ATD AIRSPACE TECHNOLOGY DEMONSTRATIONS
TECHNICAL INTERCHANGE MEETING

NASA

ATD-2 Phase 3
Multi-Airport and Flight Operator System with Trajectory Options Set (TOS)

Presentation & Discussion Panel
Session Coordinator: Greg Juro
September 23, 2021

Trajectory Option Sets (TOSs) – What Are They?

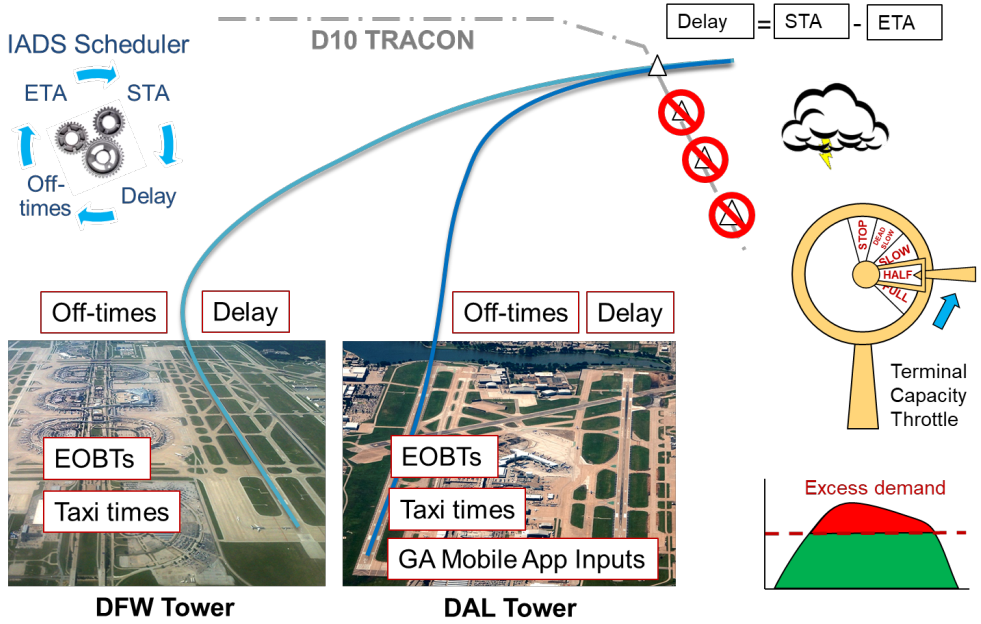
Trajectory Options Set (TOS) background

- TOS communicates flight operator route preferences to ATC
  - Relative Trajectory Cost (RTC) value used to select among trajectories in a TOS
- Originally developed for TFMS Collaborative Trajectory Options Program (CTOP)
  - Potential for application to wide range of collaborative routing needs
- FAA's TFMS/CTOP investment created TOS communication infrastructure that is currently underutilized
- Flight operators and FAA are eager to see greater TOS utilization

TOS and ATD-2 Phase 3 Multi-Airport IADS

- ATD-2 Phase 3 system requirements included accommodation of operator preferences
- Operator community (via CDM) recommended using TOSs to meet this ATD-2 requirement

ATD-2 Phase 3: Multi-Airport IADS in North Texas



Overview

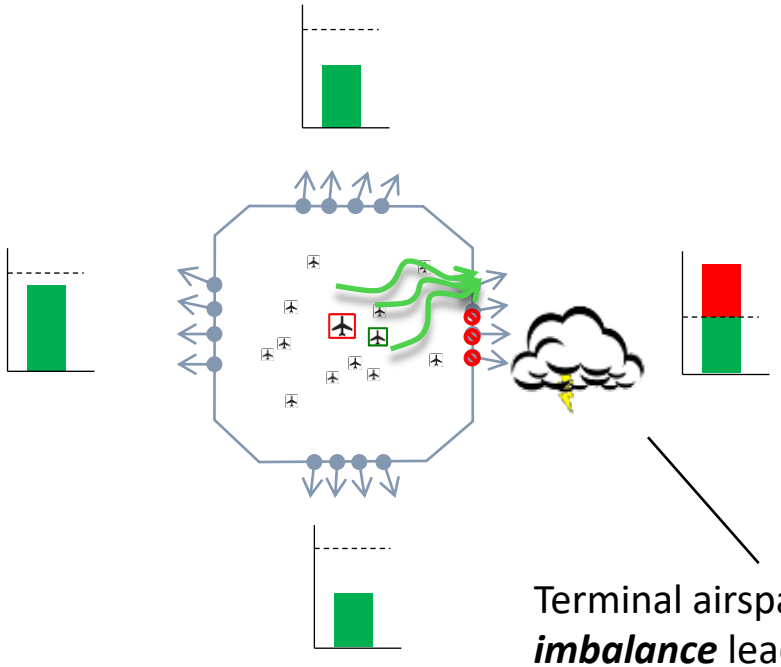
- Broad stakeholder engagement via Collaborative Decision Making (CDM) joint tasking (CDM Task #92) for Surface CDM Team and Flow Evaluation Team
- 2019 Stormy Season Initial Concept Evaluation refined requirements for Operational Evaluation
- COVID-19 dramatically reduced air traffic volume limiting opportunities for use during 2020 Stormy Season
- NASA and Partners agreed to 1-year extension to enable data collection during 2021 Stormy Season

Approach

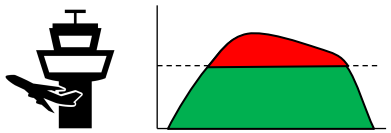
- Developed a multi-airport IADS system featuring a novel, NASA-built terminal scheduler for use by Operators and ATC in North Texas terminal environment
- Phase 3 Multi-Airport IADS system builds on the Phase 2 foundation to provide an IADS solution for the Metroplex
- Demonstrate feasibility and benefits of coordinating departures among airports in a terminal environment via operational field evaluation involving Tower, TRACON, Airport, and Flight Operator facilities
- Will transfer technology and knowledge to FAA and Industry (i.e. operators and solution providers)

ATD-2 Phase 3: Managing Multi-Airport Departures

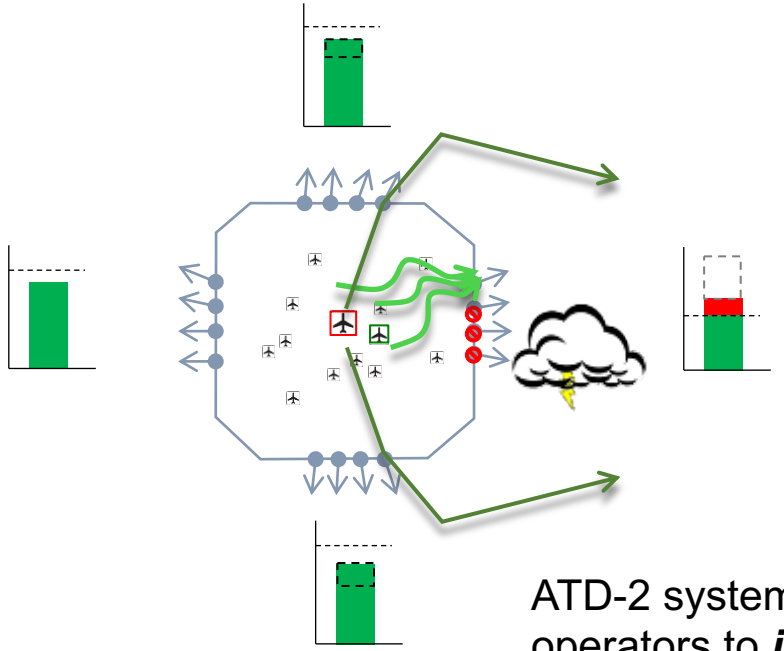
The Problem



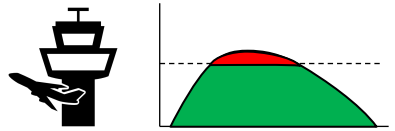
Terminal airspace ***demand/capacity imbalance*** leads to departure delays on the airport surfaces



