Integrated Demand Management Findings from March 2018 Simulation

Demonstrating Benefits of Submitting Multiple Trajectory Options

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Overview

- Quick review of IDM concept
- Summary of August 2017 EWR Simulation, with focus on impact of varying Trajectory Options Set (TOS) "participation levels" during a CTOP (i.e., the percentage of flights that submit TOSs)
- Presentation of results from March 2018 LGA Simulation with FET, which focused on benefits to individual carriers of participation

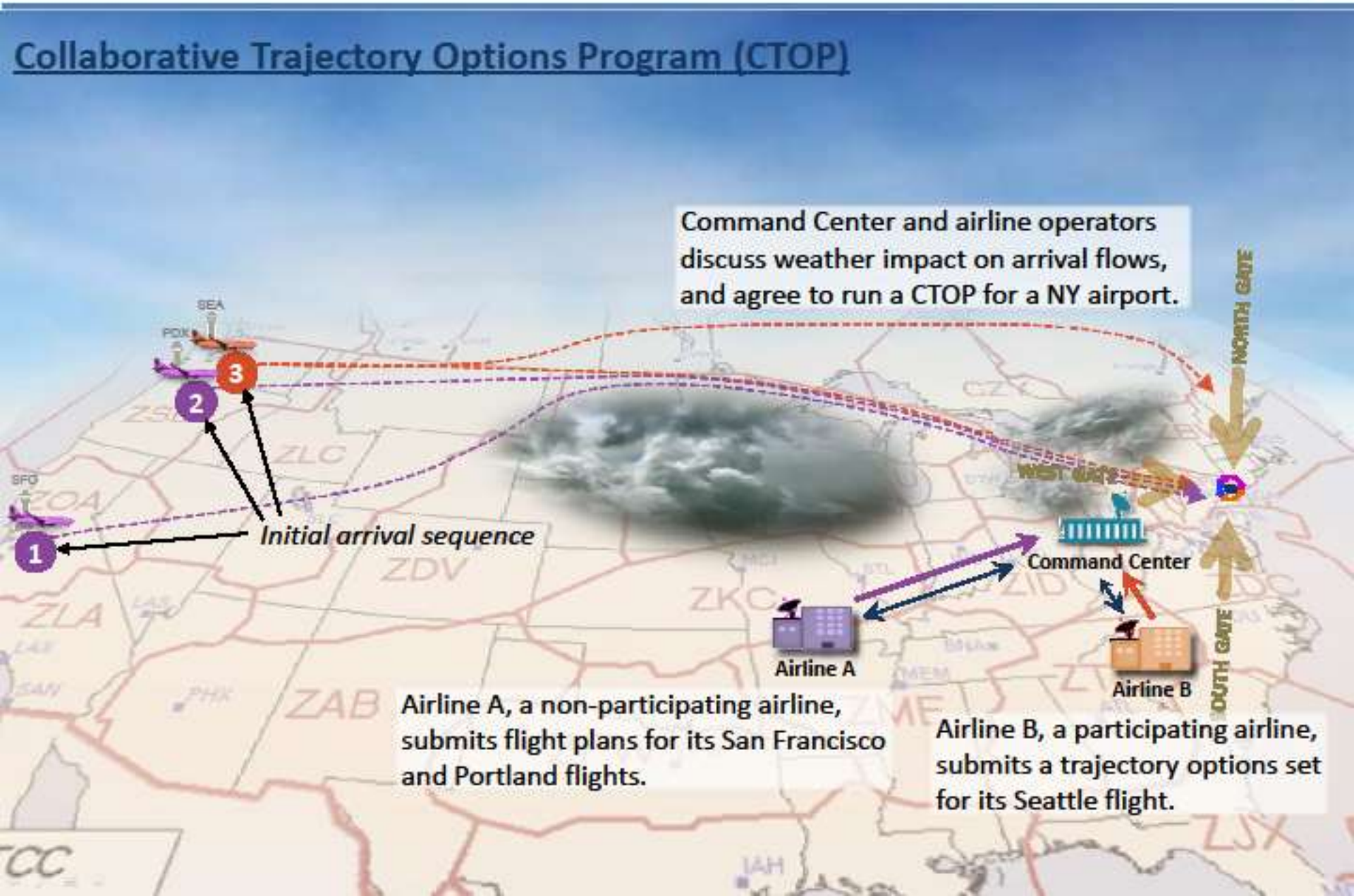
Bottom Line:

1. *Both the participating and non-participating airlines benefited when TOSs were submitted during a CTOP*
2. *Participating airlines benefited most*
3. *The improvement seen by participants was greatest when overall participation was lower*

NOTE: This briefing does *not* cover all of the IDM activities conducted in 2018

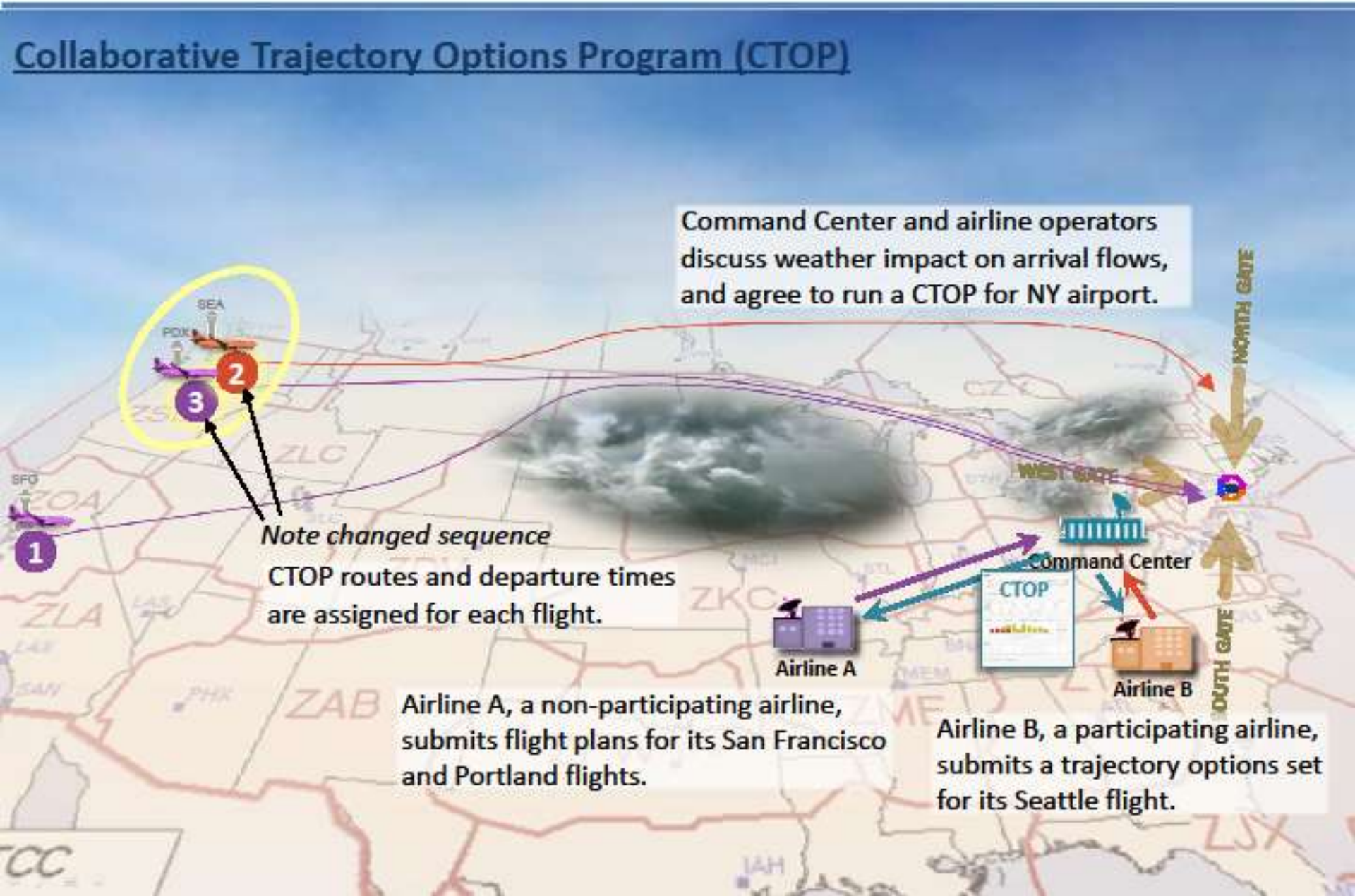
IDM Operations: CTOP Plan Development

Collaborative Trajectory Options Program (CTOP)



