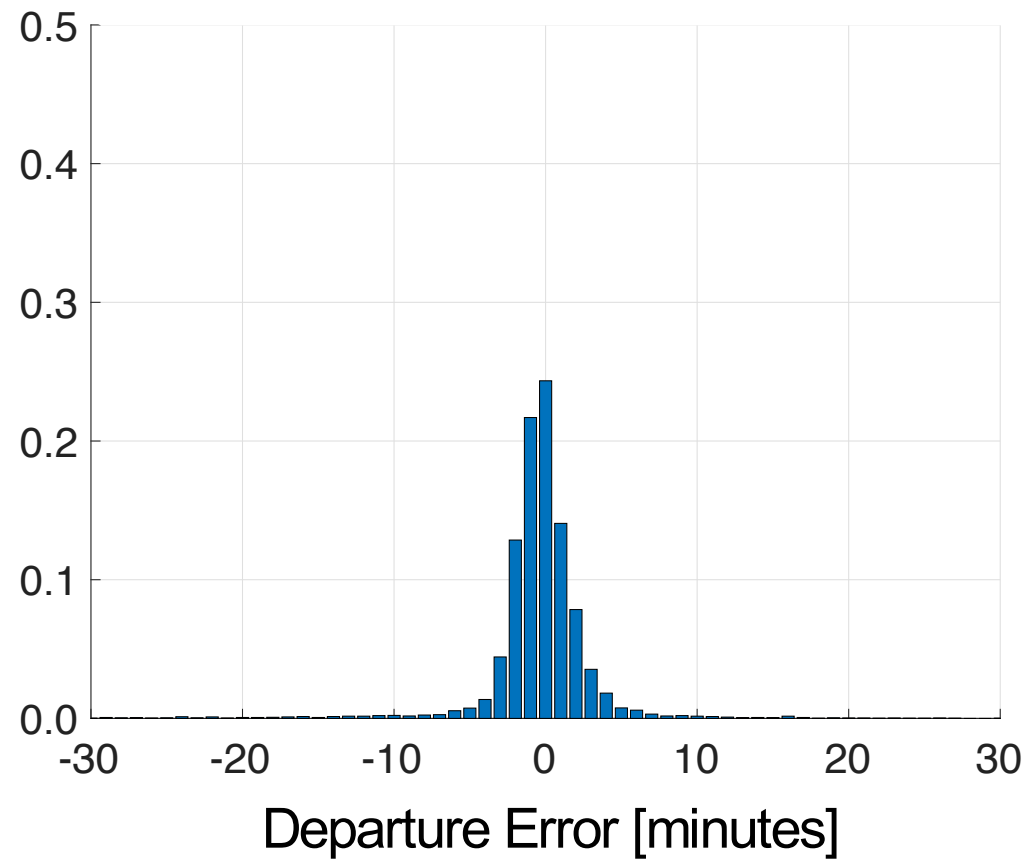
# Departure error

$$\left( \begin{array}{c} \text{departure} \\ \text{error} \end{array} \right) = \left( \begin{array}{c} \text{take-off} \\ \text{time} \end{array} \right) - \left[ \left( \begin{array}{c} \text{original} \\ \text{departure time} \end{array} \right) + \left( \begin{array}{c} \text{ground} \\ \text{delay} \end{array} \right) \right]$$

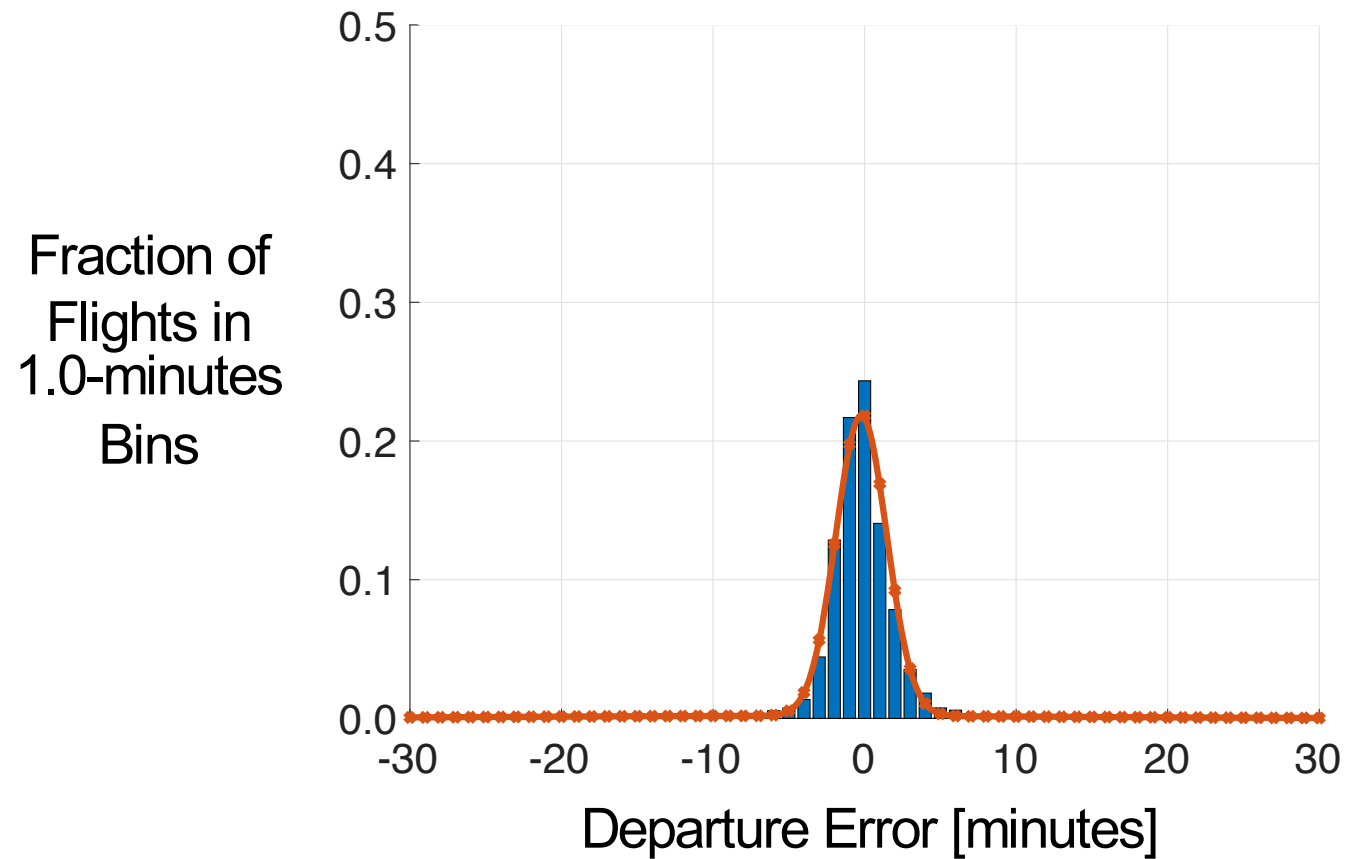
- External departures:  
historical use of Ground Delay Programs
- Internal departures:  
historical use of Traffic Management Advisor

