Performance Improvements Through Trajectory Feedback in the Future Collaborative Flight Planning Environment

ATM Seminar 2015 Lisbon, Portugal

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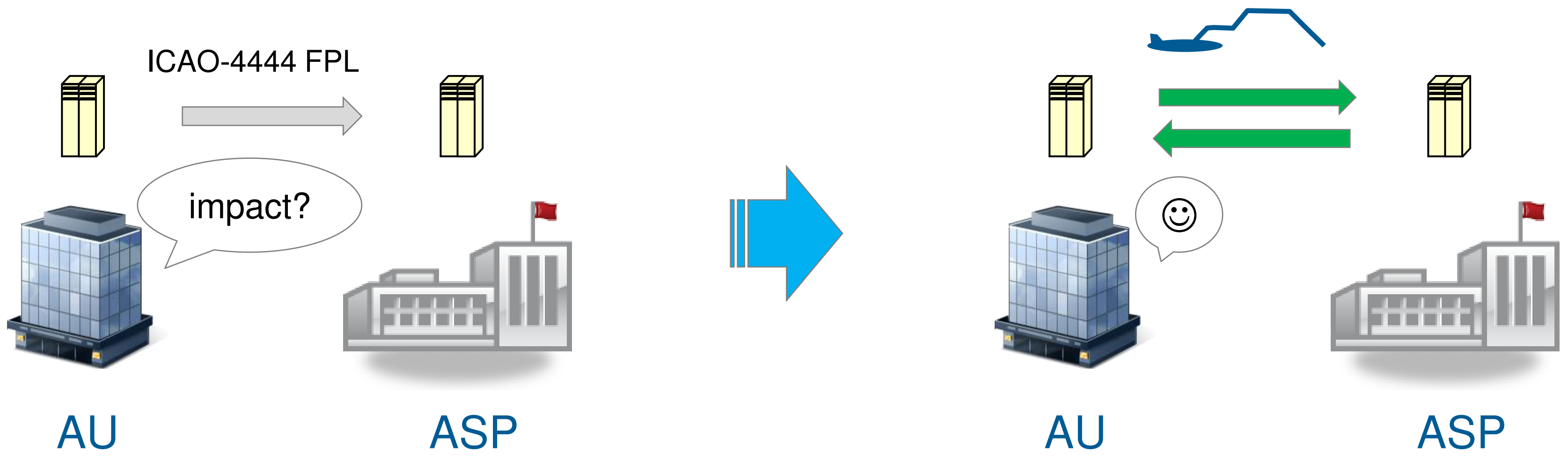
Overview

- **Background on the future collaborative flight planning environment**
  - Provides trajectory feedback in flight planning process:



- **Describe & investigate two benefits mechanisms for AUs to use feedback to**
  1. Optimize route selection
  2. Absorb delay on the ground in lieu of airborne holding

AU: Airspace User
ASP: ATM Service Provider

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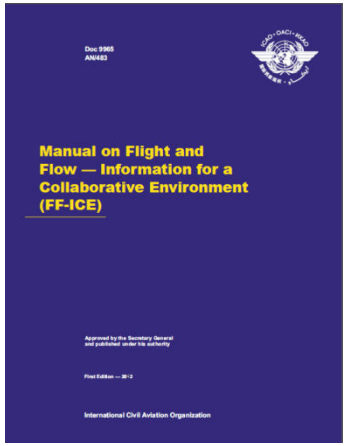
Background on the Future Collaborative Flight Planning Environment

Background on Flight Planning Changes

Nov. 2004 ICAO tasks a study group to modernize the ICAO flight planning provisions

FPLSG

- Near Term (ICAO FPL 2012) – State Letter 6/2008
- Farther term (FF-ICE)



ATMRPP

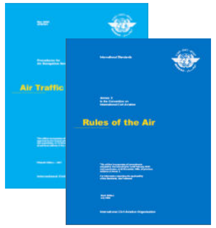
Meeting "expressed its full support for the concept and agreed there was a need for all partners to support a single concept of operations using FF-ICE"

Richer set of information exchange required for advanced capabilities

Seek extensible (XML) format allowing new items to be incorporated with shorter lead times

