

# Demonstrating the Early Adopter Benefits of Submitting Multiple Trajectory Options for Airlines

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**NASA Ames Research Center**

with

**San Jose State University, Universities Space Research Association,  
and Human Solutions Incorporated**

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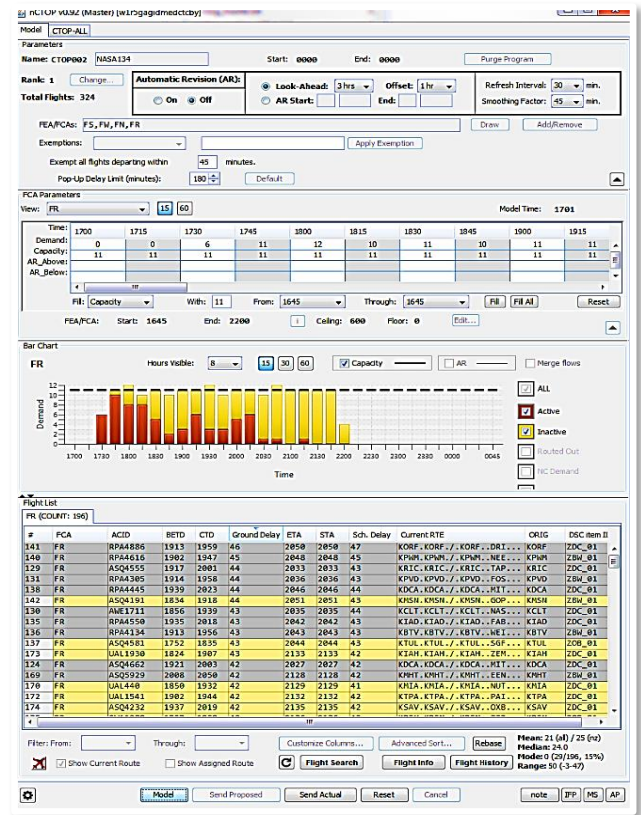


# BACKGROUND

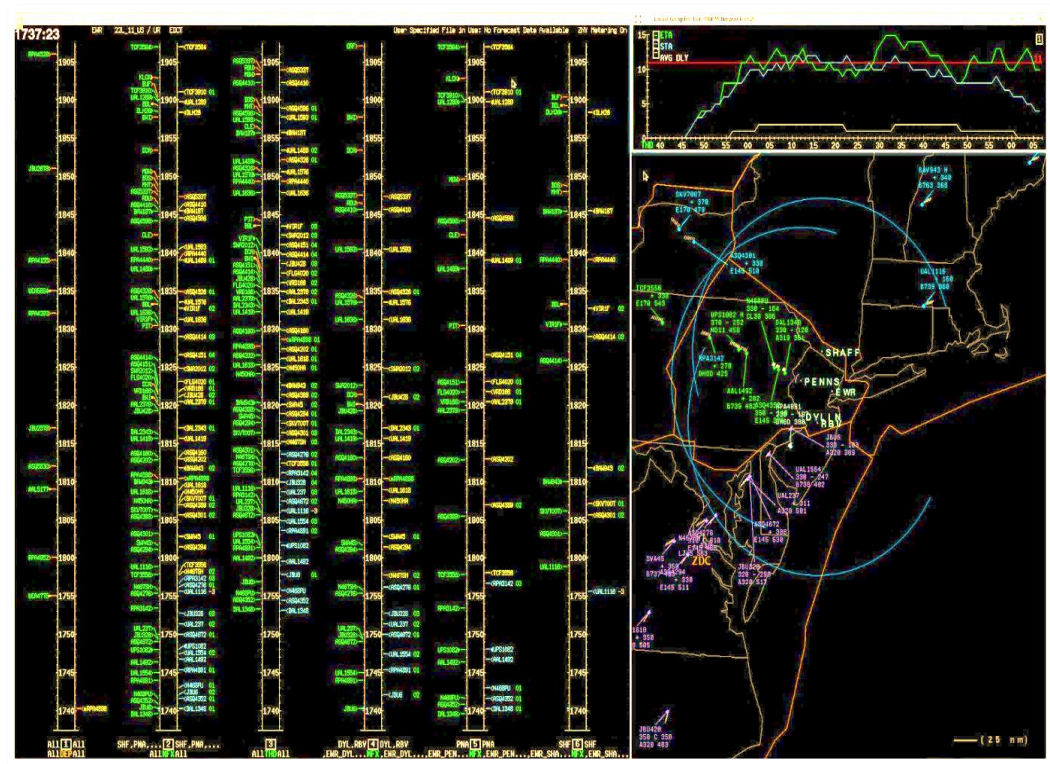
## Integrated Demand Management (IDM)

- Collaborative Trajectory Options Program (CTOP)
- Time Based Flow Management (TBFM)

### CTOP



### TBFM



# IDM scenario

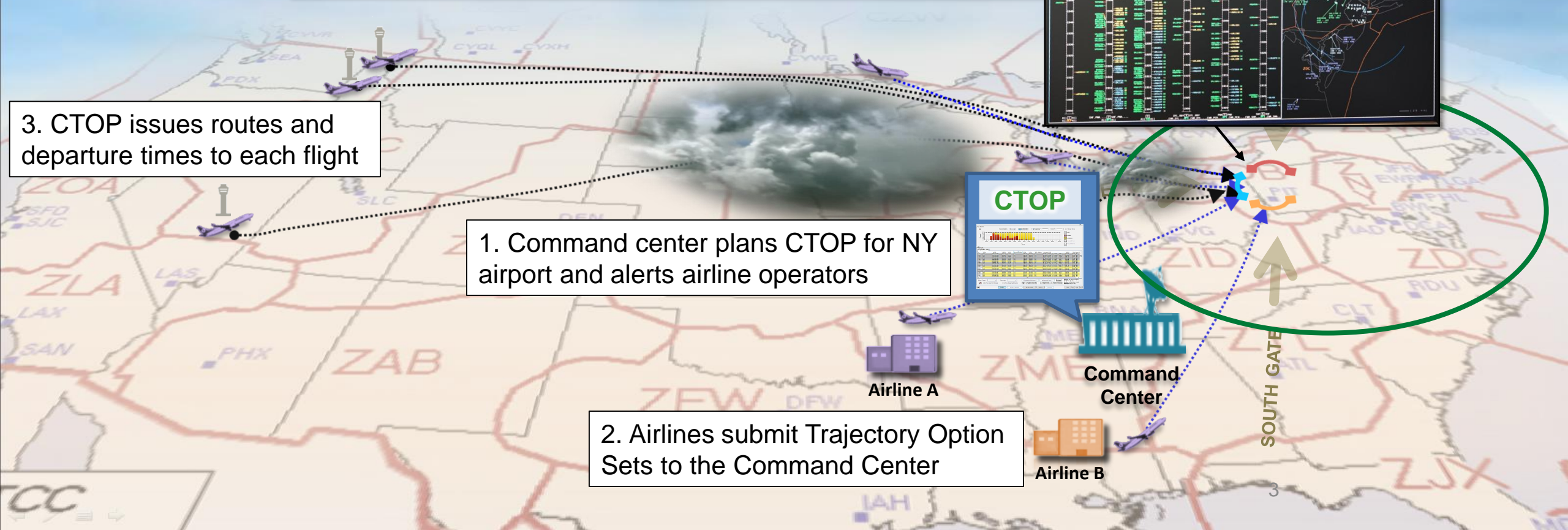
Callsign	FCA	Option #	Flight Plan
UAL556	WEST	1	KDEN./ZIRKL..MCK..LNK.J60.DJB..YNG..ETG.MIP4.KLGA
UAL556	SOUTH	2	KDEN./PER..RZC..ARG.J46.BNA.J42.BKW.J42.G
UAL556	NORTH	3	KDEN./BRYCC..TAYOT..DAYYY..RUBKI..SIKBO..TU