IDM Operations: CTOP Initiation

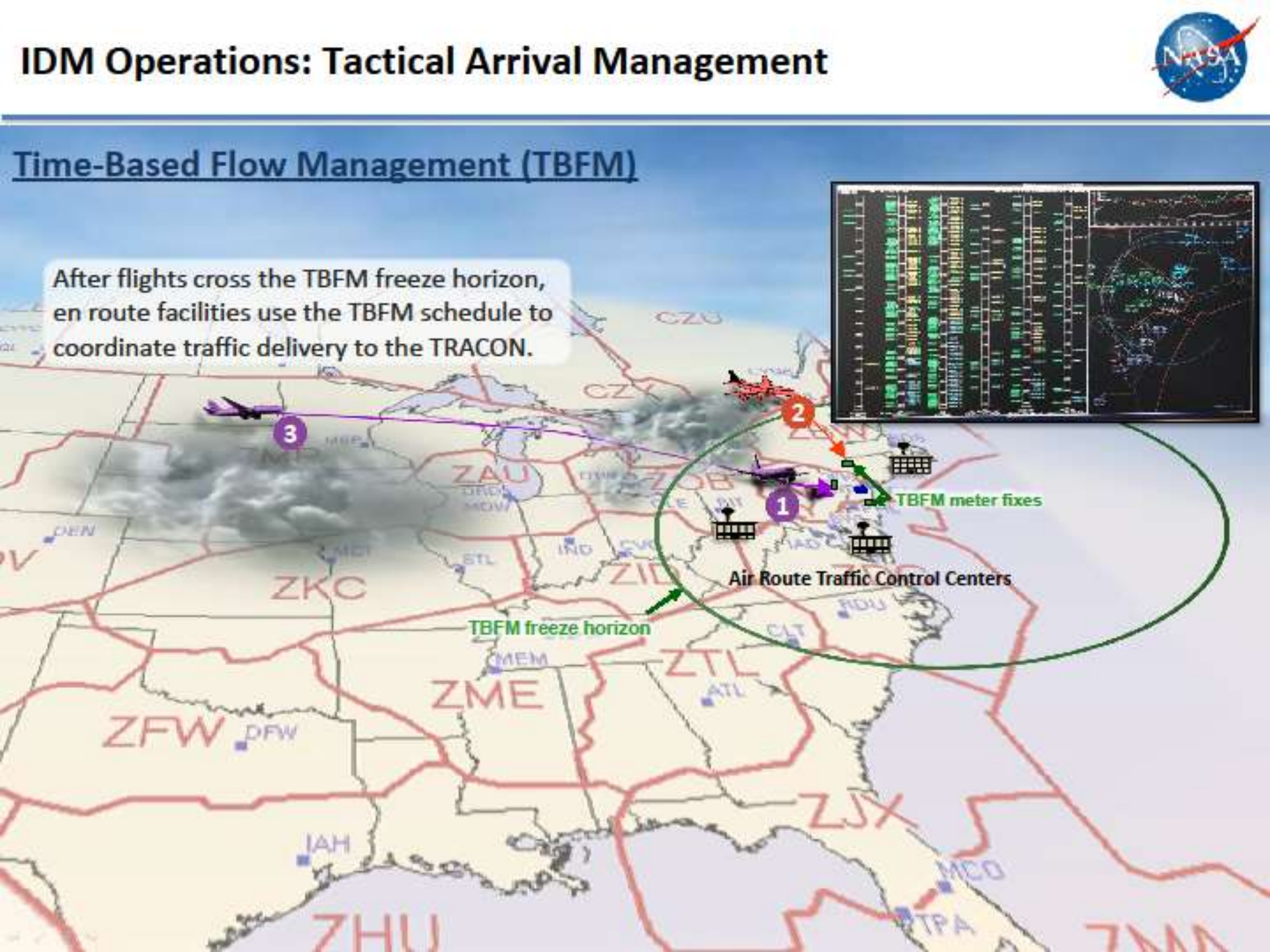
Collaborative Trajectory Options Program (CTOP)



IDM Operations: Tactical Arrival Management

Time-Based Flow Management (TBFM)

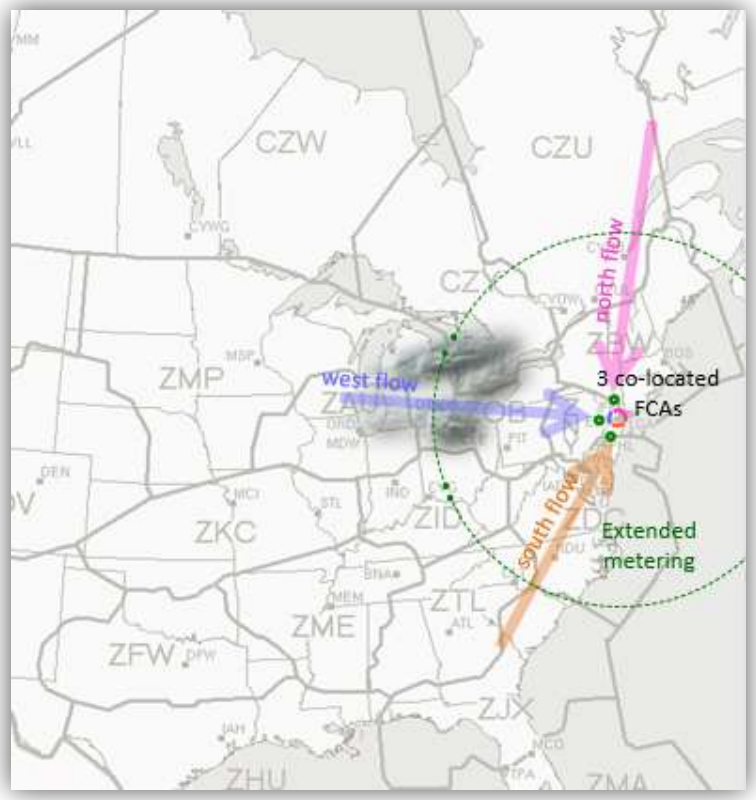
After flights cross the TBFM freeze horizon, en route facilities use the TBFM schedule to coordinate traffic delivery to the TRACON.



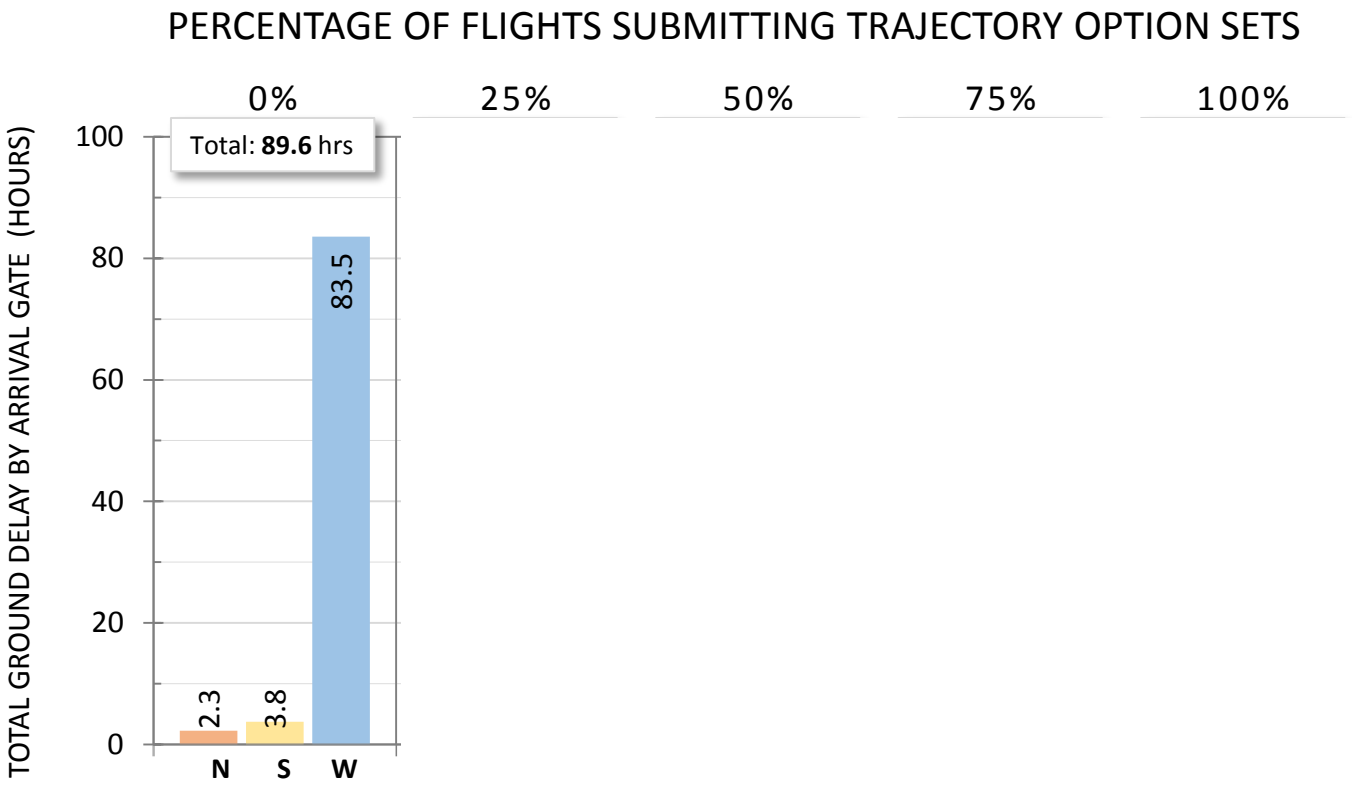
EWR SIMULATION, AUGUST 2017: IMPACT OF VARYING TOS PARTICIPATION LEVELS ON QUALITY OF OUTCOME

