NASA's Research on an Integrated Concept for Airport Surface Operations Management

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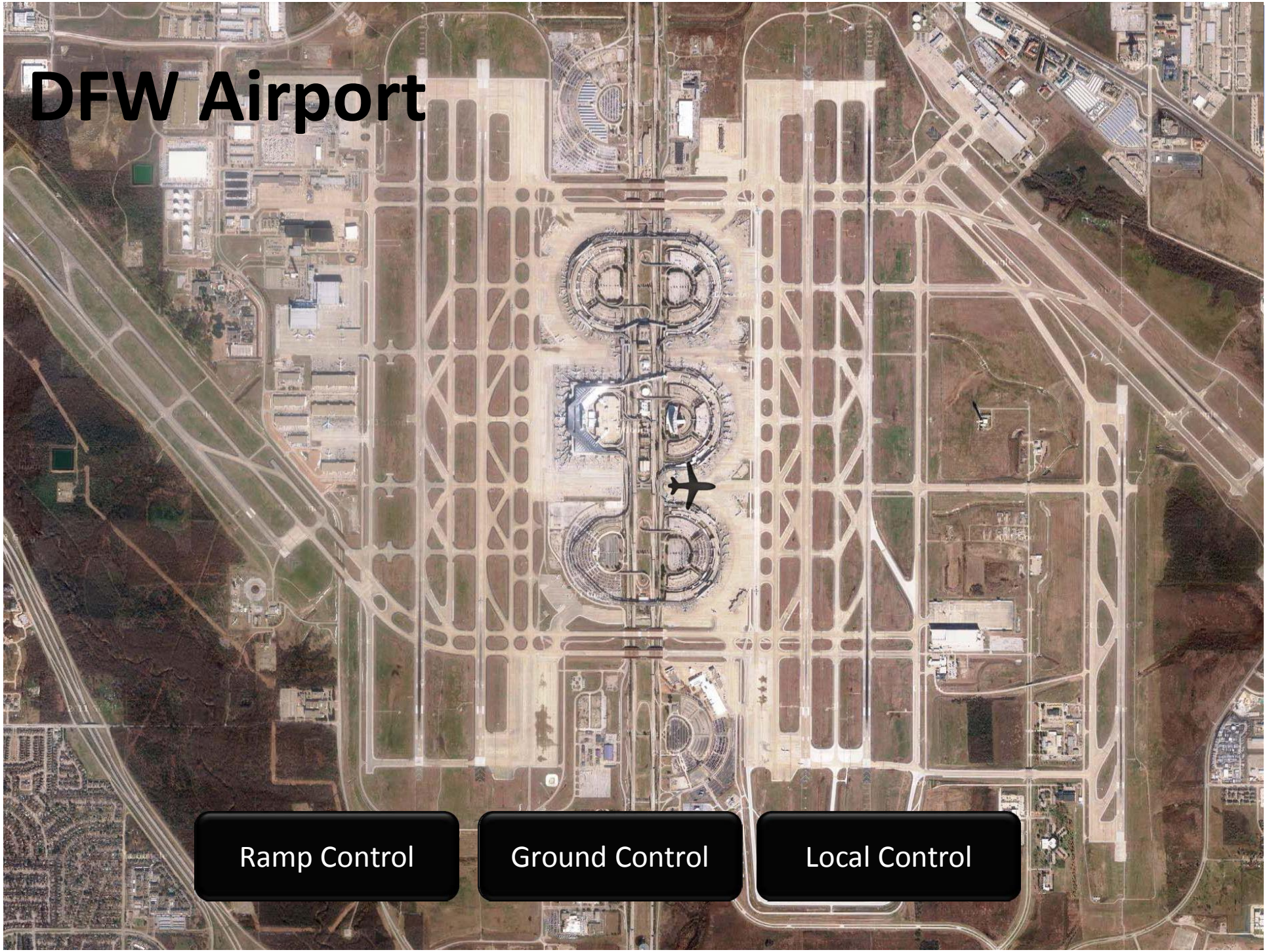
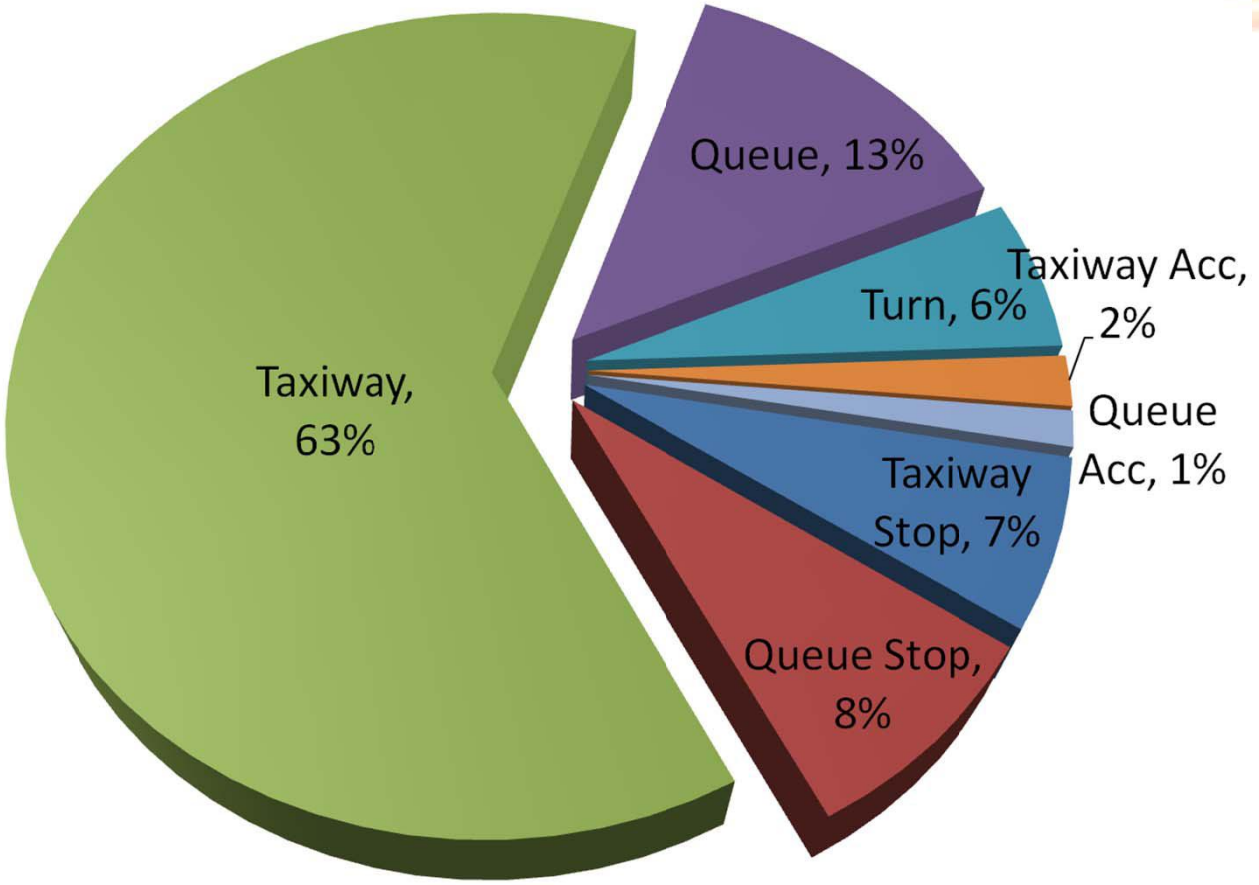
DFW Airport



Fuel Consumption at DFW

- Analyzed surface data for three months in 2008
- Estimate 120,000 kg of fuel used in surface operations per day
- Approximately 21,600kg or 6,980 gallons of fuel in stop and go per day
- Converted to a year, approx 5 million USD



Source: Nikoleris T, Gupta G and Kistler M. *Detailed Estimation of Fuel Consumption and Emissions during Aircraft Taxi Operations at Dallas/Fort Worth International Airport,* Transport Research Part D: Transport and Environment, Vol 16, 2011

DFW Airport

- Currently, aircraft delays at runway queue
- Excess taxi-out times, fuel consumption and emissions
- Departure metering: limiting aircraft near runway and taxiways

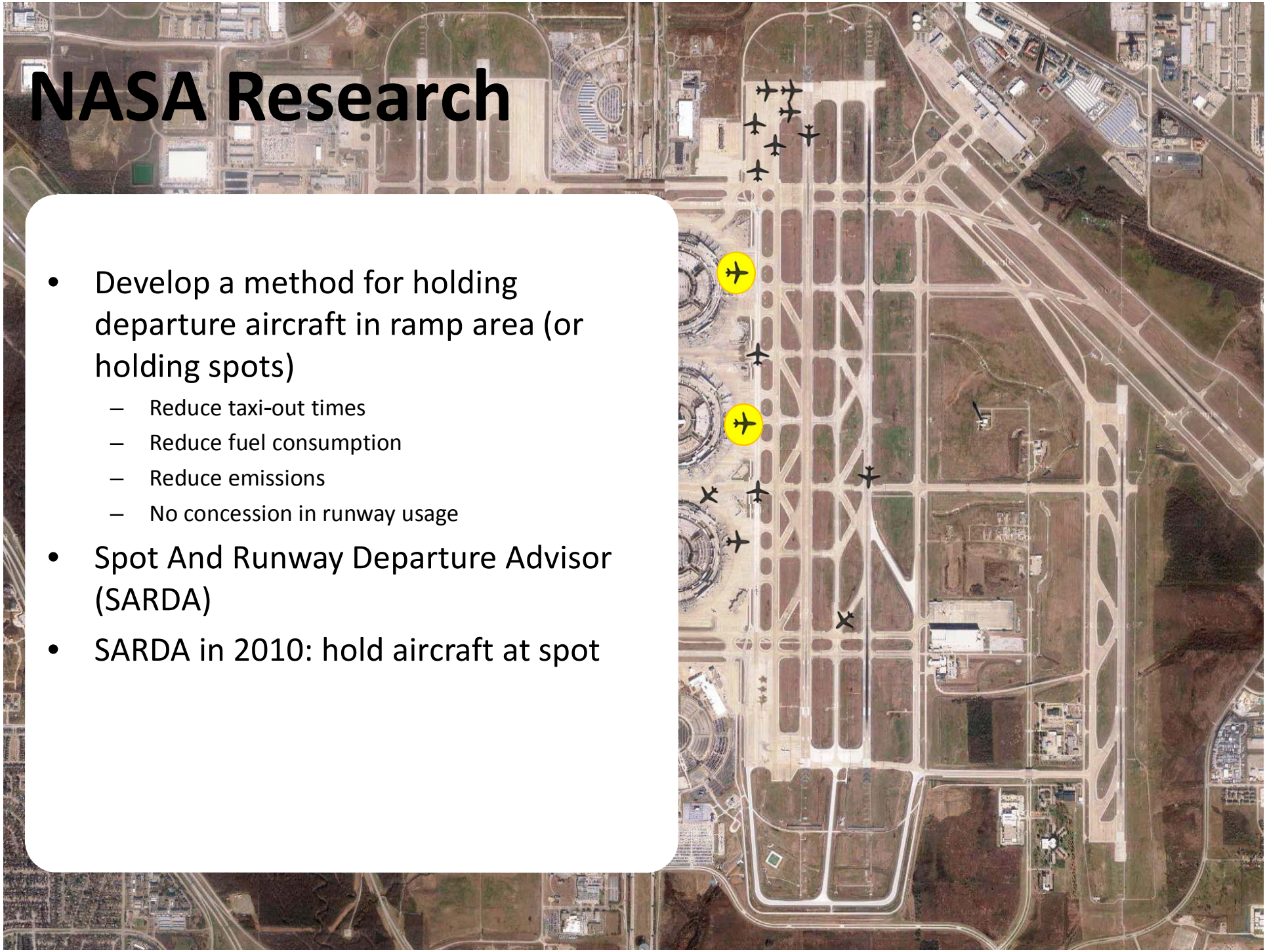
Potential Benefits of Airport Departure Metering

- Two recent FAA sponsored studies:
  - At 8 major US airports, cumulative fuel savings of **$2.3 billion USD** from 2010 to 2030[1]
  - Using FY2011 traffic data, benefits at 43 top US airports can range from[2]:
    - 52k to 372k taxi hours reduction
    - $42 million to $300 million USD fuel reduction in FY2012 dollars

1. *An Approach for Estimating Current and Future Benefits of Airport Surface Congestion Management Techniques.* Alex Nakahara, Tom Reynolds. 12th AIAA Aviation Technology, Integration, and Operations (ATIO) Conference and 14th AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference, 2012
2. *Estimating the Achievable Benefits of Airport Surface Metering.* Tim McInerney, Daniel Howell. 12th AIAA Aviation Technology, Integration, and Operations (ATIO) Conference and 14th AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference, 2012

