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# Spot and Runway Departure Advisor (SARDA) Technical Overview

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NASA-KAIA/KARI/IIAC Collaboration Kickoff Meeting  
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- **Research Background**
- **Technical Approach**
- **Concept**
- **Research Results**
- **Current Research**
- **Summary and Next Step**



## Consequences:

- Excessive taxi time and taxi delay
- Excessive fuel consumption and emissions
- Missed opportunities in merging departures into overhead stream
- Increased block time due to poor predictability

## Today's Airport Surface Operations:

- Demand-Capacity imbalance
- Huge uncertainties in surface events
- Lack of common situational awareness and coordination

# Intelligent Scheduling is the Key to Efficient Surface Management



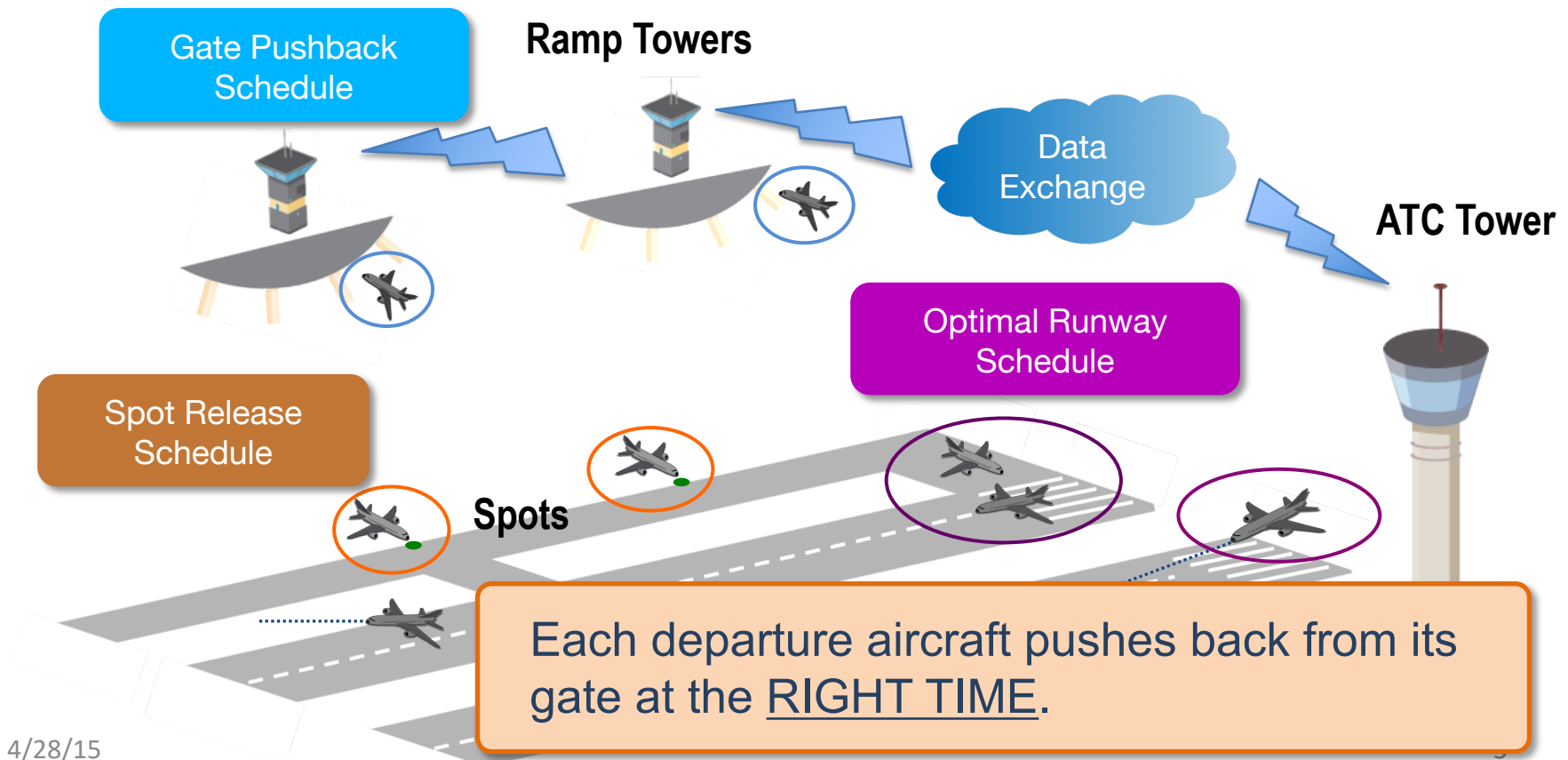
**SARDA is NASA's approach for solving this problem.**