# Internal departures

Fraction of  
Flights in  
1.0-minute  
Bins

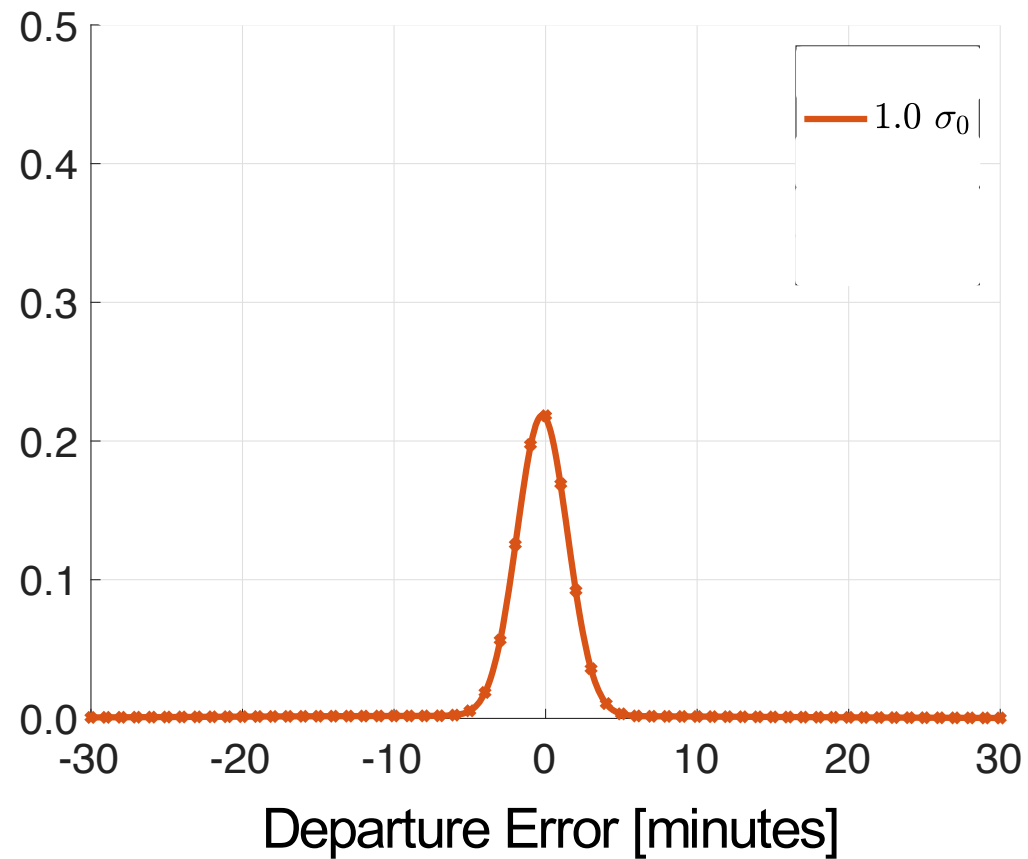


# Internal departures

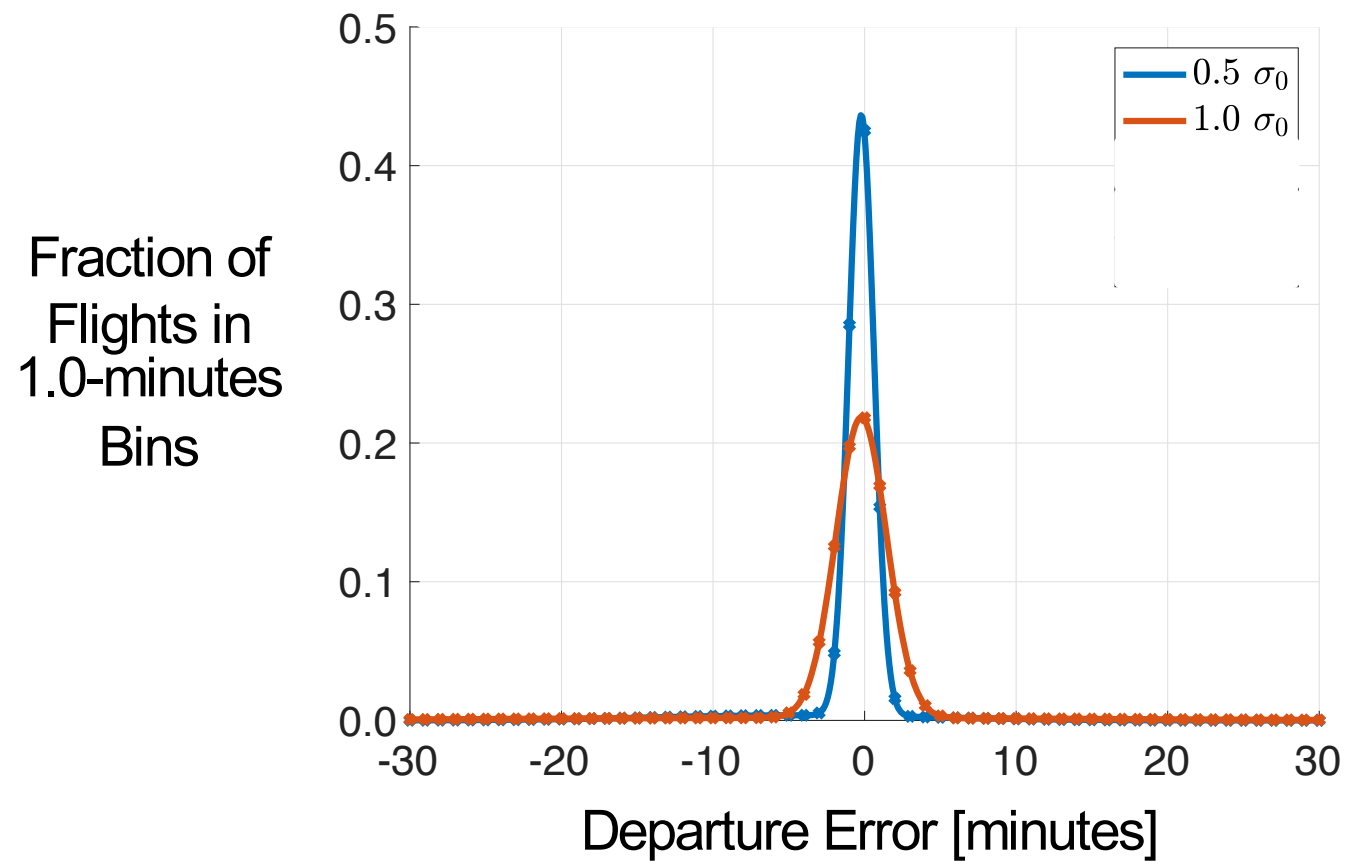


# Internal departures

Fraction of  
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Bins

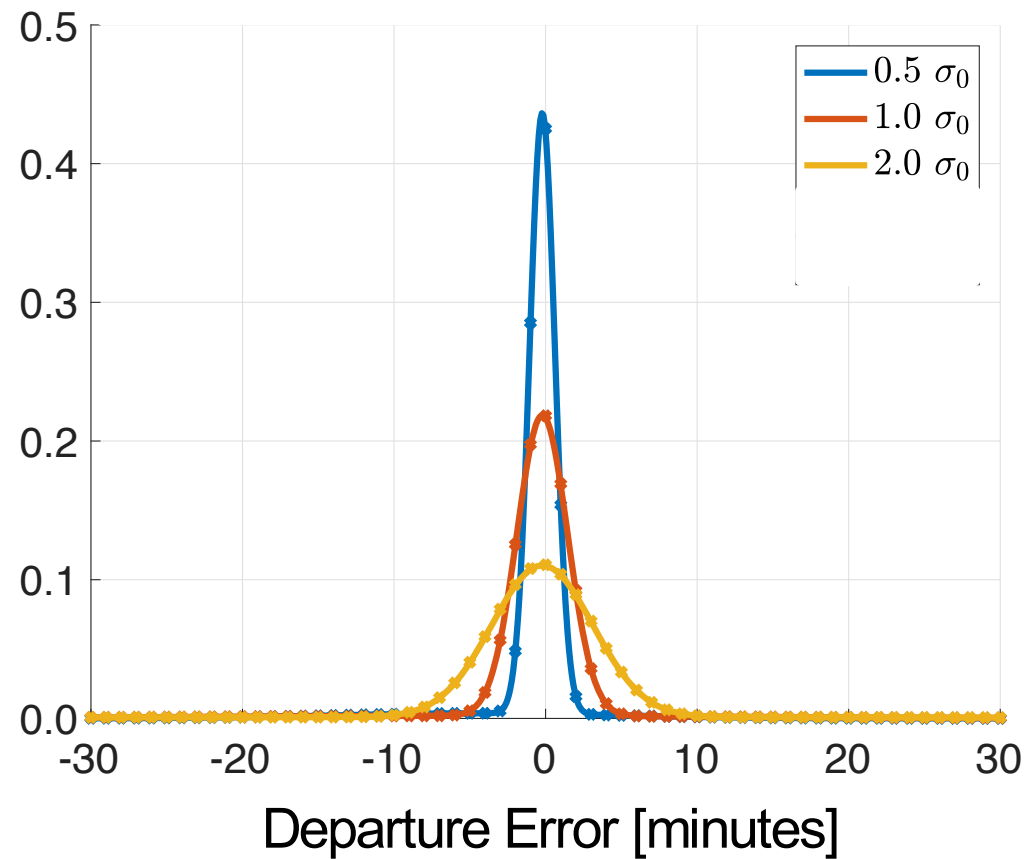


# Internal departures



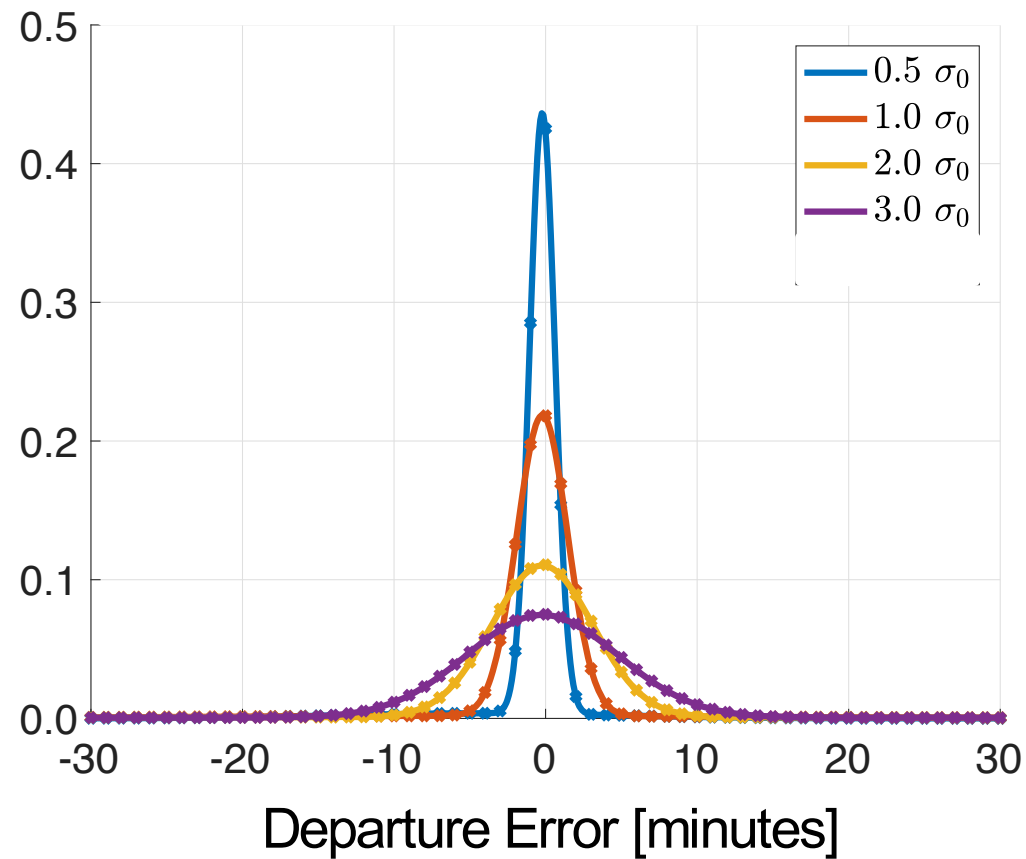
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# Internal departures

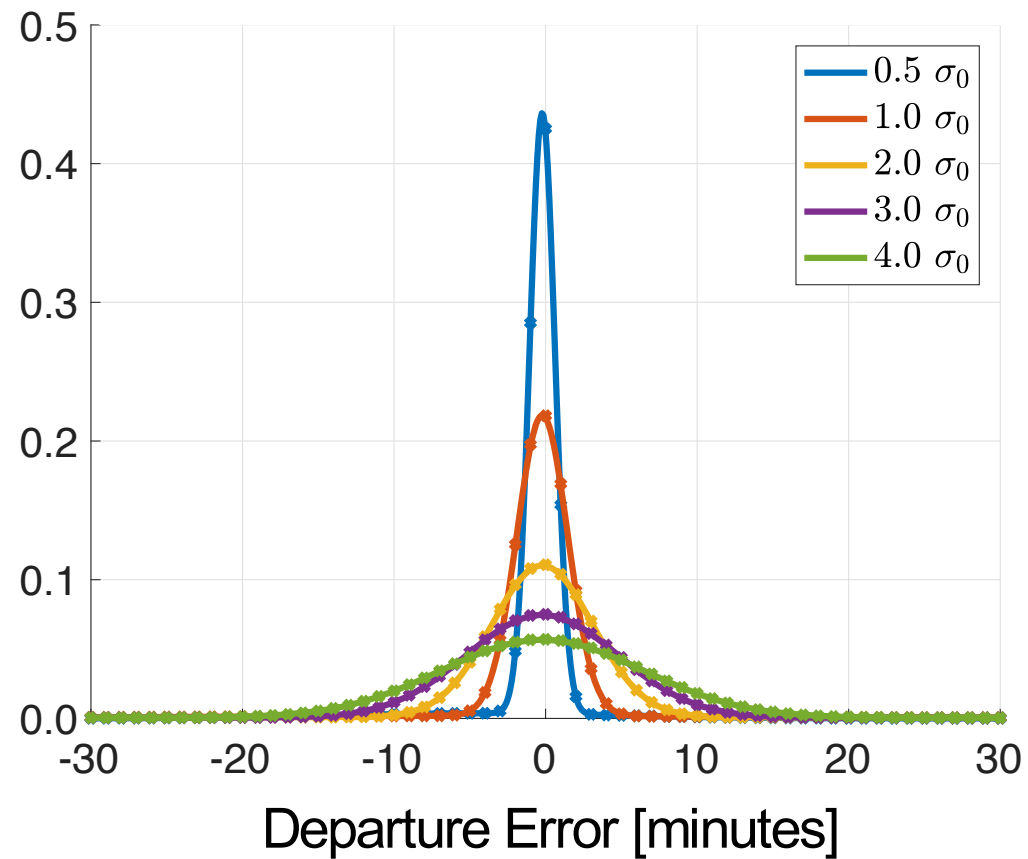
Fraction of  
Flights in  
1.0-minute  
Bins