Information Standard

+

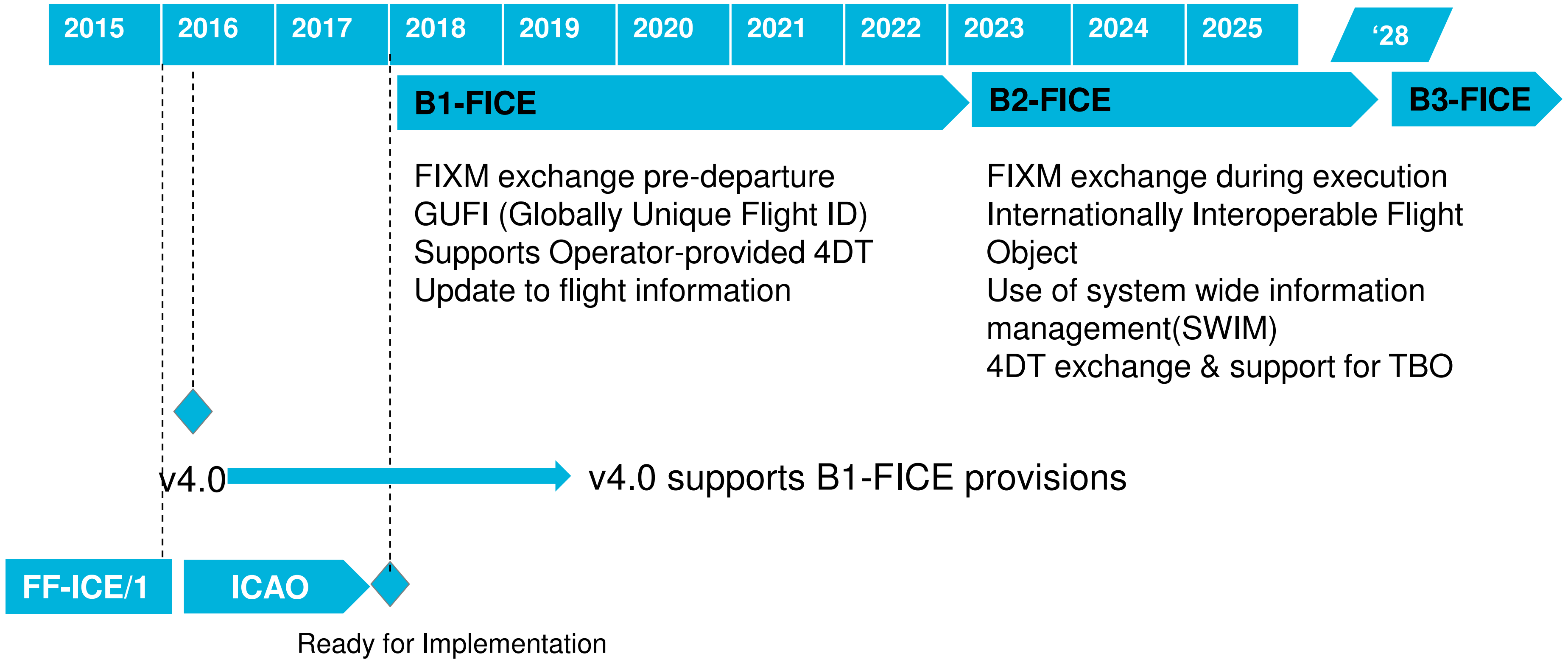


ICAO Provisions

Air Traffic Management Requirement and Performance Panel (ATMRPP)
Flight and Flow Information for a Collaborative Environment (FF-ICE)
Flight Information Exchange Model (FIXM)
Flight Plan Study Group (FPLSG)

Images: ICAO, fixm.aero

Timeline from ASBU FICE Thread



FIXM core is intended to be “globally applicable”

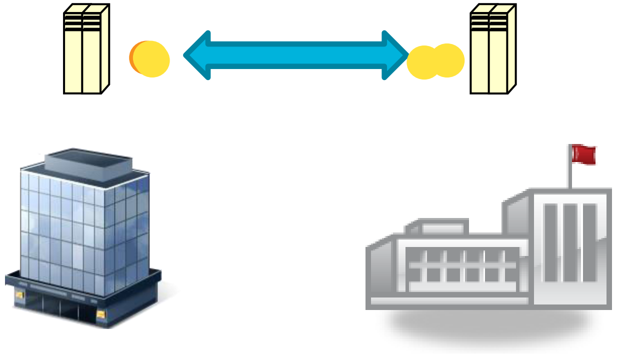
FIXM allows for Regional Extensions which are not in FIXM core

ASBU: Aviation System Block Upgrade
ASBU FICE: ASBU FF/ICE Thread

This effort focuses on some pre-departure benefits that could be delivered in Block 1

Pre-Departure 4DT Exchange Overview

Pre-departure



AU ASP

- Optional – ICAO Provisions do not describe
- ICAO Provisions will describe

Pre-negotiation

- Early Information (e.g. scheduling)
- Constraint Publication
  - Adaptation Information Exchange Model (AIXM)

Negotiation

- Flight Information & Desired 4DT
- Feedback on 4DT (Negotiating)
  - e.g. speed and altitude restrictions, re-routes

Agreement

- Plan filing and acceptance

Using Feedback to Optimize Route Selection (Pre-departure)

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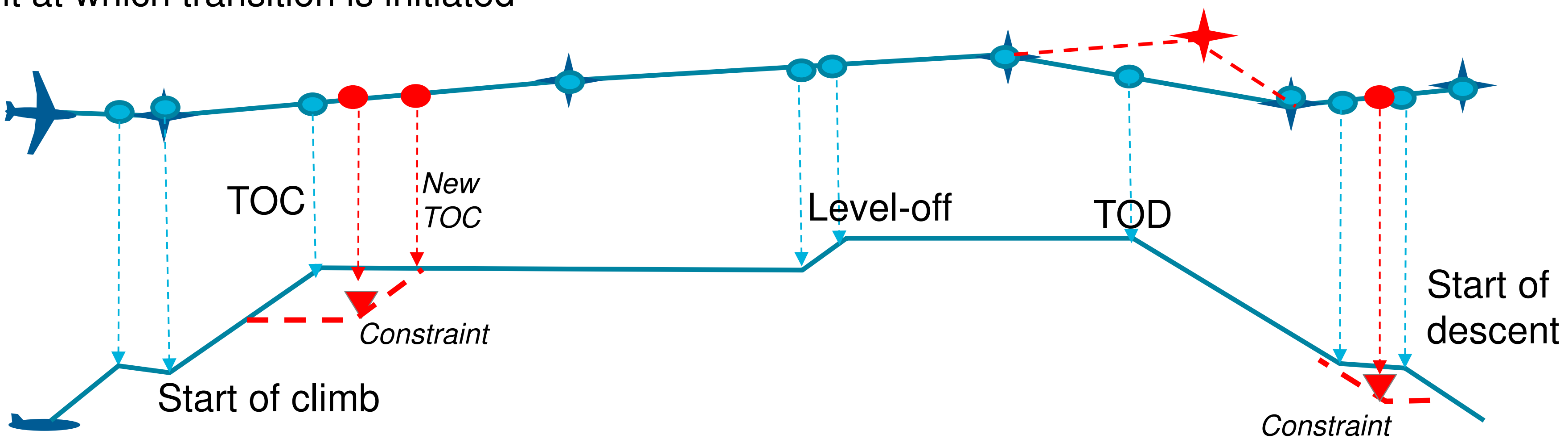
Feedback on 4DT

- **Constraints:**
  - Location of constraint
  - Altitude, speed or time values
  - Value type: AT, AT OR GREATER, AT OR LESS, BETWEEN
  - Activation type
    - Point at which the constraint is met, or
    - Point at which transition is initiated