August 2017 EWR Simulation: Overview

- **Research Question**
  - *What happens at different Trajectory Option Set (TOS) submission ("participation") levels?*
- **Problem**:
  - Newark Liberty International Airport (EWR) arrival demand exceeds target capacity
  - En route weather limits west flow capacity
- **Conditions**:
  - TOS participation levels: 0%, 25%, 50%, 75%, 100%
- **Metrics**:
  - Arrival throughput
  - Ground delay
- **Scenario Characteristics:**
  - Target arrival rate is 44 flights/hour
  - Arrival demand ~52 flights/hour for 4 hours
  - Heaviest flows from the West and South
  - West gate is limited to 12 flights/hour
  - North and South flows share remaining 32 slots



August 2017 EWR Simulation: Results*



* 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*..

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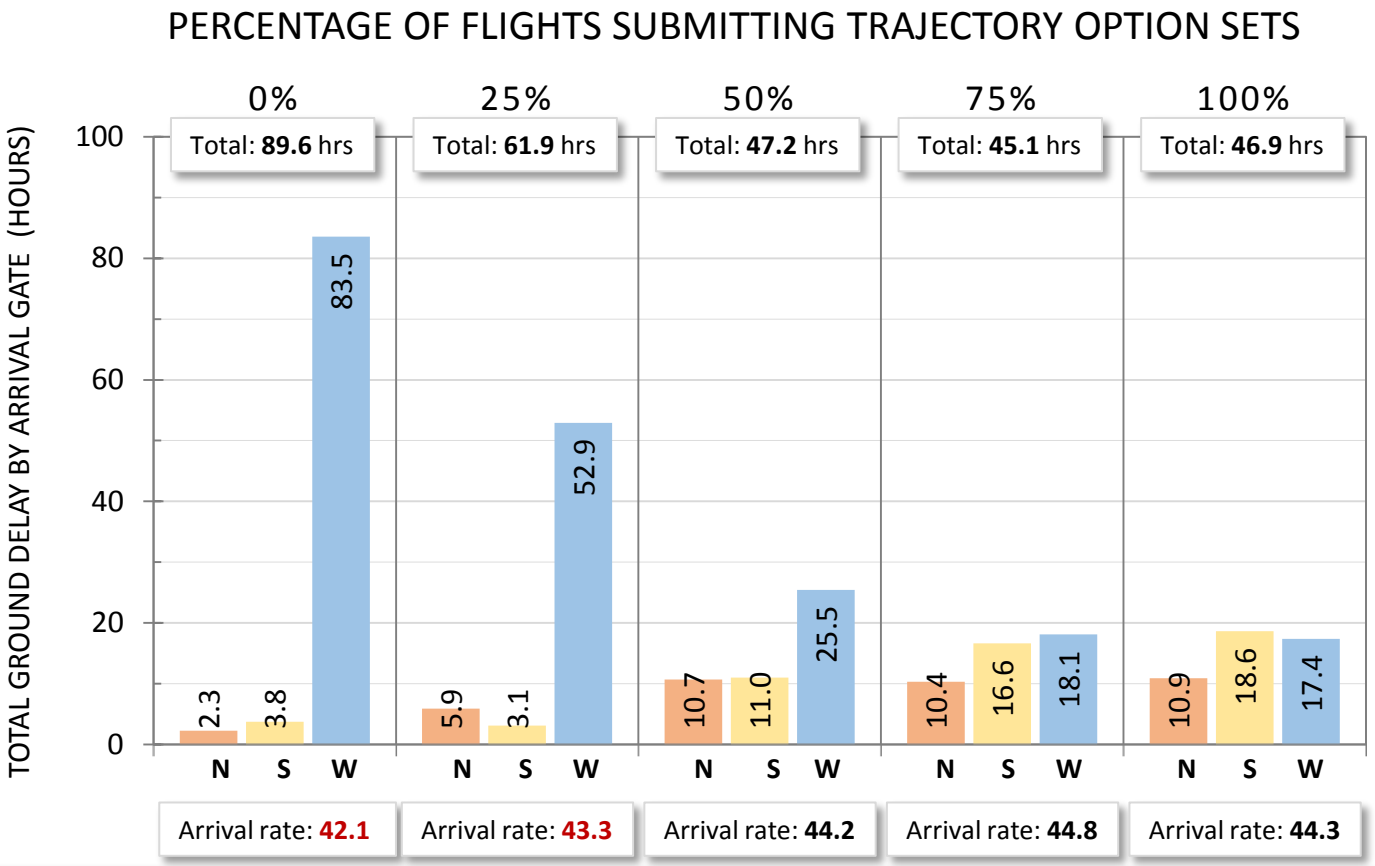


Off-loading traffic from the west flow substantially reduced ground delay for arrivals from the west and met target landing rate, when 50% or more flights submitted trajectory option sets.

* 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*..

LGA SIMULATION WITH FET, MARCH 2018: OPERATOR BENEFITS OF SUBMITTING TRAJECTORY OPTIONS SETS

March 2018 LGA Simulation: What We Did

- Human-in-the-loop simulation conducted with CDM Flow Evaluation Team
- FAA members and airline representatives from United, Delta, American, Southwest and FedEx were asked to role-play in LaGuardia Airport (LGA) simulation similar to August 2017 EWR problem
- Series of runs were completed with different airlines submitting trajectory option sets, including:
  - *All* airlines submit trajectory options sets
  - *No* airlines submit trajectory options sets
  - *Varying subsets* of airlines – United, Delta, American, Southwest and/or JetBlue – submit trajectory options sets
- After each run, output showing airline-specific impact was provided to participants
- Operators described implications for their company operations

March 2018 LGA Simulation: Overview

- **Objectives**
  - Explore IDM's concept of using CTOP to precondition traffic for TBFM when not all operators participate (i.e., submit Trajectory Options Sets)
  - Obtain stakeholder feedback on benefits for *all* users, operational feasibility and suggestions (for changes, alternative use cases, etc.)
- **Questions**
  - *What happens when different airlines submit Trajectory Option Sets (TOSs)?*
  - *Who benefits (more): Participating airlines? Or non-participants?*
- **Problem**:
  - LaGuardia Airport (LGA) arrival demand exceeds target capacity
  - En route weather limits west flow capacity
- **Metrics**:
  - Ground delay
  - TOS "reroute" count
  - Reroute-associated flight time
- **Conditions**:
  - FET members decide which airlines will "participate" during each run

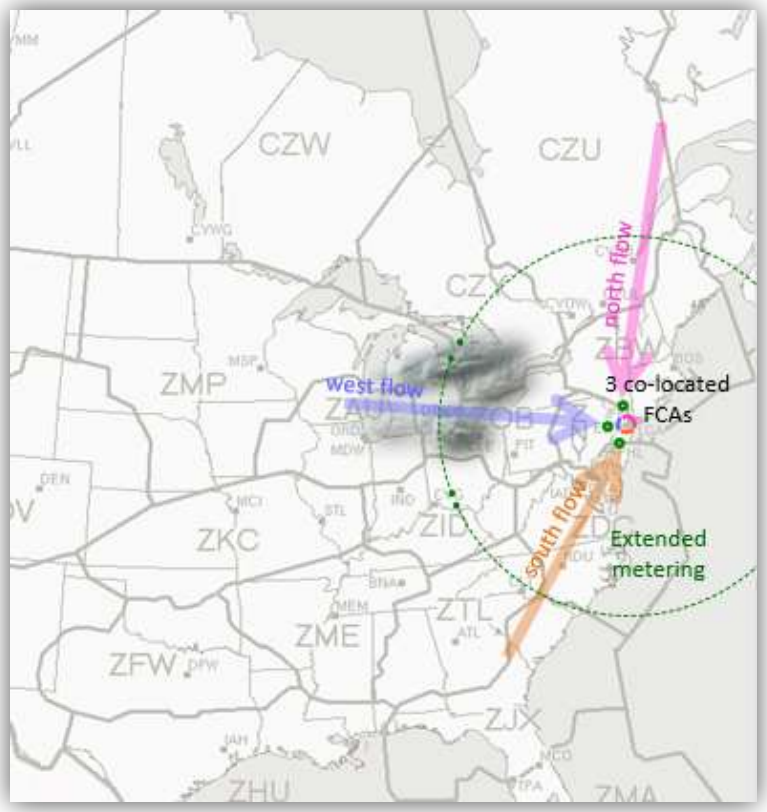
March 2018 LGA Simulation: Scripted TOS Example

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.GVE.KORRY4.KLGA
UAL556	NORTH	3	KDEN./.BRYCC..TAYOT..DAYYY..RUBKI..SIKBO..TULEG..RKA.HAARP3.KLGA

- During the simulation, CTOP used a scripted TOS for all “participating” flights.
- These TOSs included up to 3 trajectory options, representing feasible arrival routes to LGA’s North, South and/or West gates (FCAs).
- Options were ranked by estimated flight time.
- Flight plans for “non-participating” flights defaulted to Option #1 *except* in Run 5 (as described in Results).