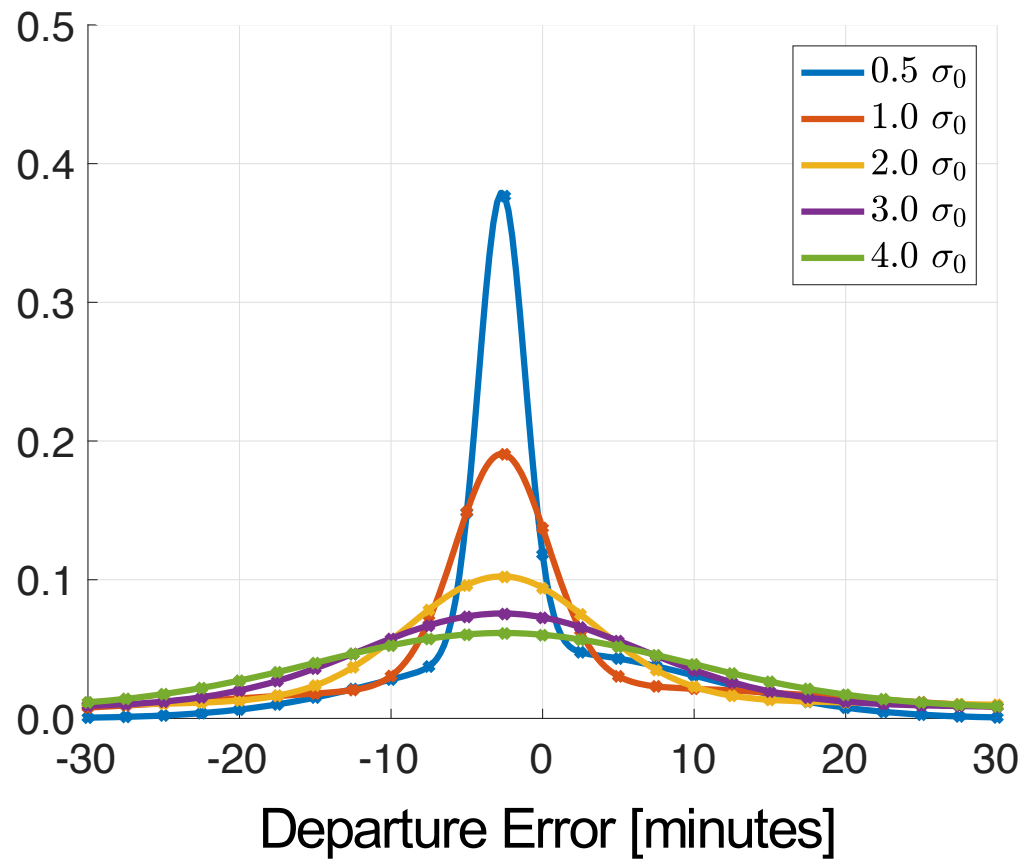
# Internal departures

Fraction of  
Flights in  
1.0-minute  
Bins

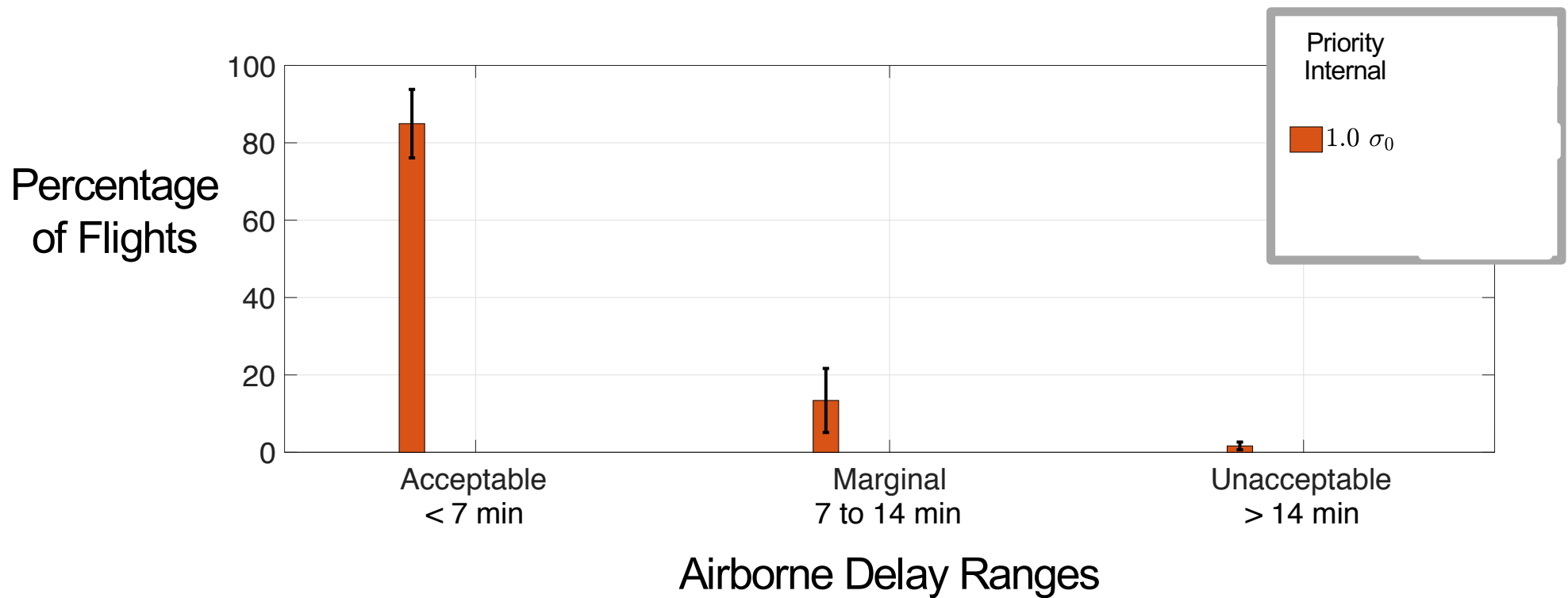


# External departures

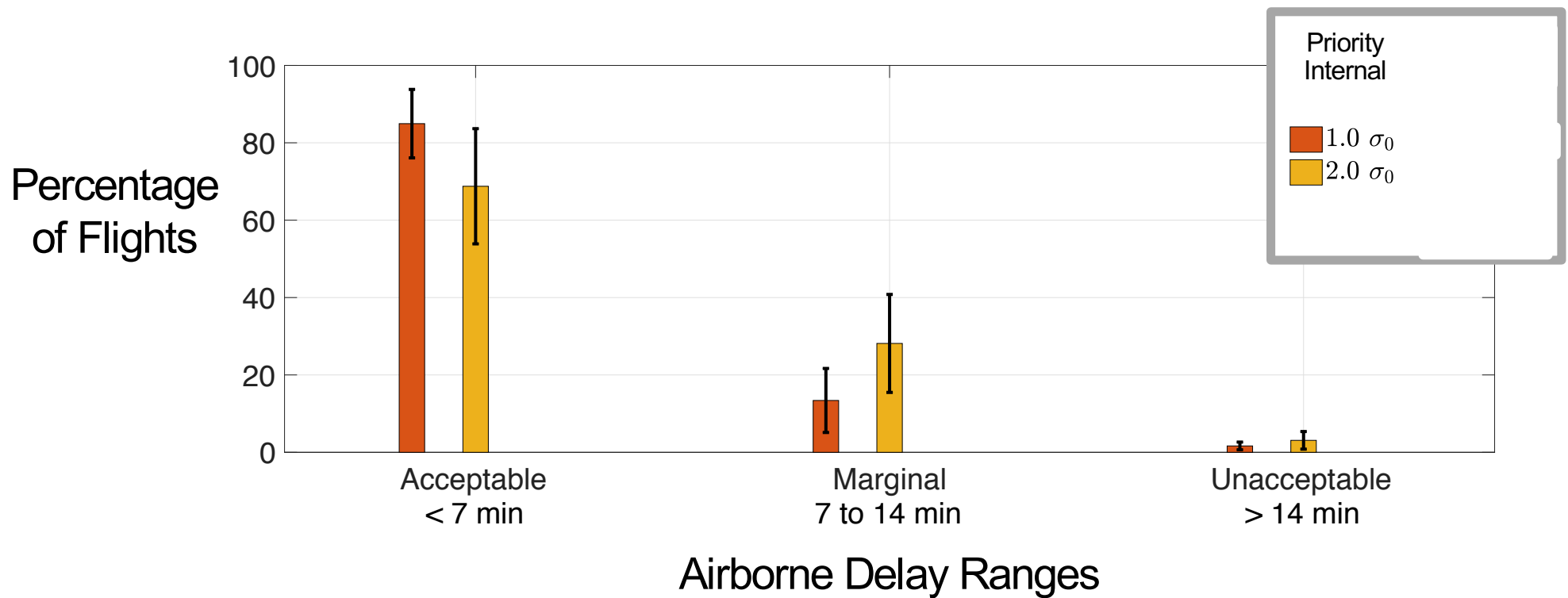
Fraction of  
Flights in  
2.5-minute  
Bins