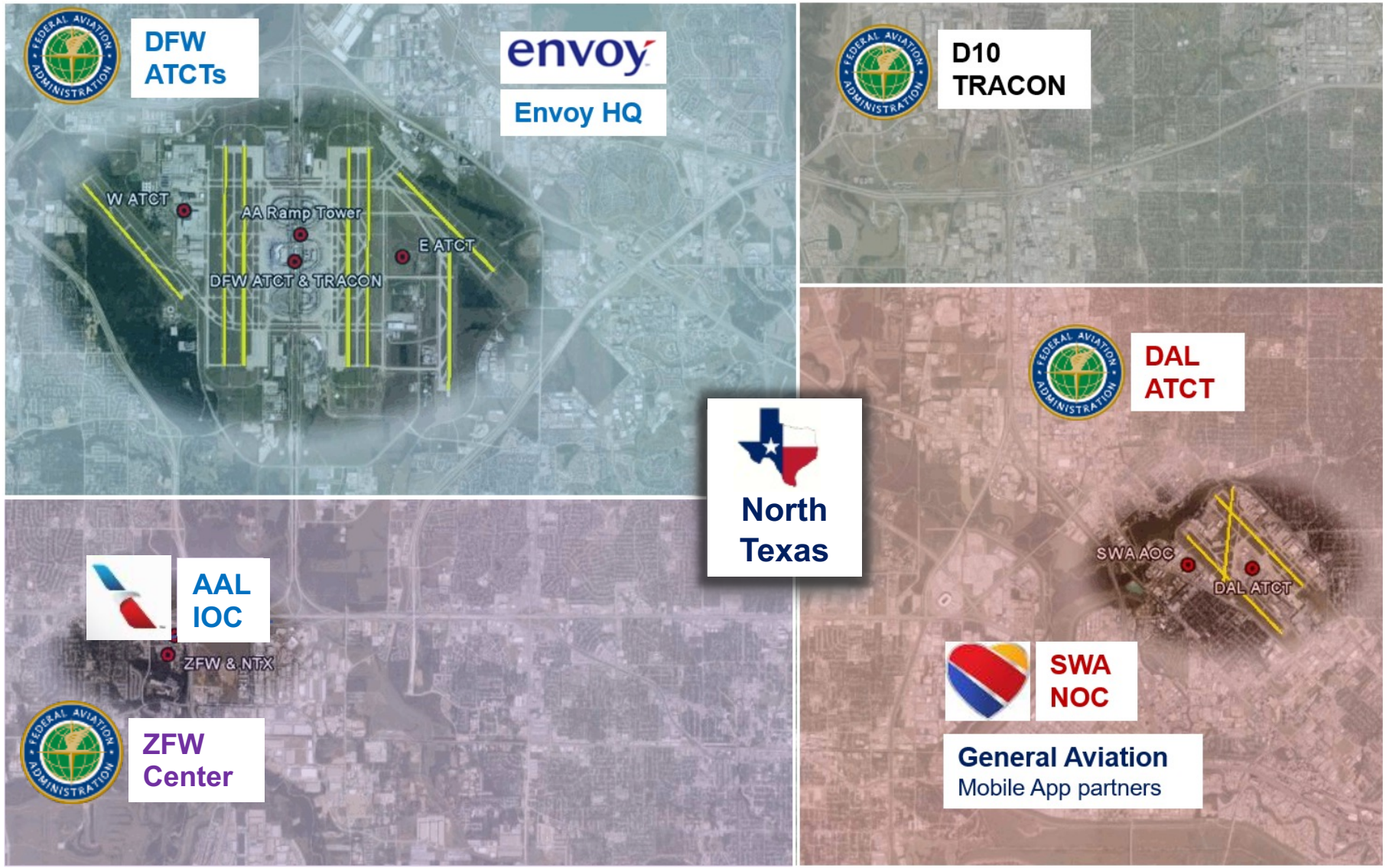
The Solution



ATD-2 system enables flight operators to ***intelligently*** request reroutes from ATC for departure fix ***load balancing***



Phase 3 Partners



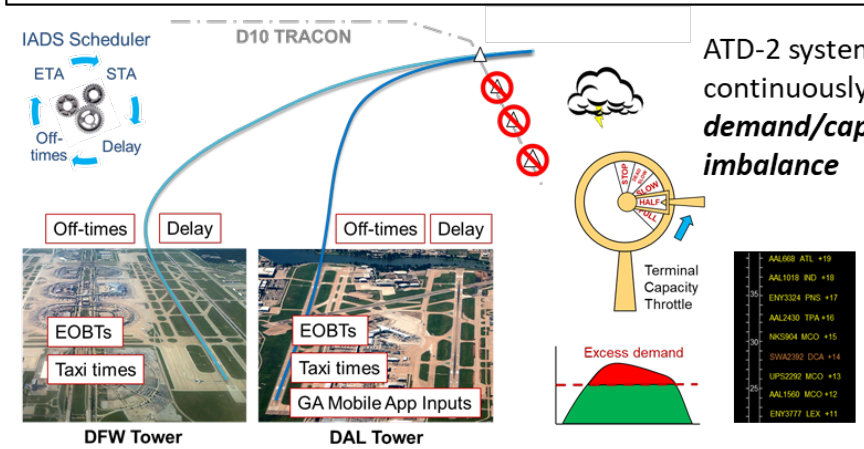
ATD-2 Phase 3: TOS-based Digital Departure Reroutes

1 Preconfigure TOS Parameters

- ATC and operators identify acceptable alternative routes
- Alternative routes codified in ATD-2 system
- Operator-specific Relative Trajectory Cost (RTC) algorithms codified in ATD-2 system

```
<TRAJ_OPTION_LIST>
  <TRAJ_OPTION>
    <TRAJ_INDEX>1</TRAJ_INDEX>
    <REL_TRAJ_COST>0</REL_TRAJ_COST>
    <ROUTE>DCT IPL J18 GBN DCT PXR J18 SJN DCT TCC J6 PNH
    <ALT>F320</ALT>
    <SPEED>N0380</SPEED>
  </TRAJ_OPTION>
</TRAJ_OPTION_LIST>
```

2 Terminal Predictive Engine Monitors Demand & Capacity



ATD-2 system continuously assesses ***demand/capacity imbalance***

3 Candidate TOSs are Presented to Operators

- ATD-2 system assesses delay savings on alternative routes
- Candidate TOSs identified when RTC thresholds are met
- Operator selects and submits TOS request to ATC

Delay savings > Relative Trajectory Cost ?

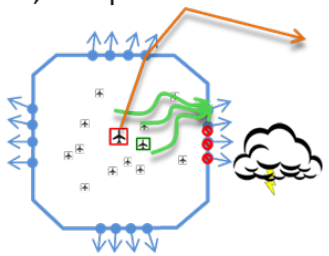
Settings Filter Field Color Alerting — **Flight TOS**

Callsign	Dest	Route	CDR	Dist	+nm	Terminal Gate	RTC	Delay	Delay Savings	Eligibility State	Coordination State	Scratch pad
AAL1560	MCO	KDFW. MRSSH2. ZALEA CREEM CEW JZ OJHAP OTK PIGLT4 KMCO	--	880	--	EAST	--	+18	0	N/A	Filed Route	Crew time out 18:10
AAL1560	MCO	KDFW FORCK2 FORCK ELD MEI OTK PIGLT4 KMCO	DFWMCO0P	885	+5	EAST	+1	+18	0	Potential	Not Submitted	
AAL1560	MCO	KDFW AKUNA7 MLC RZC ARG MEM J41 SZW OTK PIGLT4 KMCO	DFWMCO1N	1112	+232	NORTH	+15	+0	-18	Candidate	Not Submitted	Coordination
AAL1560	MCO	KDFW DARTZ7 TNV IAH LCH J2 SZW OTK PIGLT4 KMCO	DFWMCO1S	998	+118	SOUTH	+30	+2	-16	Potential	Not Submitted	Op. Submit

Undo

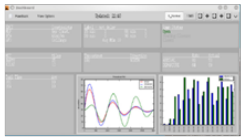
4 Operator Submitted TOSs Presented to ATC

- ATC is notified of the Operator submitted TOS route
- ATC evaluates the TOS routes for operational feasibility
- If approved, all users are notified, the filed route is amended, and pilots are cleared on the TOS route