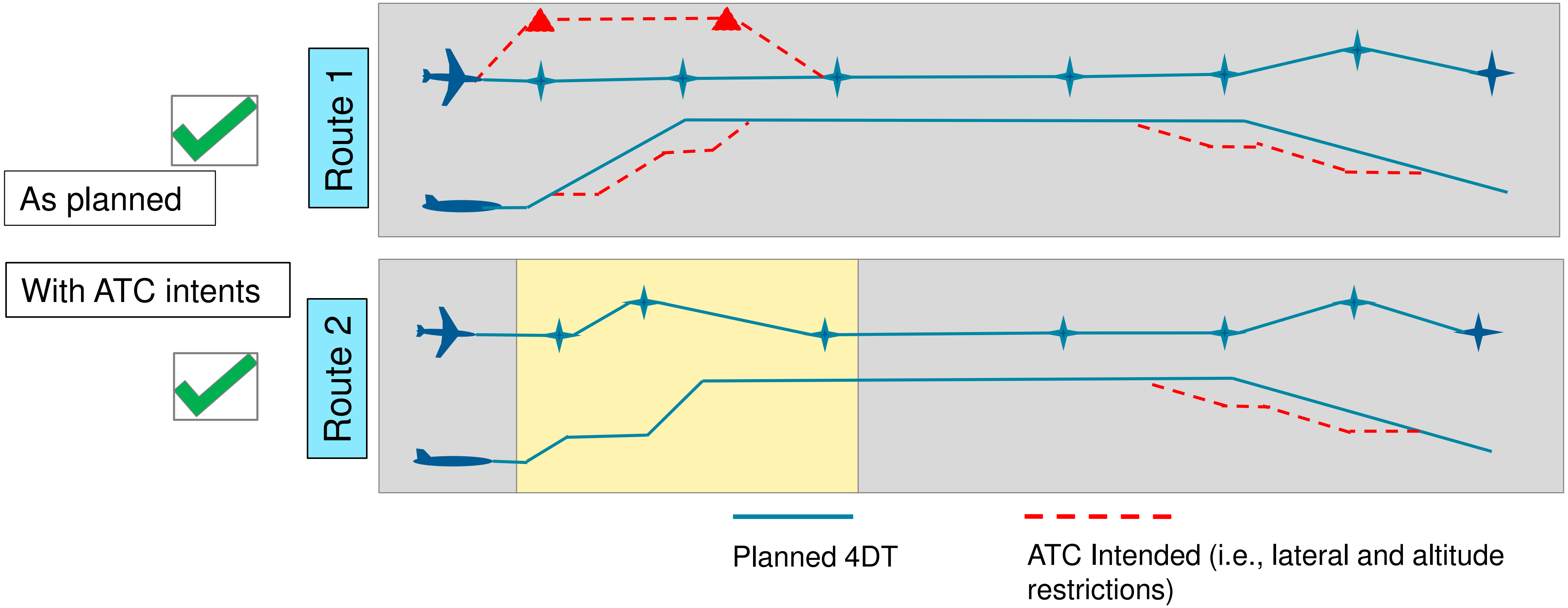
- **Lateral Path:**
  - Modified route
  - Indication of which points were modified



Profile affected by constraints

4DT Feedback for Route Optimization

- **Feedback enables AU to select optimal trajectory while meeting operational objectives**
  - FIXM supports parallel negotiations on multiple route-trajectory options



Approach

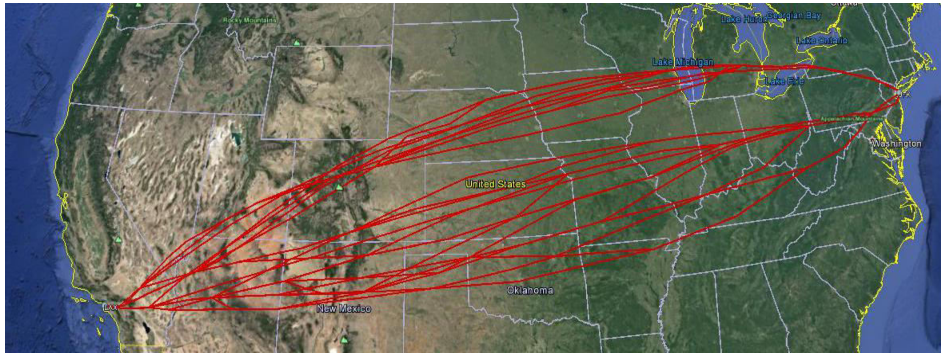
- **Cost of a trajectory for each of the N routes for a city pair**

Deterministic cost of filed 4DT

Cost of post-departure perturbations

$$C_i = c_i + \varepsilon_i + \eta_i \quad where\ i \in [1, N] \tag{1}$$

Cost of pre-departure perturbations; expected perturbations known but not currently shared by ASP