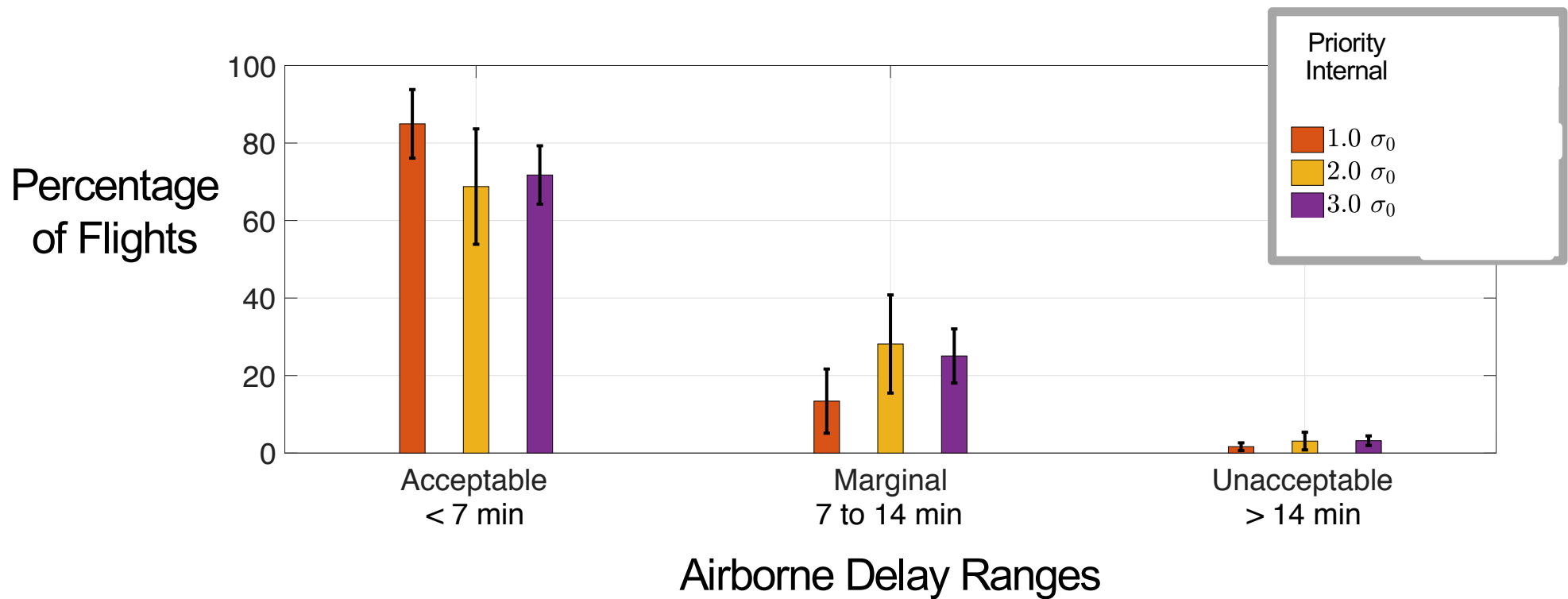
# Tactical airborne delay results



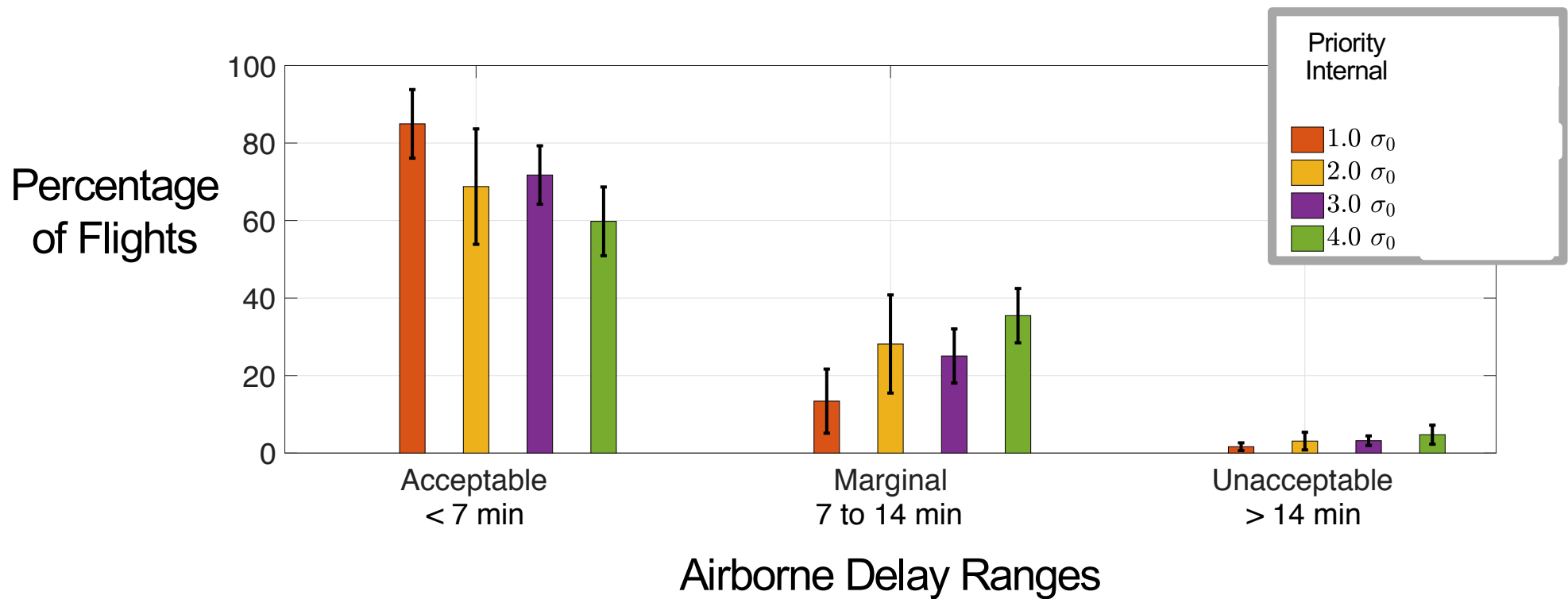
# Tactical airborne delay results



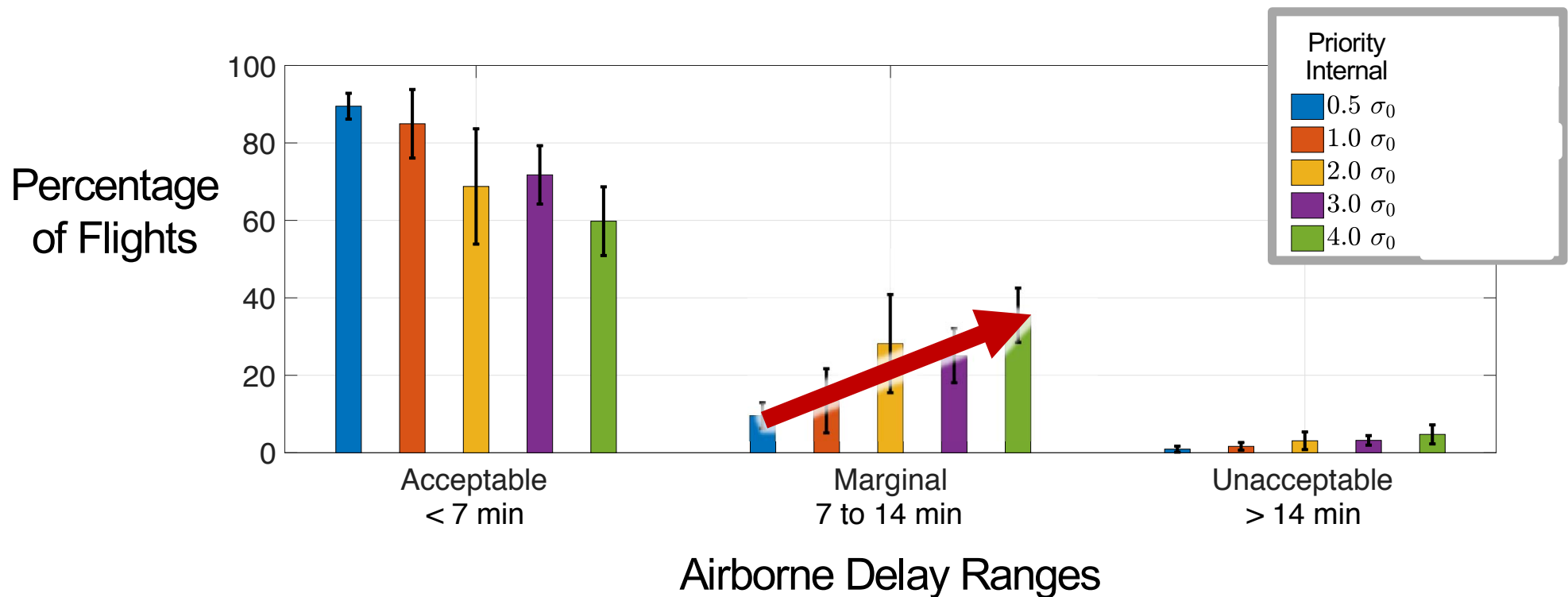
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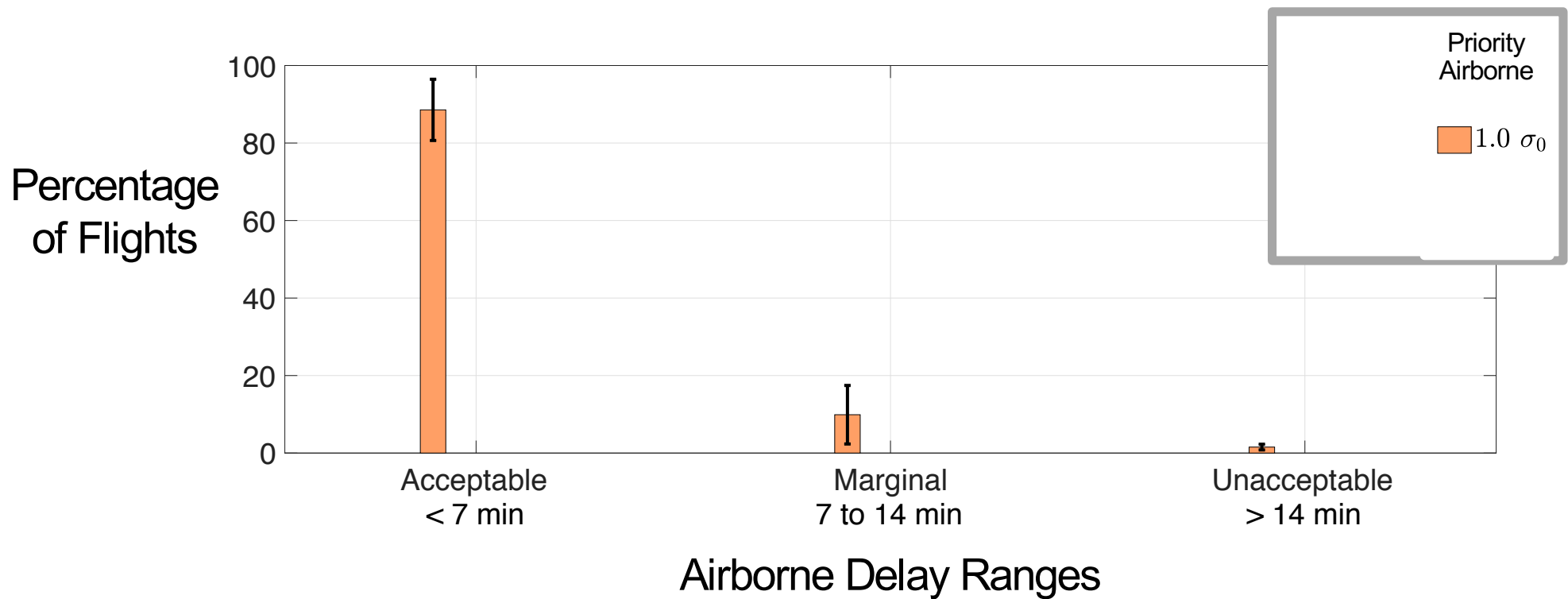


# Tactical airborne delay results



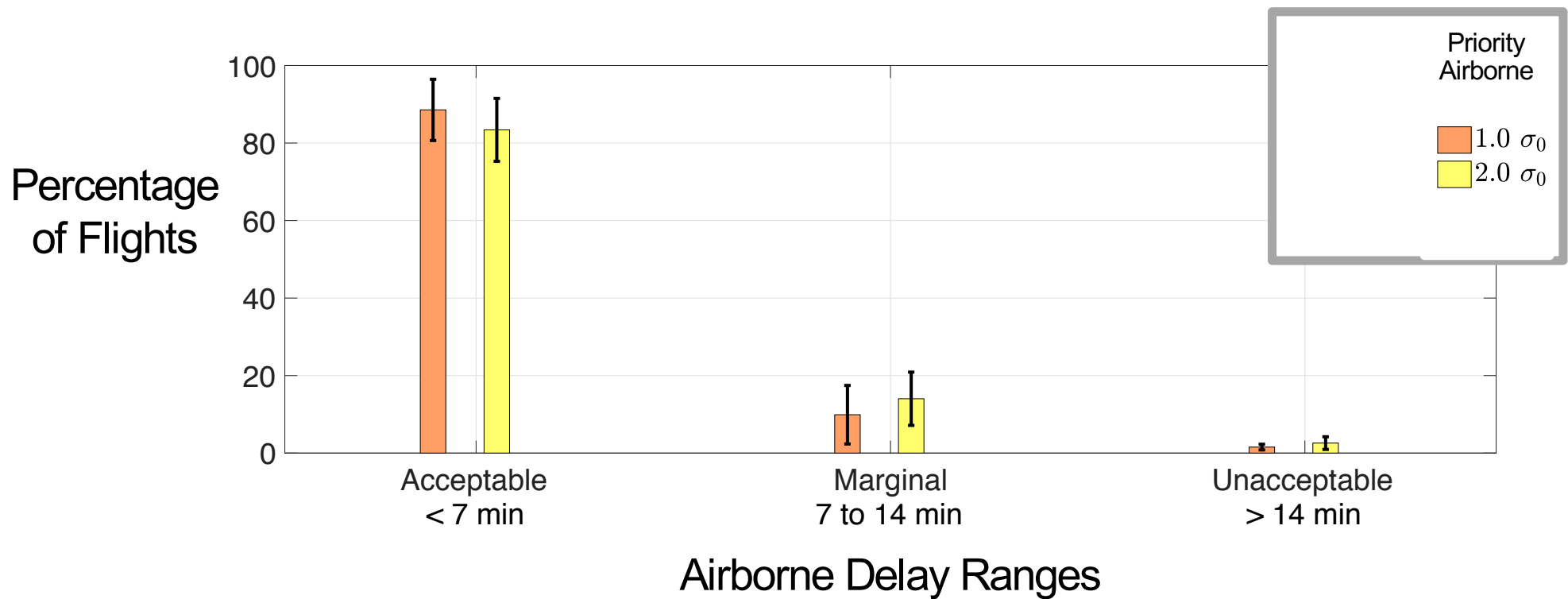
Marginal airborne delay increases with increase in departure error variance when priority is given to internal departures