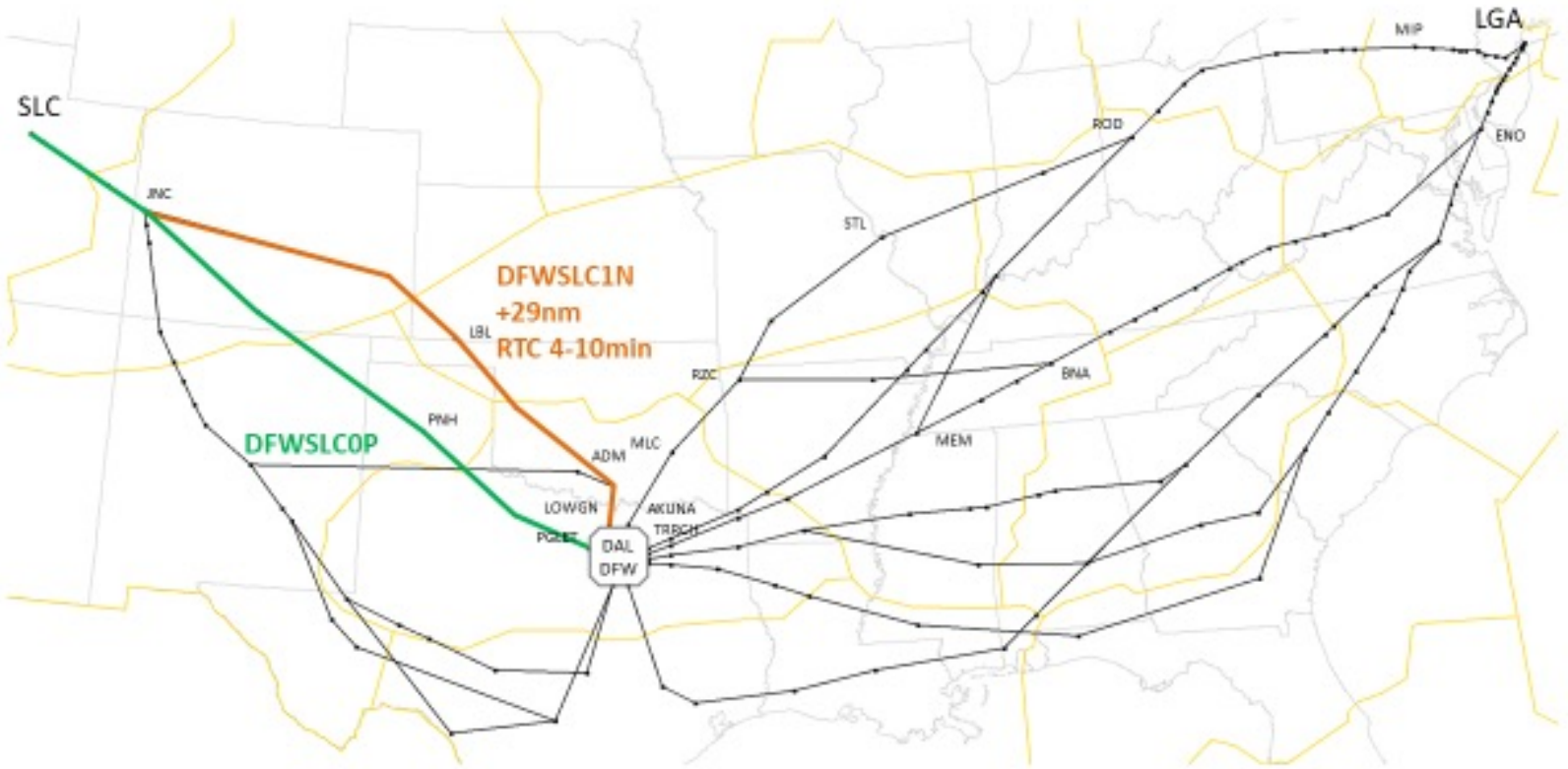


5 Post Ops Eval

- Benefits
- Lessons
- Refinements
- Analyses
- Reports



TOS – CDR and RTC

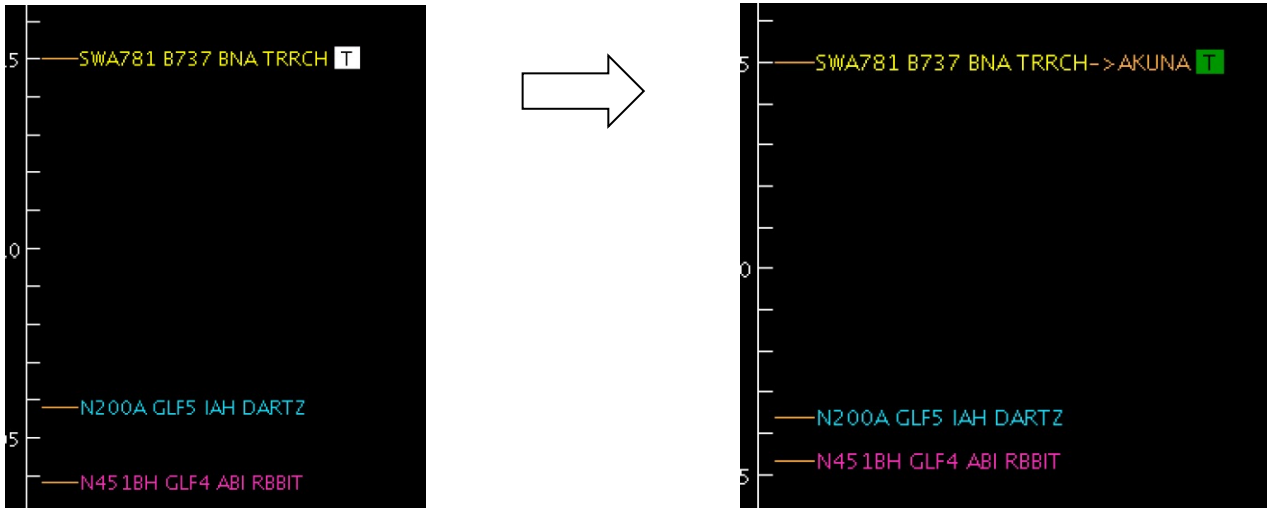


Notes:

- Subsets of CDRs as TOS alternative routes
- Examples with default RTC values

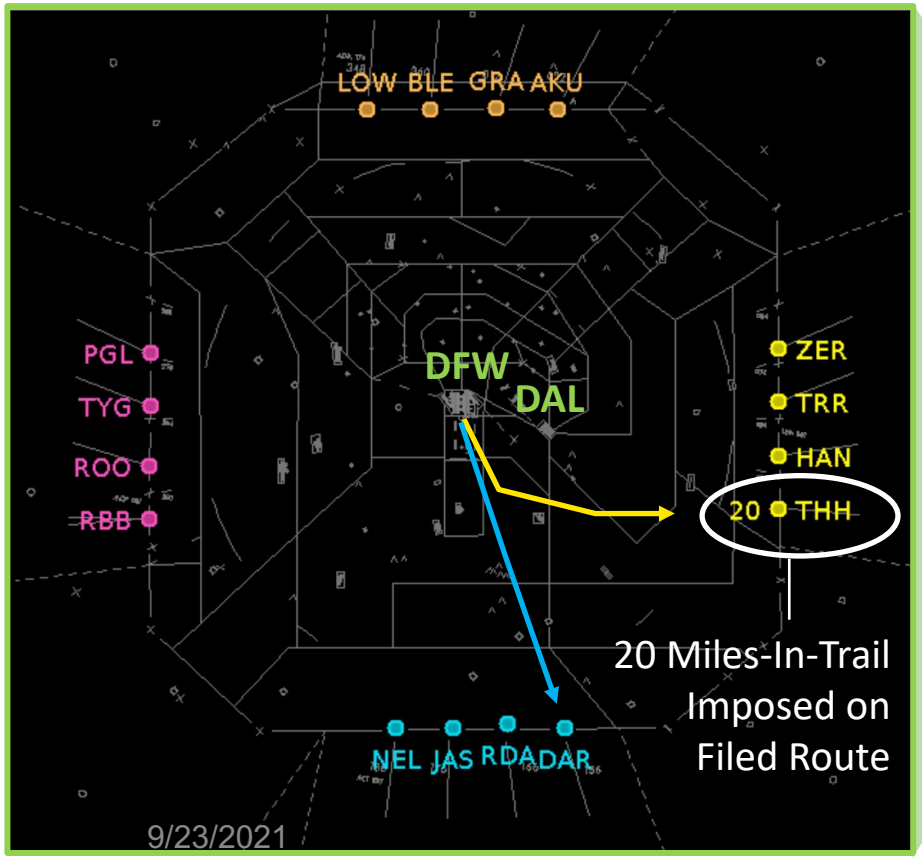
How a Flight is Rerouted with TOS Information in ATD-2

- Flight Operators use the ATD-2 interface to submit alternative routes for ATC to consider
- ATC use the ATD-2 interface to approve the flights that will be rerouted
- ATC uses the existing FAA systems to amend the flight plans, based on the CDR route that is approved on the ATD-2 interface
- ATCT relays the revised route to the flight crew via the radio frequency, or, when able, via Controller-Pilot Data Link Communication-Departure Clearance (CPDLC-DCL)



Recent Example of ATD-2 Phase 3 TOS Digital Reroute

On March 26, 2021, American Airlines 1822 flew Dallas/Fort-Worth (DFW) to Fort Myers (RSW) on a reroute approved using the ATD-2 Phase 3 system.