NASA Research

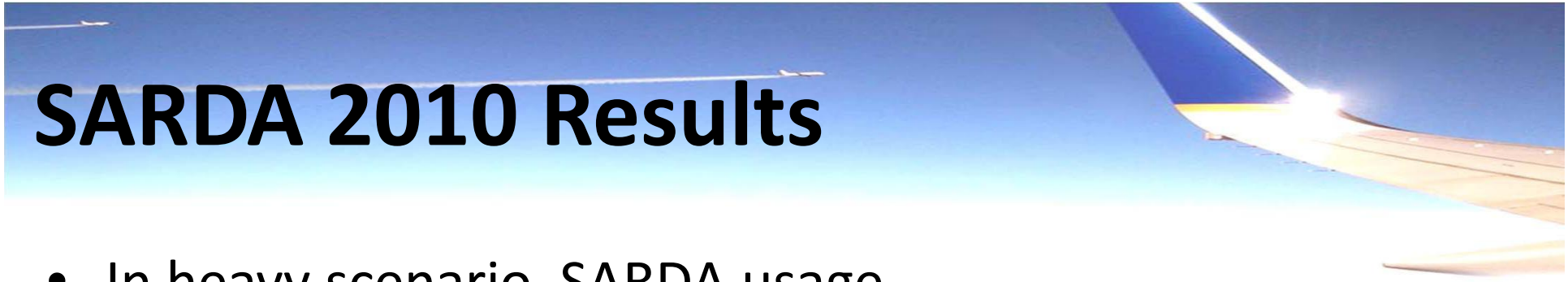
- Develop a method for holding departure aircraft in ramp area (or holding spots)
  - Reduce taxi-out times
  - Reduce fuel consumption
  - Reduce emissions
  - No concession in runway usage
- Spot And Runway Departure Advisor (SARDA)
- SARDA in 2010: hold aircraft at spot



SARDA testing in 2010

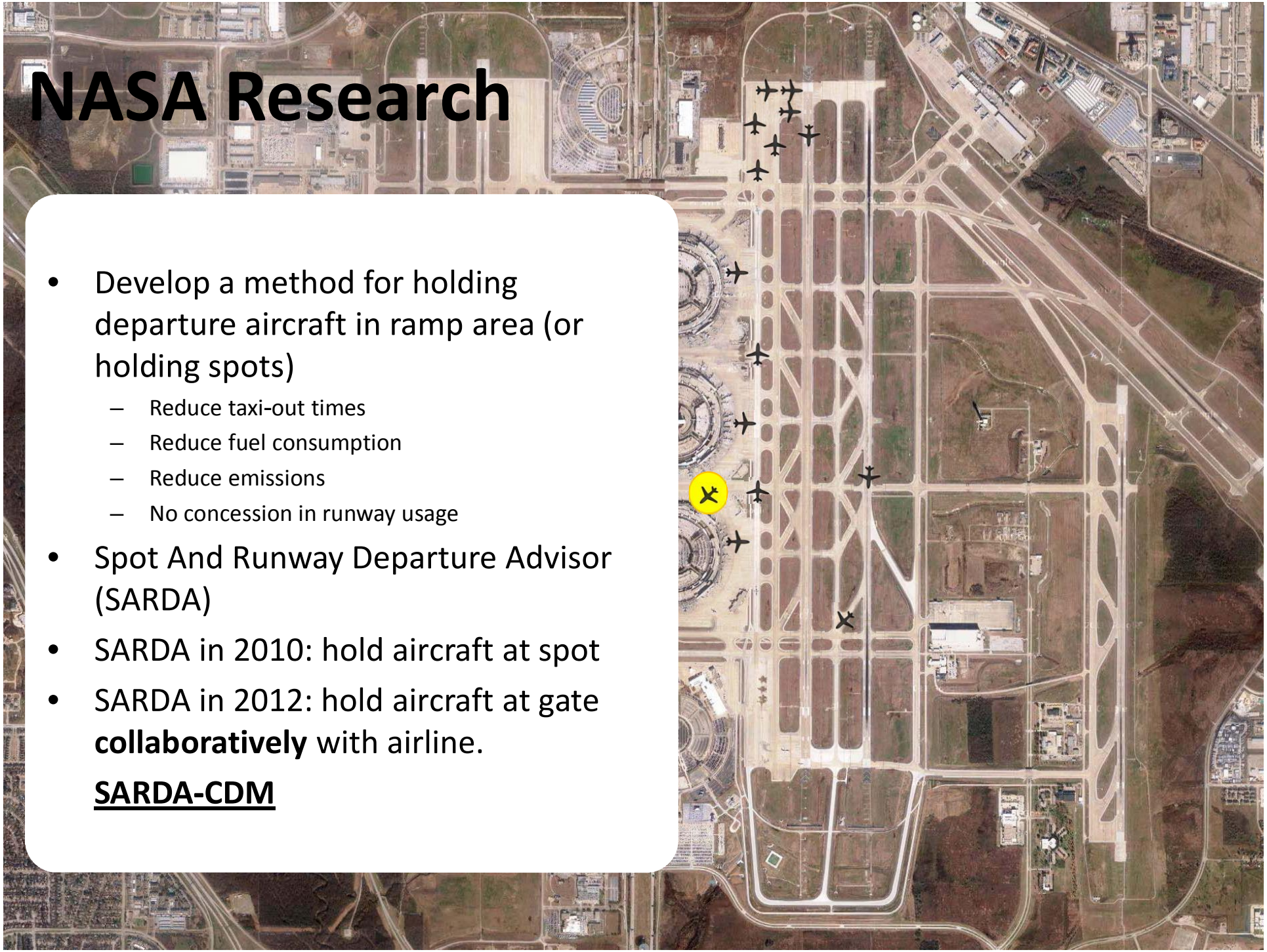
- SARDA concept: hold departure aircraft at spot **tactically**
- Provide advisories to ATCT controllers
- Human in the loop simulations
  - Retired ATCT controllers
  - Human “psuedo-pilots”
  - Selected airport modeled after DFW airport, but several differences
  - 2 weeks of simulations, 56 runs
  - Varying traffic levels (Normal and Heavy)
  - Several advisory conditions

SARDA 2010 Results



- In heavy scenario, SARDA usage
  - Decreased average departure stops from 8.5 to 5.5
  - Decreased movement area departure delay by 66%
  - Decreased movement area departure fuel consumption and emissions by 38%
- Human factor observations
  - Heavy traffic increased perceived workload
  - Little impact of advisories on perceived workload. Expectation of workload alleviation offset by advisories differing from what they would do
  - “If metering required, would like the advisory”

NASA Research



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  - Reduce taxi-out times
  - Reduce fuel consumption
  - Reduce emissions
  - No concession in runway usage
- Spot And Runway Departure Advisor (SARDA)
- SARDA in 2010: hold aircraft at spot
- SARDA in 2012: hold aircraft at gate **collaboratively** with airline.