- Optimizes at a system level by minimizing overall delay
- Plans for aircraft movement at various flow control points (gates, spots, and runways)
- Accounts for departures and arrivals
- Incorporates constraints at individual aircraft level
- Provides connectivity with airport tower, airlines, and en route facility
- Adaptable to other airports with different configurations and operating procedures

# SARDA Concept



- Builds an optimal runway schedule
- Generates spot release sequence and timing
- Determines when to push back from gates



# Anticipated Benefits

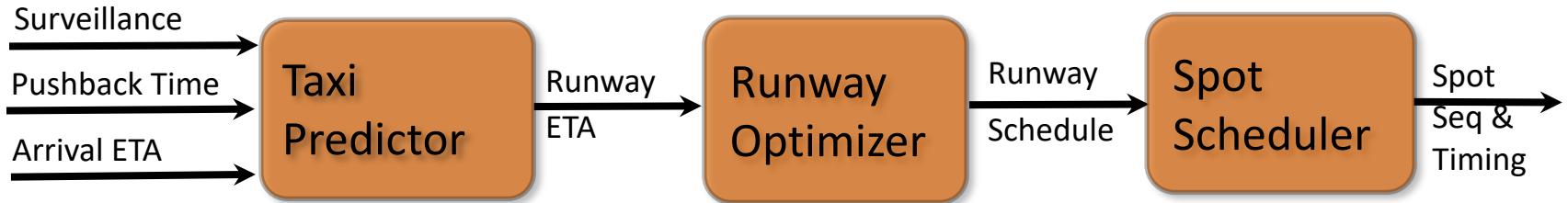


- **Increased Efficiency**
  - Reduced taxi time and taxi delay
  - Reduced runway queue length
  - Reduced fuel burn
- **Improved Predictability**
  - Reduced variation in efficiency metrics
  - Accurate OFF time prediction
- **Maintain Throughput**
  - Number of runway operations

# SARDA as ATC Tower Tool



**SARDA takes inputs from multiple sources and computes advisories for runway usage and spot release**



**Local - Runway Sequence**



**Ground - Spot Release**



# SARDA Ground Controller Advisories



11:21:54 Ground Control
East Ground Control  FFT1873   FFT1873: TX-D
18:21:53

East Ramps - Departure

FFT1384	A319	15	11:15	S47/K...EF	17R/SOL/ATL	1843	<input type="button" value="TX-D"/>
AAL1502	MD83	14	10:15	S7/JY...EH	17R/CLR/MSY		<input type="button" value="TX-D"/>
AWE558	A320	13	08:01	S42/EL...EH	17R/CLR/BTR		<input type="button" value="TX-D"/>
UAL121	A320	12	06:38	S45/K...EF	17R/SOL/ATL	1838	<input type="button" value="TX-D"/>
AAL2282	MD83	11	06:12	S15/K6...EG	17R/AKU/XNA		<input type="button" value="TX-D"/>
DAL415	B737	10	06:06	S47/K.EG	17R/GRA/BLE		<input type="button" value="TX-D"/>
AAL575	B752	9	05:29	S7/JY...EH	17R/ARD/MSY		<input type="button" value="TX-D"/>
DAL974	B737	8	04:52	S42/EL...EG	17R/AKU/MSN		<input type="button" value="TX-D"/>
AAL1286	MD83	7	04:41	S9/K.EG	17R/AKU/PIA		<input type="button" value="TX-D"/>
FFT2078	A319	6	04:39	S47/K...EH	17R/CLR/BTR		<input type="button" value="TX-D"/>
FFT1264	A319	5	03:50	S45/K...EH	17R/ARD/MSY		<input type="button" value="TX-D"/>
AWE439	A320	4	03:26	S33/K...EF	17R/SOL/ATL	1833	<input type="button" value="TX-D"/>
AWE964	A320	3	02:20	S31/K...EH	17R/CLR/MCO		<input type="button" value="TX-D"/>
AAL943	MD82	2	01:39	S29/EK...EH	17R/CLR/BTR		<input type="button" value="TX-D"/>
AAL1374	MD82	1	00:58	S7/JY...EF	17R/SOL/ATL	1828	<input type="button" value="TX-D"/>