March 2018 LGA Simulation: Scenario Characteristics

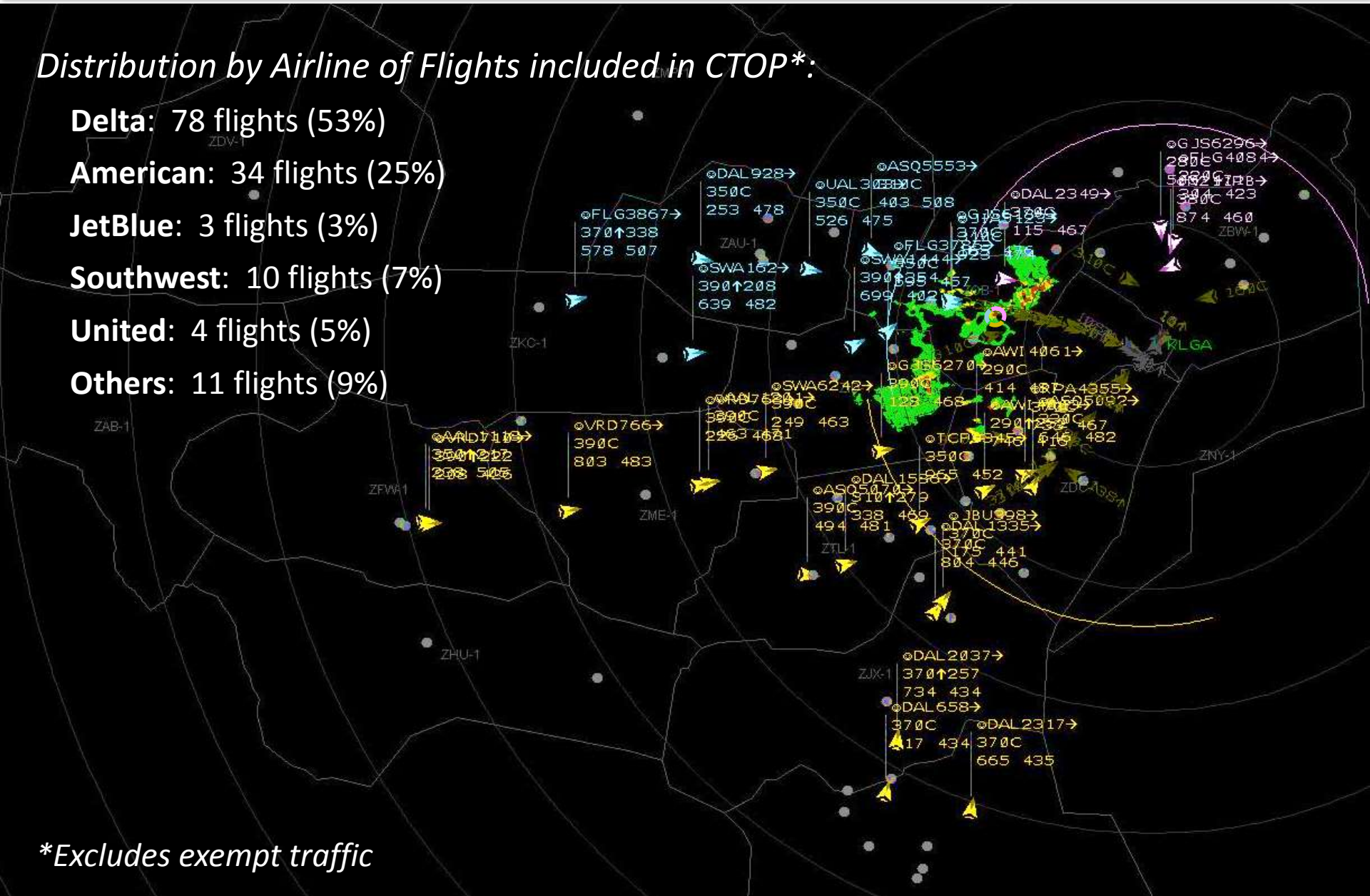
- Four hours of sustained demand at 40 to 43 flights/hour
- Target arrival rate is 36 flights/hour
- Heaviest demand from South, then West
- West gate is limited to 4 flights/hour
- North and South flows share remaining 32 slots



March 2018 LGA Simulation: Screen Capture

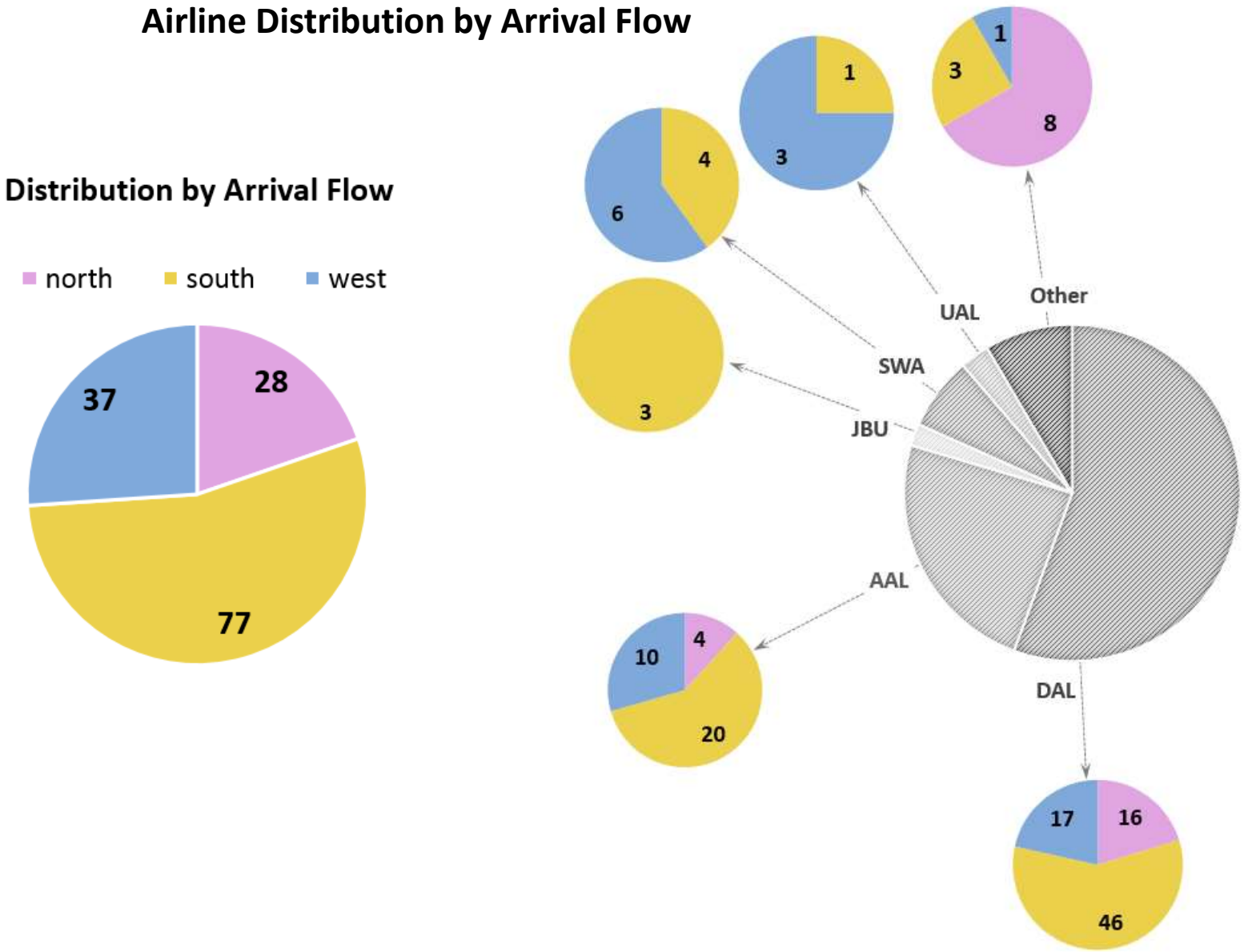
Distribution by Airline of Flights included in CTOP:*