3. CTOP issues routes and departure times to each flight

1. Command center plans CTOP for NY airport and alerts airline operators

2. Airlines submit Trajectory Option Sets to the Command Center



**CTOP**

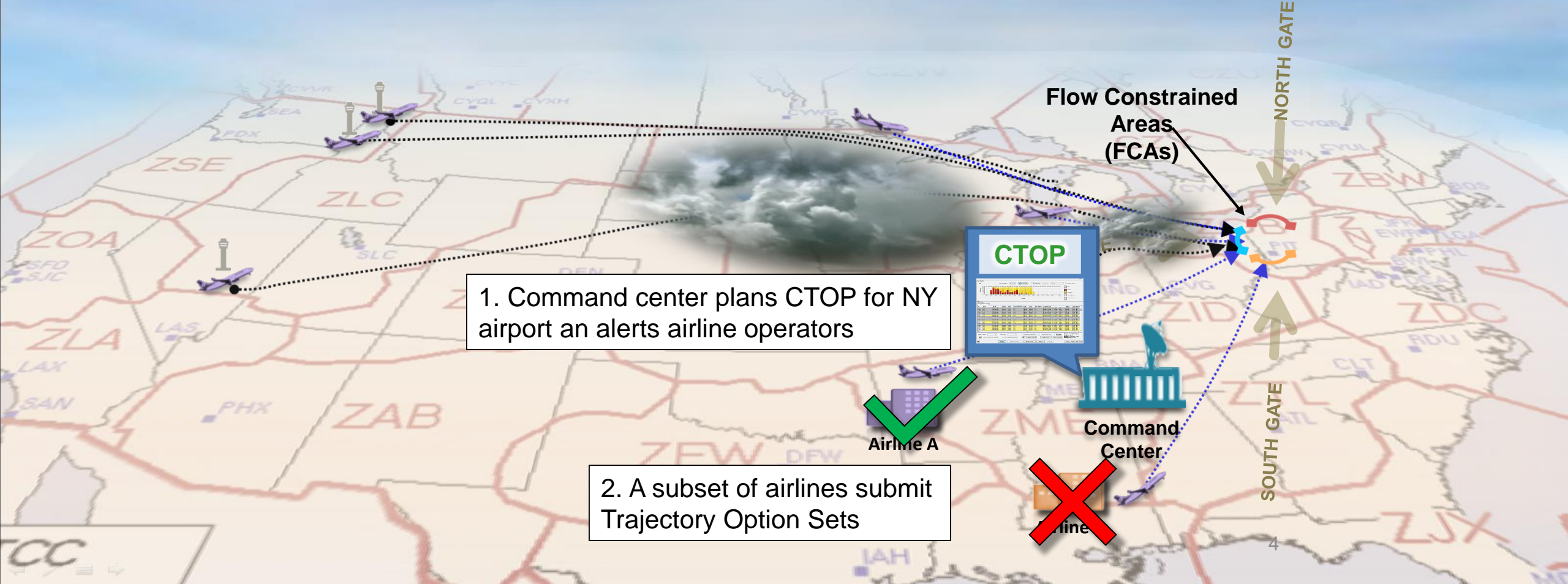
**Command Center**

**Airline A**

**Airline B**

SOUTH GATE

# IDM scenario





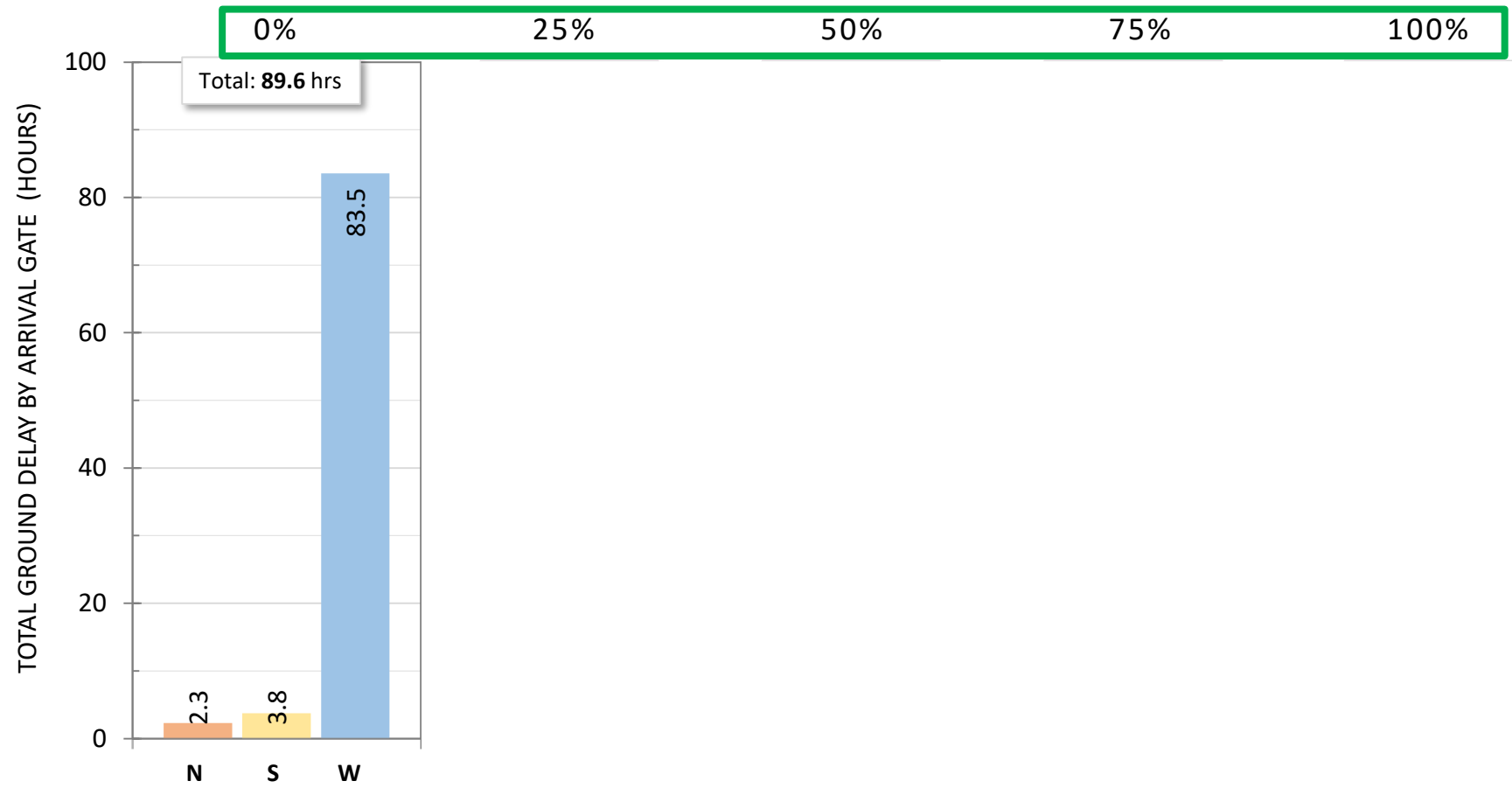
Newark simulation, August 2017:  
Impact of varying TOS participation levels on quality of outcome