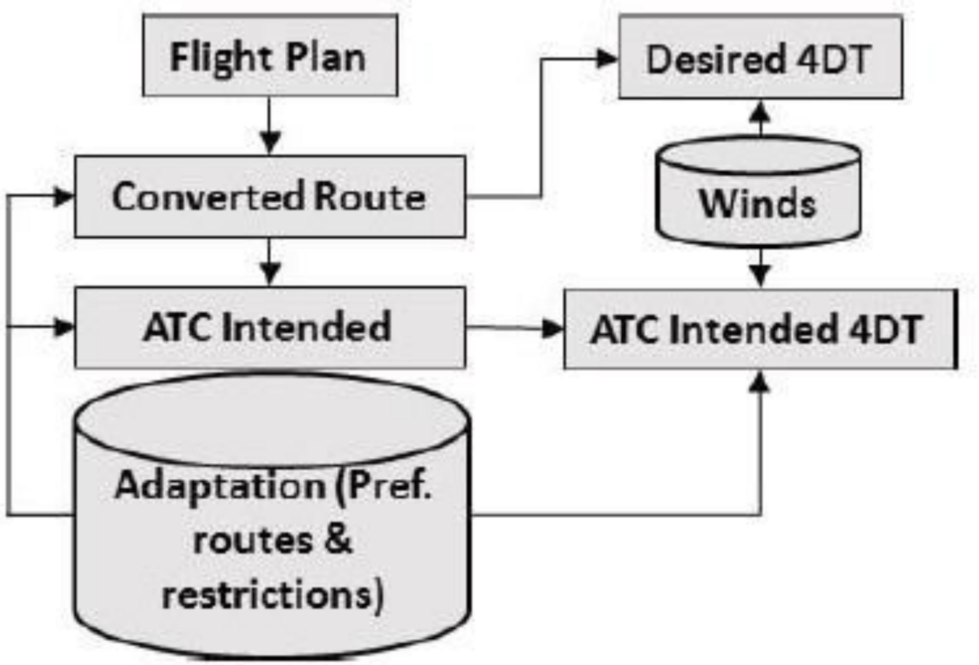


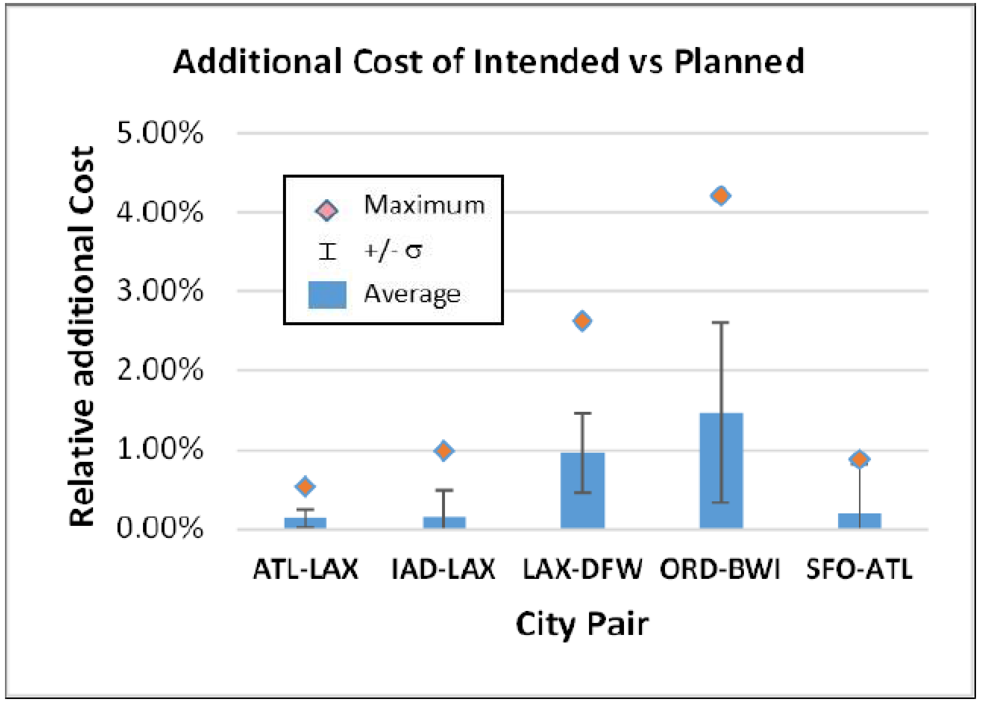
- **Selecting the least costly route**
  - Without feedback: $$C^* = \min_i \{c_i + E(\varepsilon_i + \eta_i)\} \tag{2}$$
  - With: $$C^* = \min_i \{c_i + \varepsilon_i + E(\eta_i | feedback)\} \tag{3}$$

Difference between (3) and (2) is the benefit of 4DT feedback

ε, cost of known perturbation

- ε = cost of ATC intended – cost of planned 4DT



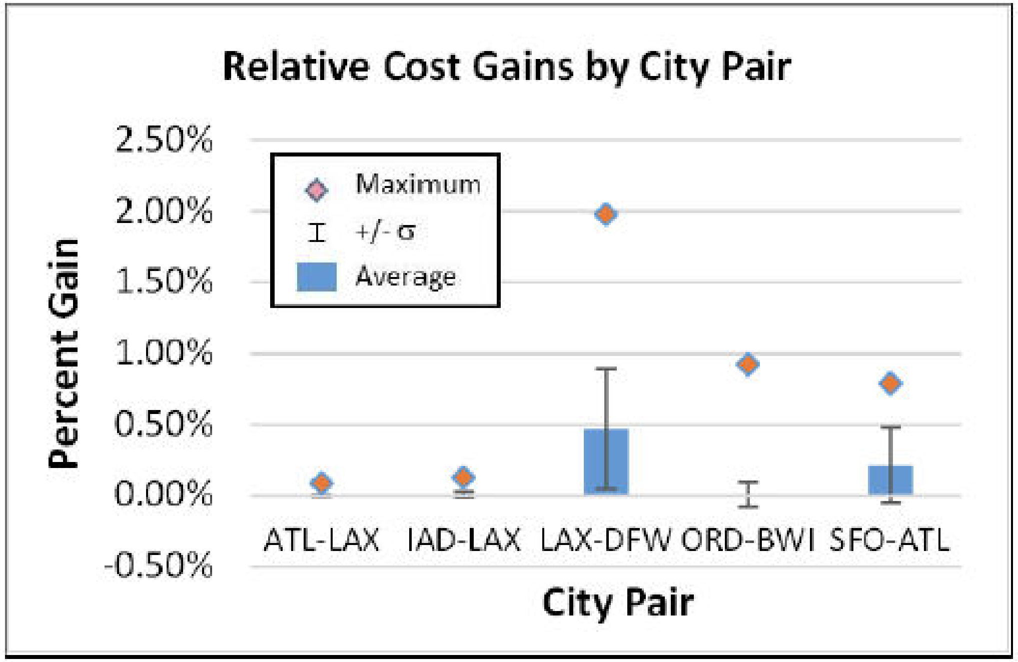


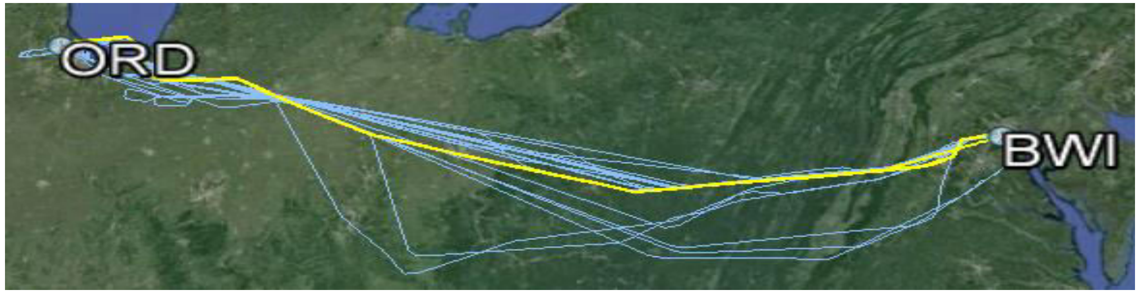
- Estimated Cost Index (CI) was used to combine the fuel and time costs
- CI was estimated by perturbing speed on the desired 4DT and obtaining resulting fuel and time perturbations