Taxi - Departure

FFT1873	A319	K.EG	17R/NOB/EWR	<input type="button" value="E Loc"/>
FFT2137	A319	K.EG	17R/TRI/SJT	<input type="button" value="E Loc"/>
AAL332	MD82	K.EG	17R/TRI/BWI	<input type="button" value="E Loc"/>
UAL891	B772	K.EG	17R/AKU/MSN	<input type="button" value="E Loc"/>

Drop List

Arrival

DAL249	MD88	M7.B	S53	<input type="button" value="TX-A"/>
AAL636	MD82	M4...K5	S10	<input type="button" value="TX-A"/>
AAL533	MD82	M3...EK	S24	<input type="button" value="TX-A"/>

Taxi - Arrival

AAL56	B763	S10	<input type="button" value="RAMP"/>
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Handoff sequence to Local controller at departure queue

Traffic Mgmt Initiative

18:21:53 ATIS D

SARDA: 2 00:55  
1821@SPOT 0803@RWY

<input type="button" value="ENTER"/>	<input type="button" value="DETECT"/>
<input type="button" value="ADD"/>	<input type="button" value="DELETE"/>
<input type="button" value="CODED"/>	<input type="button" value="MAP"/>

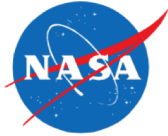
Spot release advisory shows spot release sequence & time, taxi route, departure runway queue

4/28/15

8



# SARDA Local Controller Advisories



East Local Control | Recall | Undo | DAL152: ELC -> D

17R | 17C

### Traffic Mgmt Initiative

Active runway usage advisory shows sequence for arrival crossings (white) and departure take-offs (green)

Arrival advisories show sequence for crossing active runway and the taxi-to arrival spot

Flight	Aircraft	Seq	Runway	Altitude	Initials	Buttons
FFT2587	A319	6	EG	TR1/TYS		LUAW, CFTO
AWE717	A320	5	EH	CLR/MSY		LUAW, CFTO
AWE190	B737	4	EG	AKU/MKE		LUAW, CFTO
UAL900	A320	3	EF	SOL/ATL	1823	LUAW, CFTO
AWE438	B737	2	EG	AKU/SGF		LUAW, CFTO
DAL249	MD88	1	S53			E GND
AAL636	MD82	1	S10			E GND
AAL533	MD82	1	S24			E GND

17R - Clear For Takeoff

AAL994	B752	CLR/MCO	DEP
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FFT2555	A319	17	S48	CTL	HS17R
AAL612	MD82	8	S24	CTL	HS17R
FFT1652	A319	8	S46	CTL	HS17R
UAL572	A320	8	S48	CTL	HS17R