# Tactical airborne delay results

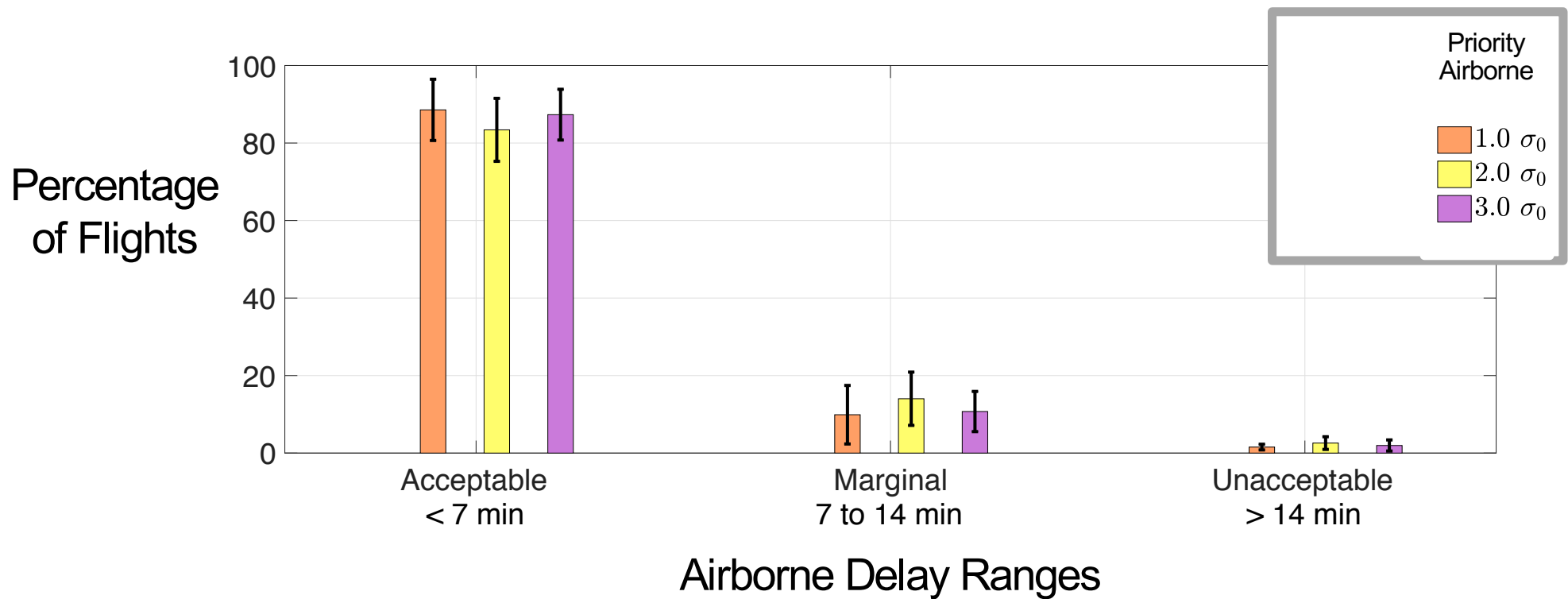




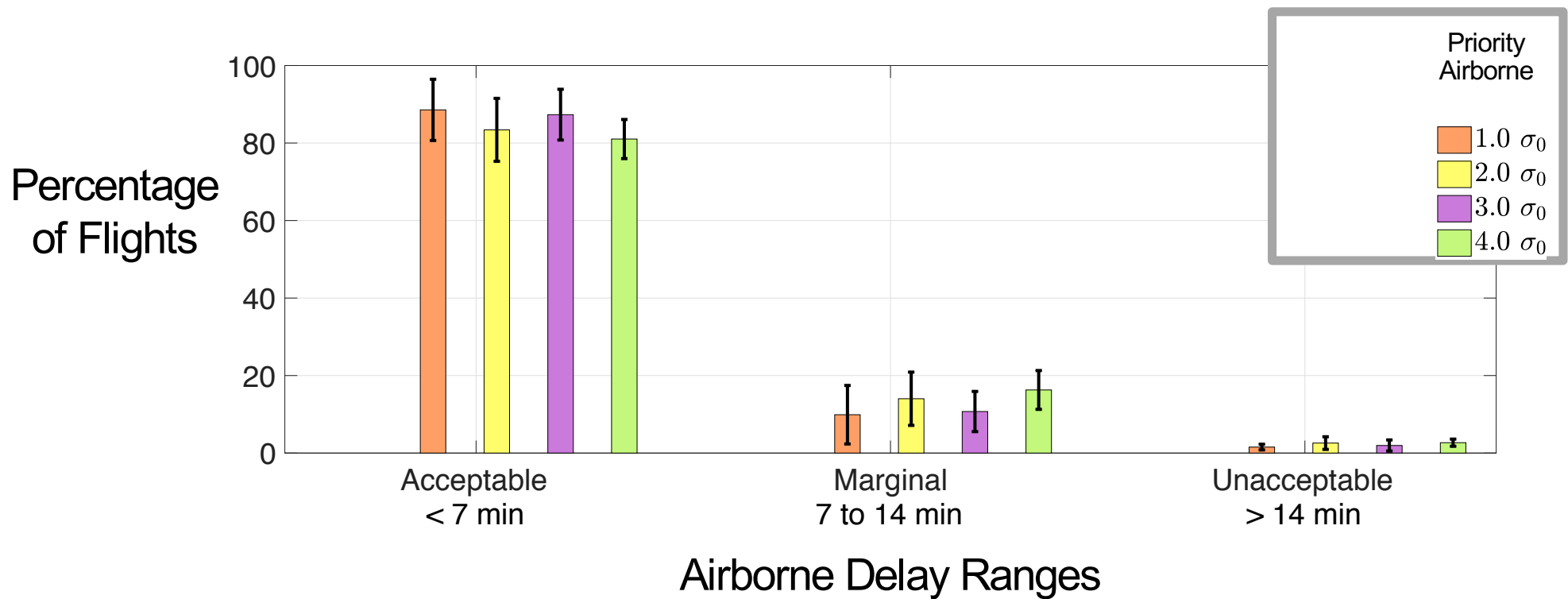
# Tactical airborne delay results



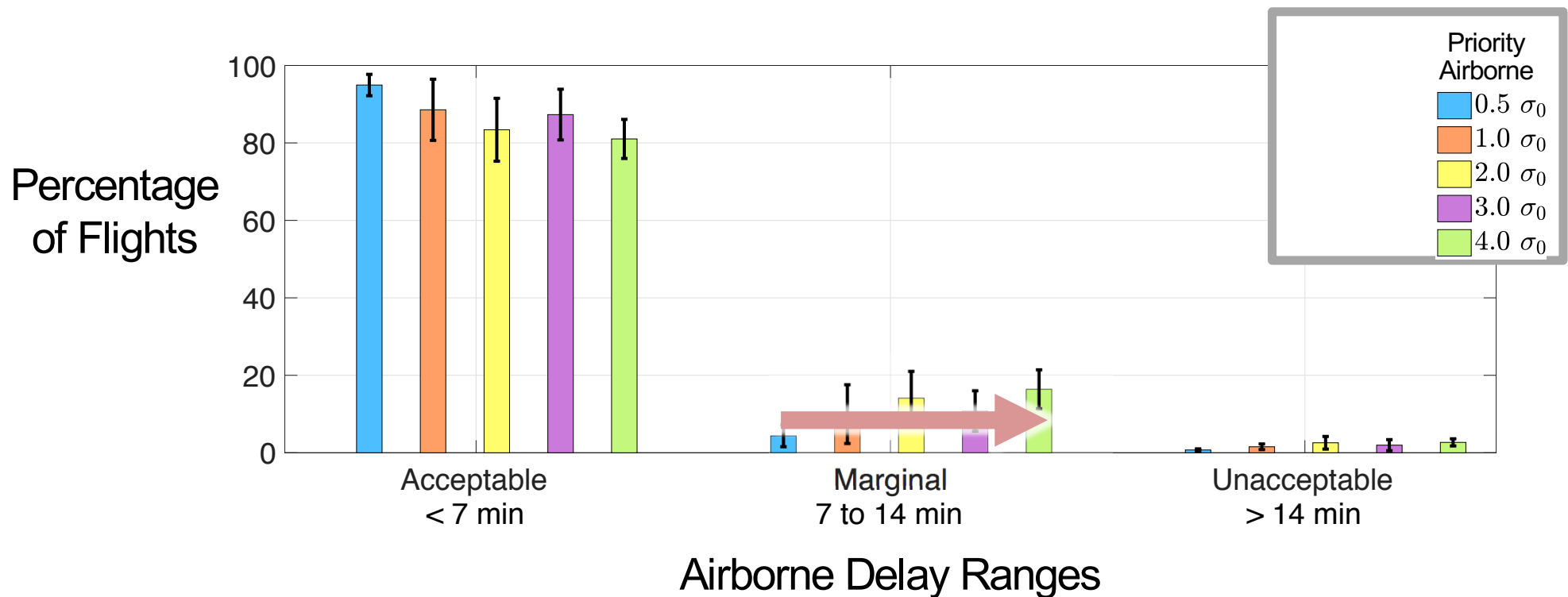
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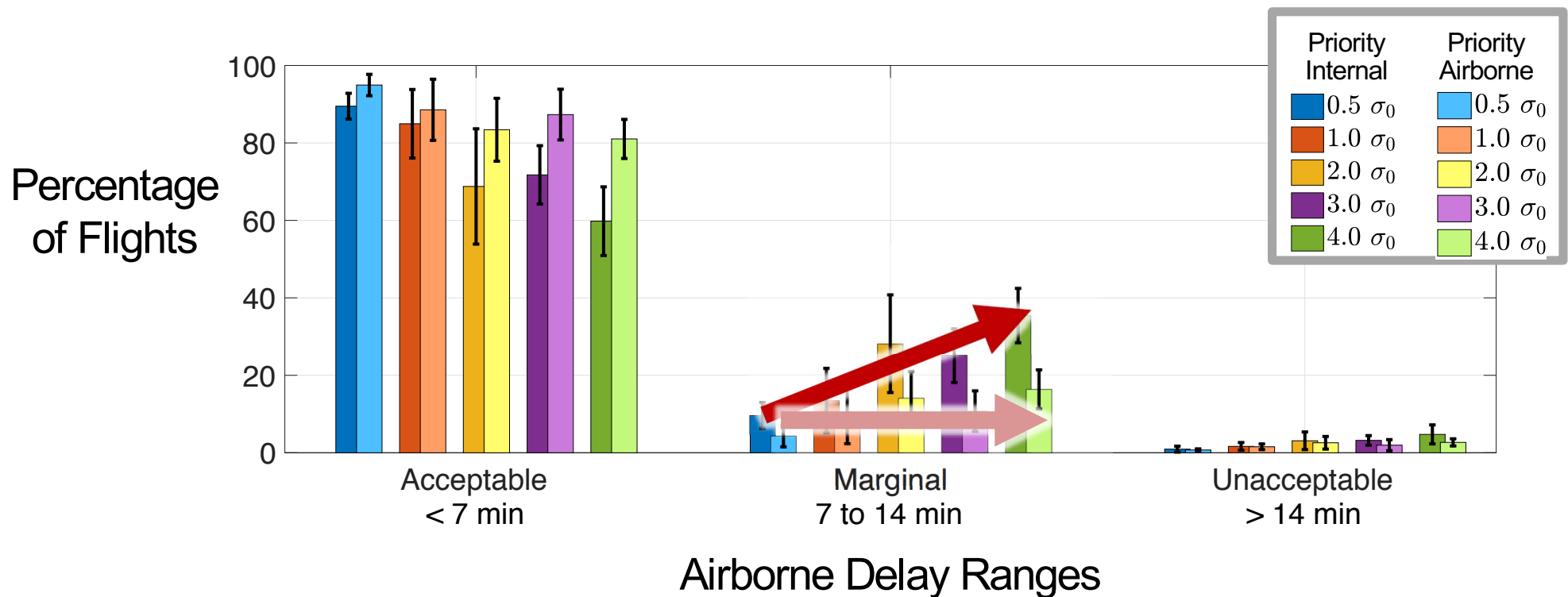


# Tactical airborne delay results



Marginal airborne delay remains relatively constant with increase in departure error variance when priority is given to airborne flights