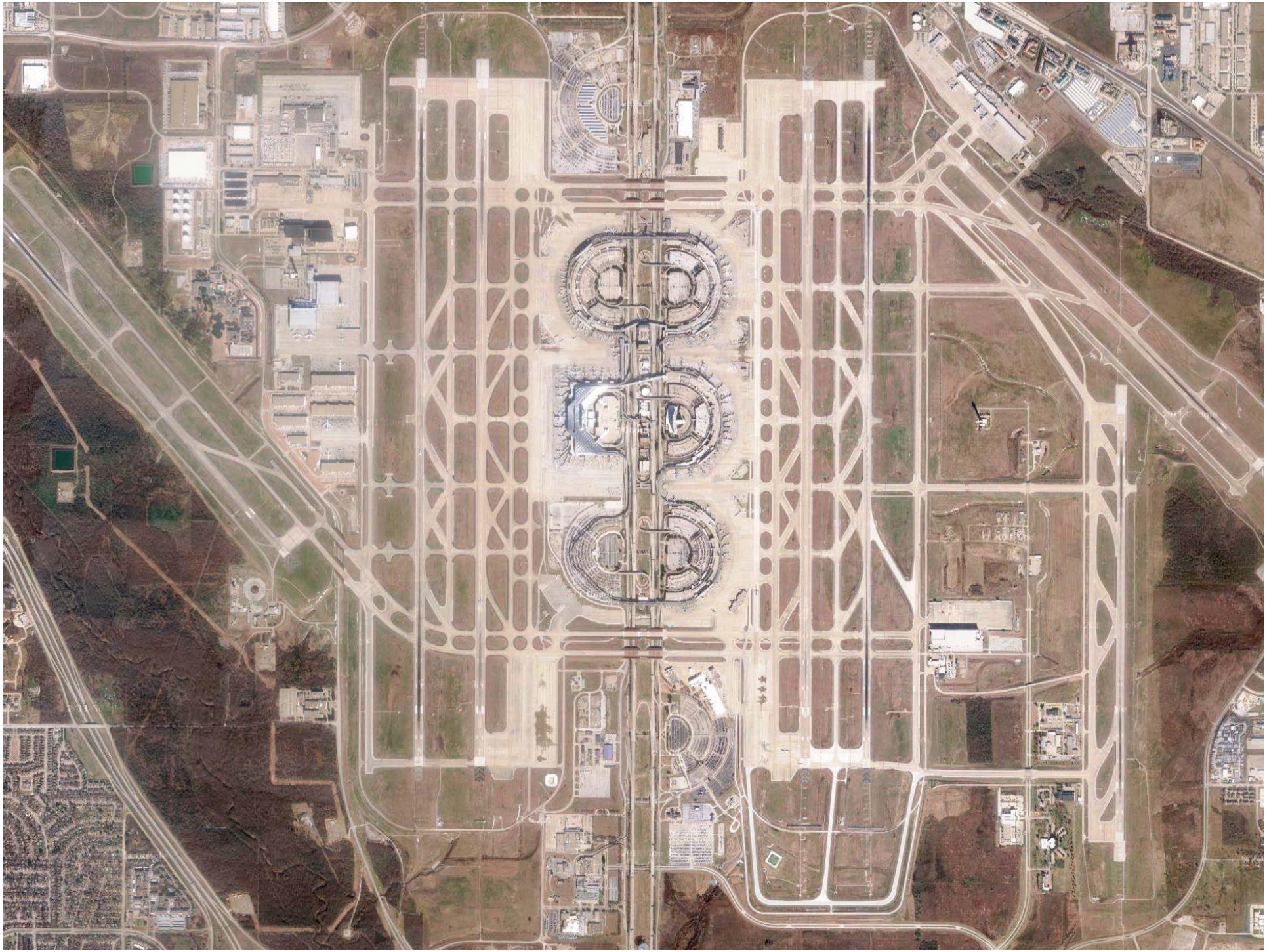
SARDA-CDM

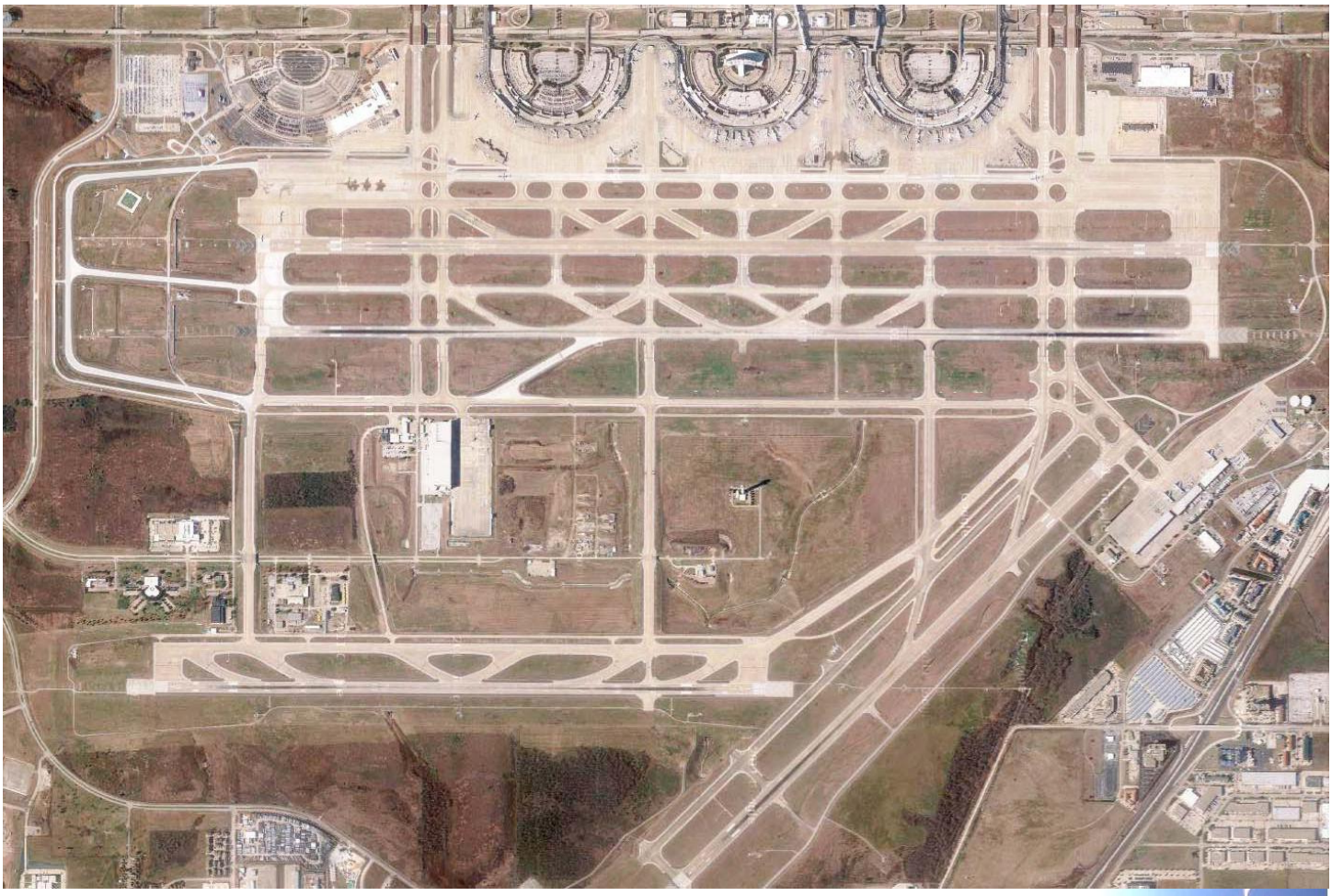
SARDA-CDM Assumptions

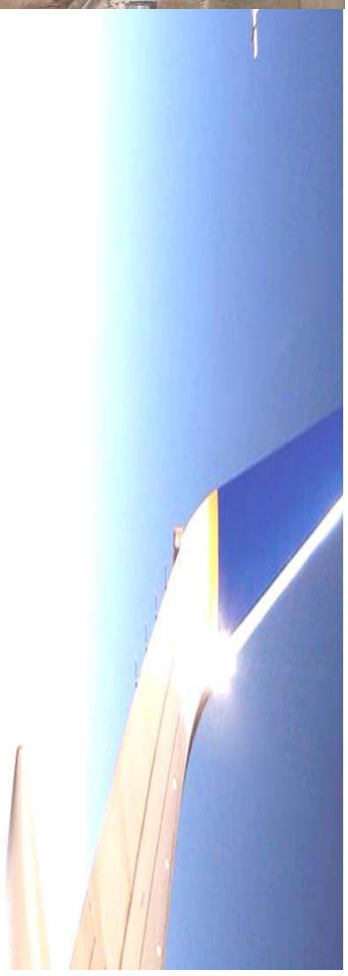
- Departure aircraft at gate – not directly under ATCT
- Ground controller can hold aircraft before taxiways
- Voice communication between cockpit and ATCT
- ASDE-X in movement area
- Aircraft position in ramp not known, but actual push-back times known
- Arrival aircraft – prediction of earliest active runway crossing

Planning Definitions

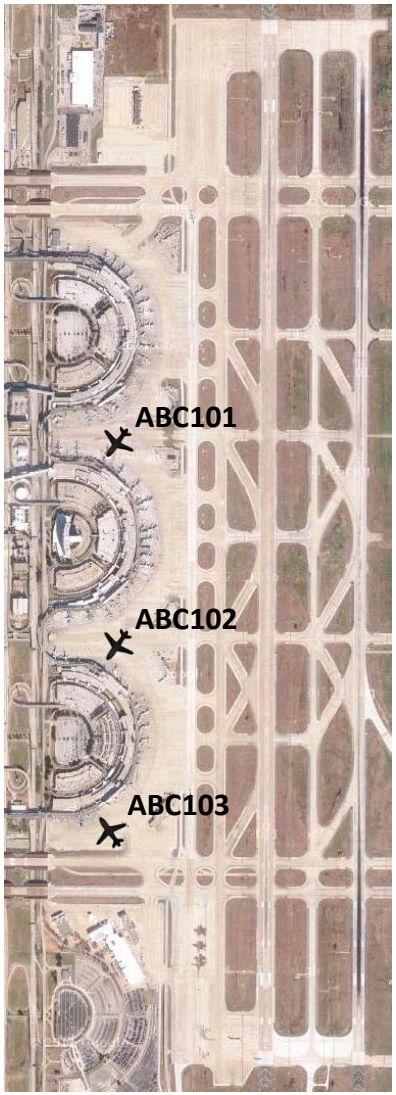
- Planning window (PW): how long each plan is. E.g. 15 minutes
- Planning horizon (PH): how soon is planning done. E.g. 30 minutes
- Planning buffer (PB): buffer time for airline response. E.g. 5 minutes







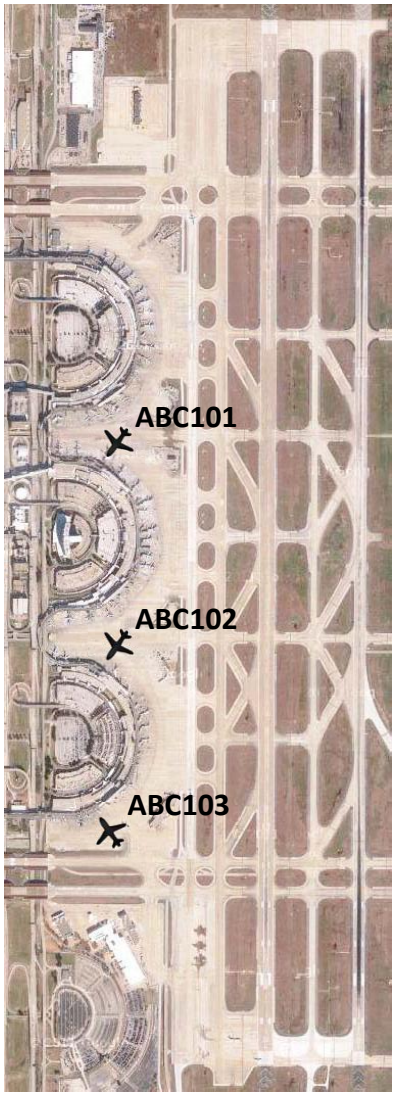
SARDA-CDM Walkthrough



Scheduled push-back

ABC101: 1502
ABC102: 1504
ABC103: 1507

SARDA-CDM Walkthrough



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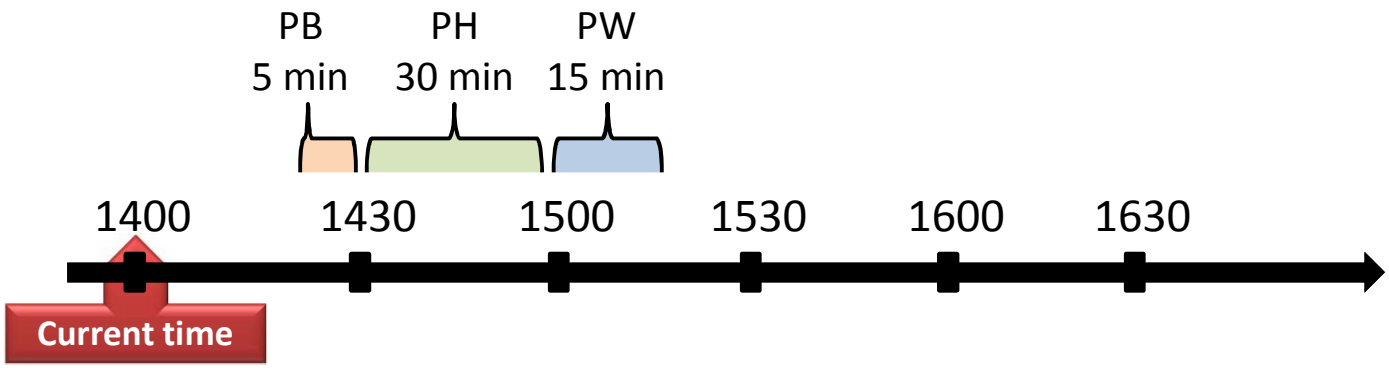

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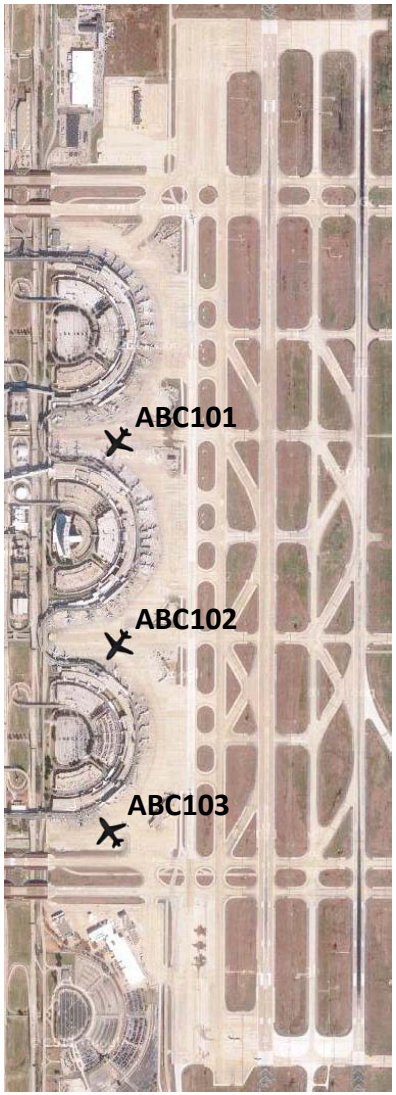
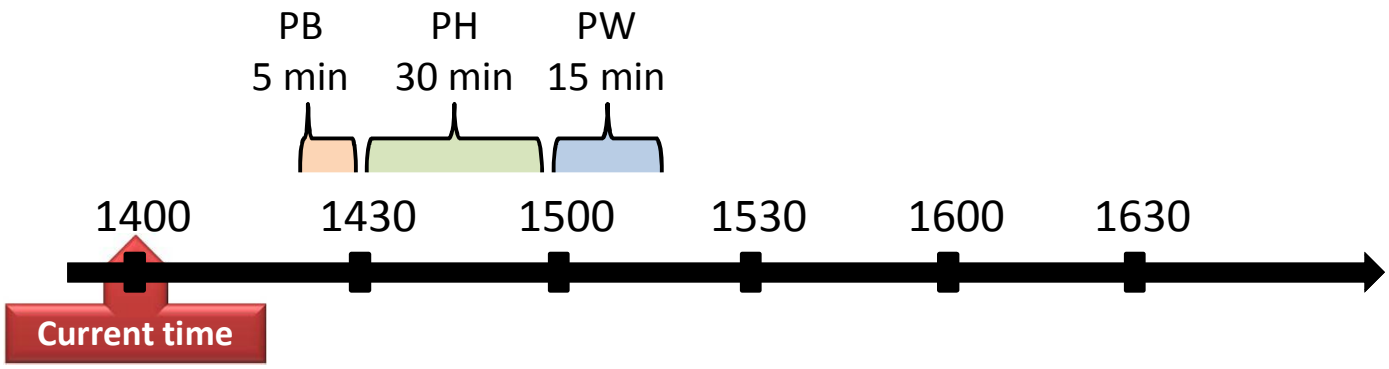


Strategic Planning Component (SPC)

Strategic SARDA-CDM Scheduler

Scheduled push-back
ABC101: 1502
ABC102: 1504
ABC103: 1507

- **Flight restrictions (TMI)**
- **Flight details**
- **Airport config**



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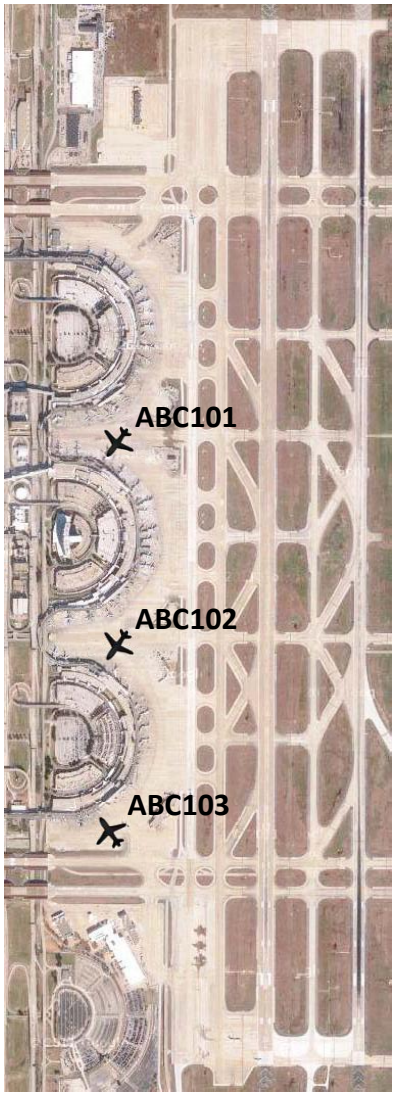