18:21:16 ATIS D | Recall

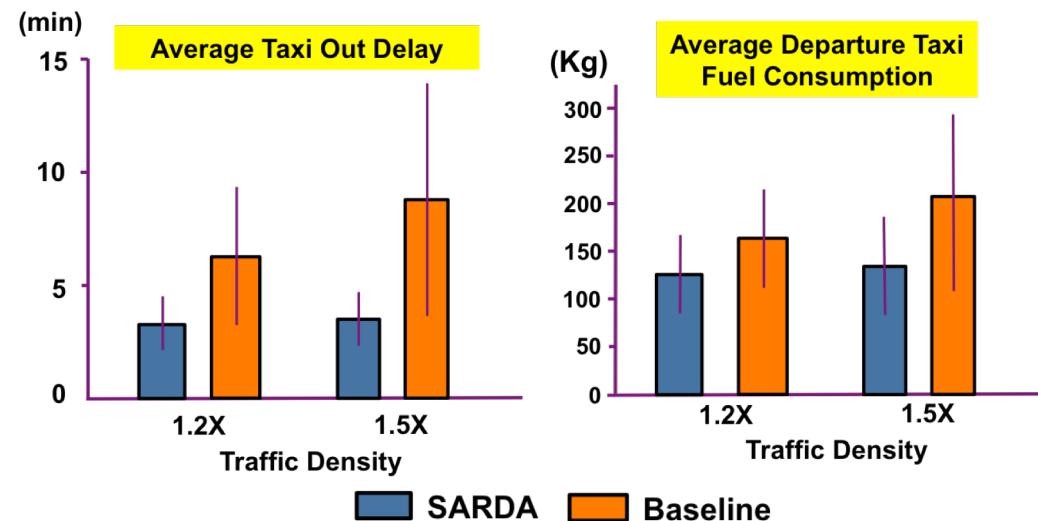
# SARDA Benefits – DFW ATC Tower Tool



- Reductions in departure taxiing delay (45% - 60%) and variability
- Reductions in fuel consumption (23 - 33%) and variability
- Consistent and accurate prediction of takeoff time
- Decreased controllers workload, less sensitive to the traffic load



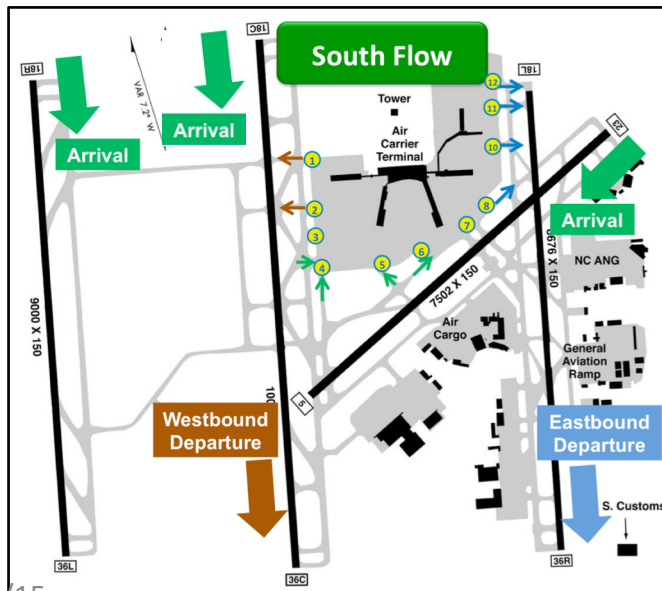
Human-in-the-loop Simulation for Dallas-Ft. Worth Airport (2012)



# Ramp Management Tool



- NASA-US Airways Collaboration (Space Act Agreement, 2013)
- Goal: Develop and test a prototype decision support tool for Charlotte International Airport (CLT) ramp operators
- Conduct a series of human-in-the-loop (HITL) simulations in 2014 & 2015
- Conduct field evaluations in 2016



# CLT Operations - Challenges

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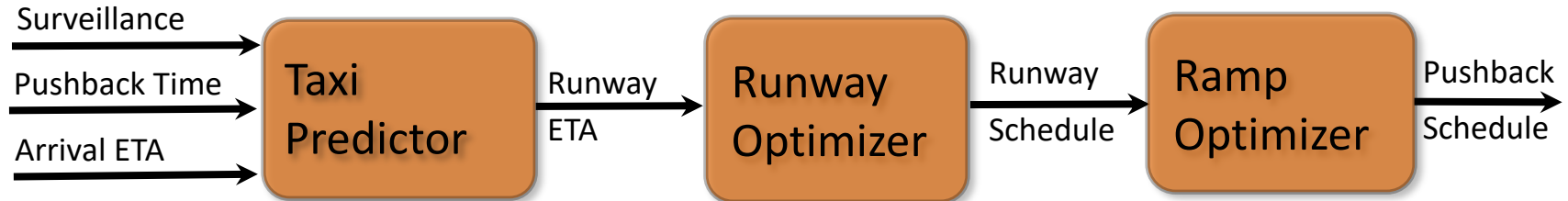


- Over 20% of time departure demand exceeds airport capacity
- Over 80% of passengers are connecting flight passengers
- Multiple banks of arrivals and departures with overlaps
- Over 35% of departures are destined to airports in north east
- Complexity in ramp area geometry (gates, taxiways)