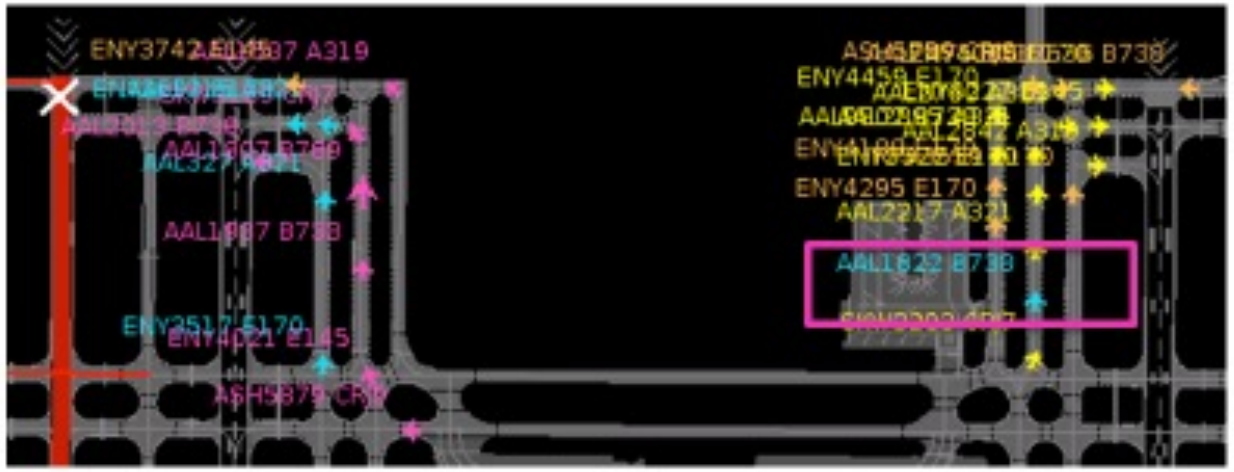


- American Airlines 1822 was initially filed on the **yellow route**
- ATD-2 projected surface delay due to constraints on the East departure gate
- Based on American TOS preferences, ATD-2 recommended the **blue reroute** out the south gate
- Even though the blue route was 42nm longer, by flying this TOS alternate reroute, American Airlines flight 1822 saved:
  - 16 minutes of surface delay (at takeoff)
  - 20 minutes of surface delay including subsequent departure flights in the American fleet (aggregate system savings)
  - 15 minutes of arrival delay (at the destination's parking gate)
    (AAL1822 was predicted to arrive 19 minutes late on the filed route vs. 4 minutes late on the TOS alternate route

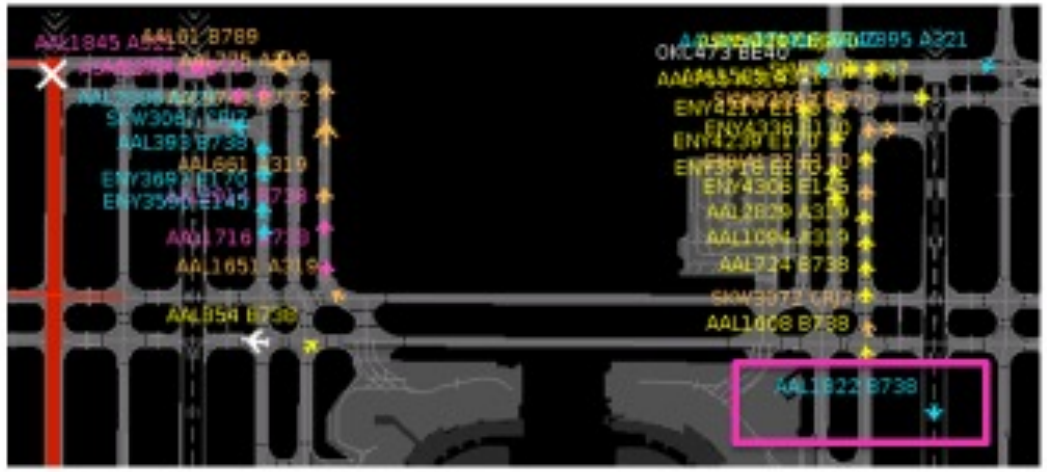


Example of ATD-2 Phase 3 TOS Digital Reroute

JOINING THE QUEUE



TAKING OFF

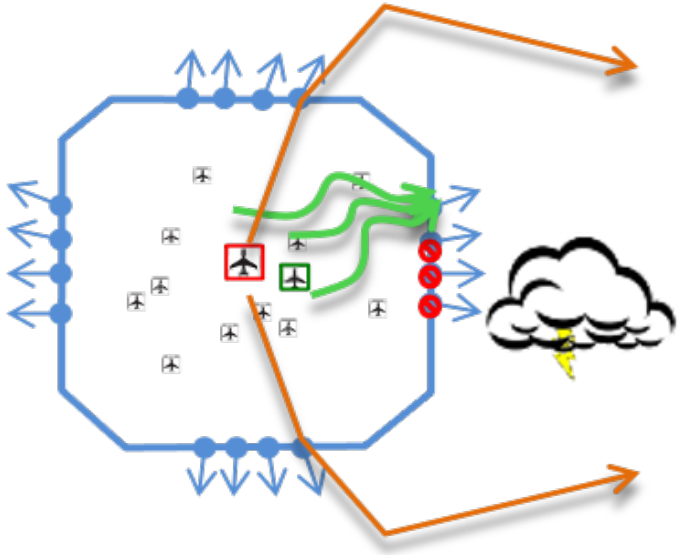


Panel Member Introductions

- American Airlines
  - Dr. Tim Niznik, Director, Integrated Operations Center Analytics
  - Bob Shirley, Dispatcher/ATC Coordinator
- Southwest Airlines
  - Bob Nursey, Chief of Air Traffic Management
- Envoy Airlines
  - Kenneth Vogt, Manager, Flight Dispatch Technologies
  - Lauren Wisener, Flight Dispatch SOC Supervisor
- FAA
  - Kristen Wilson, National ATD-2 Representative, NATCA
  - John Short, Traffic Management Coordinator, DFW
  - Chad Wakefield, National Traffic Management Officer, ATCSCC
- NASA
  - Dr. Jeremy Coupe, ATD-2 Deputy Chief Engineer
  - Dr. Eric Chevalley, ATD-2 Field Demo Team

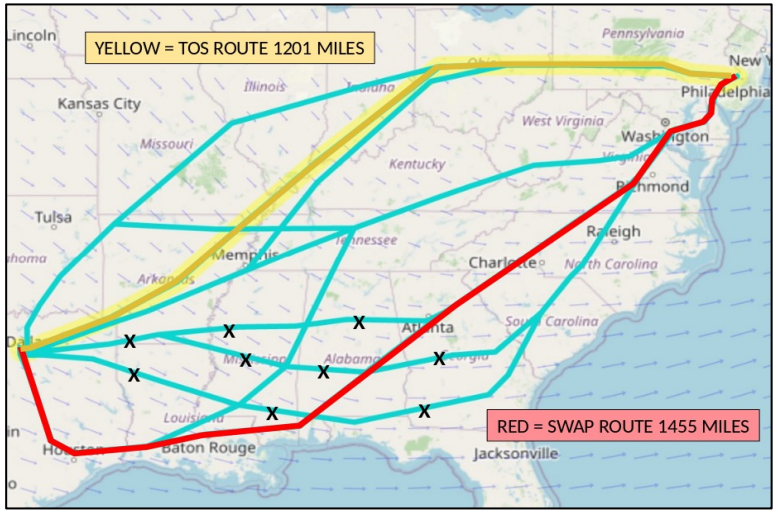
ATD-2 Phase 3 Benefits in North Texas (NTX) through August 31, 2021

Use Cases and Benefit Mechanisms



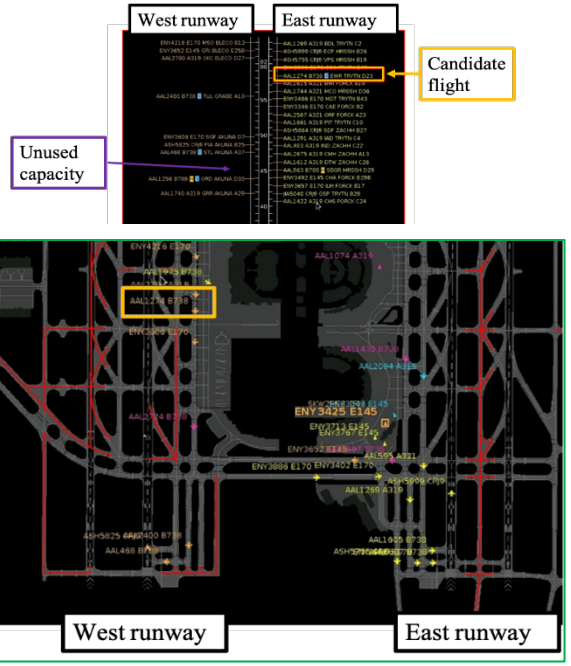
Traffic Management Initiative (TMI)