- TOS participating = multiple trajectory options
- TOS excluded = single trajectory option



# 2017 EWR Simulation: Results\*

PERCENTAGE OF FLIGHTS SUBMITTING TRAJECTORY OPTION SETS

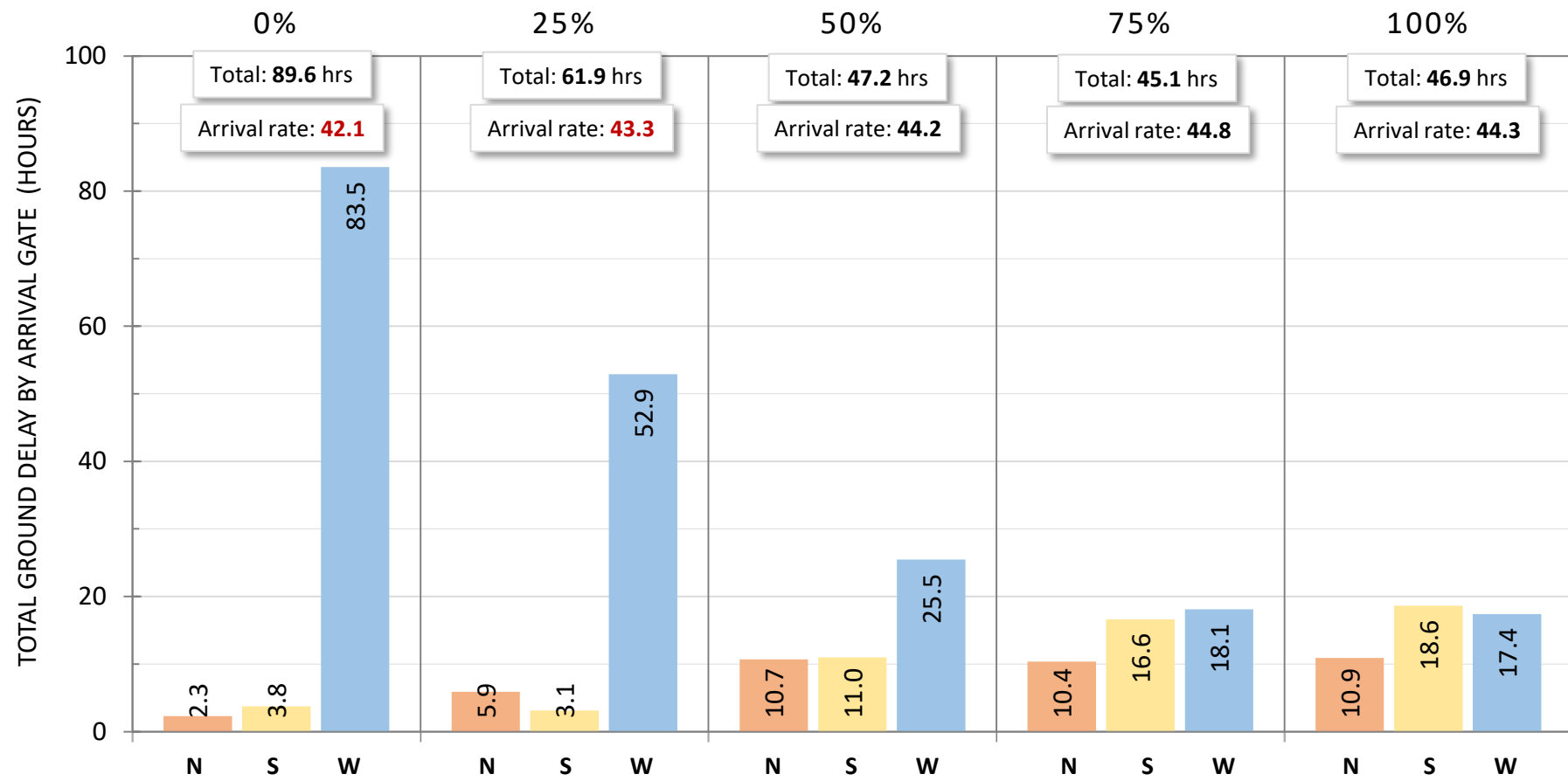


\* Hyo-Sang Yoo, C. Brasil, N. Buckley, G. Hodell, S. Kalush, P. U. Lee, N. M. Smith (2018). "Impact of Different Trajectory Option Set Participation Levels within an Air Traffic Management Collaborative Trajectory Option Program." In *18th AIAA Aviation Technology, Integration, and Operations Conference*.



# 2017 EWR Simulation: Results\*

## PERCENTAGE OF FLIGHTS SUBMITTING TRAJECTORY OPTION SETS



\* Hyo-Sang Yoo, C. Brasil, N. Buckley, G. Hodell, S. Kalush, P. U. Lee, N. M. Smith (2018). "Impact of Different Trajectory Option Set Participation Levels within an Air Traffic Management Collaborative Trajectory Option Program." In 18th AIAA Aviation Technology, Integration, and Operations Conference.



## Motivation:

- What happens when different airlines submit Trajectory Option Sets (TOSs)?
- Who benefits (more): Participating airlines? Or non-participants?