LAX-DFW and ORD-BWI flights were frequently subjected to ATC changes

Benefits are City-Pair Dependent

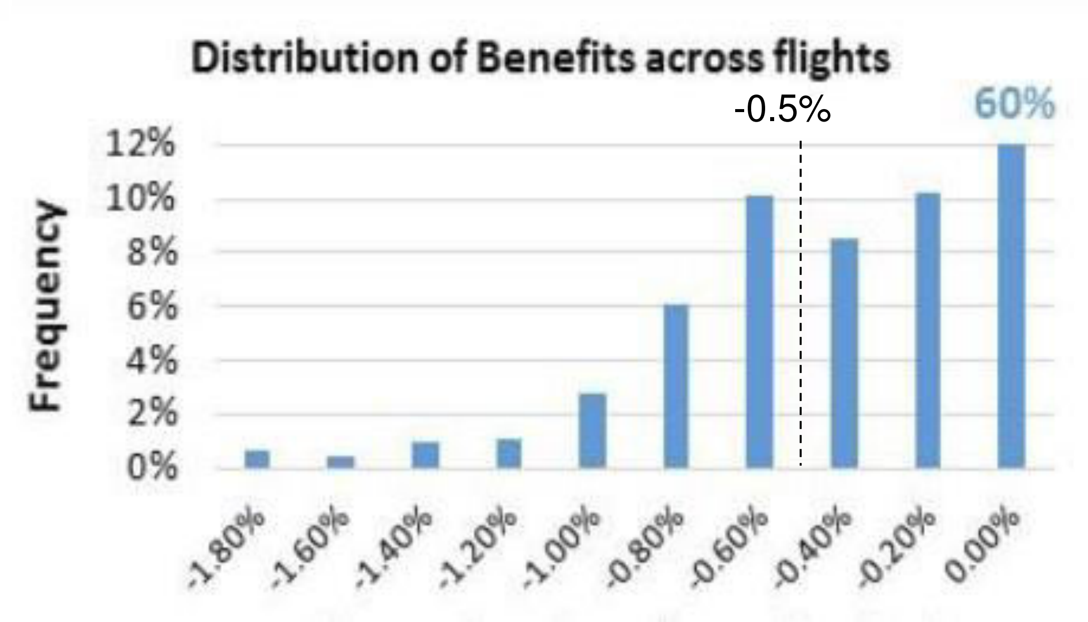
- Benefit = cost difference between best routes selected with and w/o feedback
  – Using the distribution of ε for each route



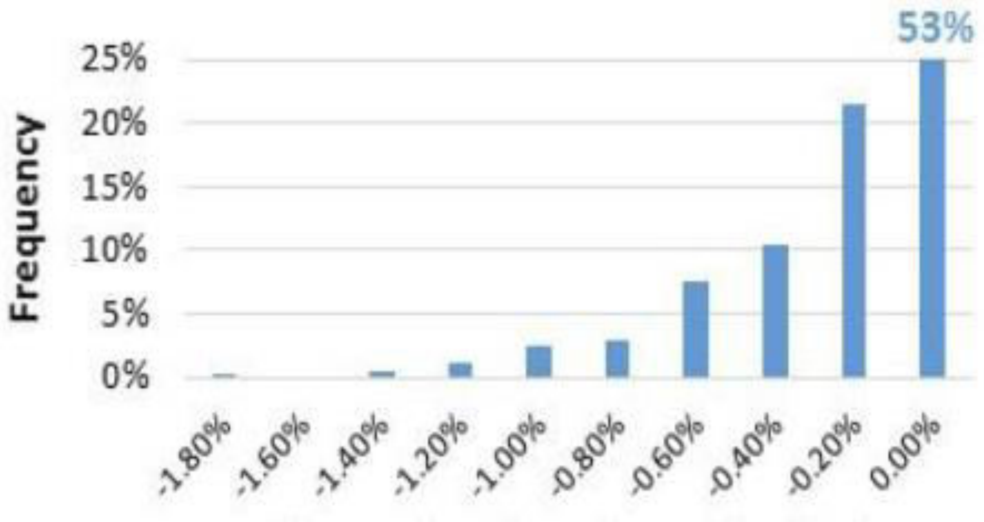


Frequently no alternative plans between ORD-BWI

Cost Savings from Trajectory Feedback



After applying route specific historical knowledge when feedback is not available



- **Average savings of 0.2% in planned flight cost**
  - 0.19% saving in fuel consumption when CI set to 0
- **Average savings in planned flight cost is reduced but still at 0.15%**
  - Shows it is more beneficial to use trajectory feedback than to guess with the past knowledge

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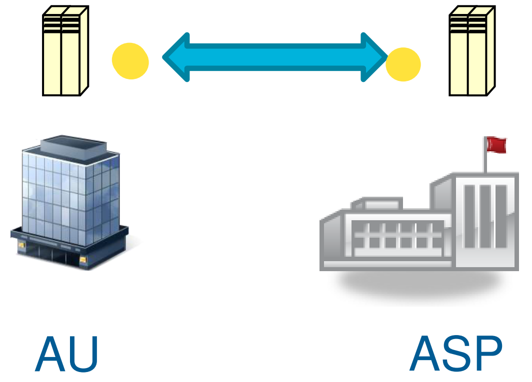
Using Feedback to Absorb Delay on the Ground versus Airborne Holding