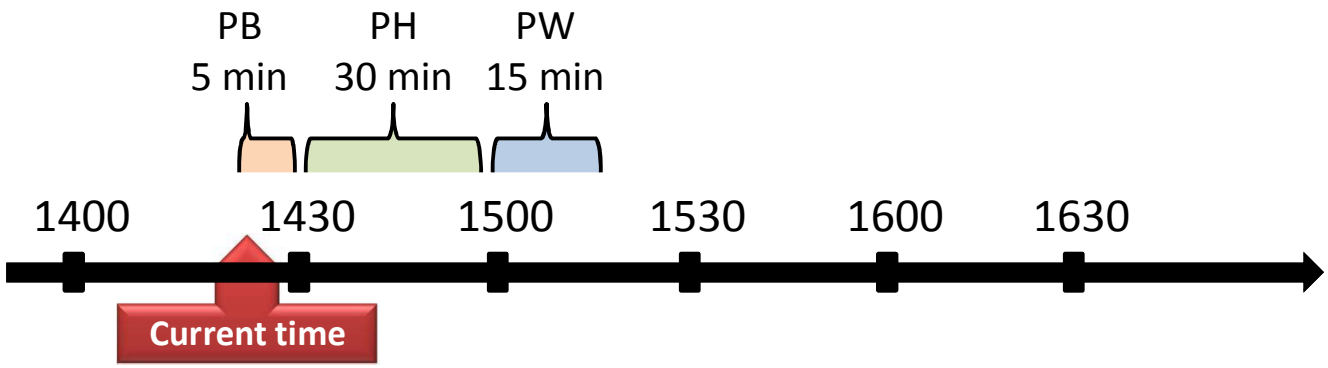
Strategic Planning Component (SPC)

Strategic SARDA-CDM Scheduler

Stage 1
Updated push-back
ABC101: 1504 (1502)
ABC102: 1510 (1504)
ABC103: 1508 (1507)

Airline

Preferences
- Later push-back
- Swaps



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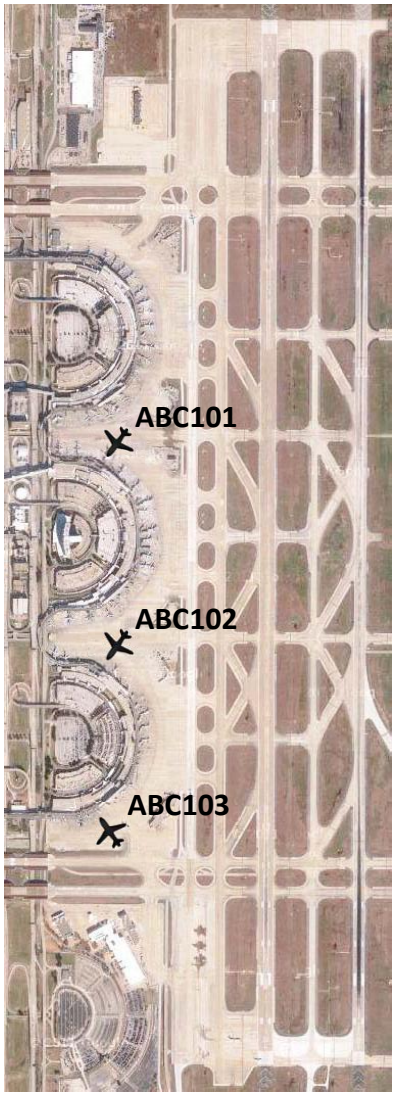

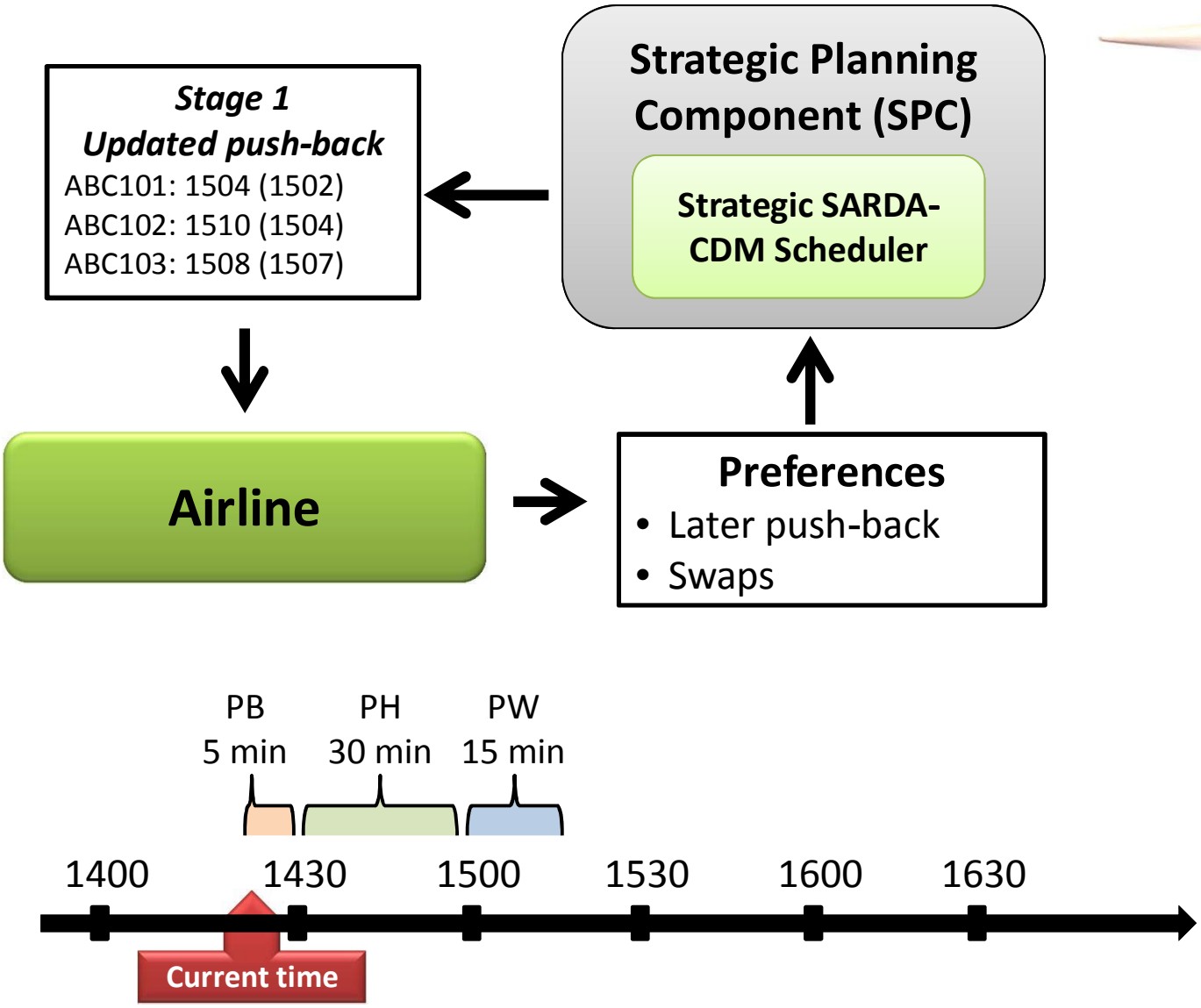

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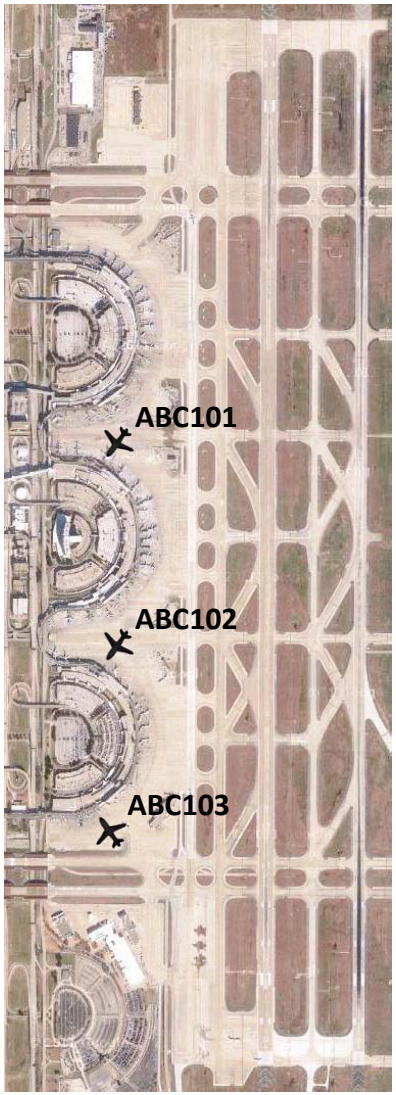
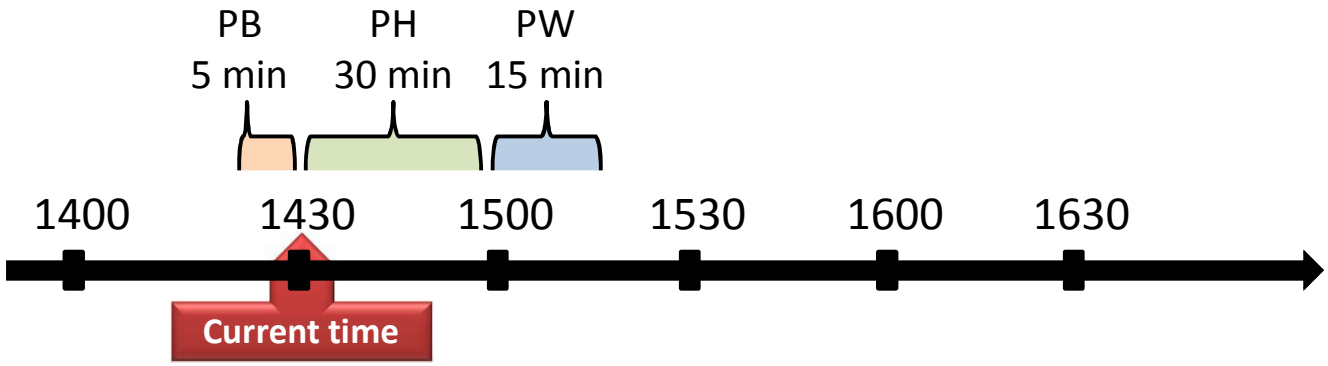


Stage 2
Updated push-back
ABC101: 1504 (no change)
ABC102: 1510 (no change)
ABC103: 1508 (no change)

Strategic Planning Component (SPC)

Strategic SARDA-CDM Scheduler

Airline



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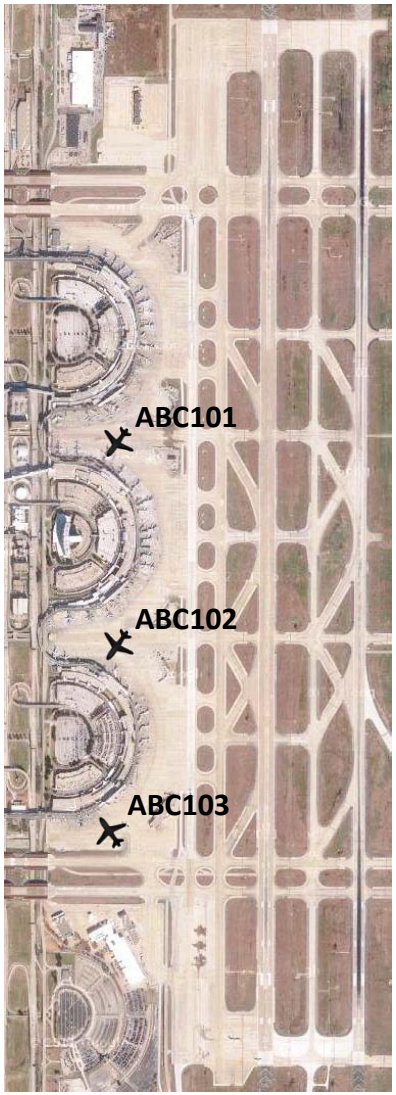

Stage 2
Updated push-back
ABC101: 1504 (no change)
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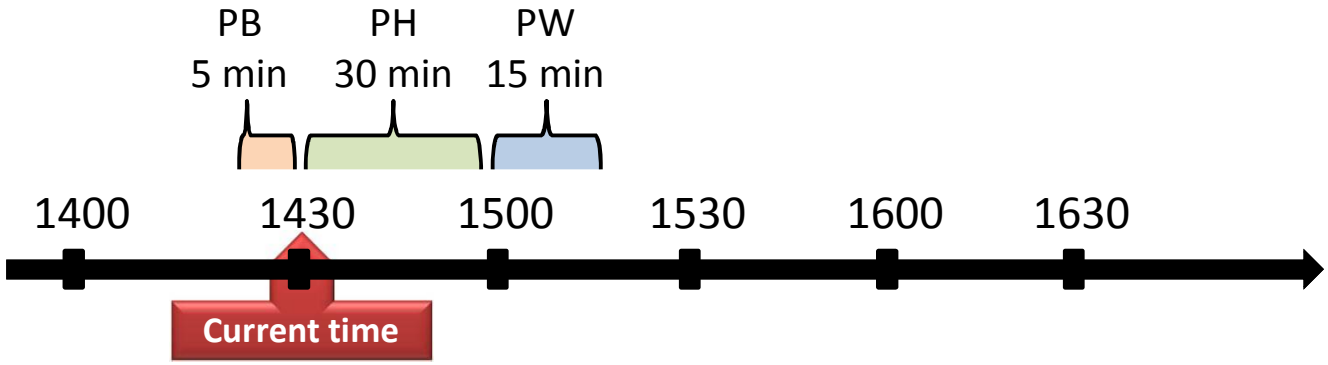
ABC103: 1508 (no change)