## Objective:

- Explore IDM when a subset of airlines participate in TOS submission
- Obtain stakeholder feedback on perceived benefits, feasibility, and suggestions

LaGuardia simulation with FET, March 2018:

Operator benefits of submitting trajectory option sets



- Human-in-the-loop simulation conducted with CDM Flow Evaluation Team
  - FAA members and airline representatives from United, American, Southwest

## ***Run Characteristics***

**Run 1. No one** submits TOSs (baseline)

**Run 2. All airlines** submit TOSs

**Run 3. Only Delta** submits TOSs

**Run 4. American, JetBlue, Southwest** and **United** submit TOSs

**Run 5.** No one submits TOSs, *but FET members choose preferred route* from scripted TOS

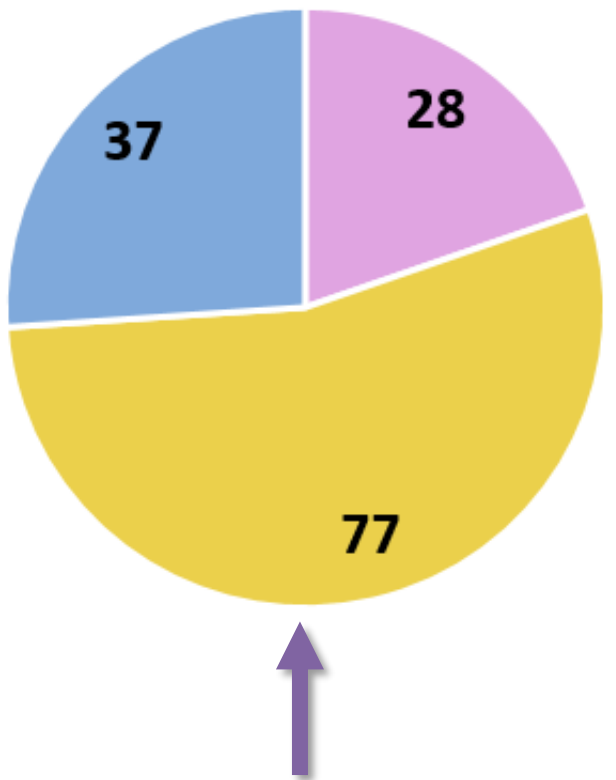
- Discussions and feedback
  - After each run, output showing airline-specific impact was provided to participants
  - Participants described implications for their company operations



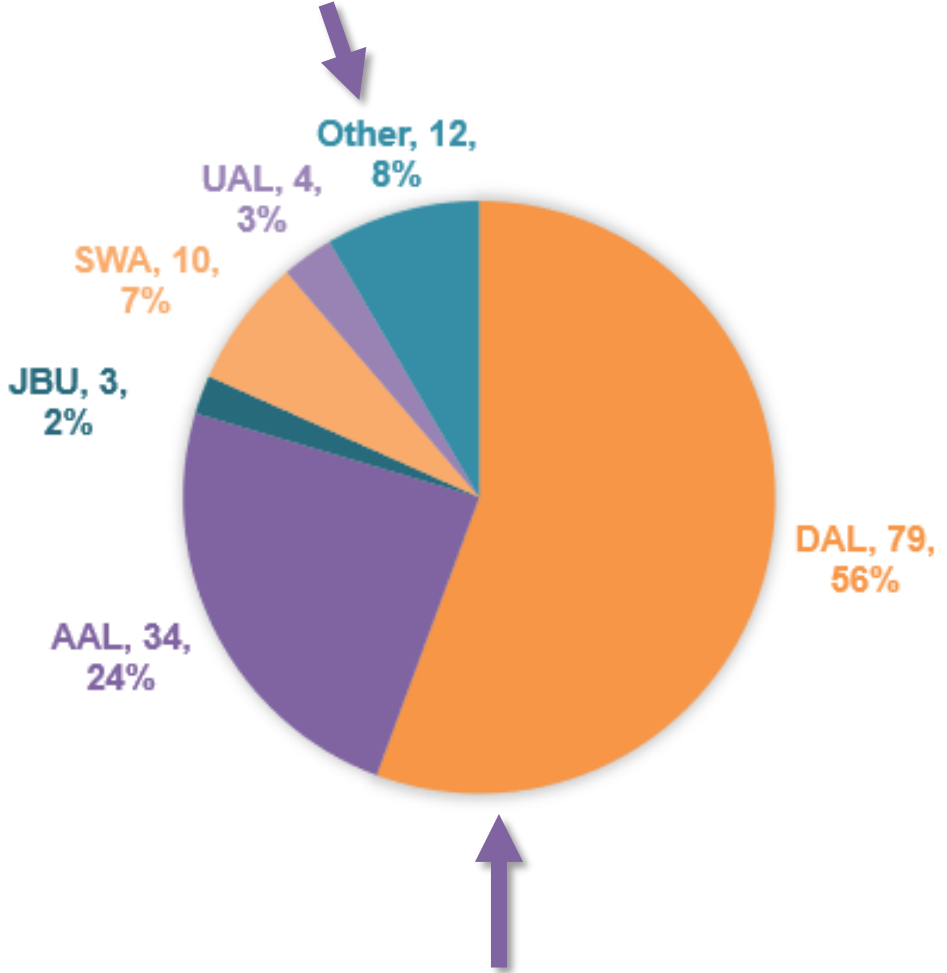
# Distribution of Inbound Flights Included in CTOP

### Distribution by Arrival Flow

■ north   ■ south   ■ west



### Non-exempt Flights by Airline





1. System performance
2. Sole-carrier analysis
3. Automation vs. human selection of trajectory assignment
4. Flow Evaluation Team feedback