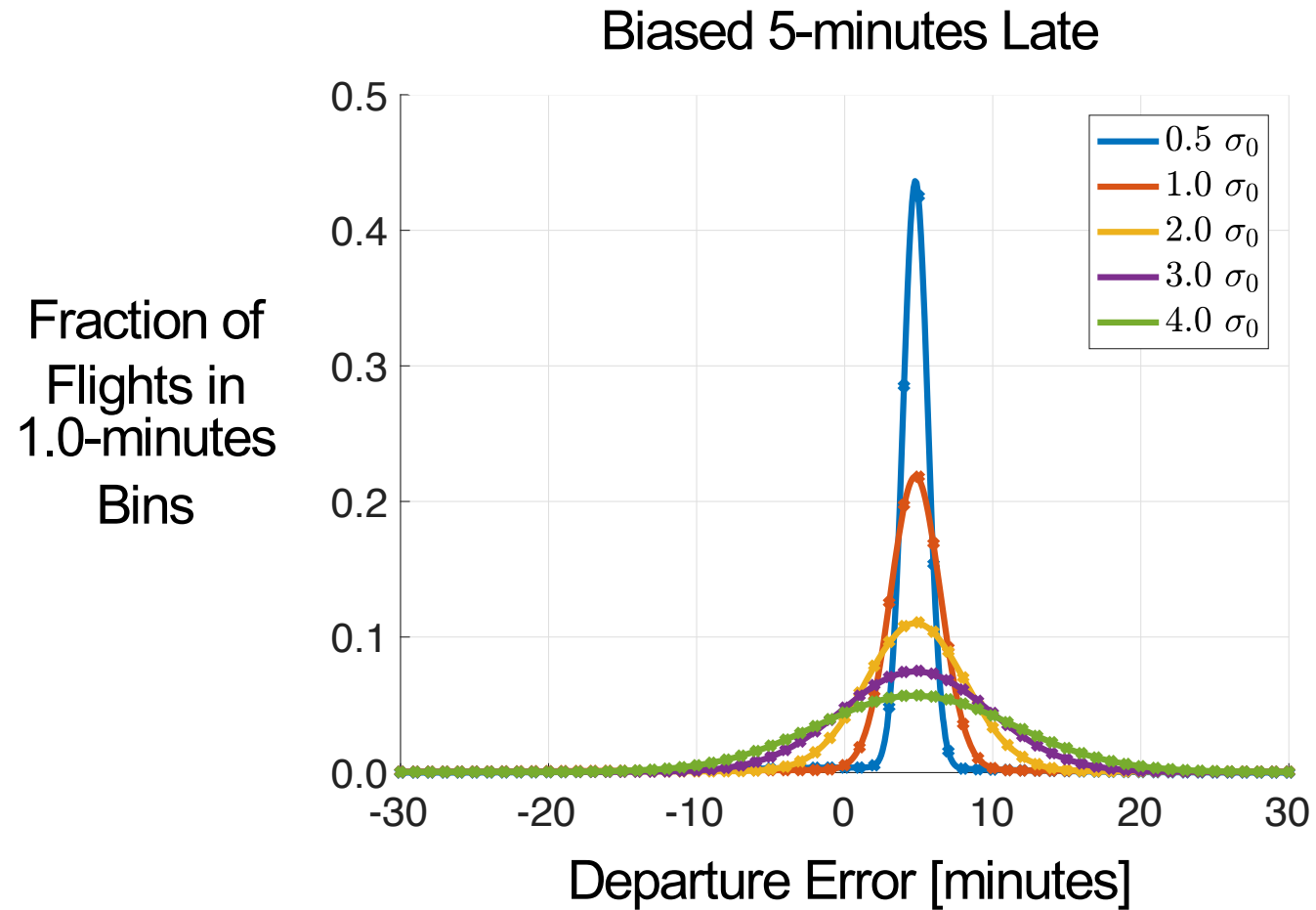
# Tactical airborne delay results



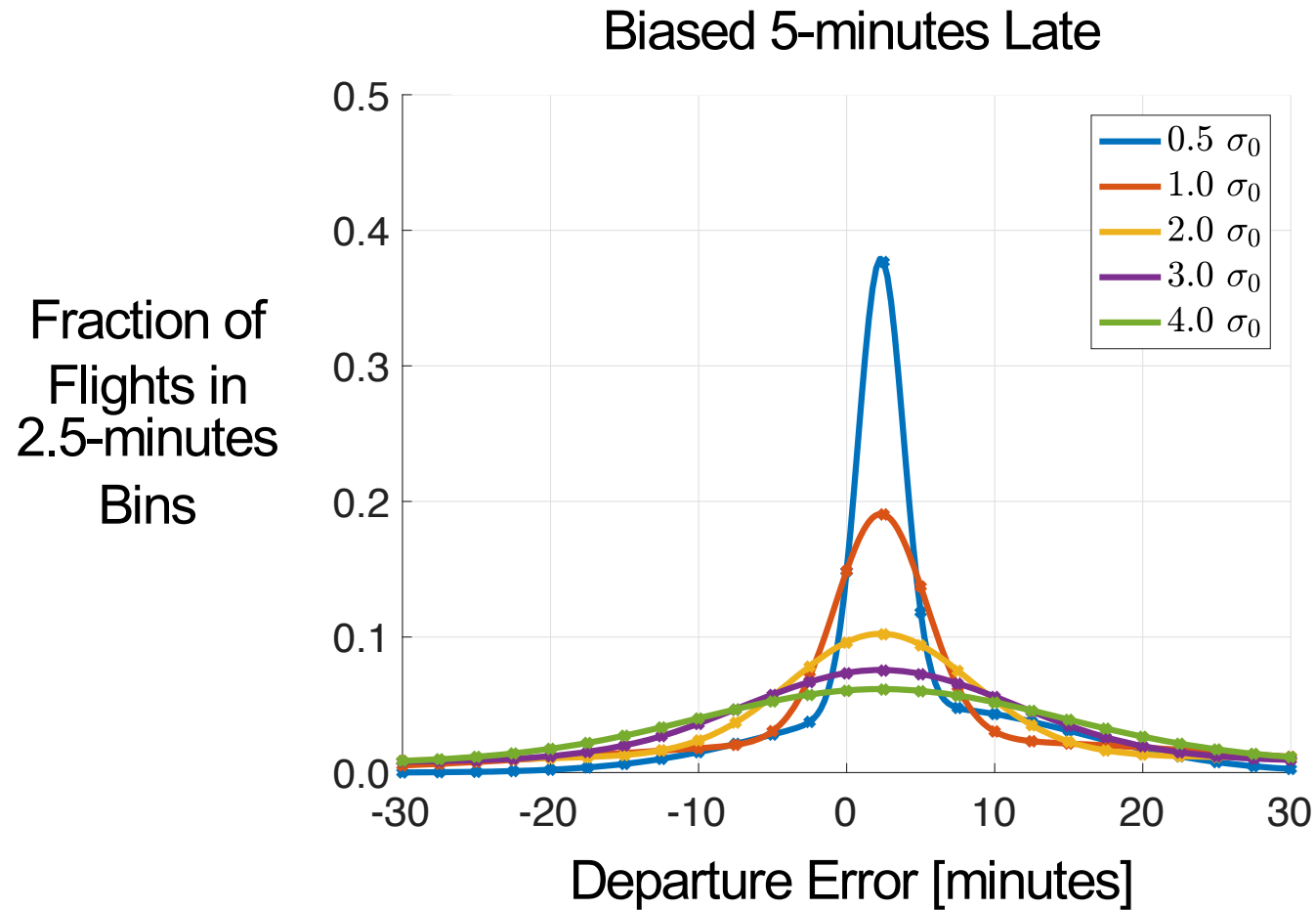
Marginal airborne delay decreases when switching from priority internal to priority airborne

- Overview of tactical planner
- Experiment setup
- **Tactical airborne delay results**
  - Departure error variance
  - Departure error bias
- Summary
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# Internal departures