Strategic Planning Component (SPC)

Tactical Advisory Component (TAC)

Tactical SARDA-CDM Scheduler



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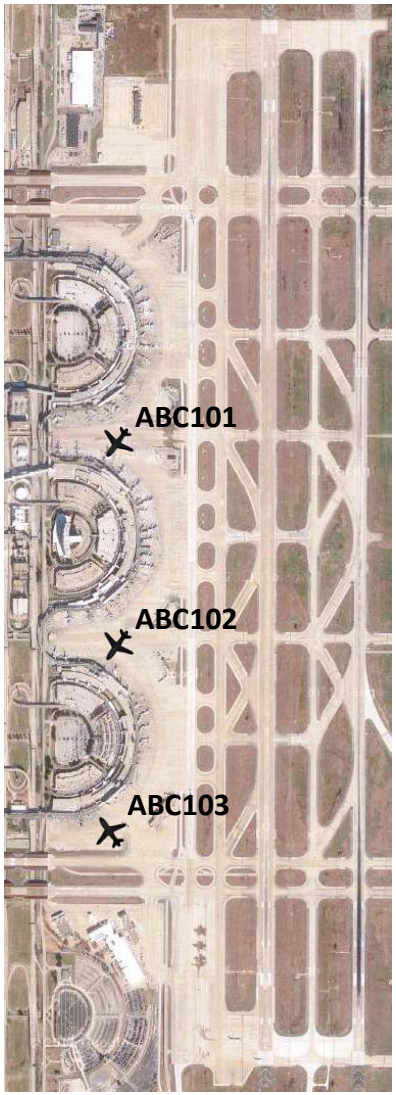
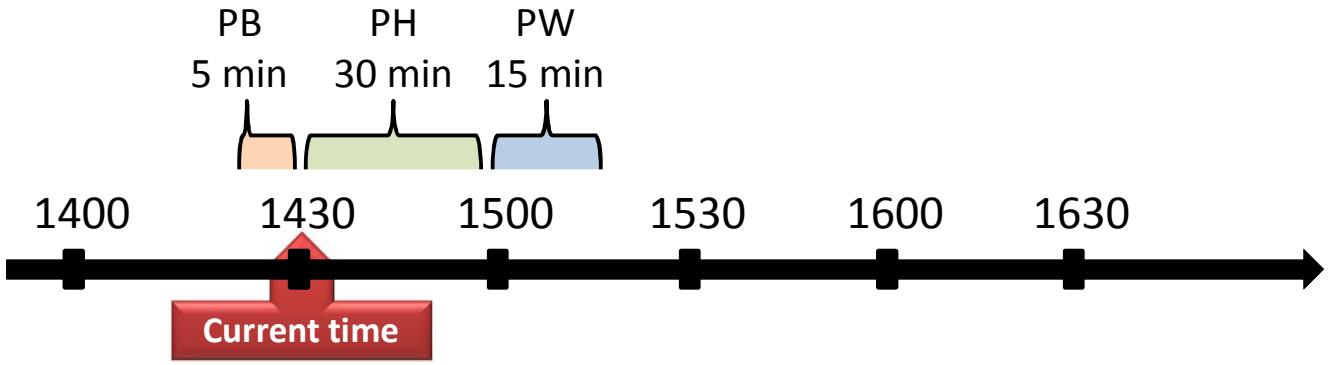


Strategic Planning Component (SPC)

Agreed push-back times

Tactical Advisory Component (TAC)

Tactical SARDA-CDM Scheduler



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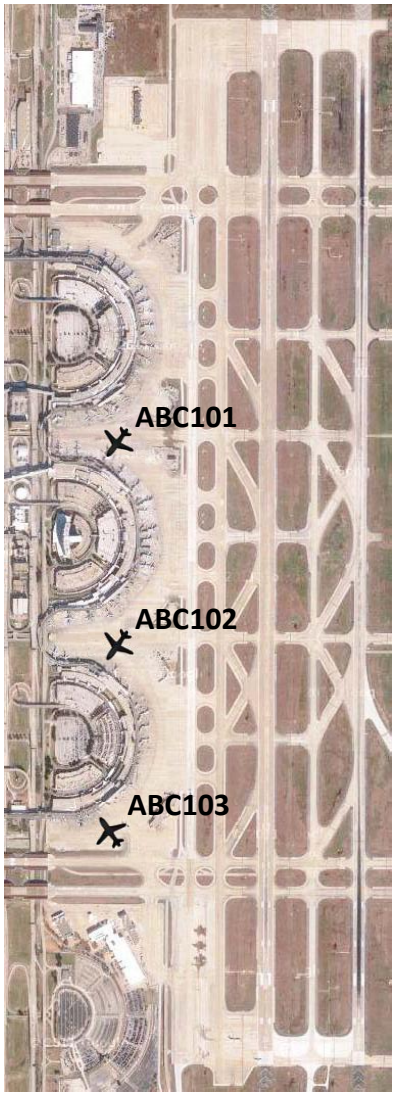


Actual push-back
ABC101: 1507 (1504) late
ABC102: 1500 (1510) early
ABC103: 1508 (1508) on-time

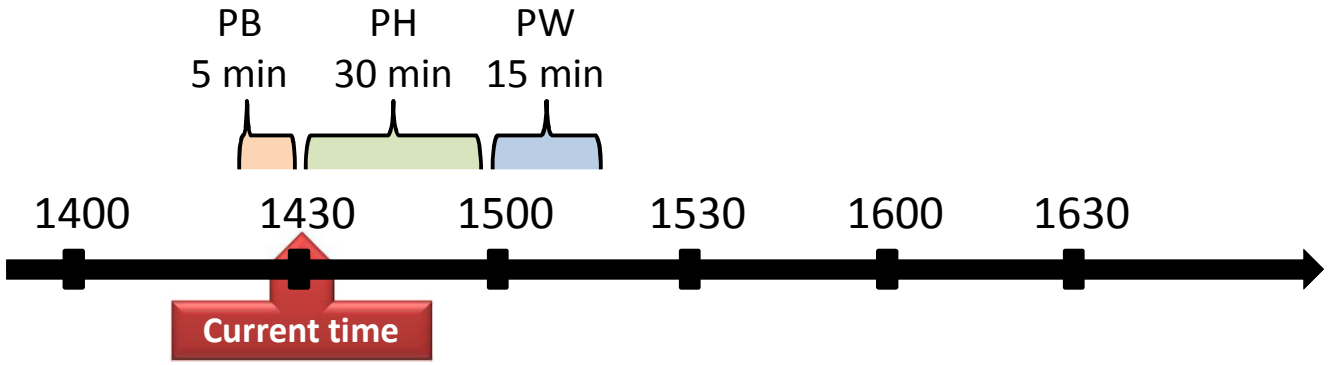
10 sec update of all aircraft positions

Strategic Planning Component (SPC)

Agreed push-back times

Tactical Advisory Component (TAC)

Tactical SARDA-CDM Scheduler



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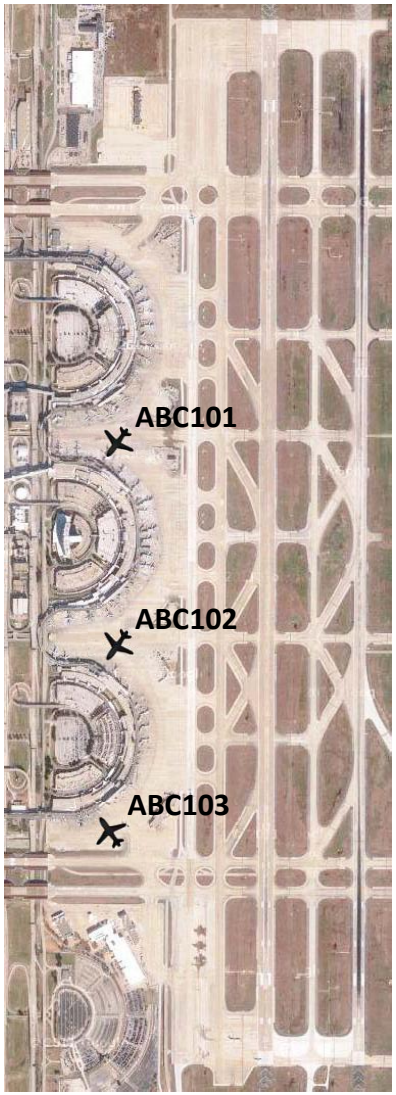

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Strategic Planning Component (SPC)

Agreed push-back times

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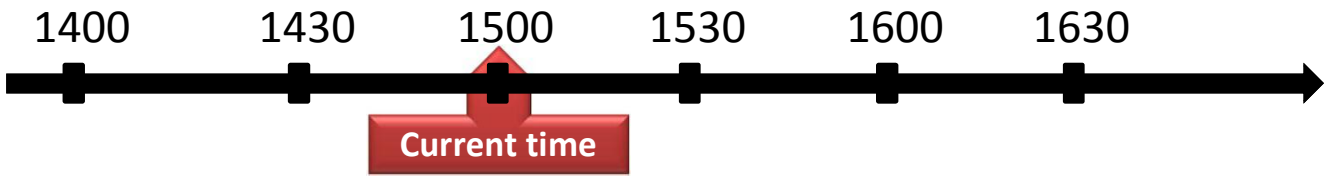
Tactical SARDA-CDM Scheduler

ATCT Advisories



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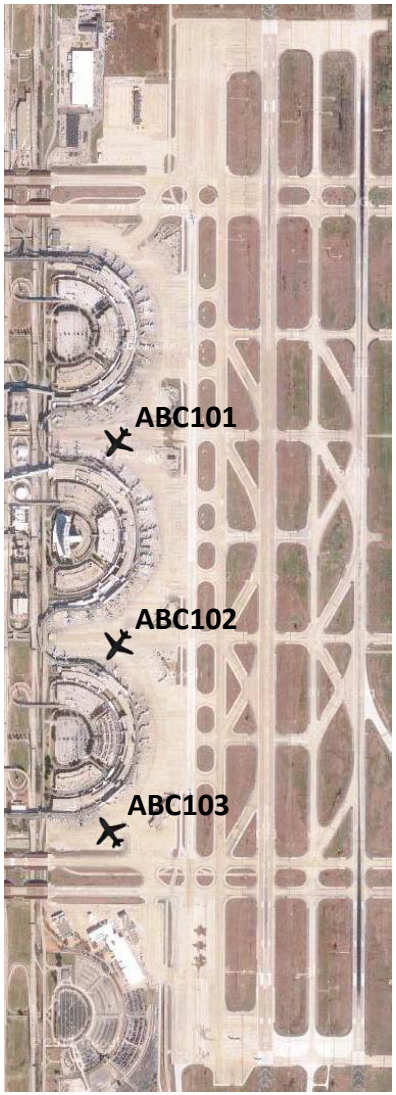

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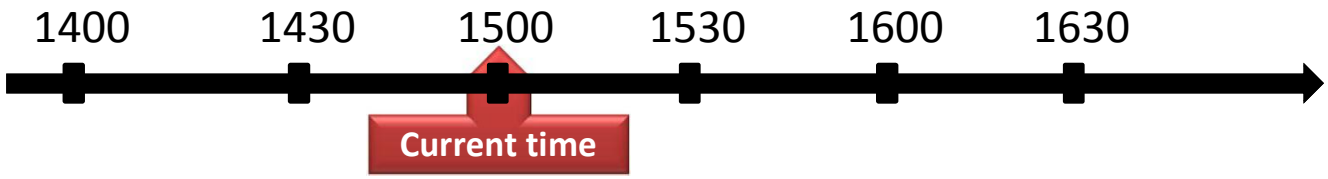

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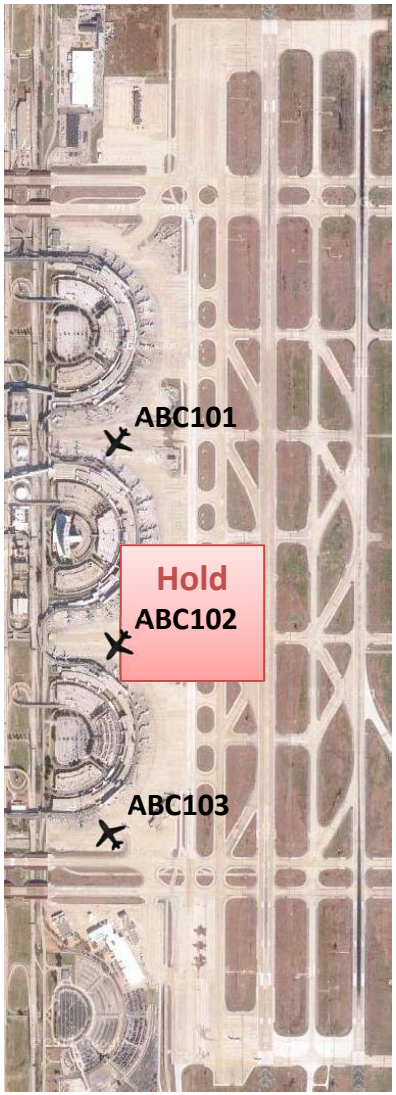