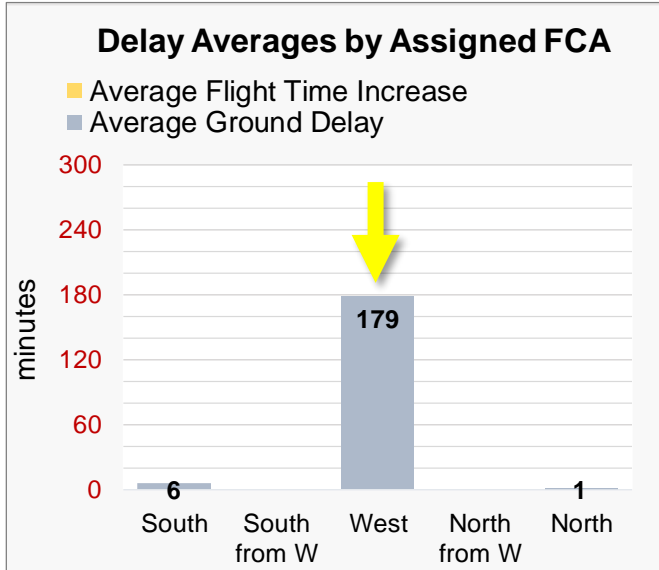
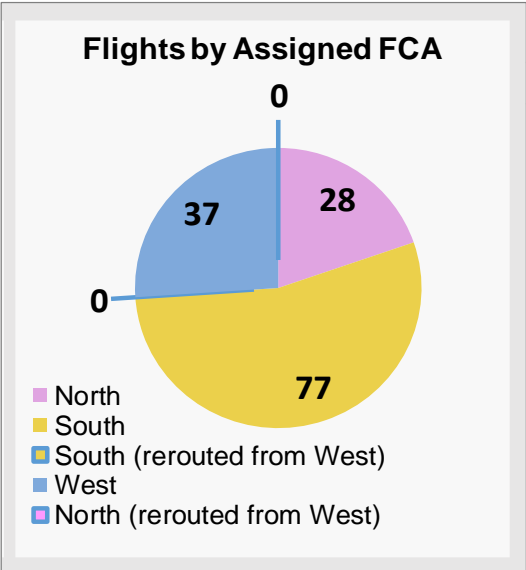
# System performance



# All airlines general summary

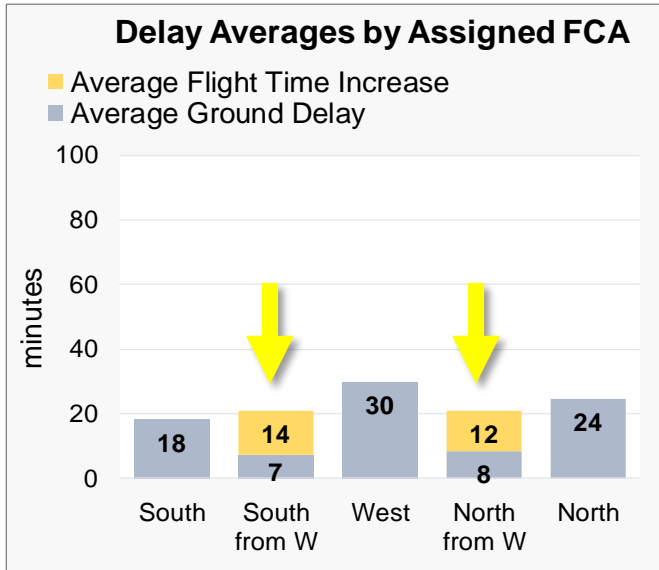
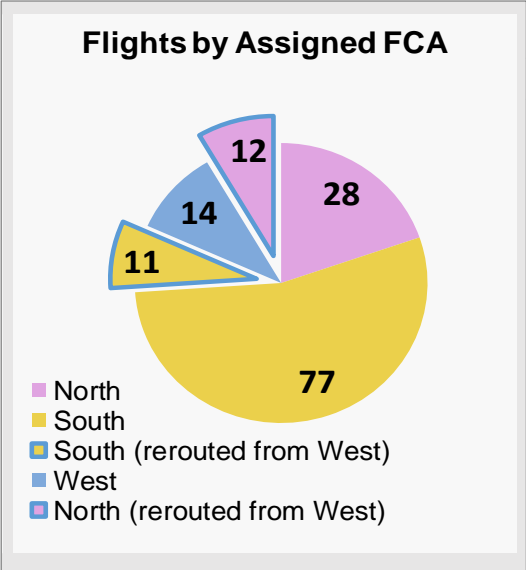
## Run 1. No one submits TOS (“baseline”)

Throughput: **33** flights/hour  
 Ground Delay (total): **118.5** hours



## Run 2. Everyone submits TOS

Throughput: **36** flights/hour  
 Ground Delay (total): **44.6** hours  
 TOS-reroutes: **23** flights  
 Added flight time (total): **5.0** hours

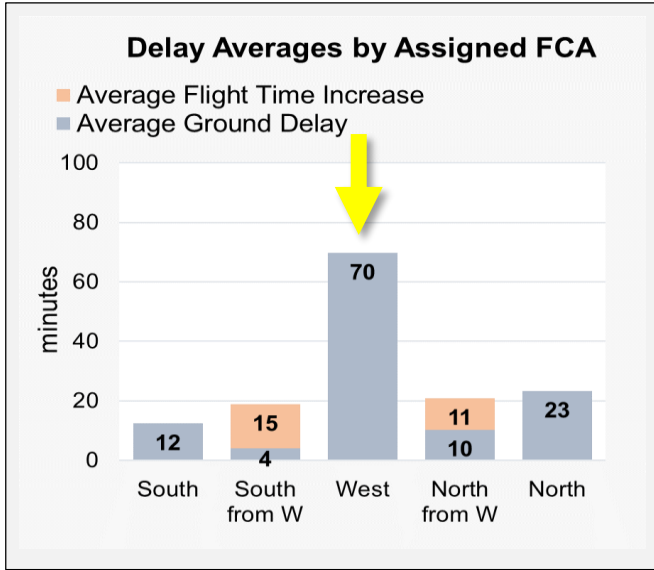
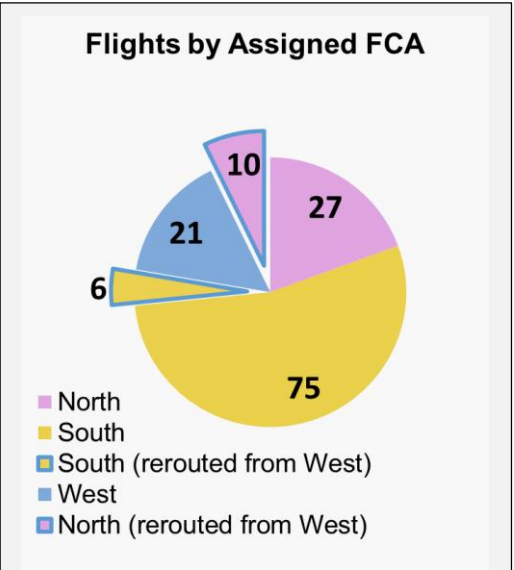