- Filed route is most direct route but subject to TMI
- Filed route remains through the original departure gate
- TOS route through adjacent departure gate and requires additional flight time
- TOS reroute reduces surface delay in exchange for increased flight time



Recovery from SWAP

- Filed route is amended by ATC through an adjacent departure gate during a SWAP event
- SWAP event ends and TOS routes through the original Filed departure gate much shorter than SWAP route
- TOS reroute reduces surface delay and also has shorter flight time compared to SWAP route



Non-TMI Tactical Reroutes

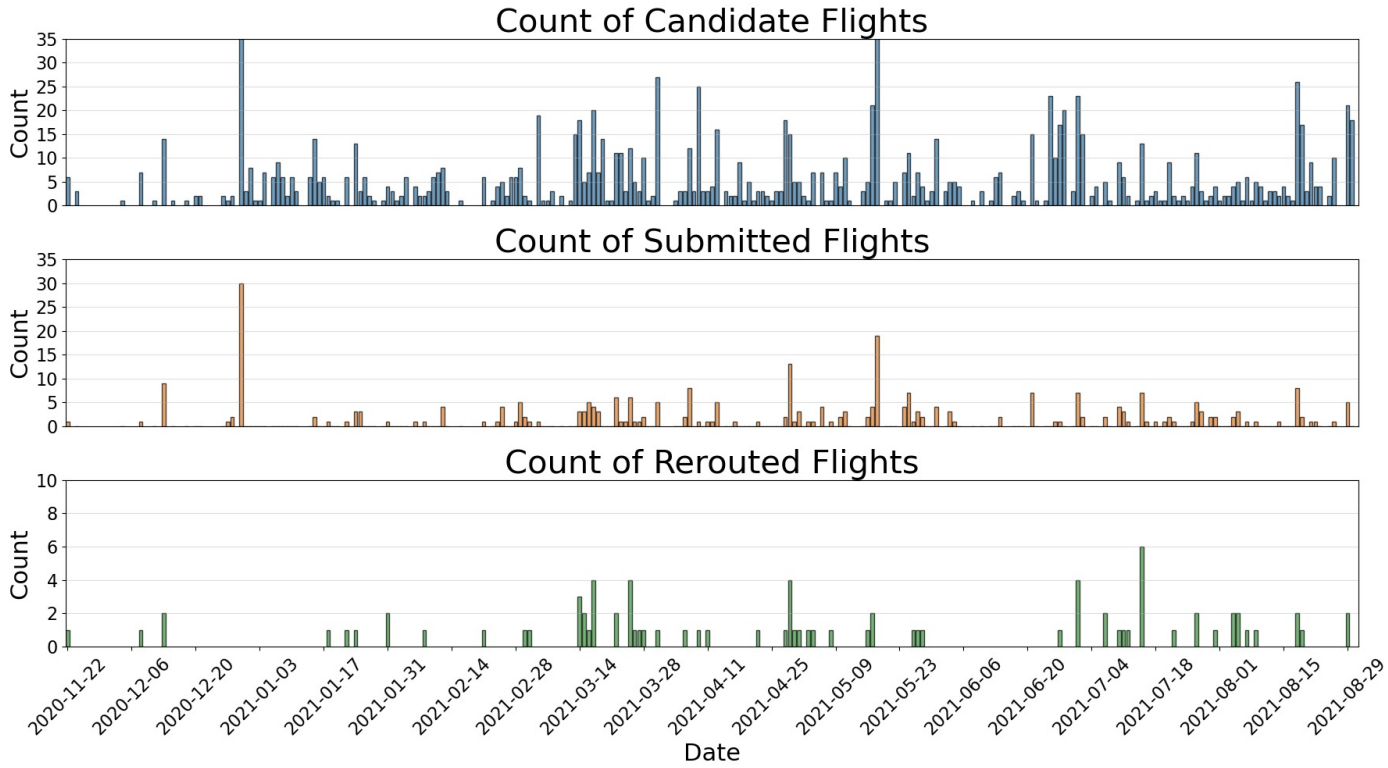
- Often occurs when the parking gate is physically closer to the TOS runway than the Filed route runway
- Provides tactical opportunities to load balance runway demand to take advantage of unused capacity

NTX TOS† Reroutes Over Time

1,250 Candidate Flights

313 Airline Reroute Requests

104 ATC Approvals and Reroutes



- Between November 22nd, 2020 and August 31st, 2021 a total of **1,250 CANDIDATE flights** were identified by IADS system
- Airlines have **submitted 313 TOS reroute REQUESTS** to ATC
- ATC has **APPROVED and REROUTED 104 flights**
- 20 flights excluded for various reasons leaving **84 flights for benefits analyses**

NTX Delay Savings Benefits

Individual benefit to rerouted flight getting OFF the surface

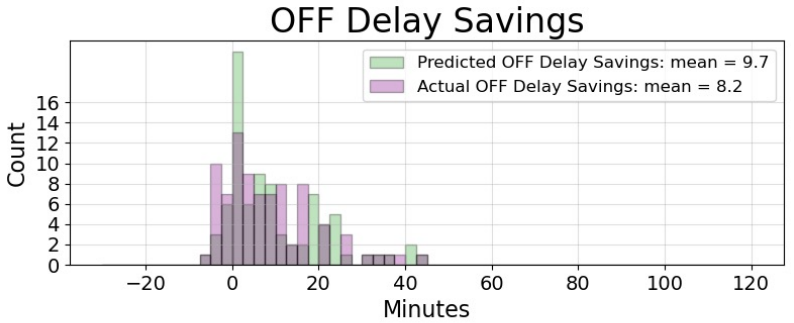
- Predicted Savings = (Predicted taxi time Filed route) - (Predicted taxi time TOS route)
- Actual Savings = (Predicted taxi time Filed route) - (Actual taxi time TOS route)
- Example of Actual Savings: (Predicted Filed taxi **25**) - (Actual TOS taxi **10**) = **15**

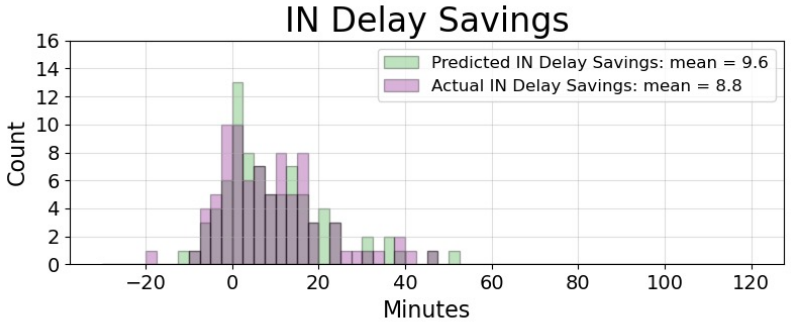
Individual benefit to rerouted flight getting IN to the destination

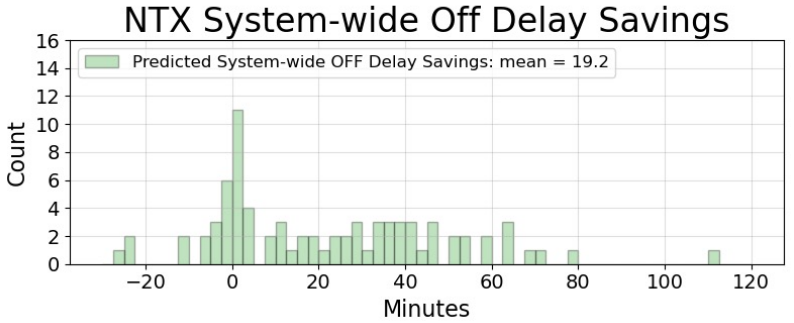
- Predicted Savings = (Predicted OFF delay savings) - (TOS route additional flight time)
- Actual Savings = (Actual OFF delay savings) - (TOS route additional flight time)
- Example of Actual Savings: (Actual OFF savings ***15***) **-** (Additional flight time **3**) = **12**

NTX system-wide benefit to all flights getting OFF the surface

- Predicted Savings = Total OFF delay savings for all NTX flights
- System-wide savings prediction generated from what-if scheduler modelling
- System-wide savings is inclusive of rerouted flight