# SARDA as Ramp Tool

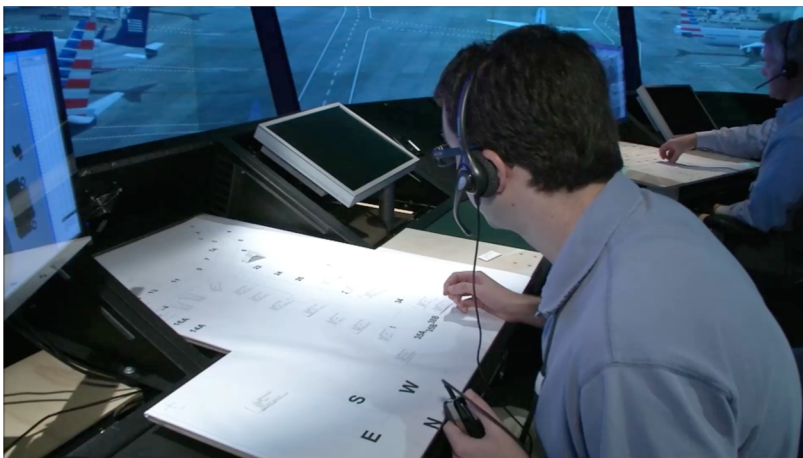


**SARDA takes input from multiple sources and computes advisories for gate pushback**



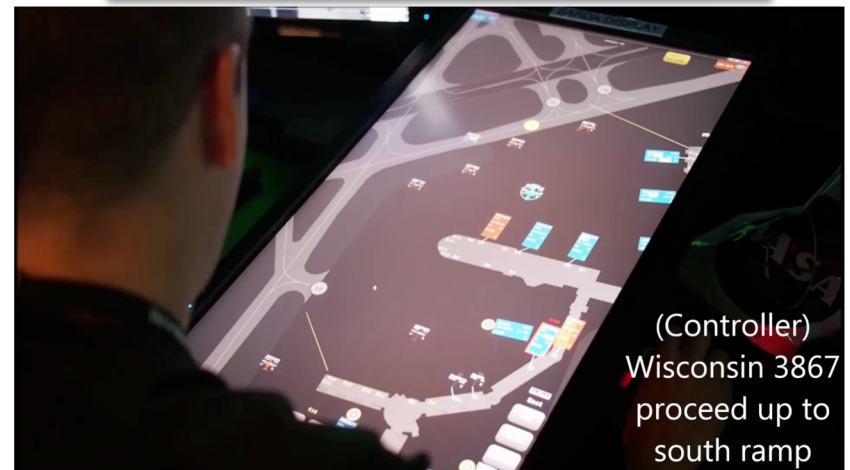
## Today's Operation:

- Paper ramp area map
- Paper flight strips



## SARDA Ramp Tool:

- Electronic Flight strips
- Surface map & surveillance
- Pushback advisories

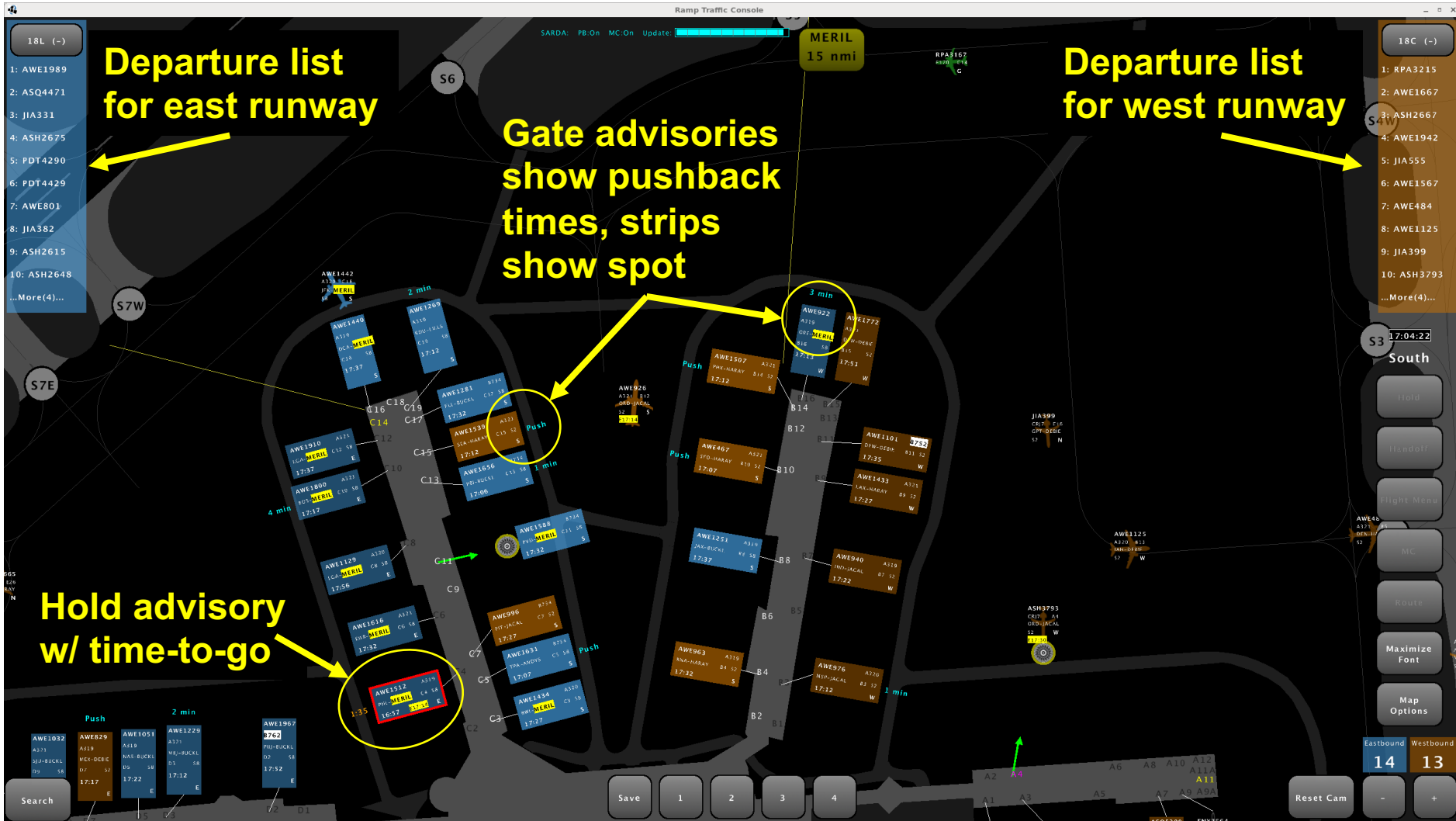


(Controller)  
Wisconsin 3867  
proceed up to  
south ramp

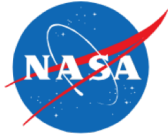
# SARDA Ramp Controller Advisories



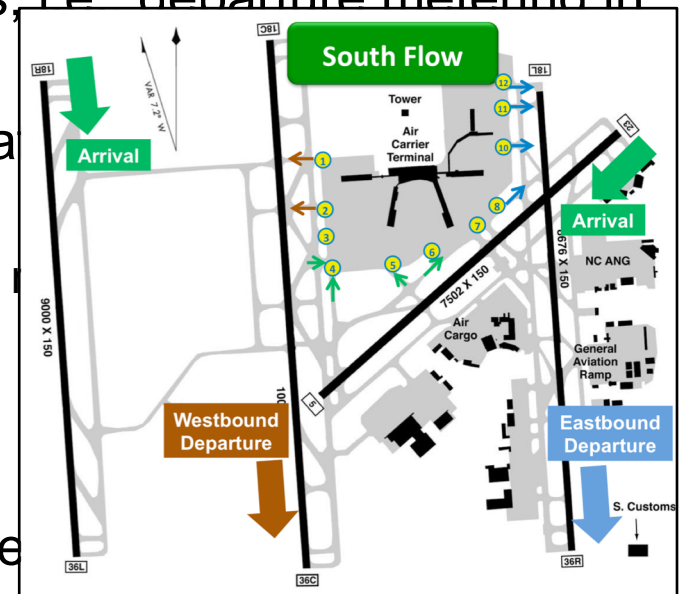
Ramp Traffic Console (RTC) displays SARDA advisories on ramp surface map