# All airlines general summary

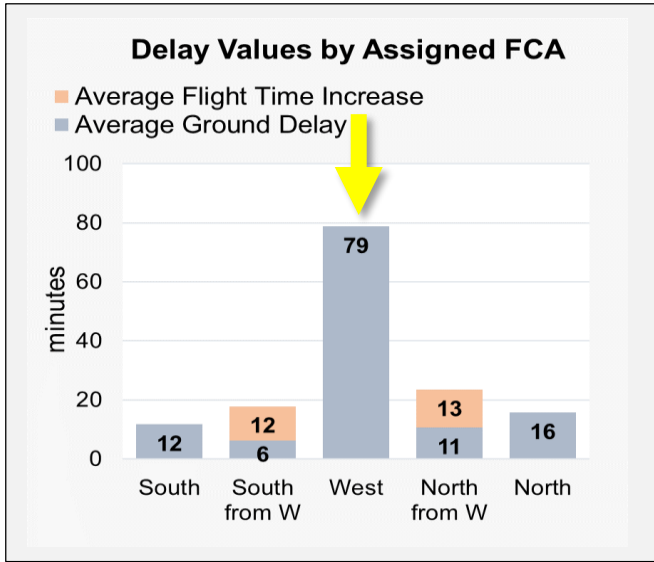
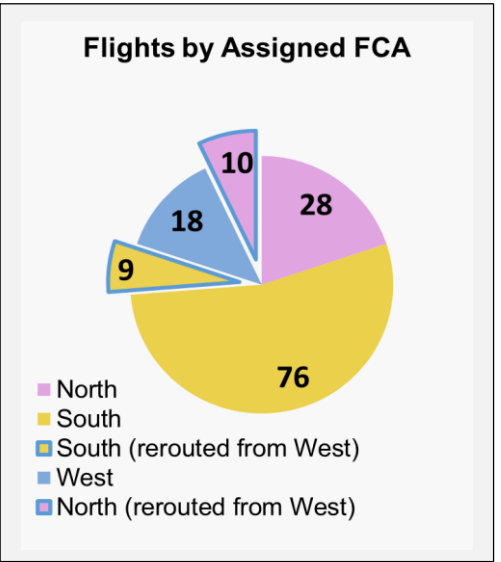
## Run 3. Only Delta submits TOSs (56% participation)

Throughput: **36** flights/hour  
 Ground Delay (total): **52.5** hours  
 TOS-reroutes: **16** flights  
 Added flight time(total): **3.3** hours



## Run 4. American, JetBlue, Southwest and United submit TOSs (36% participation)

Throughput: **36** flights/hour  
 Ground Delay (total): **48.5** hours  
 TOS-reroutes: **19** flights  
 Added flight time (total): **3.9** hours





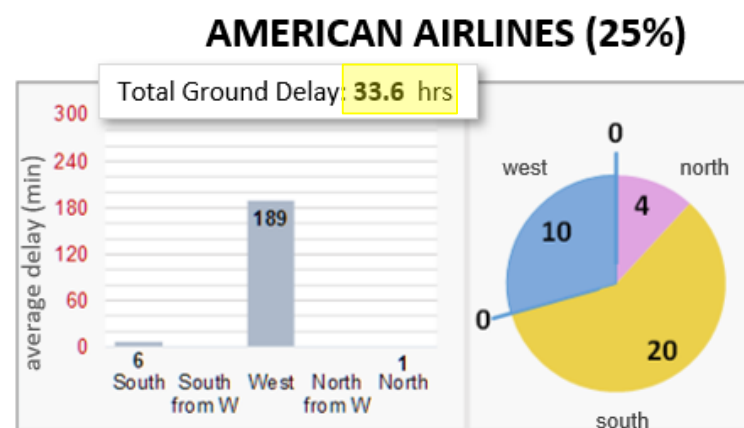
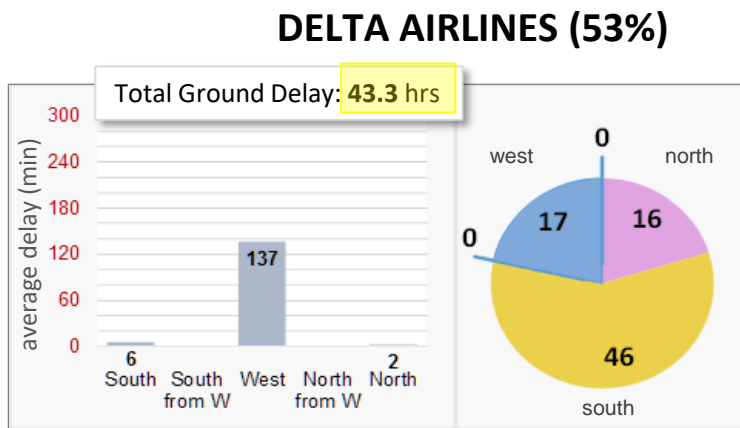
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# Sole-carrier analysis

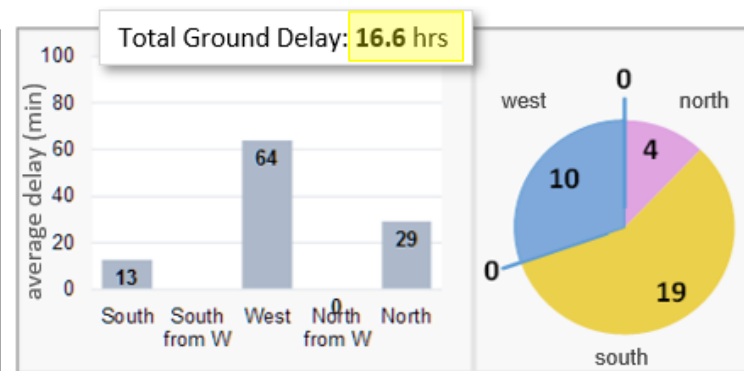
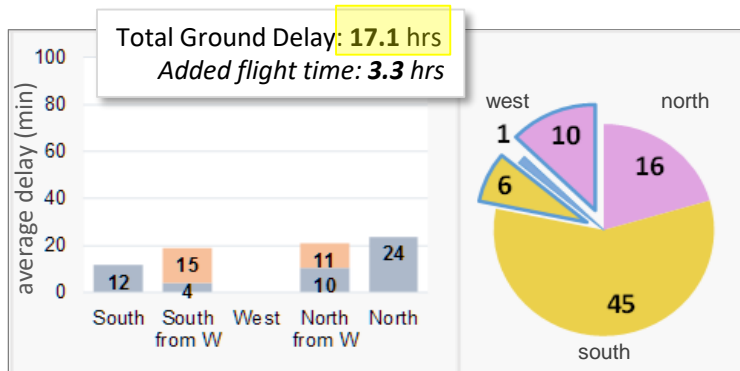