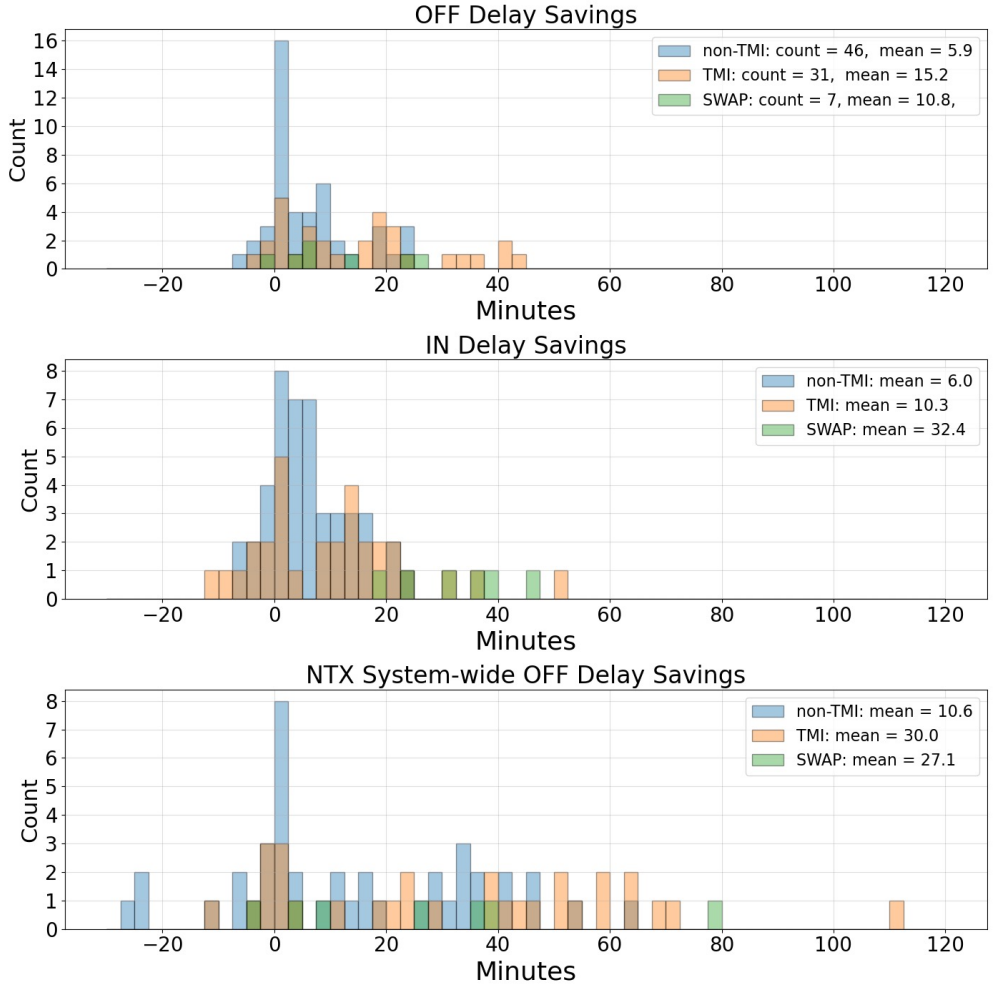




❑ The average NTX system-wide OFF delay savings of 19.2 minutes is more than double the benefit to the individual rerouted flight

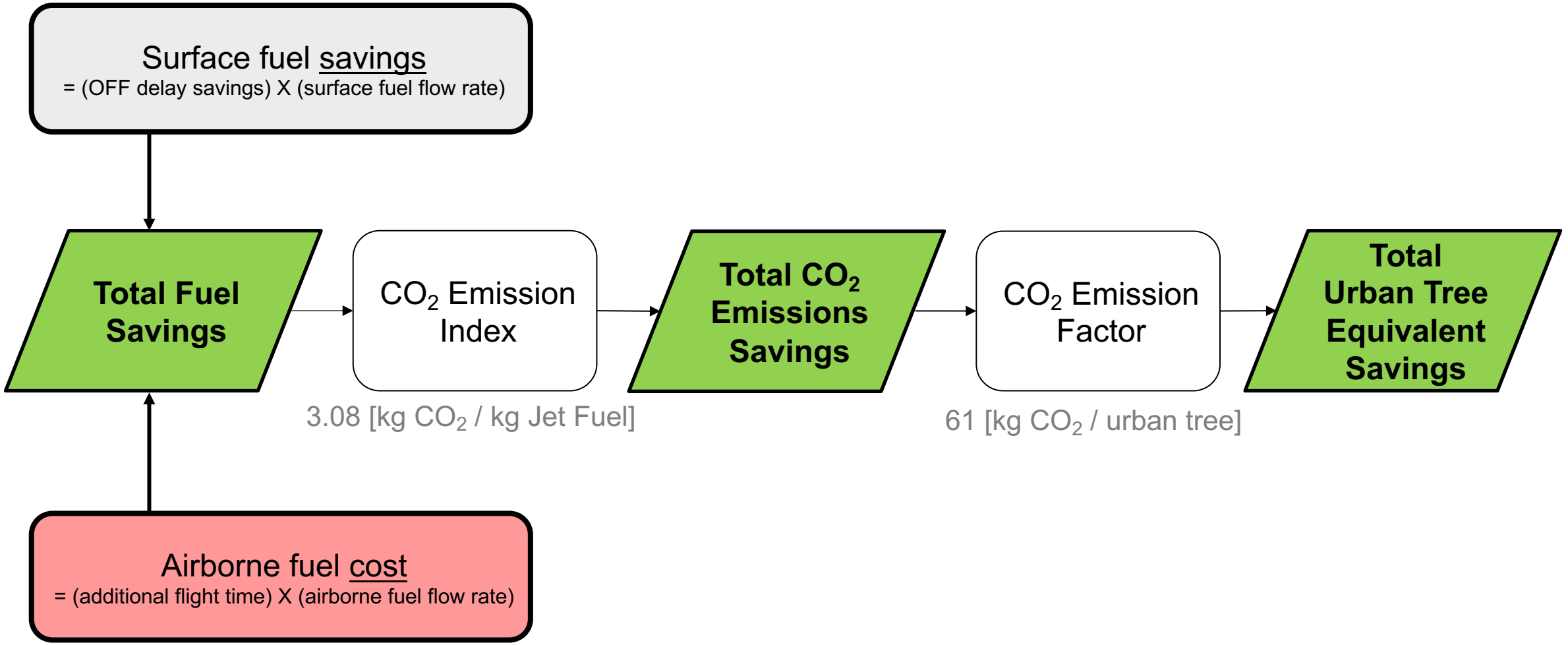
NTX Delay Savings Benefits by Use Case

- Count of reroutes by use case
  - non-TMI: 46
  - TMI: 31
  - SWAP: 7
- TMI has largest OFF delay savings and the largest NTX system-wide savings
- SWAP has the largest IN delay savings
- Non-TMI has the most Candidates and TOS reroutes, but has the smallest delay savings benefits



❑ TMI use case provides the best combination of reroute opportunities combined with large OFF delay savings and NTX system-wide OFF delay savings

Environmental Benefits Methodology



- Surface fuel savings is inclusive of the NTX system-wide OFF delay savings for the total environmental benefits shown on the next slide

NTX Total Environmental Benefits



- The average TOS reroute saves 265 kg of fuel reducing CO2 emissions by 816 kg which is equivalent to planting 13 urban trees

NTX Benefits Summary

- Number of flights: 84
- Individual time/money savings for rerouted flights
  - Total OFF delay savings: 11.51 hours
  - Total IN delay savings: 12.26 hours
  - Passenger cost savings: $78,800
  - Crew cost savings: $18,066

Individual rerouted flights only

- NTX system-Wide aggregated fuel/emissions savings
  - **21,978.9 kg** (48,455.6 lbs) of **fuel** saved
  - **67,694.9 kg** (149,241.5 lbs) of **CO_2 emission** saved
  - **1,109.8 urban trees** saved

Individual rerouted + other aggregated flights

Benefits totals from Phases 3 of the ATD-2 field demonstration at
D10 North Texas Metroplex (22 Nov 2020 – 31 Aug 2021)

Saved 48,455.6 lbs of fuel

Fuel

Saved 149,241.5 lbs of CO_2 = 1,110 urban trees

Emissions

Saved 11.5 hours of OFF delay

12.3 hours of IN delay

Delay Savings

Reduced NTX System-wide delay by 24.6 hours

Saving passengers an estimated **$78,800** in value of time and operators an estimated **$18,066** in flight crew costs

Backup

Trajectory Option Sets (TOSs) – What Are They?