Using pre-departure exchange between a flight operator and a downstream ANSP

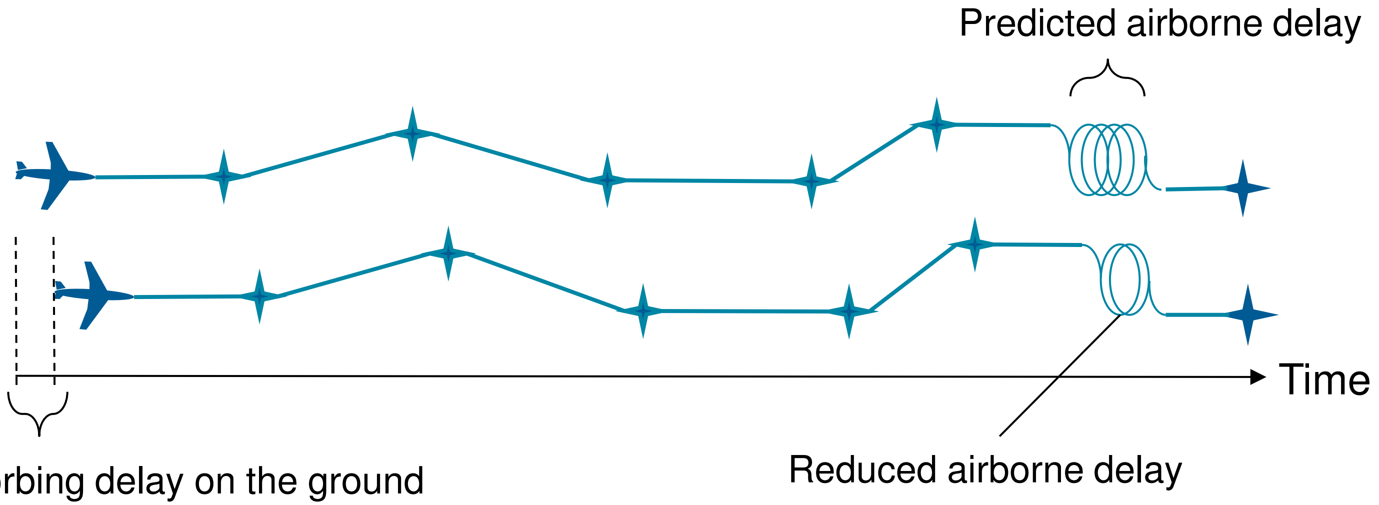
4DT Feedback for Delay Optimization

- **Enables downstream ASP-AU dialogue on ATFM constraints†**
  – AU may choose the best delay absorbing strategy (e.g. ground delay, speed control)



Negotiation
- Initial 4DT
- Estimated flight-specific delay distribution
- Revised 4DT with delay absorbing strategy

As an example, this paper estimates benefits of AU taking portions of delays on the ground



†*Many alternative strategies could be developed using FF-ICE as enabler*

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Approach

- **Two Monte Carlo simulations were developed to estimate delays**
  a. Tactical airborne delays
     - Arrival spacing based on airport capacity and First-Come-First-Serve (FCFS) approach

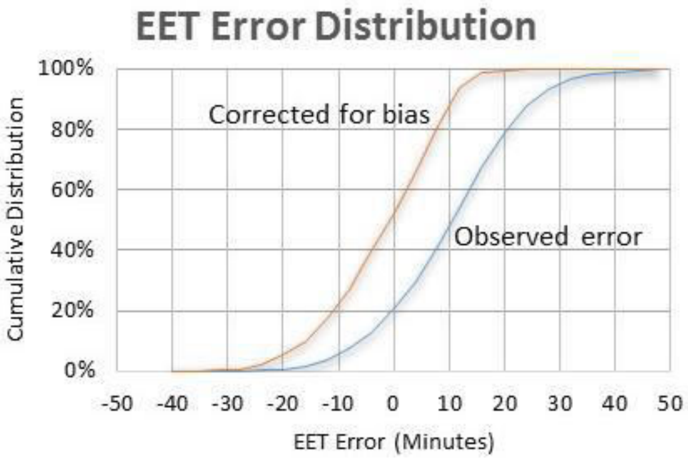
Filed scheduled departure time

Filed estimated elapsed time (EET)

$$\hat{t}_{arr} = t_{sched} + \varepsilon_{dep} + t_{flight} + \varepsilon_{EET}$$

Departure time error

EET error

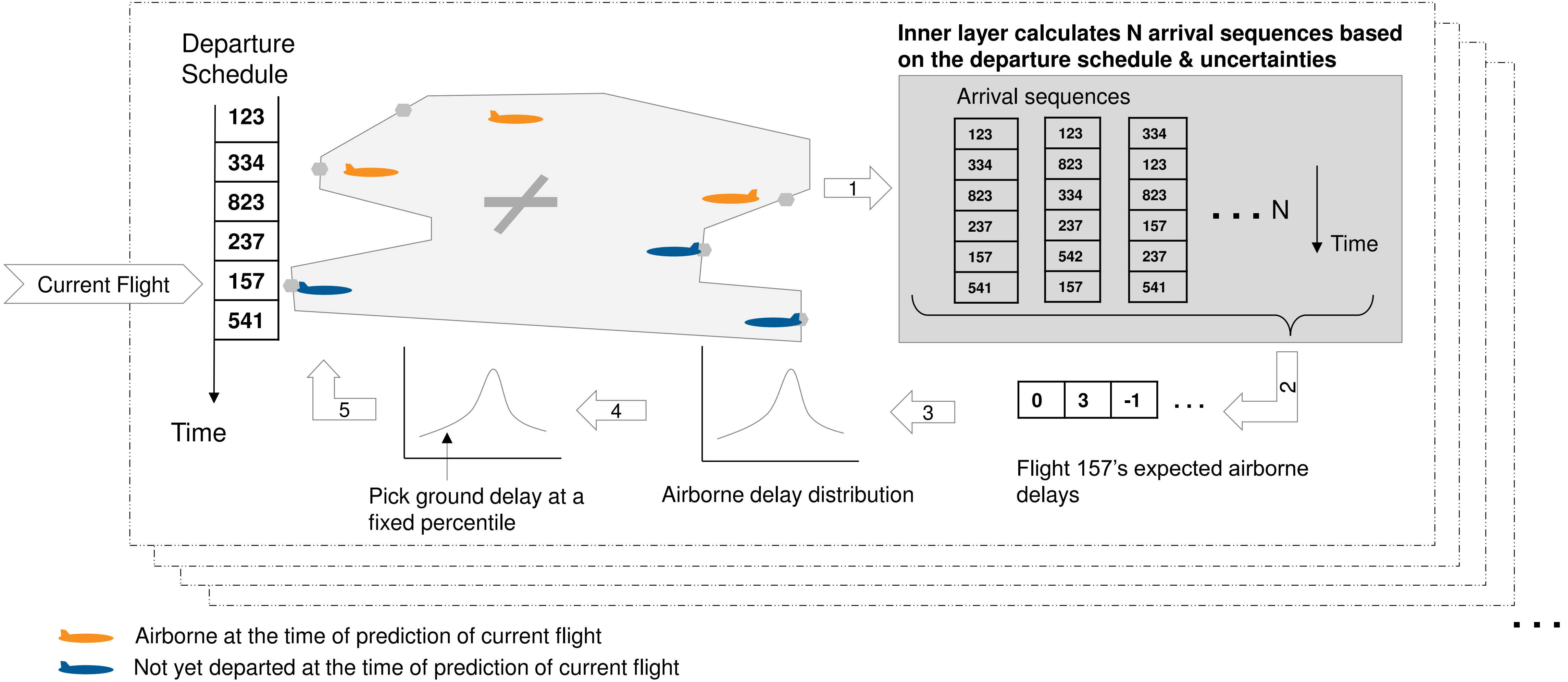


- Distribution obtained from operational data
- Similar approach to departure time error (simulation did not condition on departure airport)

  b. Absorbing some of the airborne delays on the ground
     - Multi-layer Monte Carlo simulation, detail as follows