# “Who benefits?” DELTA to AMERICAN comparison

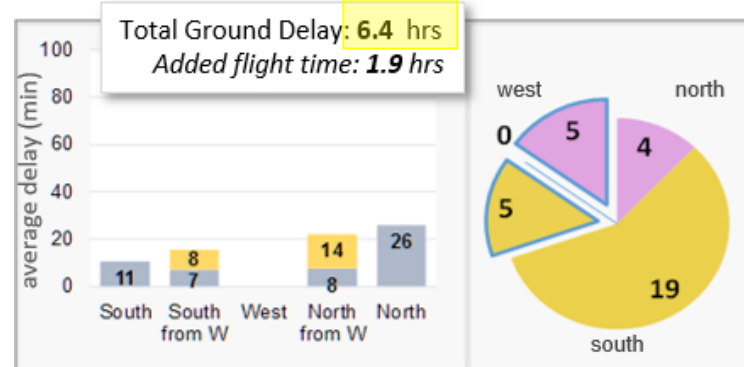
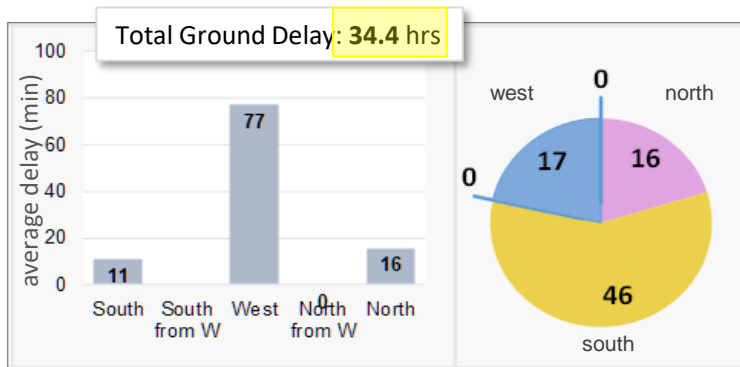
**Run 1.** No one submits TOSs.



**Run 3:** Only Delta submits TOSs. (56%)



**Run 4:** American, JetBlue, Southwest and United submit TOSs. (36%)

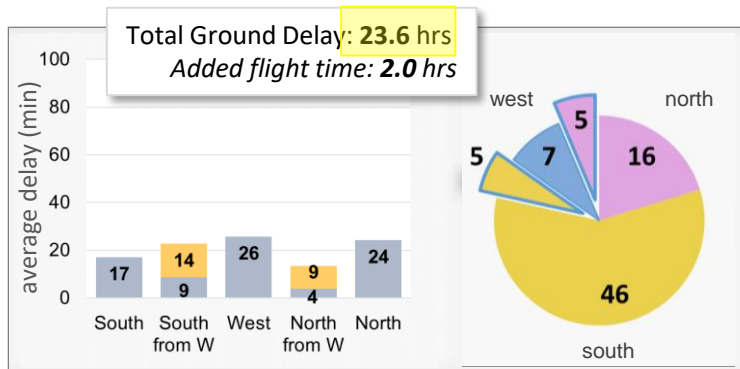




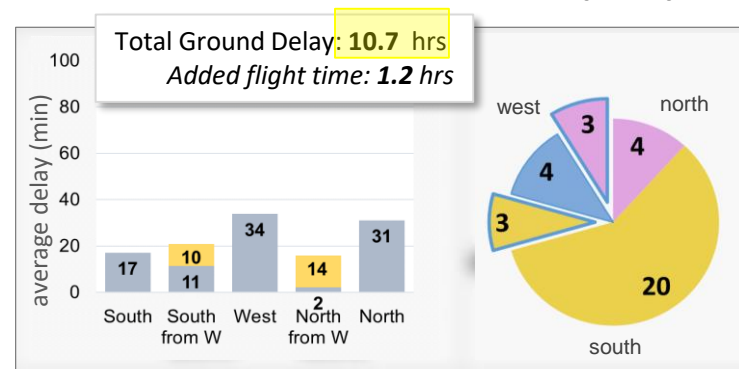
# “Early adopters” impact? DELTA to AMERICAN comparison

**Run 2.** Everyone submits TOSs.

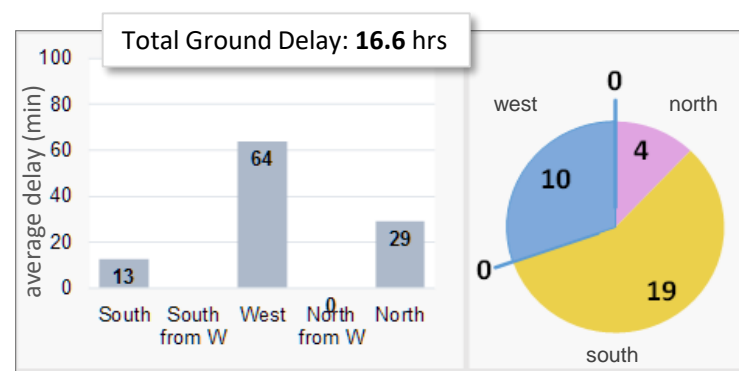
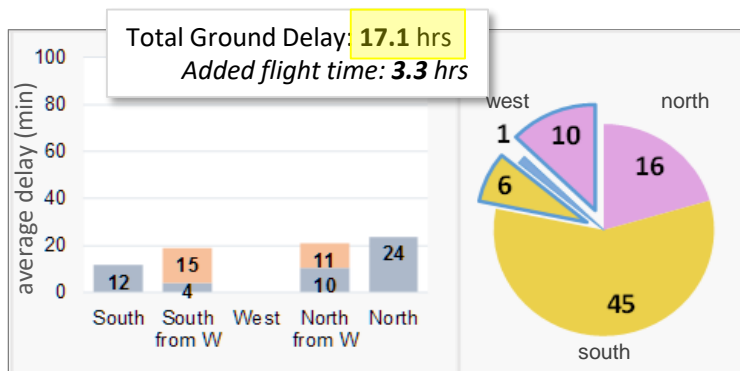
## DELTA AIRLINES (53%)



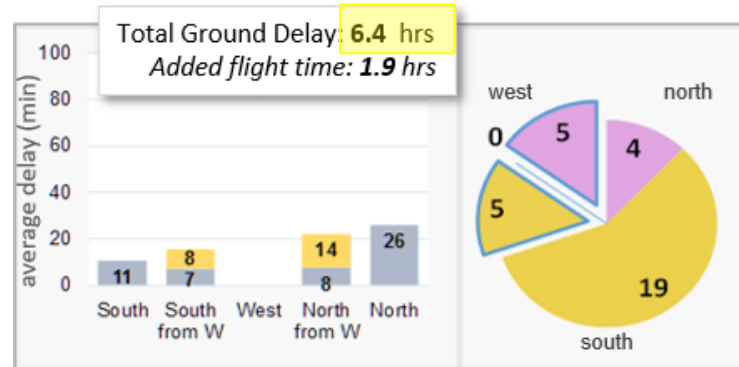
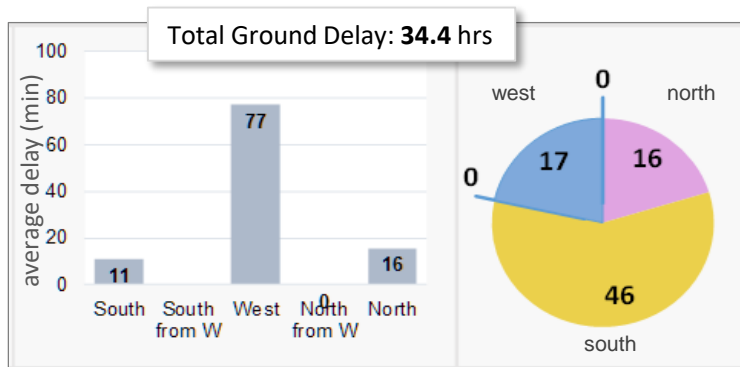
## AMERICAN AIRLINES (25%)