- **Delta**: 78 flights (53%)
- **American**: 34 flights (25%)
- **JetBlue**: 3 flights (3%)
- **Southwest**: 10 flights (7%)
- **United**: 4 flights (5%)
- **Others**: 11 flights (9%)



**Excludes exempt traffic*

Distribution of Inbound Flights Included in CTOP



MARCH 2018: RESULTS

LGA Simulation: Run Characteristics, Results Preview

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

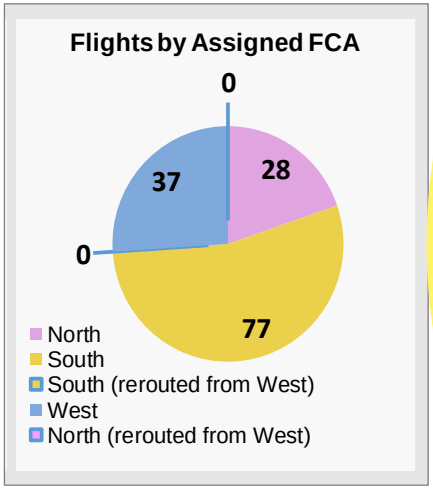
Results/comparisons that will be presented:

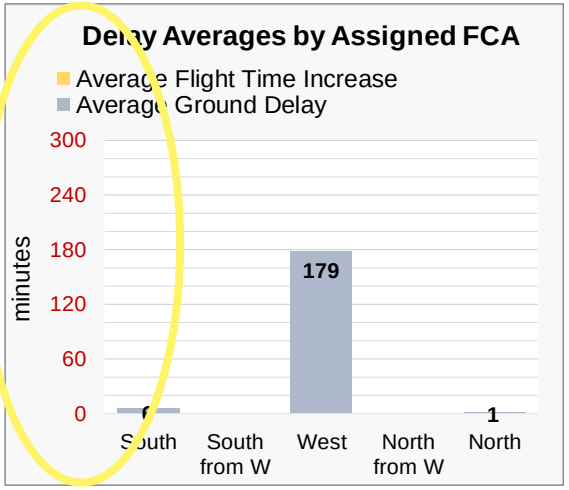
1) No-one participates or everyone participates **(Run 1, Run 2; all traffic)**
2) No-one participates but FET picks route, or everyone participates **(Run 5, Run 2; all traffic)**
3) Outcome will vary based on who participates **(Run 3, Run 4; all traffic)**
4) *Who benefits?* Compare Delta and American results **(Run 1, Run 3, Run 4; airline subset)**
5) *"Early adopters" impact?* Compare Delta and American **(Run 2, Run 3, Run 4; airline subset)**
6) Airline impact depends on fleet distribution. Compare American, JetBlue, Southwest and United **(Run 1, Run 4; airline subset)**

1) No one participates or everyone participates

Run 1. No one submits Trajectory Options Sets (worst case "baseline")

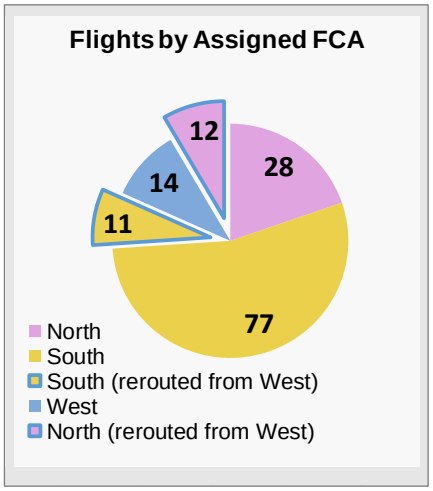
Throughput: **33** flights/hour
Ground Delay (total): **118.5** hours

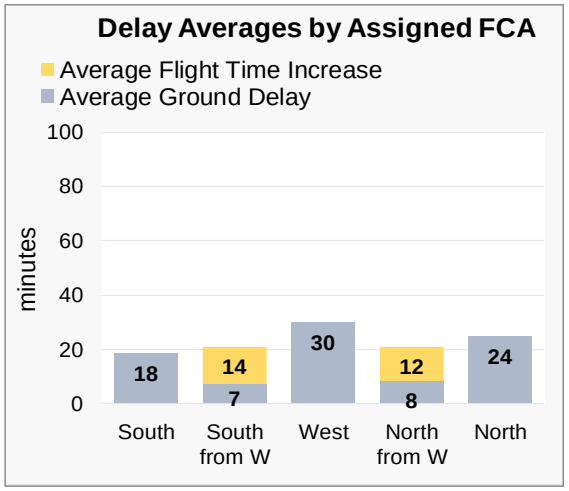




Run 2. Everyone submits Trajectory Options Sets

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

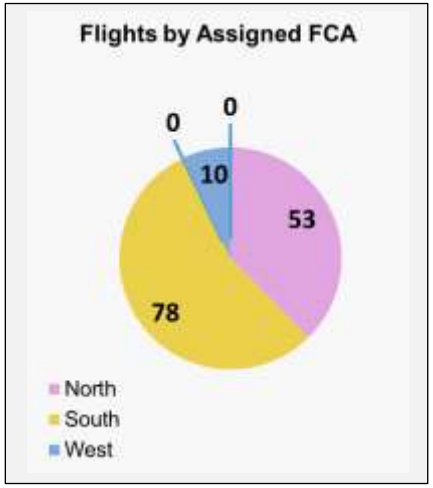


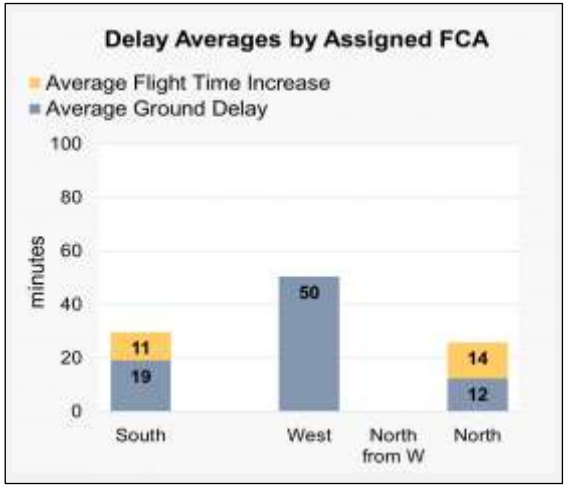


2) FET picks route, or everyone participates

Run 5. No one submits Trajectory Option Sets <u>but FET selects route option</u>

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





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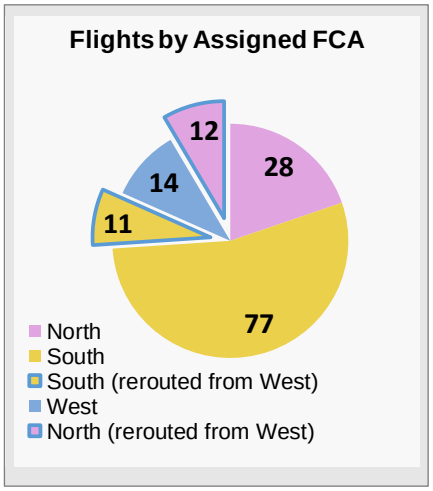
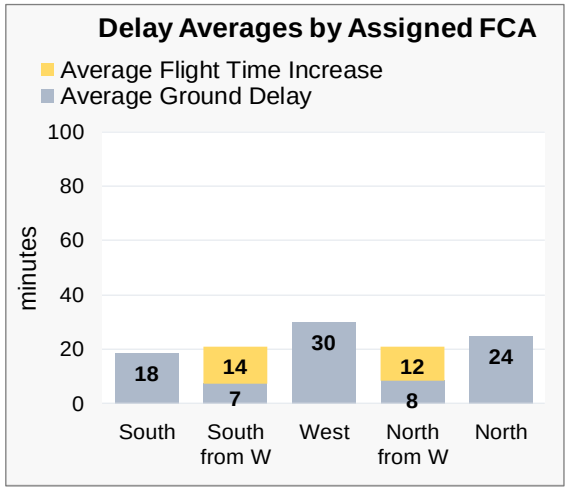
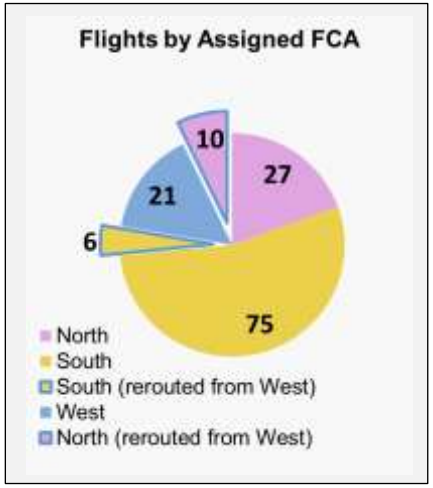