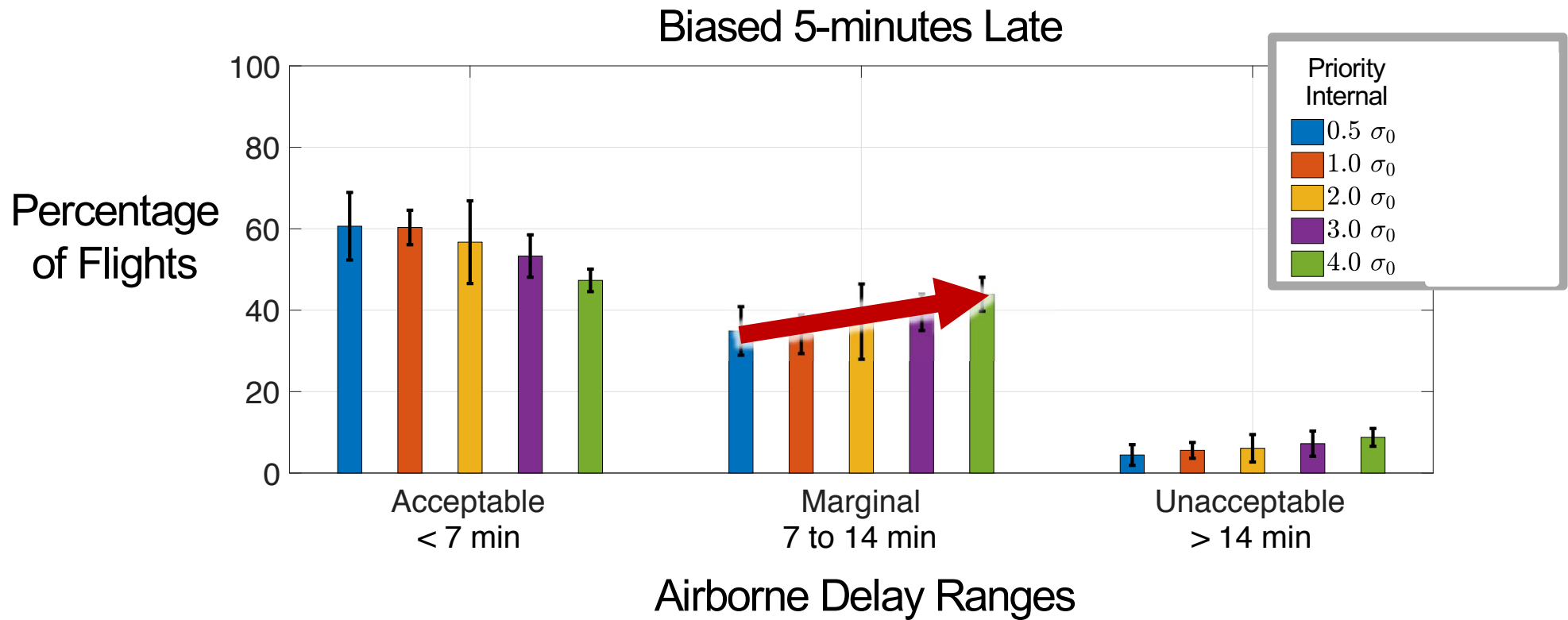


# External departures

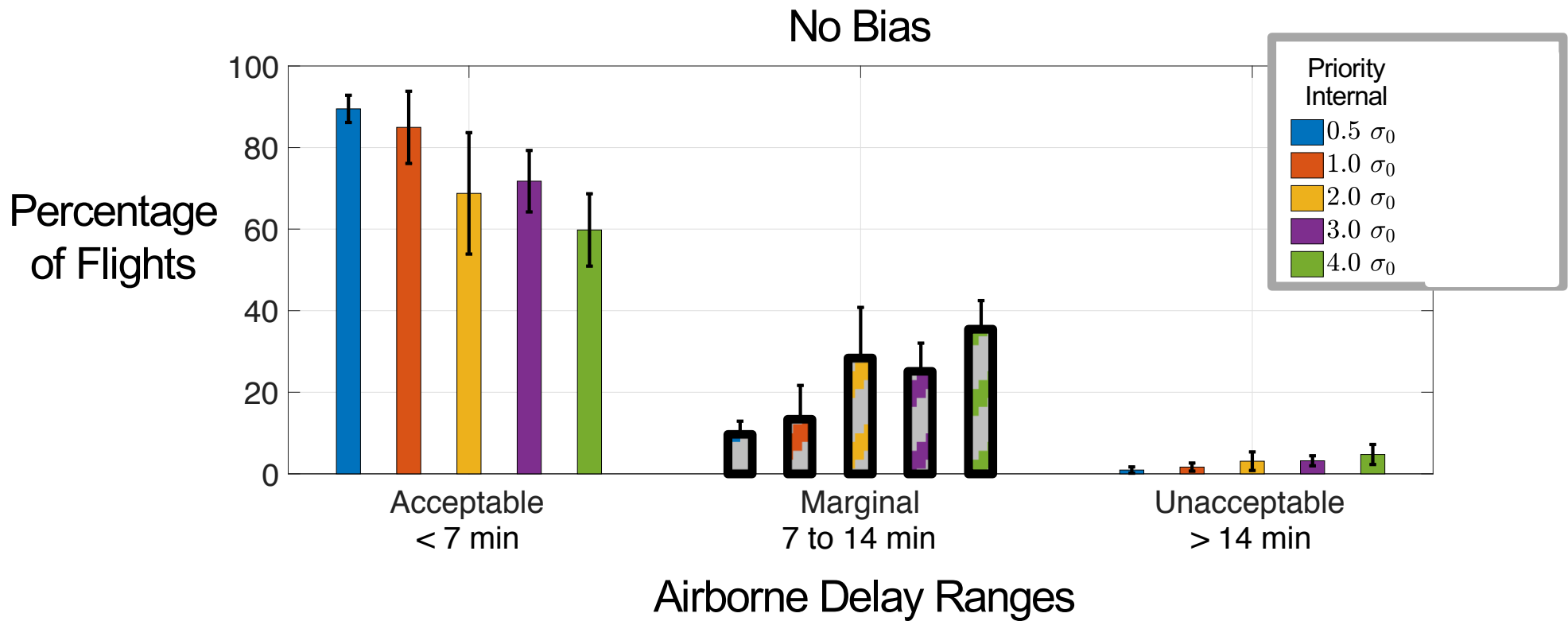




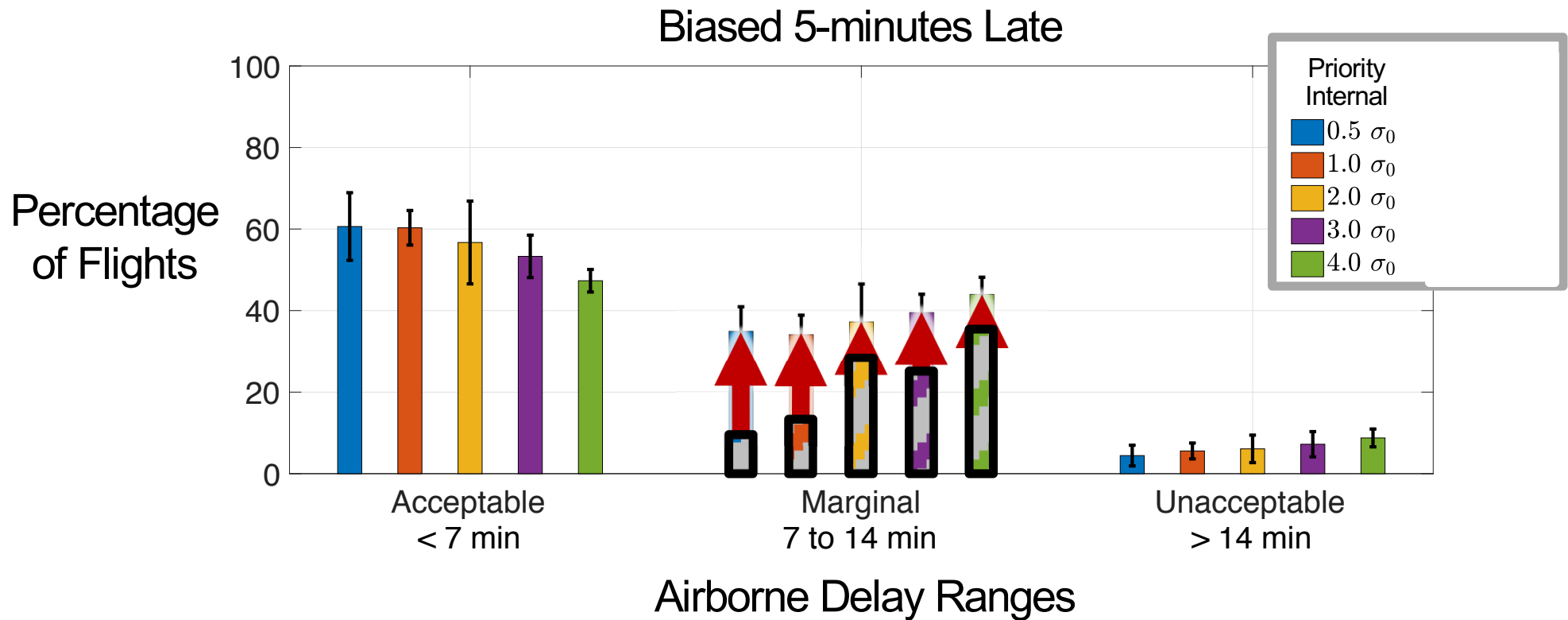
# Tactical airborne delay results



# Tactical airborne delay results

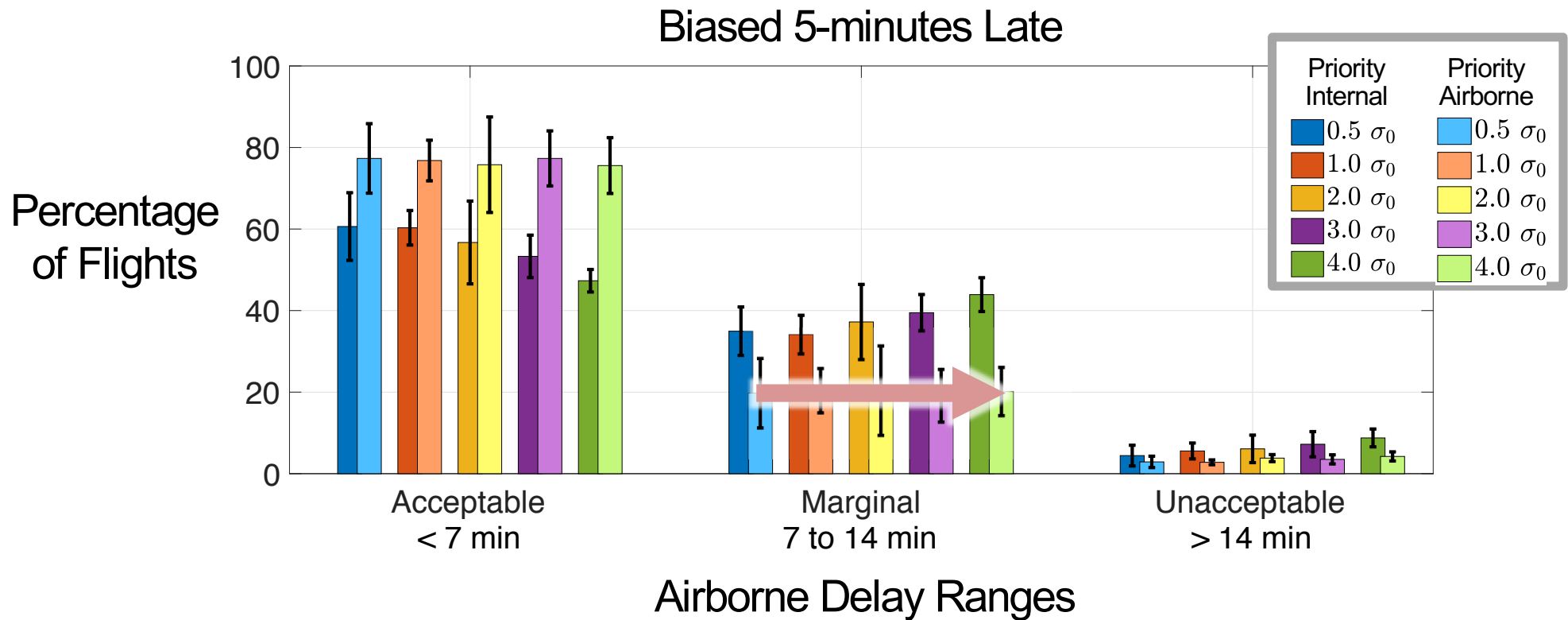


# Tactical airborne delay results



Marginal airborne delay increases with consistently late departures when priority is given to internal departures

# Tactical airborne delay results



Marginal airborne delay remains manageable with consistently late departures when priority is given to airborne flights

# Summary

- As departure error variability increases  
Marginal airborne delay ...
  - Increases when priority is given to internal departures
  - Remains relatively constant when priority is given to airborne flights
  - Decreases when switching from priority internal to priority airborne
- As departure error shifts 5-minutes late  
Marginal airborne delay ...
  - Increases when priority is given to internal departures
  - Remains manageable when priority is given to airborne flights

- Expand departure error analysis:
  - Additional biases
  - Vary bias by airport
  - Recalculate strategic delay periodically
- Implement and study extended metering
- Identify scenarios for further investigation with human-in-the-loop simulations

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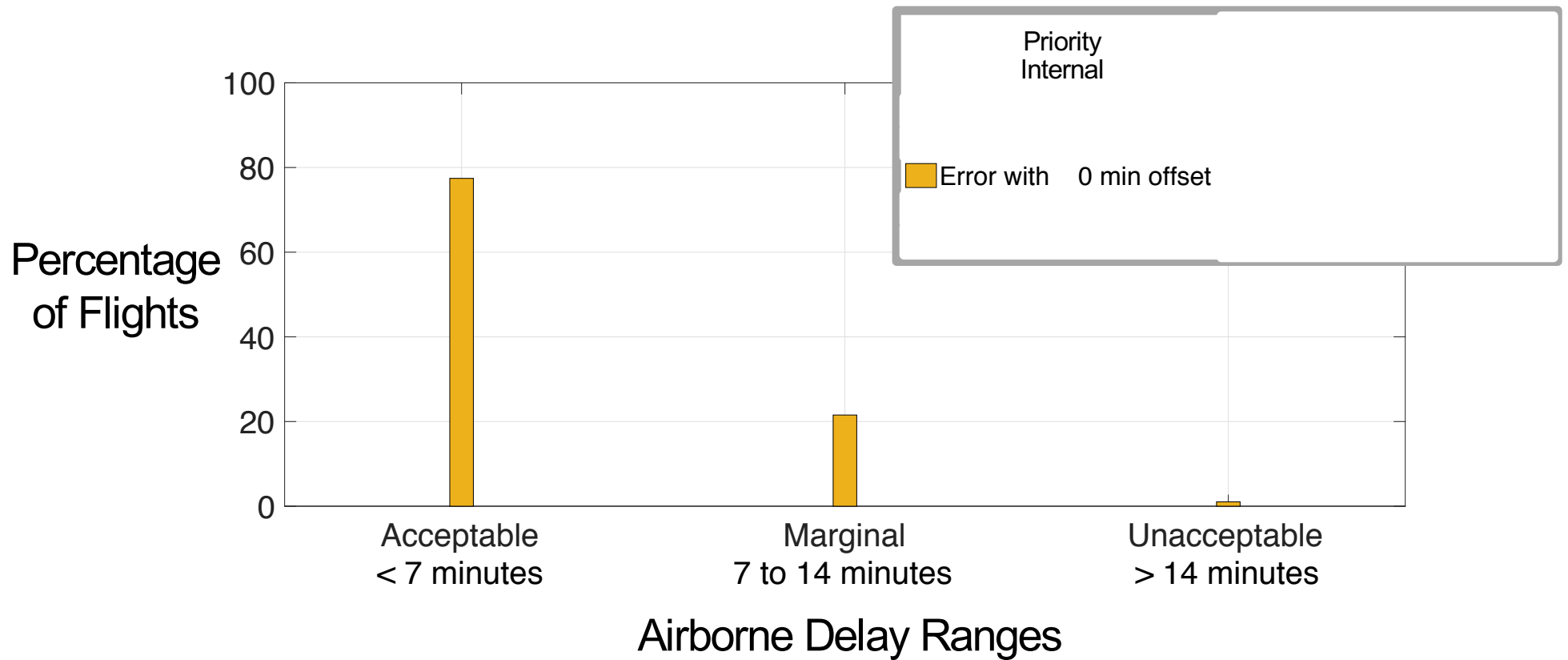