Multi-layer Monte Carlo Simulation Illustrated

Outer layer, each run produces a departure schedule for the simulation



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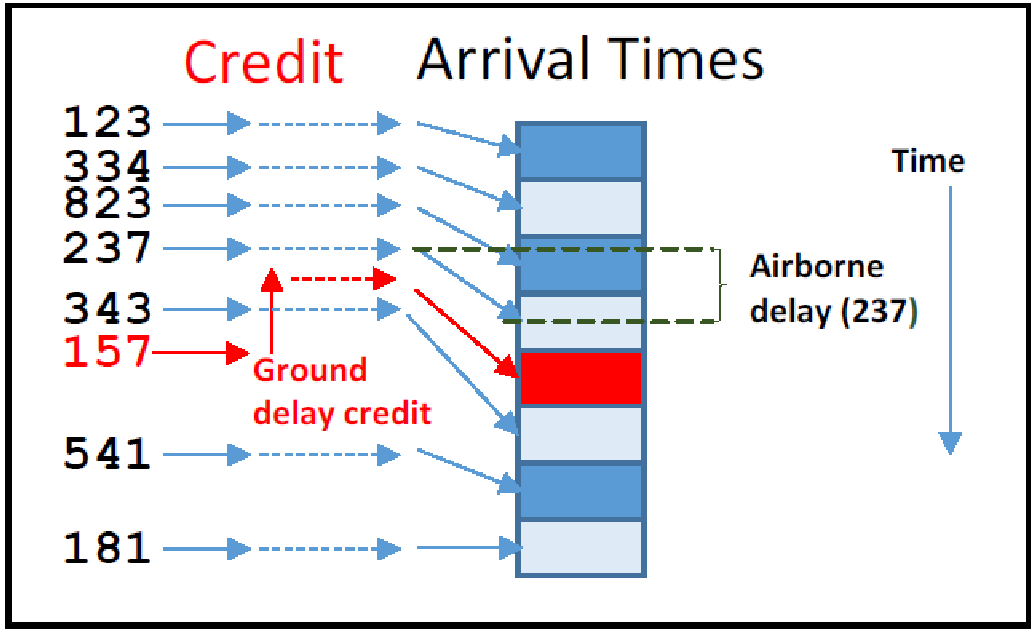
Absorbing Delays on the Ground

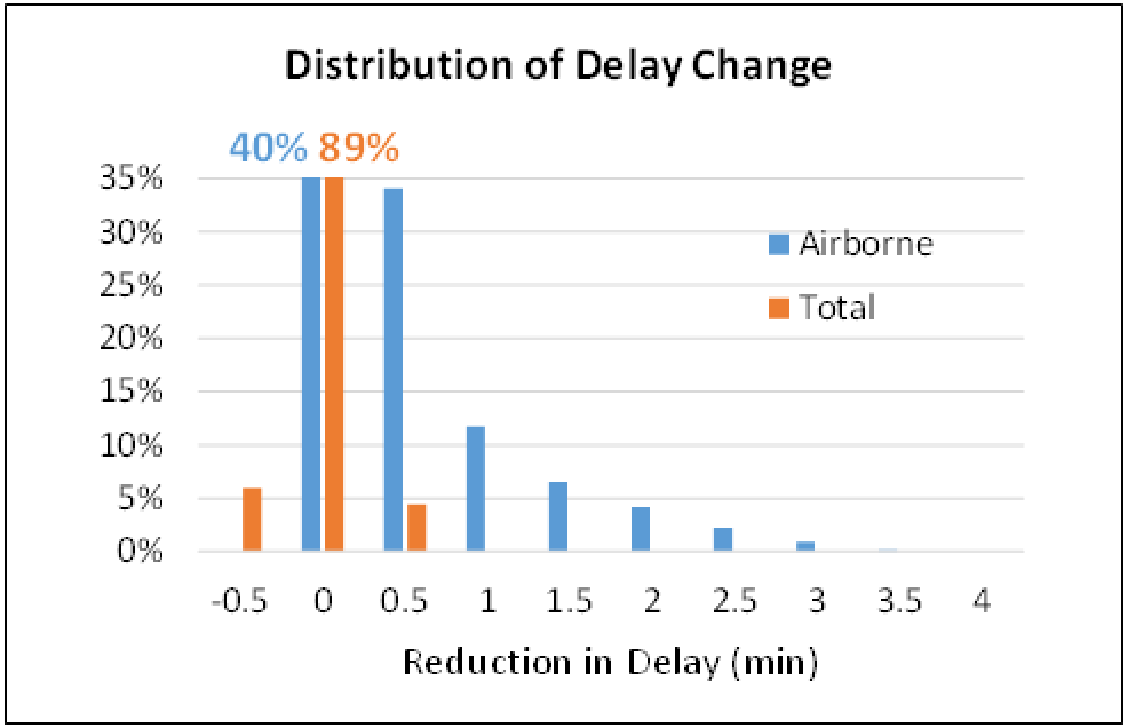
- **Credit system that honors delay taken on the ground**
  - FCFS assignment modified by ground delay credit