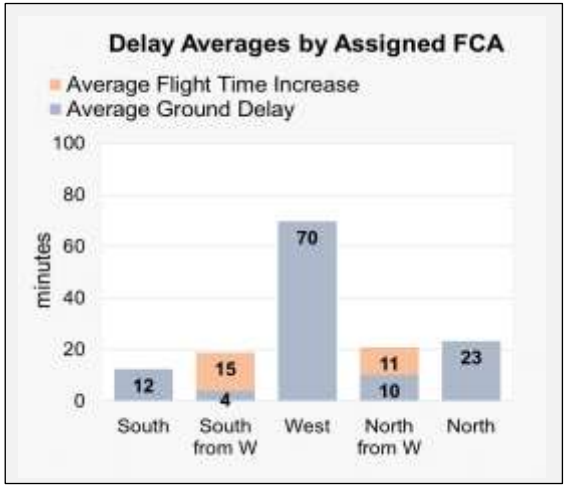


Results (3): Outcome will vary based on who participates

Run 3. Only **Delta** submits TOSs (53% participation)

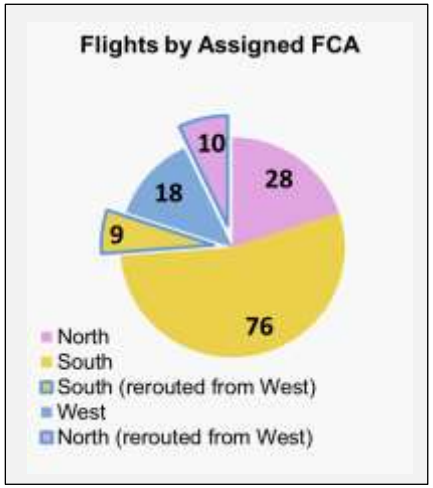
Throughput:	**36**	flights/hour
Ground Delay (total):	**52.5**	hours
TOS-reroutes:	**16**	flights
Added flight time(total):	**3.3**	hours

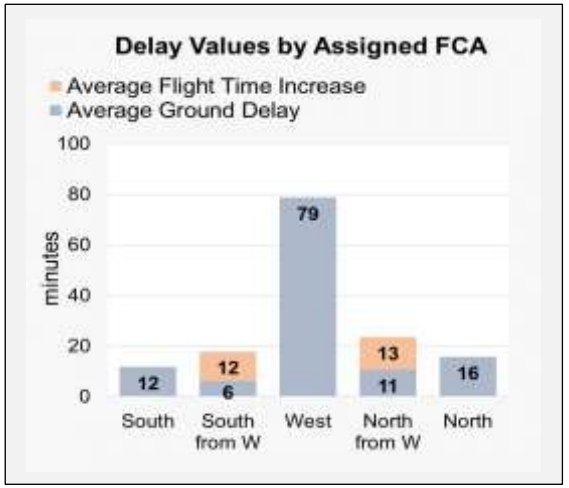




Run 4. American, JetBlue, Southwest and **United** submit TOSs (40% participation)

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





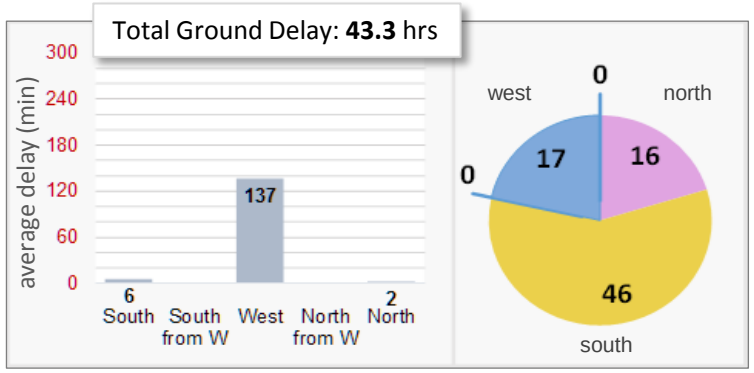
4) *"Who benefits?"* DELTA to AMERICAN comparison

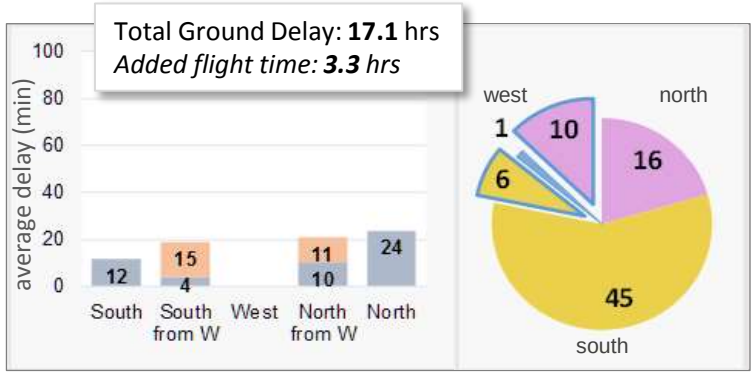
Run 1. No one submits TOSs.

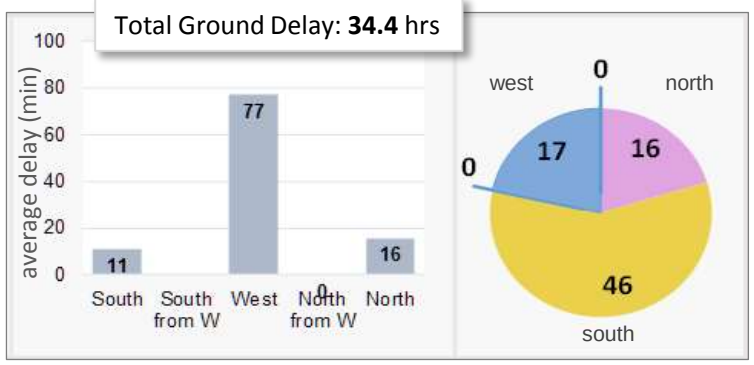
Run 3: Only Delta submits TOSs. (53%)

Run 4: American, JetBlue, Southwest and United submit TOSs. (40%)

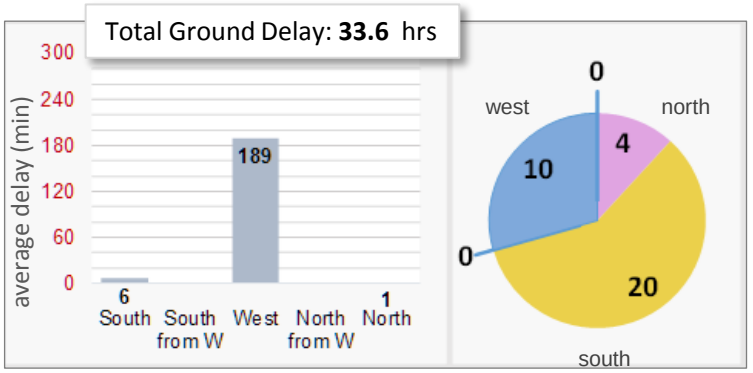
DELTA AIRLINES (53%)