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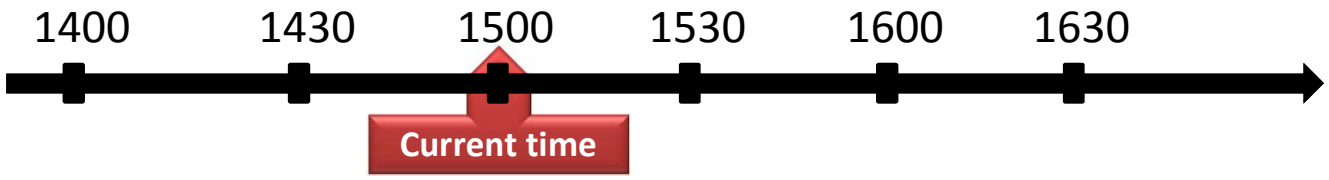

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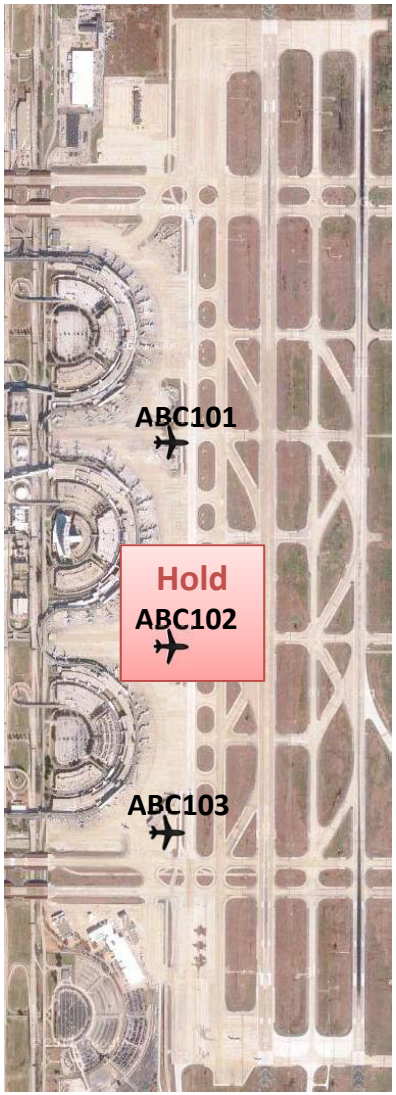

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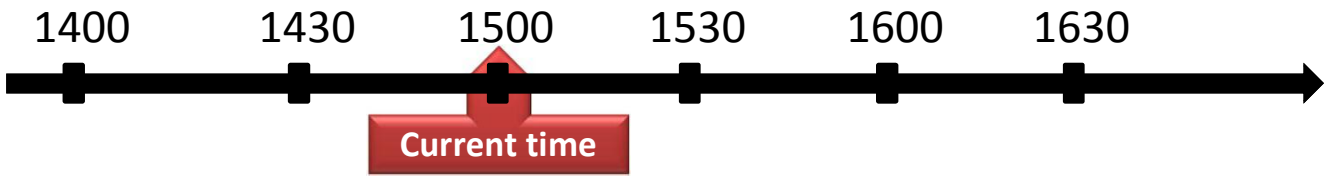


CDM Compliance

- After gate push-back agreement, three potential outcomes:
  - On-time push-back
  - Early push-back: ground controller holds till allotted time
  - Late push-back
    - Compliance encouraged by public performance metrics based on agreed push-back times
    - If late, spot release by ground controller as early as possible, **without affecting complying aircraft**

SARDA-CDM Components and Uses

- Airline collaboration through SPC
  - Move delays from runway queue to gate
  - Fuel and emission reductions
  - Potentially better connections
- Ground controller advisory
  - Compliance to SARDA-CDM for early push-back
- Local controller advisory
  - Improve predictability for downstream (TRACON) integration of departure aircraft
  - Improve predictability of arrival aircraft movement on taxiways

Strategic or Tactical Gate Hold

- Dichotomy in providing delayed push-back to airline
  - If push-back to be delayed, knowing about it sooner might be better
  - Estimates of push-back readiness difficult to provide

- Tactical gate push-back through SARDA-CDM
  - Merge SPC and TAC, and use one version of SARDA scheduler
  - Effectively planning horizon = 0 minutes
  - Gate push-back readiness updates provided by airlines
  - Gate advisories updated and provided to airlines at frequent intervals

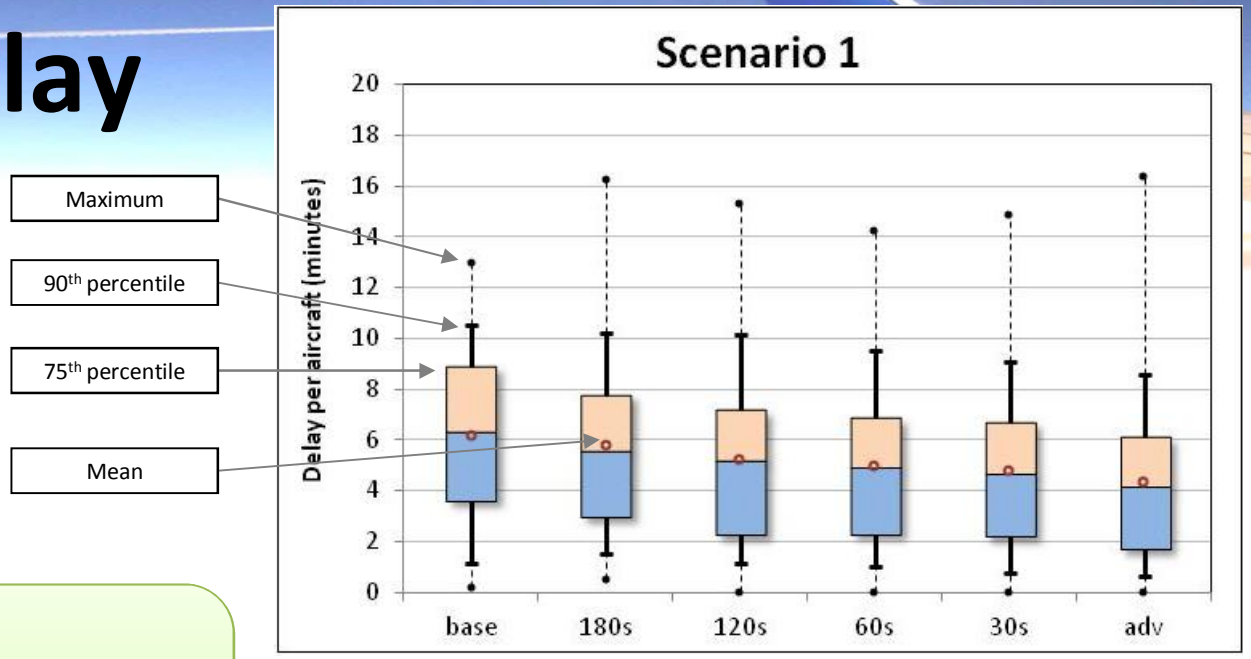
Tactical Gate-Hold Implementation

- SARDA-CDM implemented in SDSS-ATG closed loop
  - SDSS: a decision support tool to assist ATCT controllers
  - ATG: aircraft movement, provides flight tracks
- Real time simulation environment
  - Closed-loop: automatic aircraft movement by ATG using SDSS inputs (10 second updates); SDSS emulates controllers
  - Open-loop: ATG movement by pseudo-pilots based on controller instructions
- Open-loop used in human-in-the-loop studies
- Taxi speed uncertainty (12 to 17 knots)

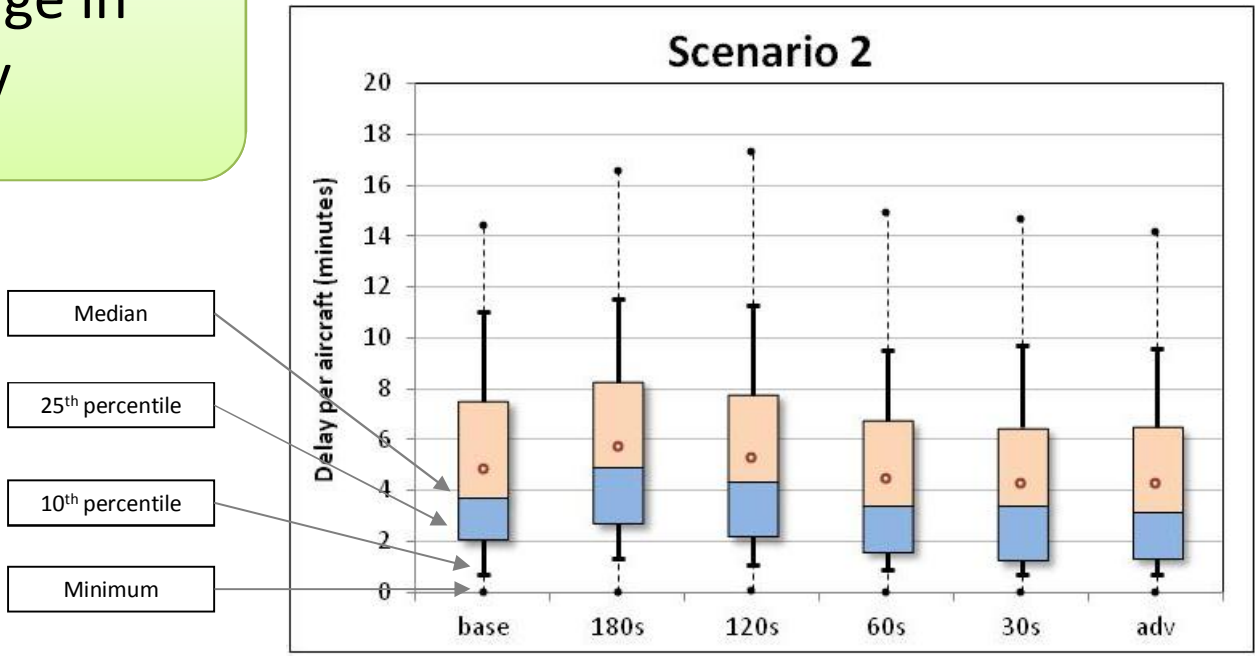
Cases

- Baseline (base)
  - no metering
  - release from spot when possible
  - runway usage based on swapping heuristic, not first-come-first-served
- Advisory (adv): complete compliance with no push-back uncertainty
- Increasing push-back uncertainty
  - 30s, 60s, 120s, 180s
  - Positive only, delay in push-back
  - Early push-back held, late push-back could lead to throughput loss
- 2 scenarios, 1 hour each, 1.5x current day operations
- Each scenario and case run 10 times