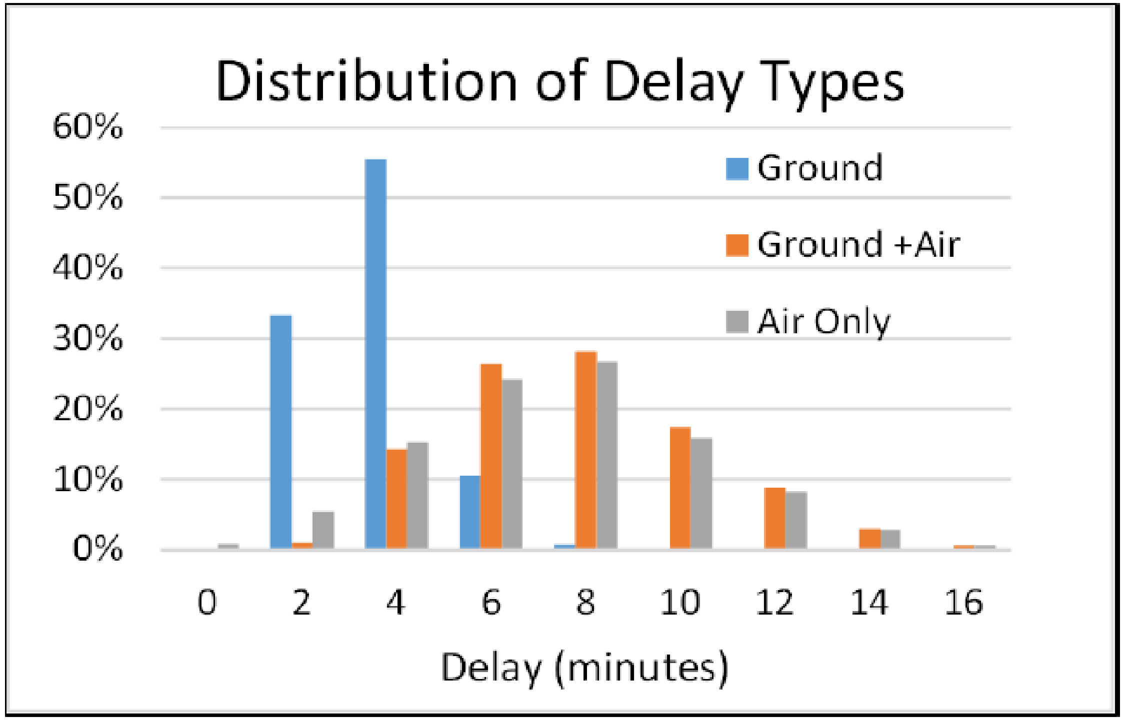
- **Ground delay threshold**
  - Only take minimal airborne delay on the ground to prevent missing arrival slots (i.e., the deterministic component of the delay distribution)
  - Future search: consider the probability of system-wide delay instead of the single-flight delay

Simulation Results

All Flights



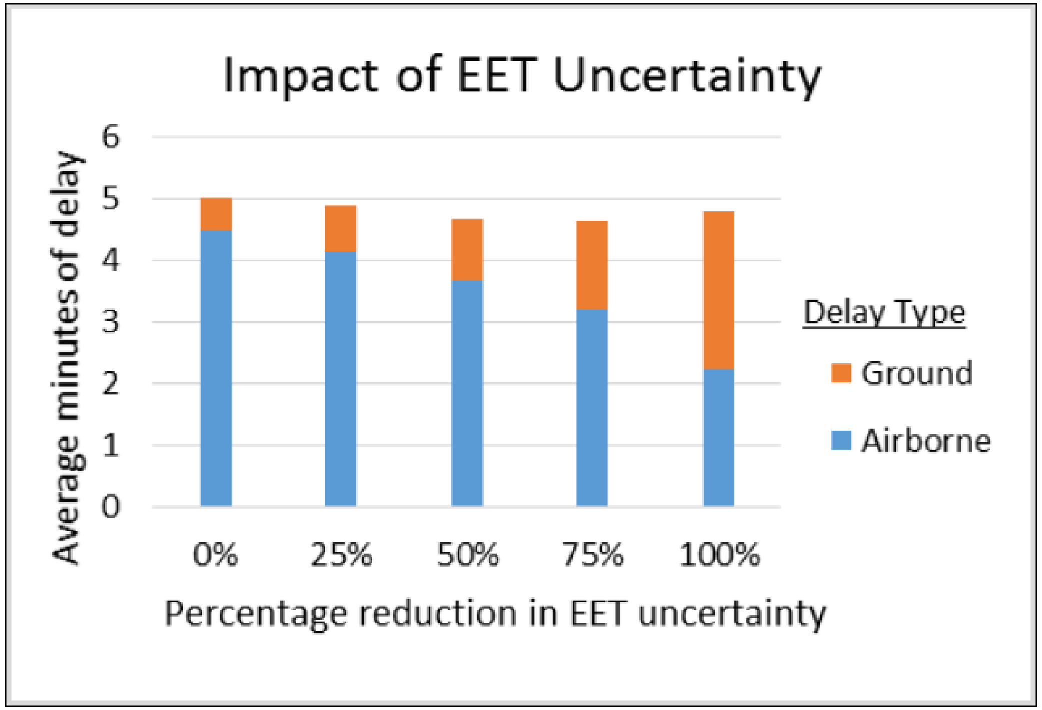
Those that took ground delay



- Total delay – flights sometimes do better, other times not
- Airborne delay – majority of flights get a reduction

- 4.1 minutes of airborne delay (with ground delay) vs 6.4 minutes airborne delay (without)
- Ground delay averages 2.6 minutes, when taken

Impact of Uncertainty



- Illustrates impact of improving trajectory prediction
- Improved airborne uncertainty allows greater certainty of delay prediction
- Total delay remains approximately constant
- Eliminating EET uncertainty results in 50% reduction in airborne delay

Conclusions

- **Pre-departure feedback on automation-imposed re-routes and altitude/speed constraints:**
  - Allows users to pick a more optimal plan → 0.2% improvement in planned cost of flight
  - Applying historical impacts → 0.15% improvement in planned cost of flight
  - Across major US carriers, these cost changes are on the order of $100 million per annum
  - Further evaluation to include estimates of as-flown perturbations (η) is necessary
- **Use of pre-departure feedback to enable improved ground/airborne allocation**
  - Recognize this is an example of a benefit that may have significant operational challenges
  - Illustrates one way in which FF-ICE/1 allows one ASP to influence flights earlier for benefits:
    - In our example: 138 flights potentially could save ~ 5-13 million kg of fuel per annum at one airport
  - Other mechanisms (e.g. linear holding) could be applied post-departure (FF-ICE, ASBU Block 2)
- **Further exploration of FF-ICE/1 benefits through pre-departure flight-specific feedback is needed**

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Thank you