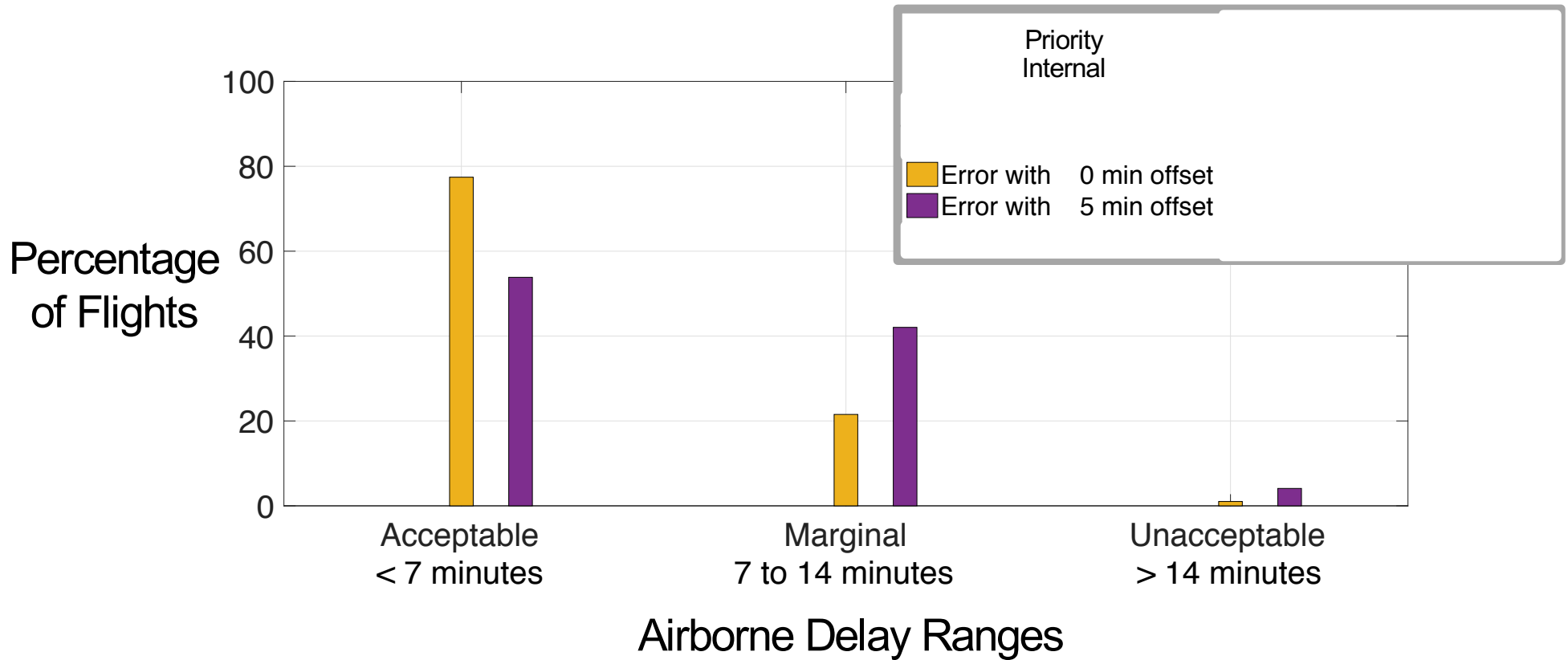


# Backup

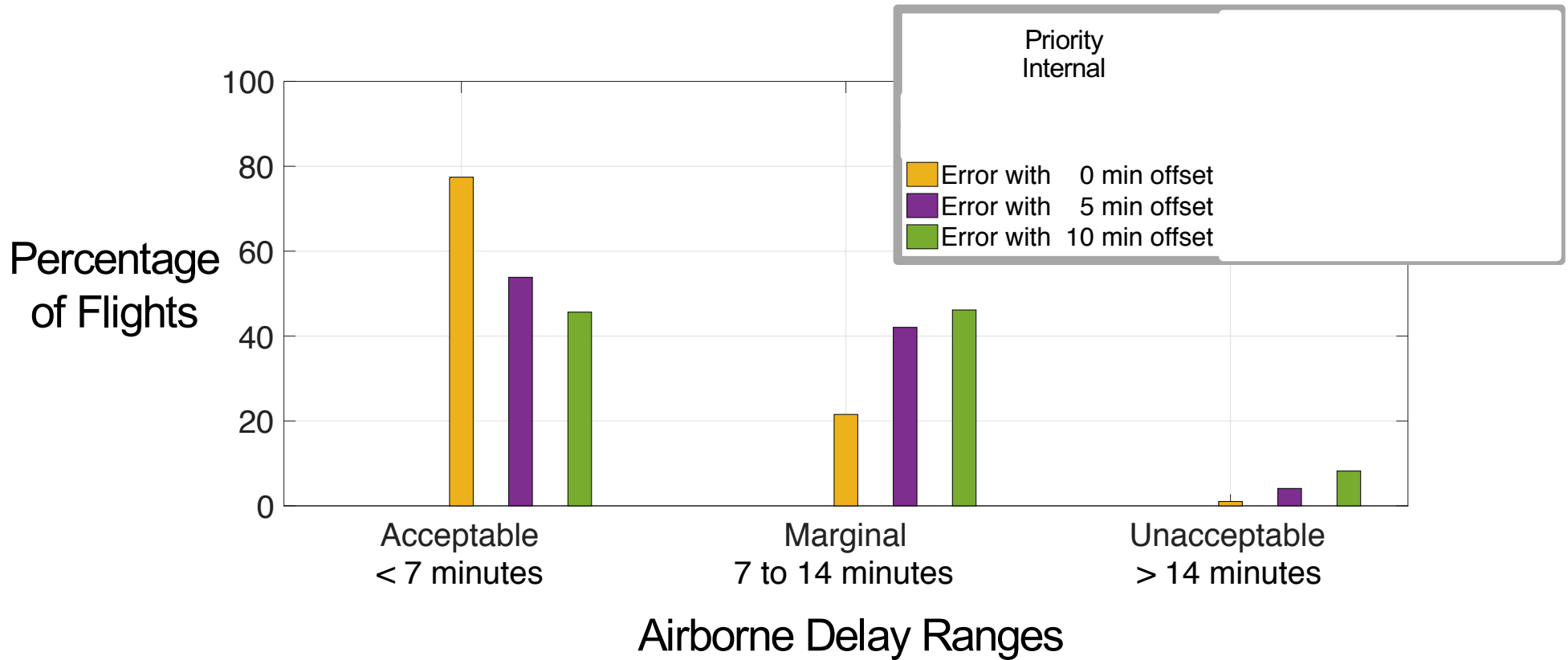
# Tactical airborne delay results



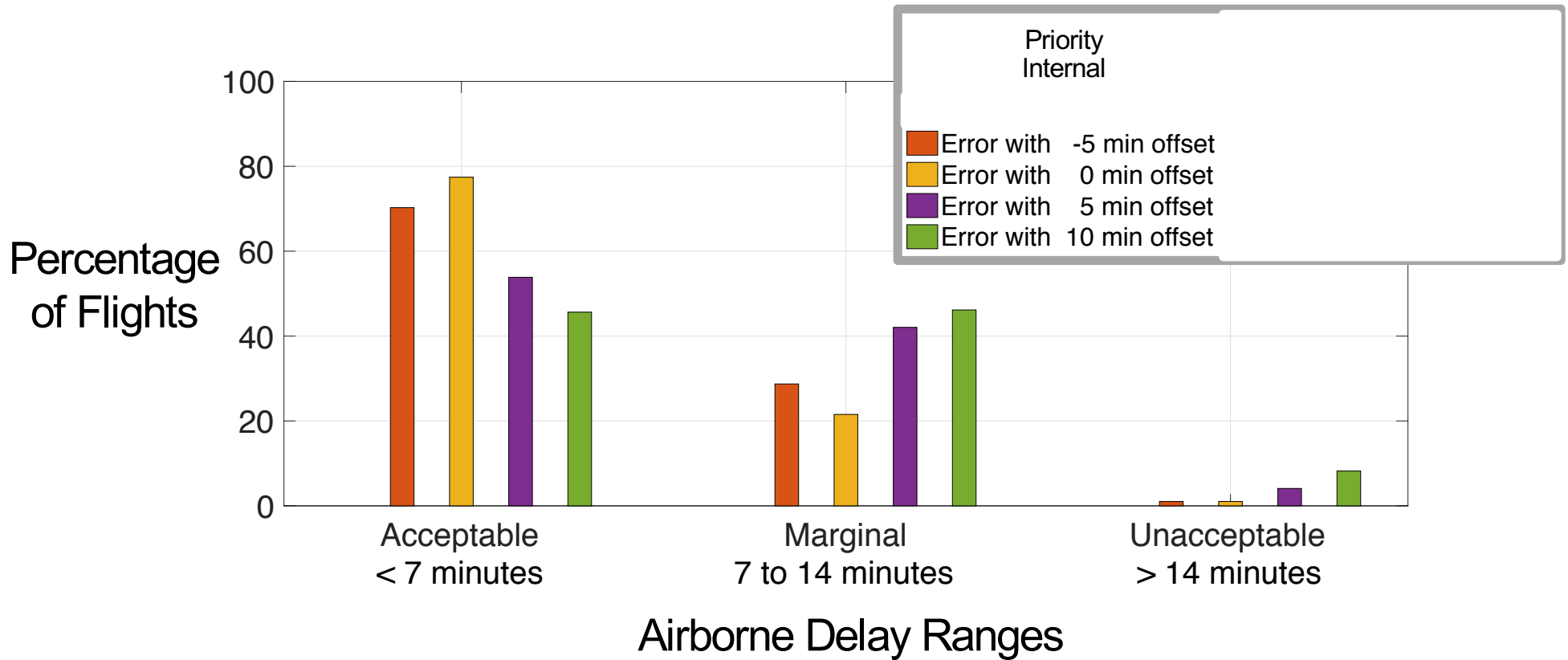
# Tactical airborne delay results



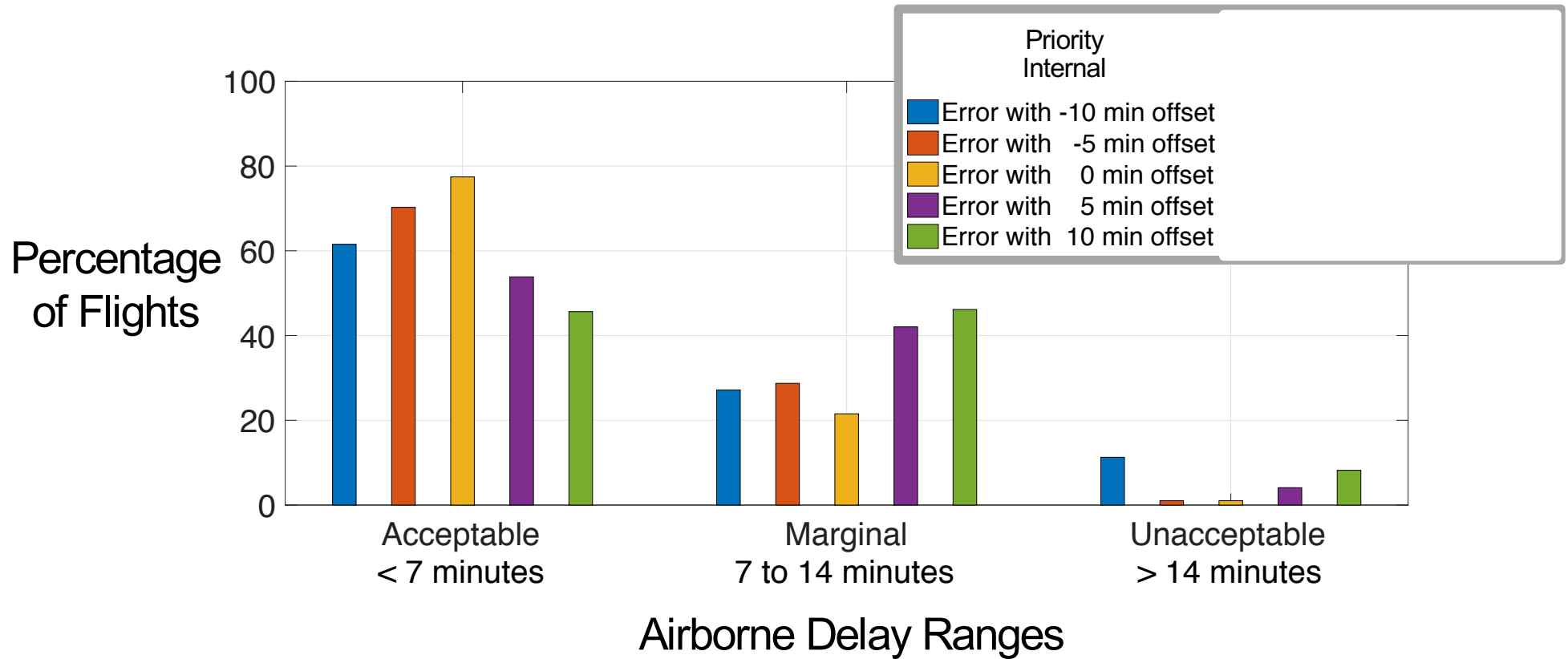
# Tactical airborne delay results



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