Trajectory Options Set (TOS) background

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  - Relative Trajectory Cost (RTC) value used to select among trajectories in a TOS
- Originally developed for TFMS Collaborative Trajectory Options Program (CTOP)
  - Potential for application to wide range of collaborative routing needs
- FAA's TFMS/CTOP investment created TOS communication infrastructure that is currently underutilized
- Flight operators and FAA are eager to see greater TOS utilization

TOS and ATD-2 Phase 3 Multi-Airport IADS

- ATD-2 Phase 3 system requirements included accommodation of operator preferences
- Operator community (via CDM) recommended using TOSs to meet this ATD-2 requirement
- ATD-2 Phase 3 initial concept evaluation (Summer 2019) saw first ever multi-operator use of TOS

CTOP TOS vs. ATD-2 TOS

- CTOP
  - ATC ***must*** initiate CTOP program after which operators submit TOSs
  - Operators ***must*** comply with re-routes selected from their TOSs by TFMS/CTOP Ration-by-Schedule (RBS) algorithm
- ATD-2
  - Operators provided with information that enables intelligent re-route ***requests*** via TOS communication infrastructure
  - ATC ***may*** approve re-route requests if they are feasible given overall traffic management situation

Important Note - TOS versus CTOP

"The concept of TOS is distinct from and has value apart from the concept of CTOP in a number of important ways. First of all, a Trajectory Options Set (TOS) is simply a means of data communication with TFMS about route preferences for a given flight much like an operator would communicate other flight information to TFMS such as delays, cancellations, EOBT's, etc. TFMS uses this information to create the most accurate view of demand both in the airspace and at the airports. Once a significant demand/capacity imbalance is projected ATC may choose to implement any number of different traffic management initiatives (TMI's) such as GDPs, AFP's, reroutes, or a CTOP.

While the concept of a TOS was developed and created during the development of CTOP, both operators and ATC have begun to realize that TOS's have value and use outside of CTOP. In fact, as more and more creative use cases are developed and conceived, ***it could very well evolve that TOS's have their primary and greatest uses outside of official CTOP TMI's****.*

…Several carriers are in the process of purchasing or developing new flight planning capabilities, and use-cases like the ones mentioned above will ensure that TOS becomes a required capability enabling even more opportunities for use."

Dr. Tim Niznik, Director Operations Systems and Decision Support, American Airlines

Providing TOS Opportunities

- Information Integrated from FAA & Flight Operators to Provide TOS Opportunities
  - Earliest Off Block Times in addition to L-times, Scheduled times, and OOOI – improves the accuracy of predicting takeoff times (includes voluntary use of mobile app from GA FO's at DAL to be expanded to other N TX GA airports)
  - Radar track data, such as ASDE-X (at DFW) – provide flight position updates
  - Runway configuration and utilization – ATC entries that assist with predicting taxi times and assigned runway
  - Restrictions via NTML – Fix closures, route combinations, SWAPs (ZFW-D10) – Center entries electronically relayed to TRACON are parsed by ATD-2 system to help with predicting delays at takeoff at at the terminal boundary. In addition, this provides Flight Operators with situational awareness they did not previously have
  - DCC GDP, GS, AFP, Reroutes (not FCA related reroutes yet) – TFM data used to exclude destinations and/or routes
  - APREQs – TBFM data used to exclude flights with wheels-off time from TOS reroutes
  - CDRs used as alternate routes in flights' TOS – provides agreed upon routes for ATC to manage and for flight Operators to submit TOS without further coordination
  - Flight Operators' factor to compute Relative Trajectory Cost (RTC) Values – computed based on flight operator provided algorithms to determine when alternative routes become beneficial to fly extra miles

How ATD-2 Predicts Delays Savings to Leverage TOS Benefits

Spacing and sequencing at RWY = Surface delay

Restriction is entered: Fix combined 10MIT Spacing and Sequencing at Dep Fix = Surface + Terminal delay

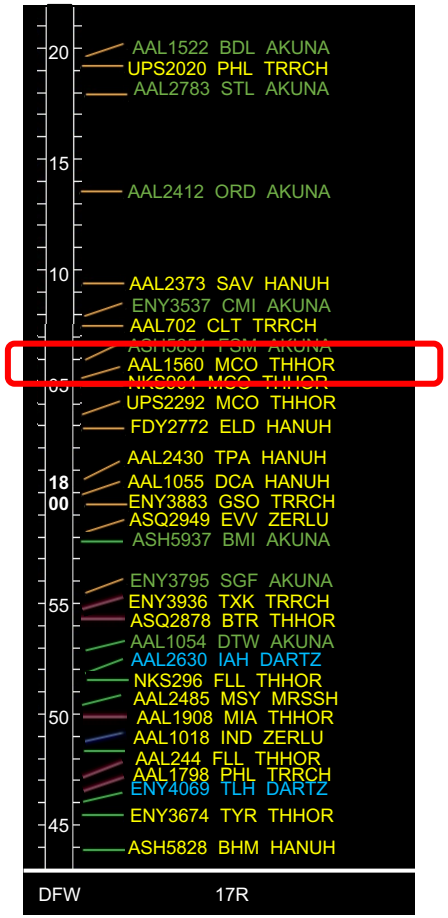
TOS Reroute Opportunities (Off-loading Demand) = Update demand and delay

Delay AAL1560 = 0min

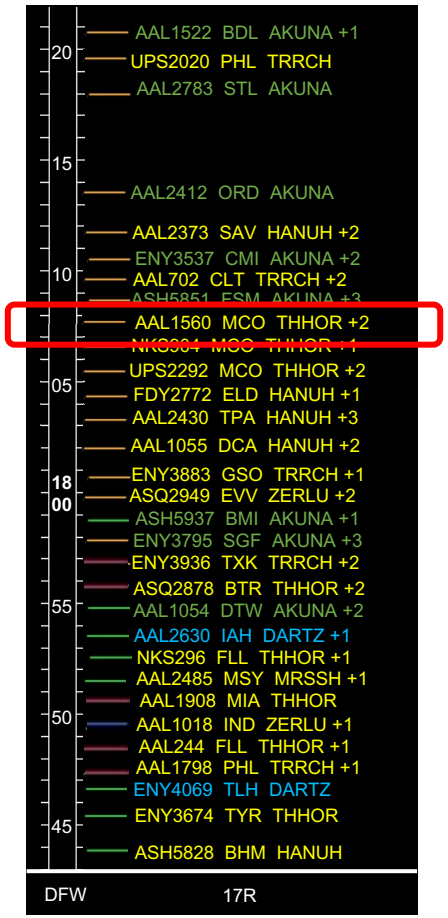
Delay AAL1560 = 2min

Delay AAL1560 = 12min

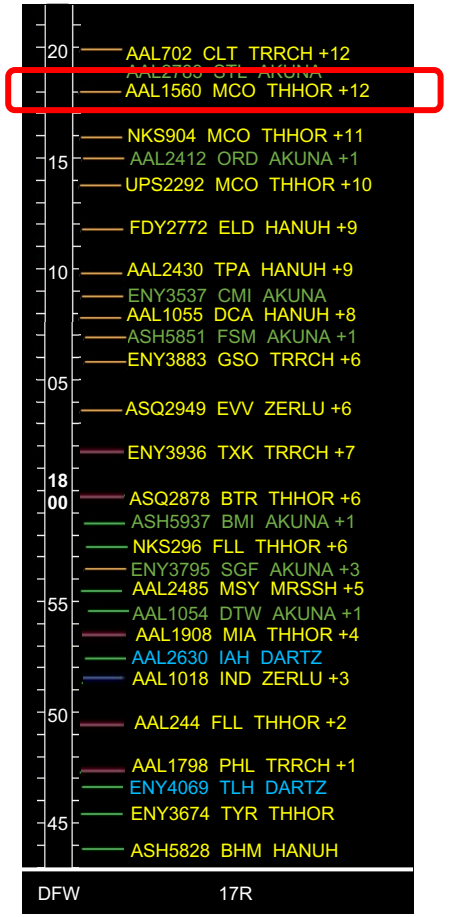
Delay AAL1560 = 0min
Delay Savings = 10min



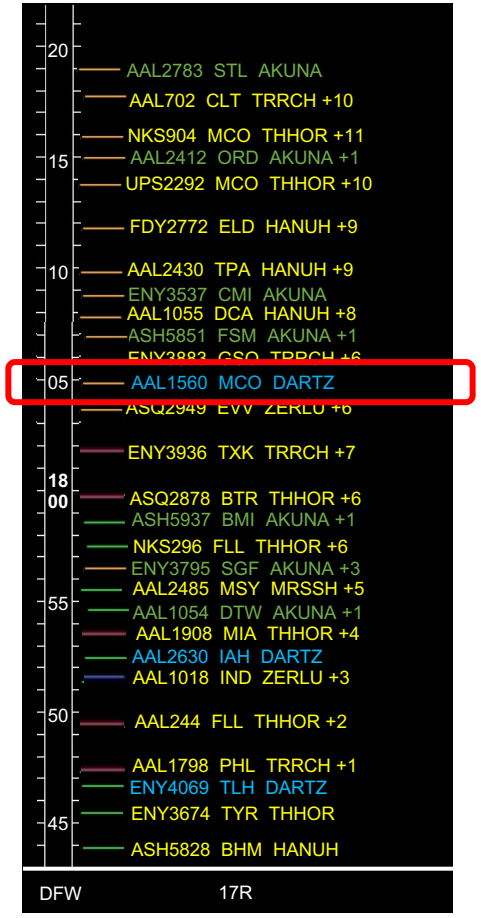
Undelayed TakeOff Times



Estimated TakeOff Times Incl. RWY spacing



Estimated TakeOff Times Incl. Terminal Restrictions



Updated Estimated TakeOff Times

Development and Engagement with Partners

Development Effort

- Concept development in 2018-2020
- Software enhancements 2019-2021
- 29 software releases (14 major, 15 patches, 1,600 software tickets) from May 2019 to September 2021
- 8 versions of the ATD-2 client (1 for each partner)
- 29 machines installed at partner's facilities