Schedule Delay



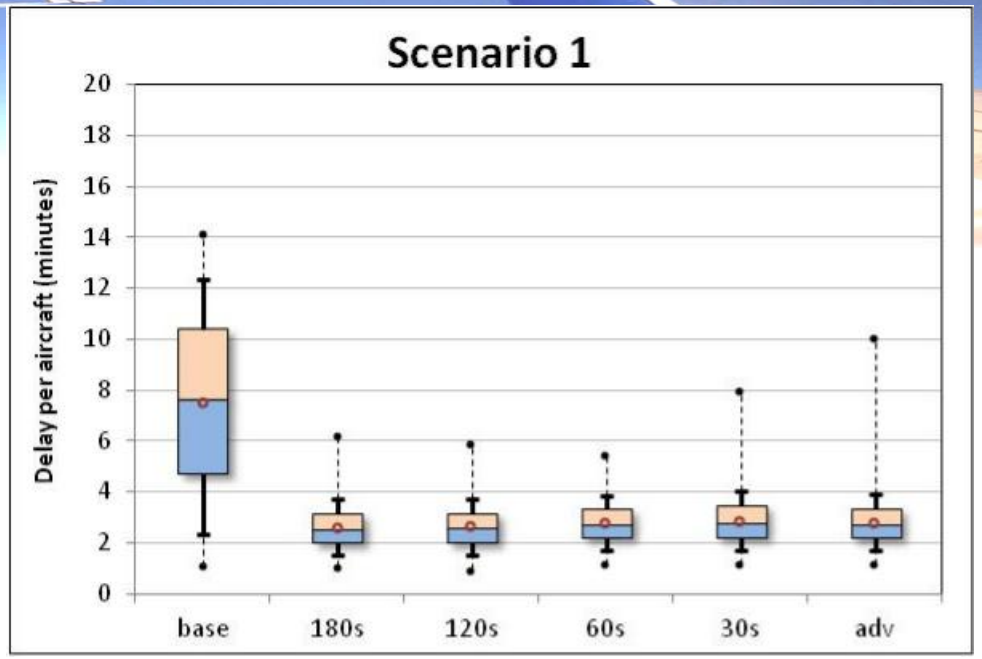
No significant change in schedule delay

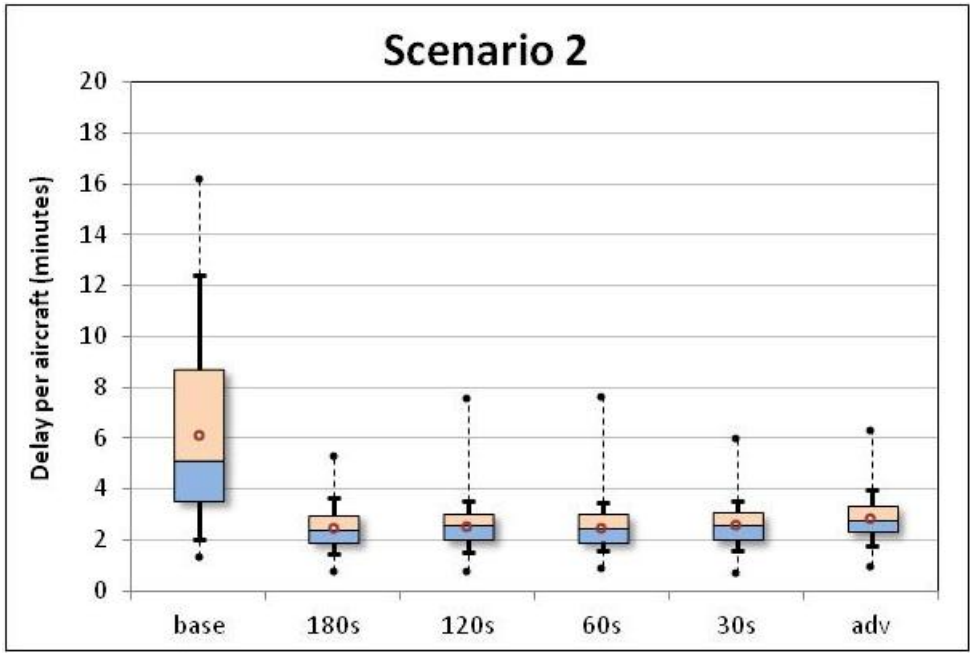


Taxiing Delay

Delay in ramp and active movement area

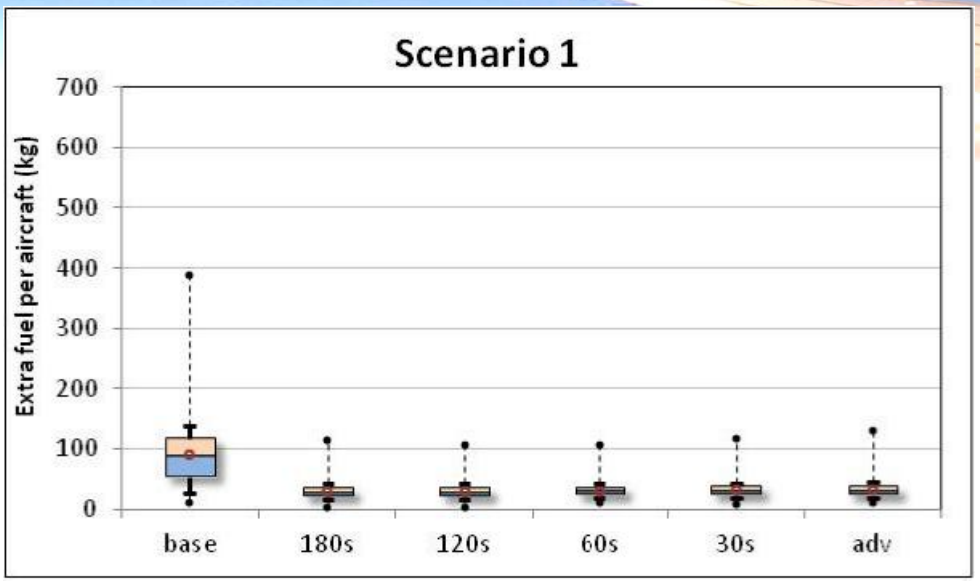
Even with increasing uncertainty in gate push-back, there is little increase in taxiing delay

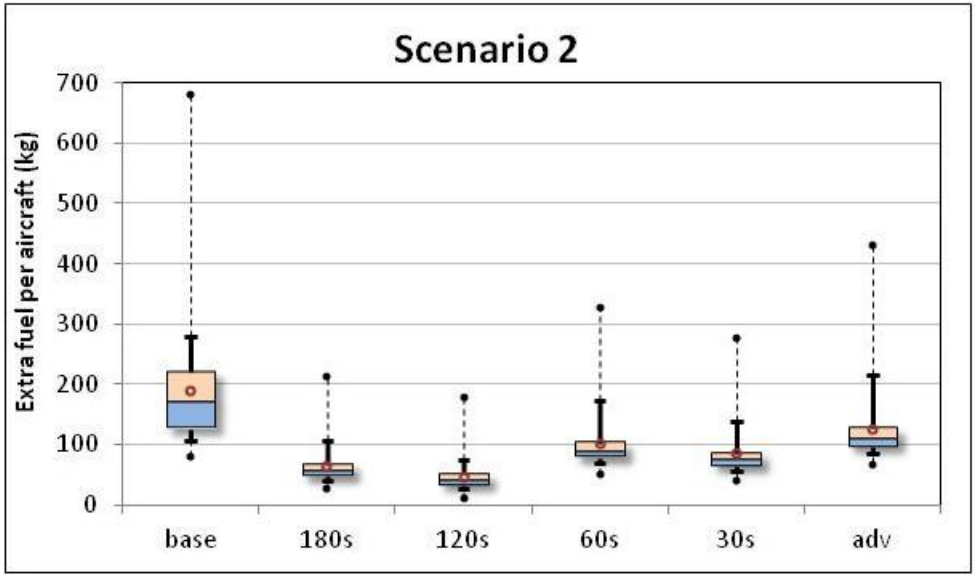




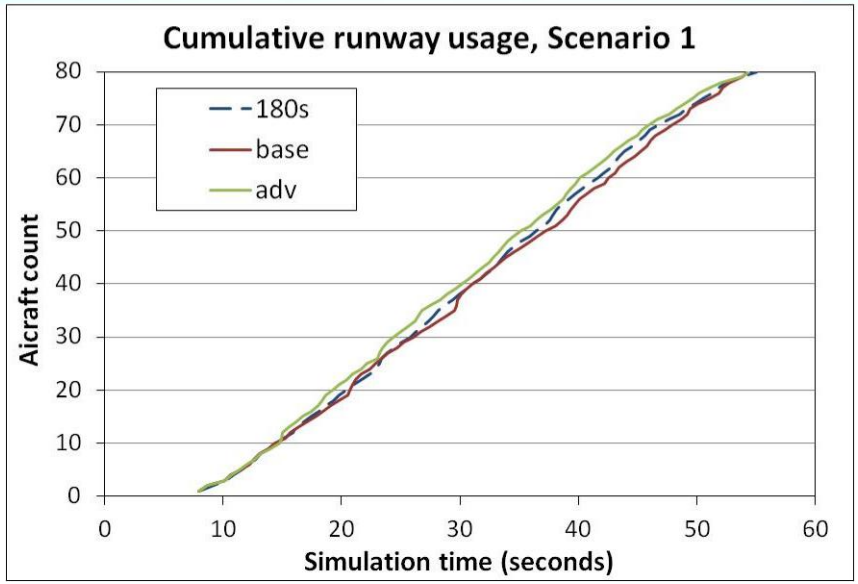
Extra Fuel Used

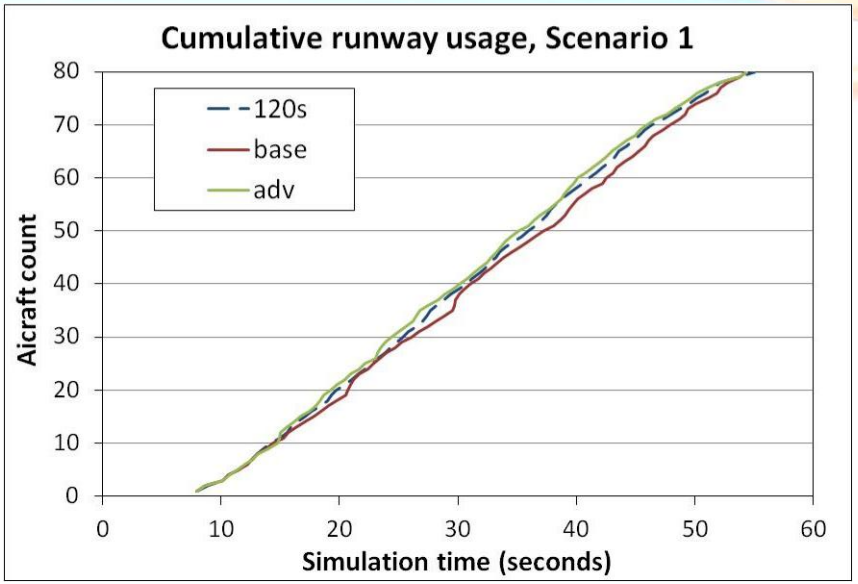
Avg reduction per aircraft
50kg in scenario 1
150 kg in scenario 2