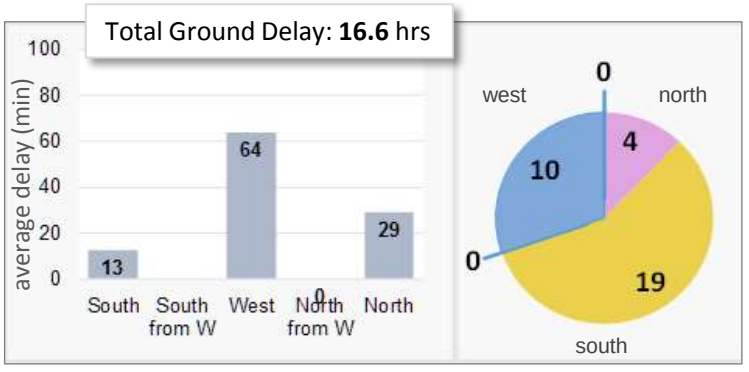


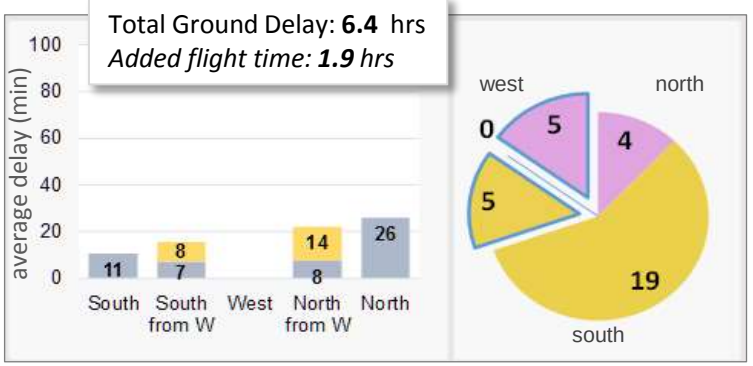




AMERICAN AIRLINES (25%)







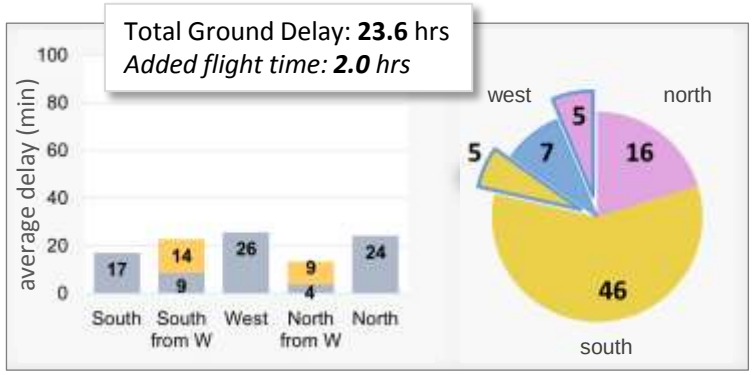
5) *"Early adopters" impact?* DELTA to AMERICAN comparison

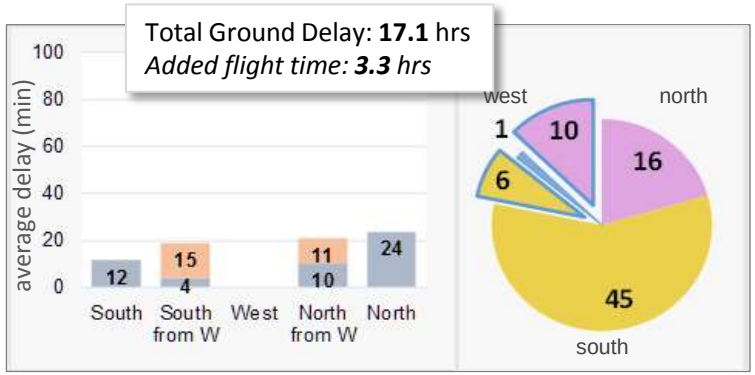
Run 2. Everyone submits TOSs.

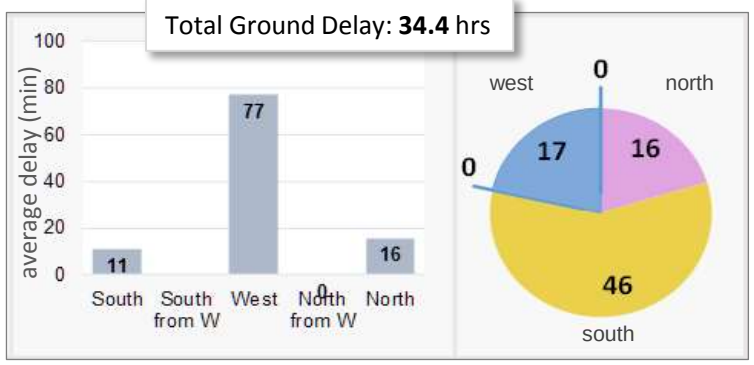
Run 3: Only Delta is an "early adopter" (airline that submits TOSs). (53%)

Run 4: American, JetBlue, Southwest & United are "early adopters" (airline submitting TOSs). (40%)

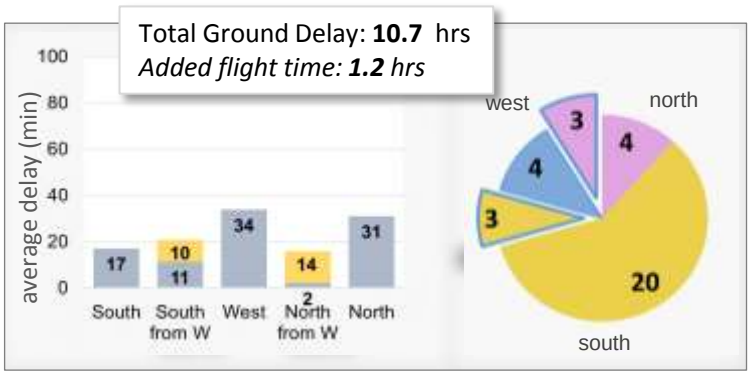
DELTA AIRLINES (53%)

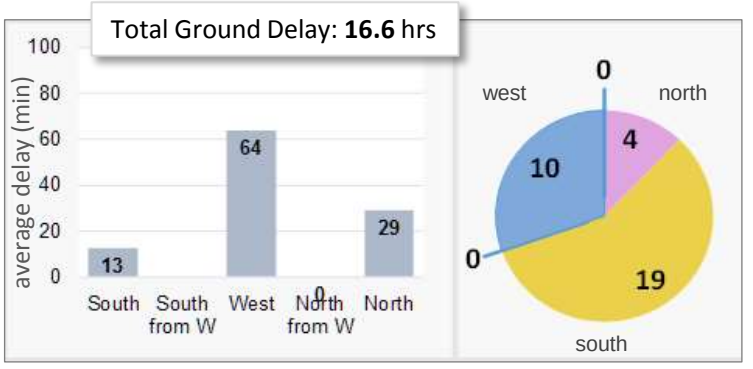


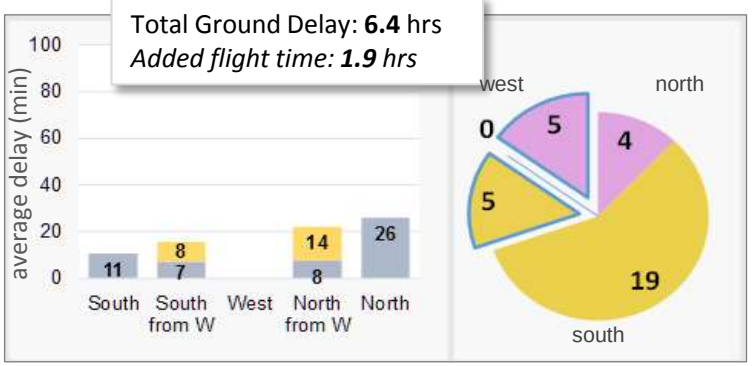




AMERICAN AIRLINES (25%)





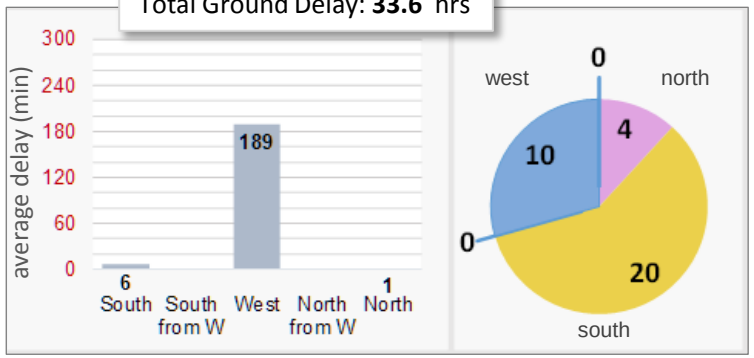


6) Airline impact depends on fleet distribution (1 of 2)

RUN 1: No one submits trajectory options.