Engagement and Training

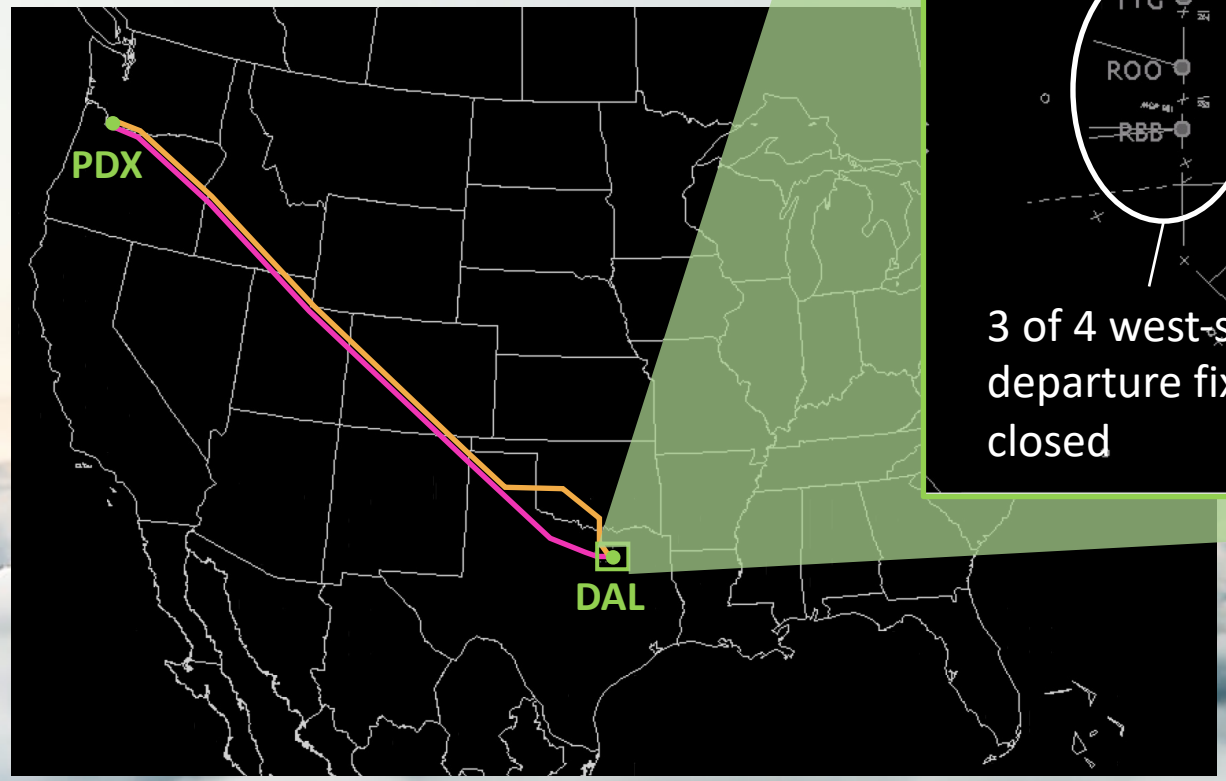
- Numerous preparatory meetings with field-demo partners at local and national levels
- Bi-weekly meetings from October 2020 to September 2021 (*"how goes it?"*)
- 85 field personnel trained
- Face-to-face training until COVID sheltering in place measures
- Remote training sessions after COVID
- 19 online tutorial videos on various aspects of the ATD-2 tool
- Slides tutorial packages
- 500+ pages of user manual accessible on operational machines

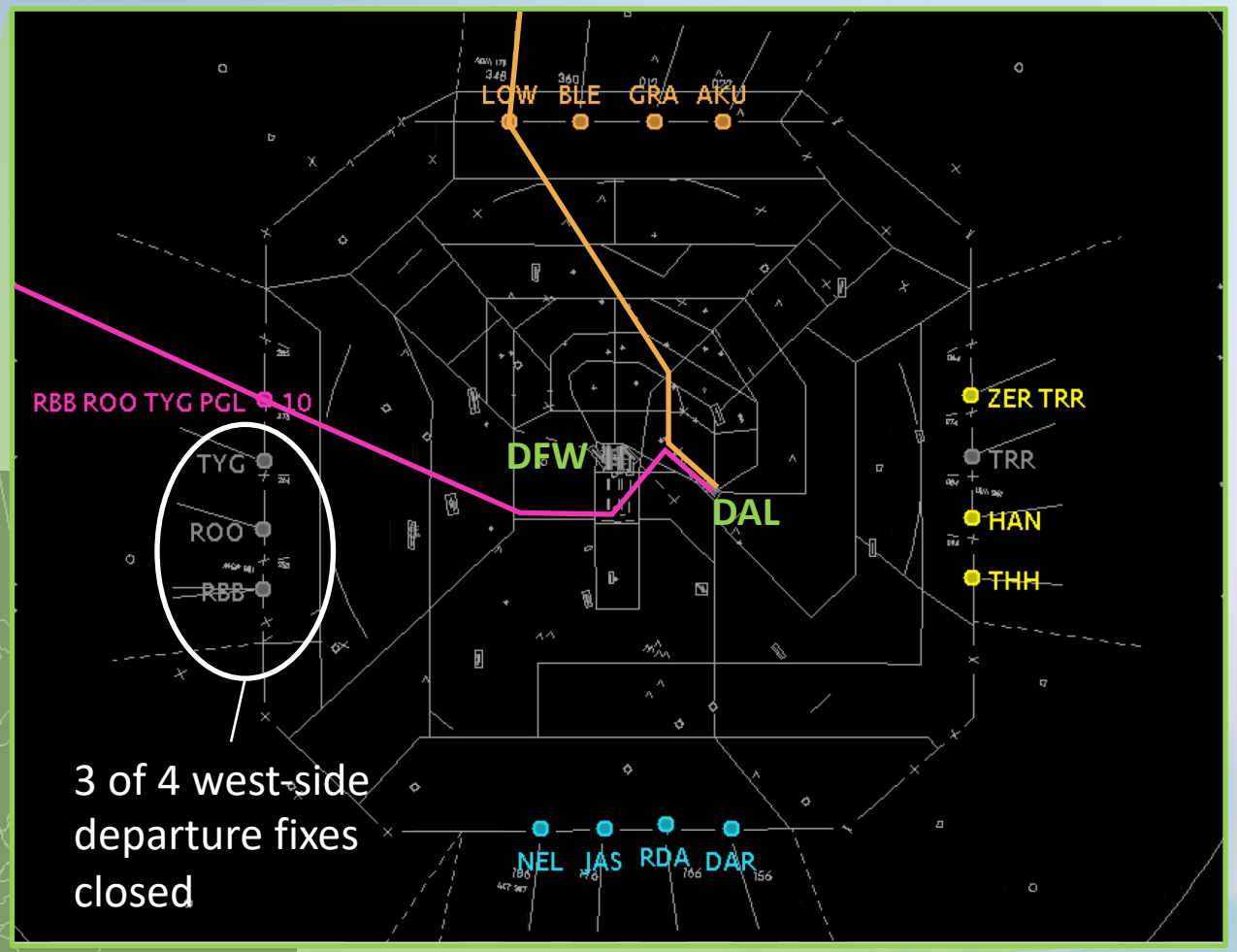
Notes Regarding Excluded Flights

- Date: 2020/11/22 to 2021/08/31
- 104 fights have received ATC reroutes
- 20 flights excluded from benefits:
  - Outliers (7)
  - Pilot refused (5)
  - Flight plan not amended after approval (2)
  - Flow change after approval (2)
  - Other unusual activity (3)
  - MEL after pushback (1)

Example of ATD-2 Phase 3 TOS Digital Reroute

- Southwest 2230 was initially filed on the **magenta route**
- ATD-2 projected surface delay due to constraints on the west departure gate
- Based on Southwest's TOS preferences, ATD-2 recommended the **orange re-route** out the north gate
- Even though the orange route is 37nm longer, Southwest 2230 flight saved 7 minutes of surface delay by taking the alternate reroute





On July 22, 2019, Southwest 2230 flew Dallas (DAL) to Portland (PDX) on the first reroute approved using the ATD-2 Phase 3 system.