**Run 3:** Only Delta is an “early adopter” (airline that submits TOSs). (56%)



**Run 4:** American, JetBlue, Southwest & United are “early adopters” (airline submitting TOSs). (36%)





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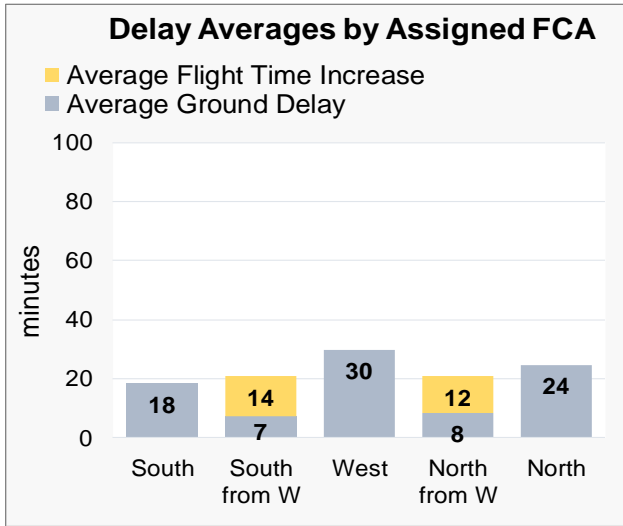
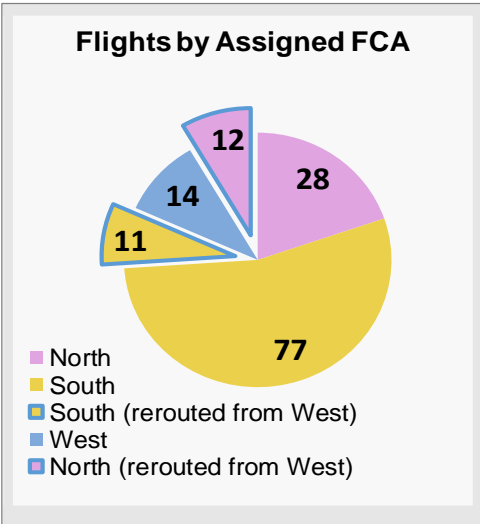
# Automation vs. human selection of trajectory assignment



# Automation vs. human general summary

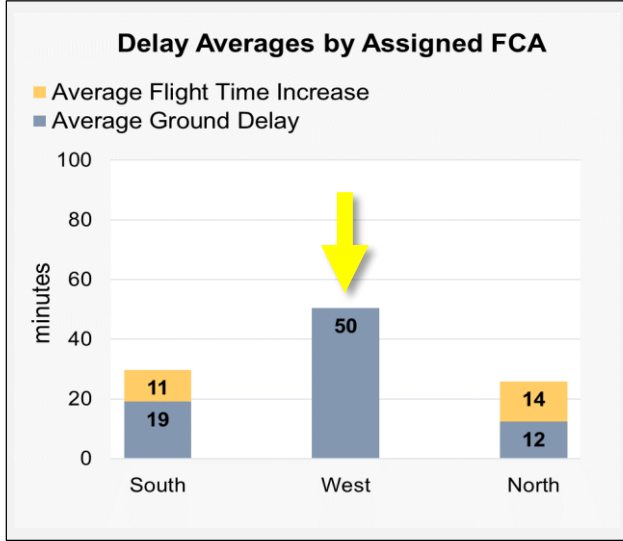
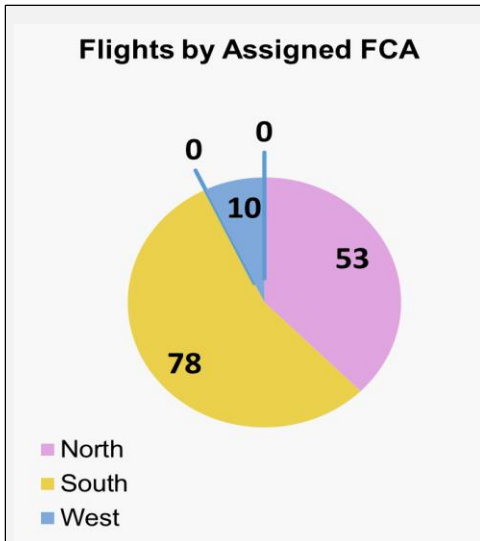
## Run 2. Everyone submits Trajectory Options Sets

Throughput: **36** flights/hour  
 Ground Delay (total): **44.6** hours  
 TOS-reroutes: **23** flights  
 Added flight time (total): **5.0** hours



## Run 5. FET selects route option

Throughput: **36** flights/hour  
 Ground Delay (total): **44.0** hours  
 Alternate routes: **31** flights  
 Added flight time (total): **6.8** hours





# Flow Evaluation Team feedback



## Quotes

- LGA problem really struck home for FET: role-playing seemed crucial to impact.

*I'm happy that it turned out the way we hoped it would as far as who gets the benefit. The fact that just because you are the only carrier that is using TOS you're not simply going to be moving out of the way so that everybody else can get the benefit. You're still the one that's getting the most benefit out of it. So that's good for the airlines to see.*

- Advantages of concept and CTOP itself were immediately apparent.

*What the data seems to be showing at this point is no matter what the case is, running a CTOP is doing better than what we're doing today.*

- General consensus: everyone was happy when role-playing 'early adopters' to see others benefit, but only if they got greater benefit.



## Additional Thoughts

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- Modeling capabilities would be useful to airlines
  
- Test TOS in other locations
  - ORD provides a good use case



- System performance was best when airlines participated: target throughput was achieved, and delay was reduced and redistributed.
- Both participating and non-participating airlines benefit when compared to the “no participation” (baseline) condition, and participating airline saw the largest benefit.
- As more airlines participate the system outcome improves, and the contrast between participants and non-participants is reduced.
- When FET chose preferred route the outcome was similar to full participation, however far more flights were rerouted than was necessary, resulting in ~2 hours of excess flight time.



# Acknowledgements

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The authors would like to thank the Flow Evaluation Team for participating in this demonstration and offering their expert opinions and insights to the project. We would also like to thank all the subject matter experts who have contributed immensely to the IDM concept.

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