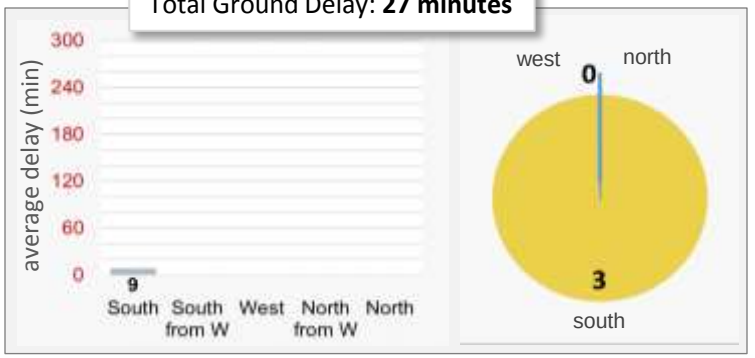
AMERICAN AIRLINES (25%)

Total Ground Delay: **33.6** hrs



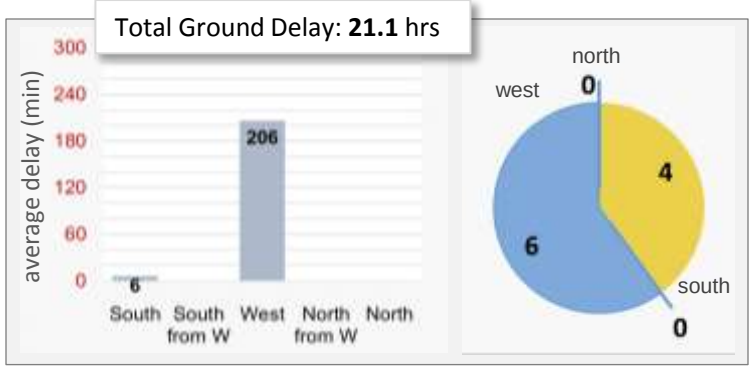
JETBLUE (3%)

Total Ground Delay: **27 minutes**



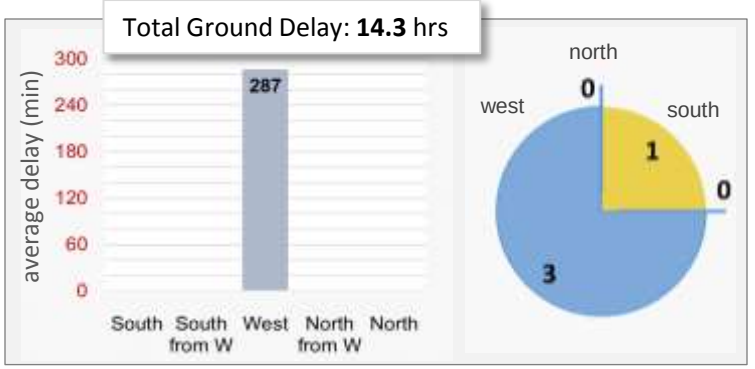
SOUTHWEST (7%)

Total Ground Delay: **21.1** hrs



UNITED (5%)

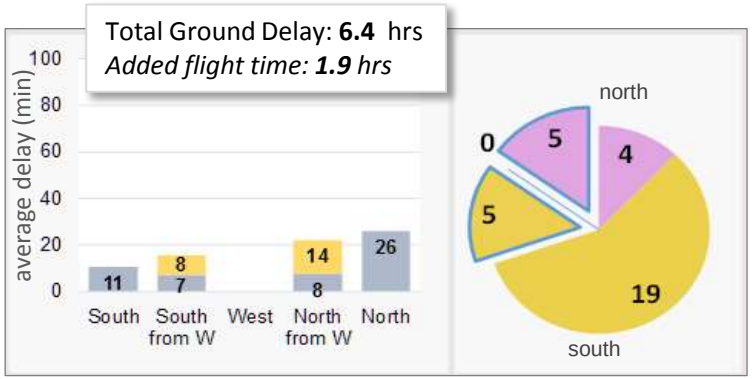
Total Ground Delay: **14.3** hrs



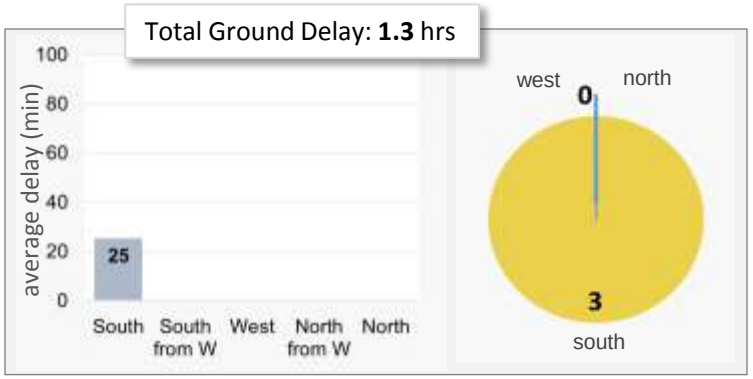
6) Airline impact depends on fleet distribution (2 of 2)

RUN 4: American, JetBlue, Southwest and United all submit Trajectory Options Sets

AMERICAN AIRLINES (25%)



JETBLUE (3%)



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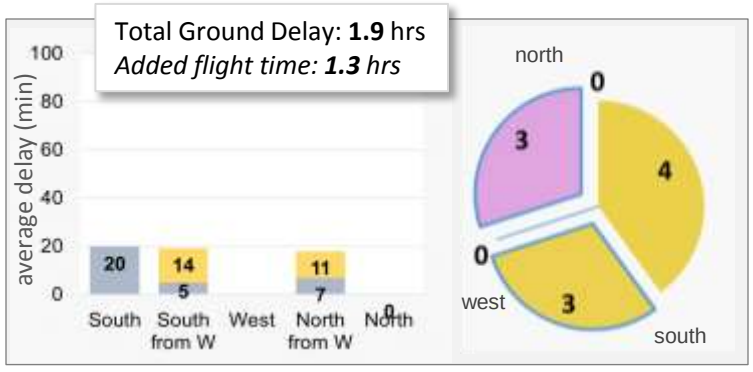
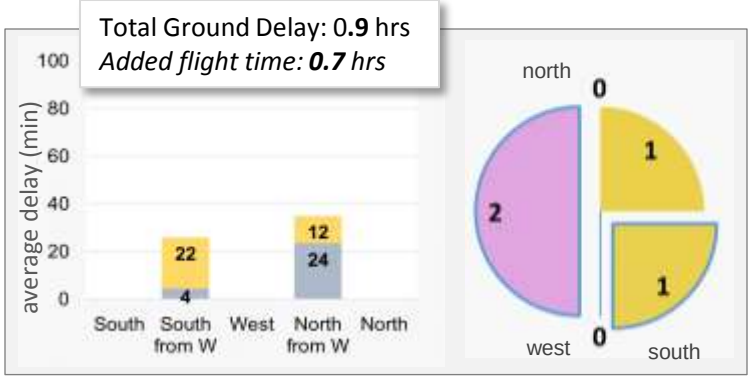


UNITED (5%)



Results Summary

1) No-one participates or everyone participates
   - *System performance was best when airlines participated: target throughput was achieved, and delay was reduced and redistributed.*
2) No one participates but FET selects route vs. everyone participates
   - *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.*
3) Outcome will vary based on who participates
   - *Number of participating flights, or number of participating airlines is only one factor in determining outcome. Also matters where the flights are coming from, where they are in the schedule and what options are available to them.*
4) *"Who benefits (more)?"* Compare Delta and American outcomes
   - *Both participating and non-participating airlines benefit when compared to the "no participation" (baseline) condition, and participating airline saw the largest benefit.*
5) *"Early adopters" impact?* Compare Delta and American
   - *As more airlines participate the system outcome improves, and the contrast between participants and non-participants is reduced.*
6) Airline impact depends on fleet distribution.
   - *Airlines with many flights on the constrained route benefit most.*

Additional Thoughts

- LGA problem really struck home for FET: role-playing seemed crucial to impact.
- Advantages of concept and CTOP itself were immediately apparent.
- Our study used pre-scripted TOSs that included feasible routes for each gate a flight might use.
- General consensus: everyone was happy when role-playing ‘early adopters’ to see others benefit, but only if they got greater benefit.

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QUESTIONS?

TOS List Sample

Original FCA

Main carrier regional flights are identified by an R in the call sign. UAL = UAR

Callsign	FCA	TOS 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.GVE.KORRY4.KLGA
UAL556	NORTH	3	KDEN./.BRYCC..TAYOT..DAYYY..RUBKI..SIKBO..TULEG..RKA.HAARP3.KLGA
UAR4314	WEST	1	KCLE./.FAILS..JFN..ETG.MIP4.KLGA
UAR4314	NORTH	2	KCLE./.FAILS..ERI..JHW..MEMMS..WILET..RKA.HAARP3.KLGA
UAR5706	WEST	1	KORD./.MOBLE..ADIME..GERBS.J146.ETG.MIP4.KLGA
UAR5706	NORTH	2	KORD./.HANKK..EXTOL..RKA.HAARP3.KLGA
UAR5706	SOUTH	3	KORD./.EARND..ELANR..EMMLY..ERECO..IIU.J526.BKW.J42.GVE.KORRY4.KLGA
UAR6256	SOUTH	1	KIAD./.AGARD.KORRY4.KLGA