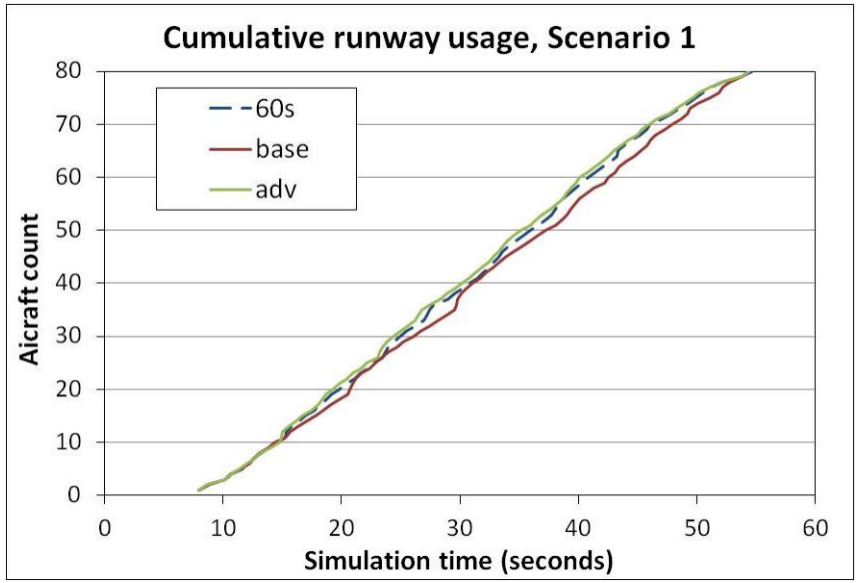


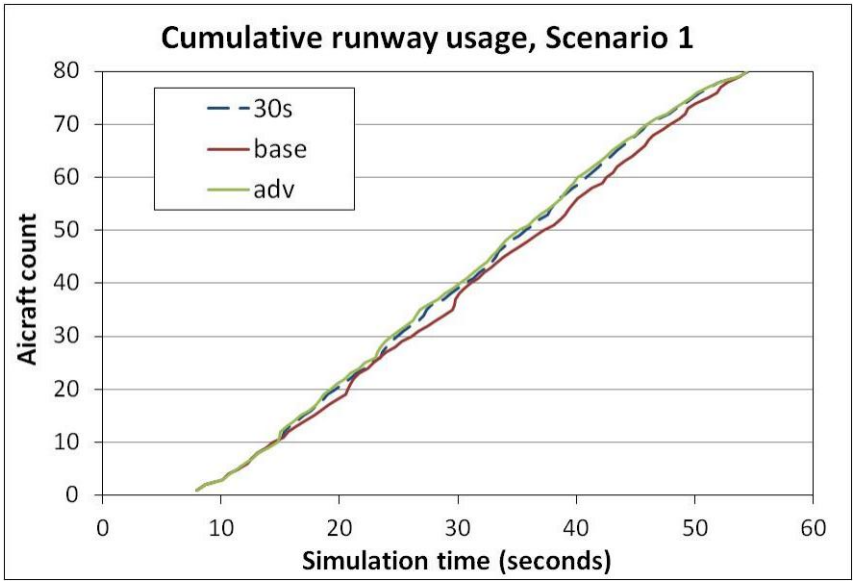


Cumulative Runway Usage

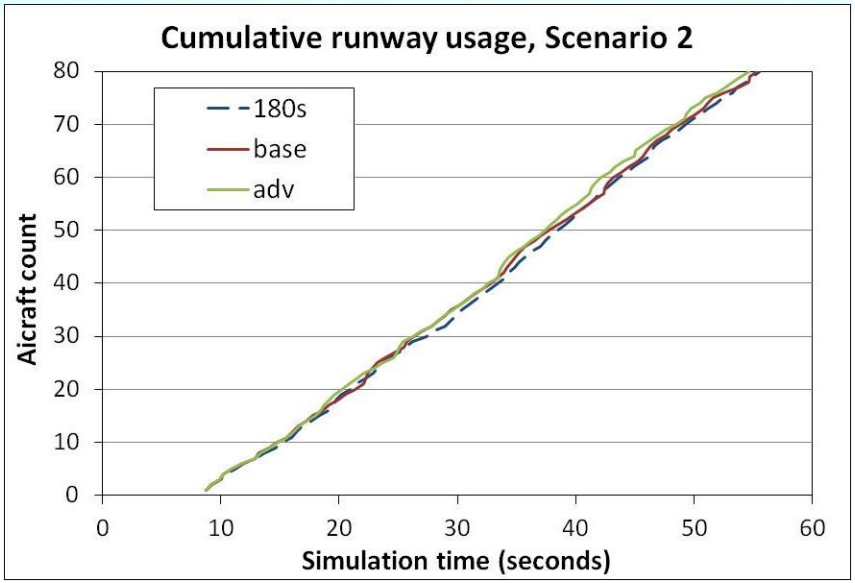


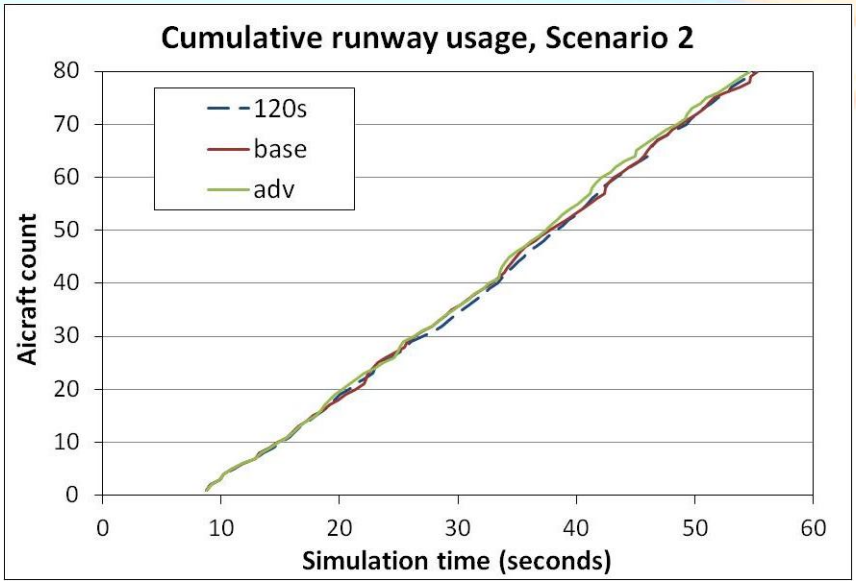


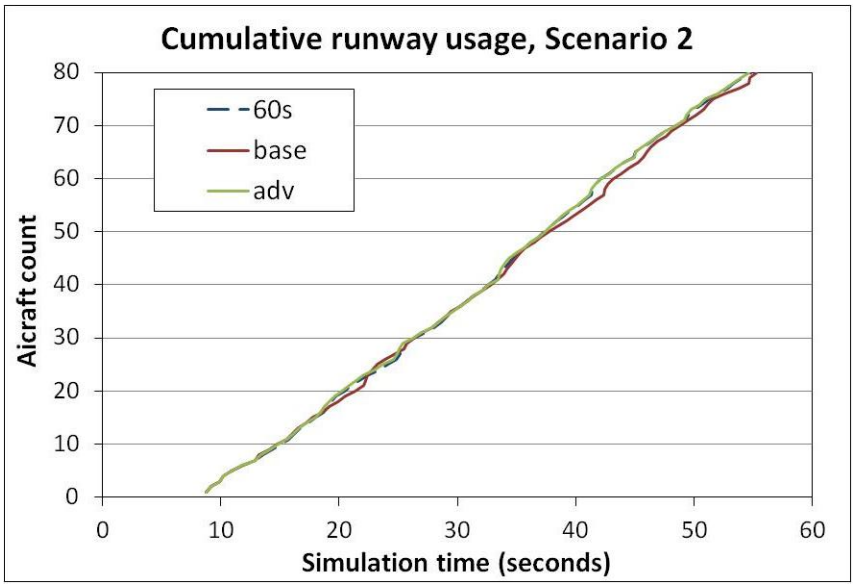


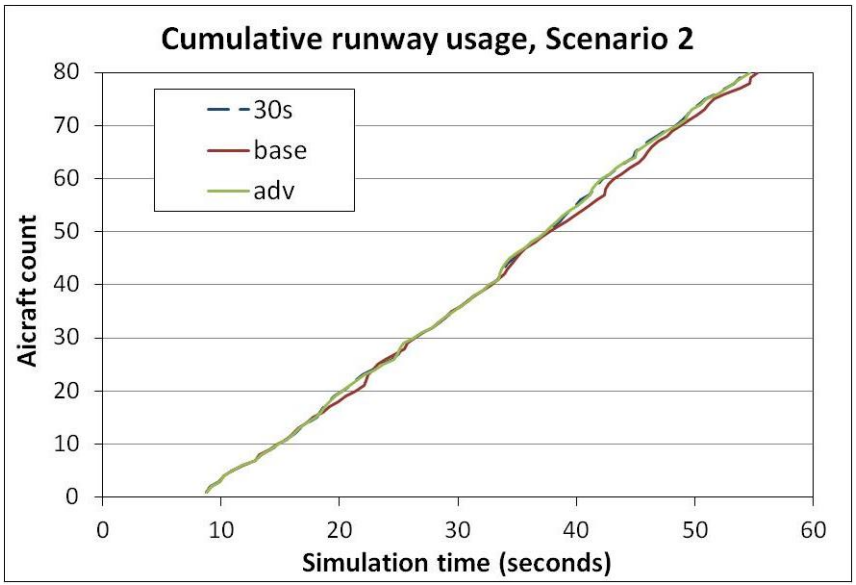


Cumulative Runway Usage

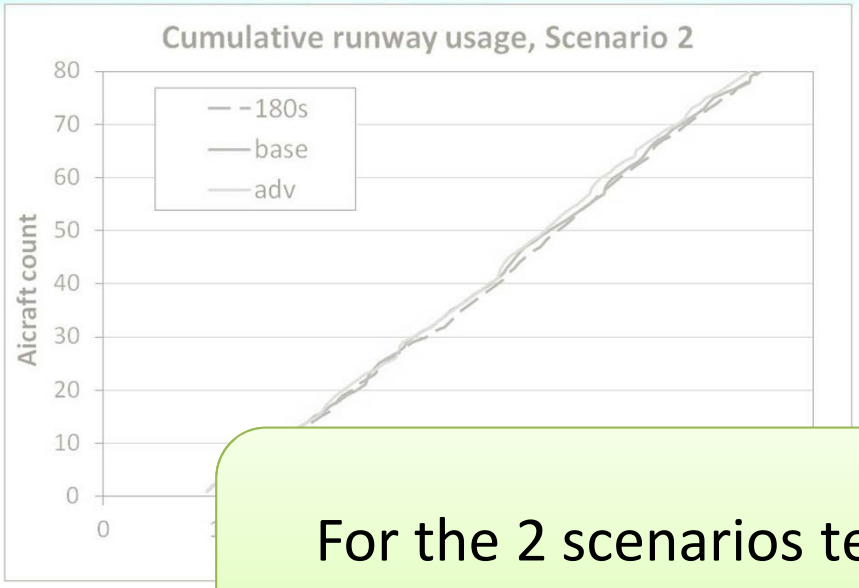


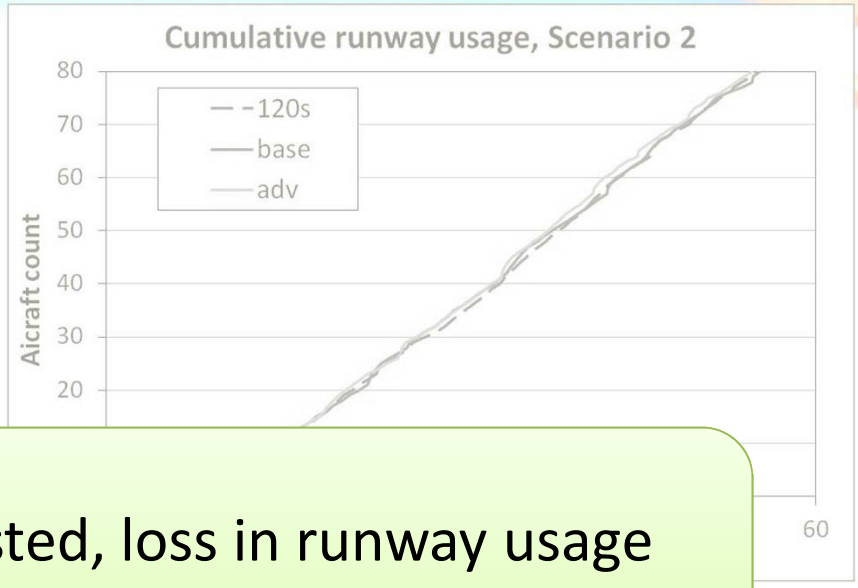




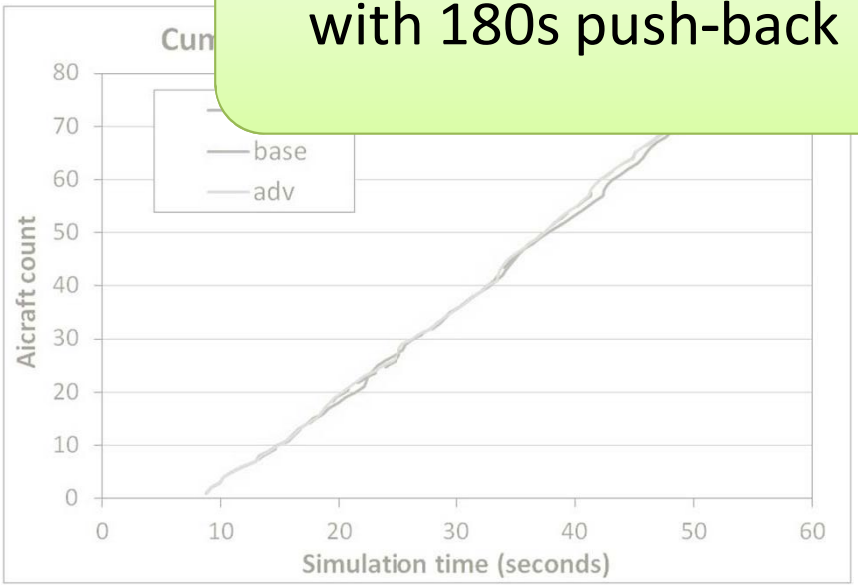


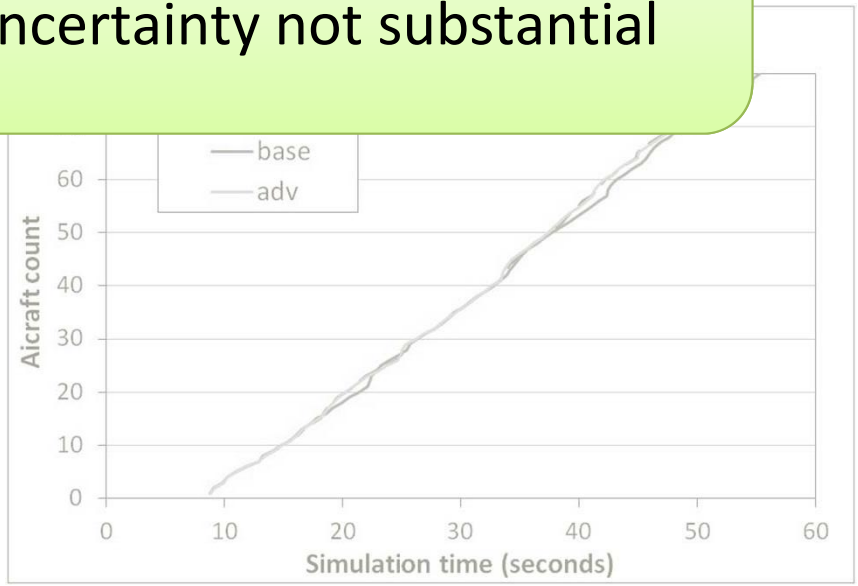
Cumulative Runway Usage





For the 2 scenarios tested, loss in runway usage with 180s push-back uncertainty not substantial





Research Questions

- Interface for airline inputs and ATCT
- Best planning horizon, window, airline input mechanism
- Policy issues (on-time performance metric)
- Attempts to game
- Scheduler design under uncertainty
- System effects
  - Taxi delay, fuel and emission benefits
  - Passenger connectivity
  - Disadvantages (e.g. throughput loss due to push-back uncertainty)
  - Predictability

Ongoing Research

- SARDA
  - Human in the loop simulations conducted in May 2012
  - Full tower simulation
  - Data analysis underway
- Exploring collaboration with
  - airline industry for field tests
  - FAA for integration in future surface CDM tools