# HITL Simulation Details (Oct 2014)



- Advisory runs – Ramp controllers were asked to follow pushback advisory as much as possible
- Baseline runs – Current day operations, i.e. departure metering in place (queue size < 15)
- 2 scenarios created based on actual traffic compressed in time
  - Departure push with the first part of the
  - Each scenario is about 1 hour long
- Clear weather - VFR
- TMIs (MIT @ MERIL 20 nm, EDCT) in effect
- Four-sector configuration for ramp area
- South-flow configuration (Departing: 18L, 18C; arriving: 23, 18R) with the Arrival-Departure Window (ADW) rule enforced



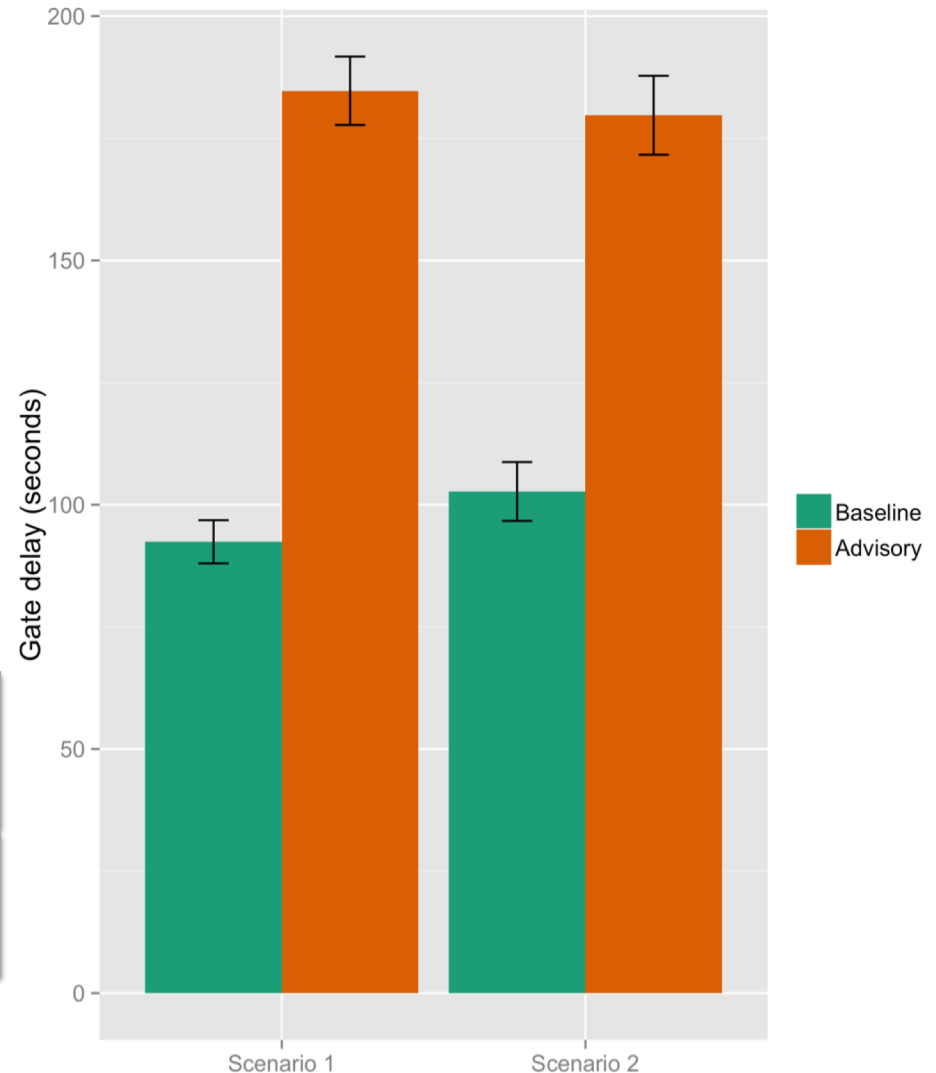
# Gate Hold



$$\text{gate\_delay} = \text{actual\_out\_time} - \text{pushback\_ready\_time}$$

Departures are held at gates longer in Advisory runs

1.53 min increase in Scenario 1 (99.7%)  
1.29 min increase in Scenario 2 (75.4%)

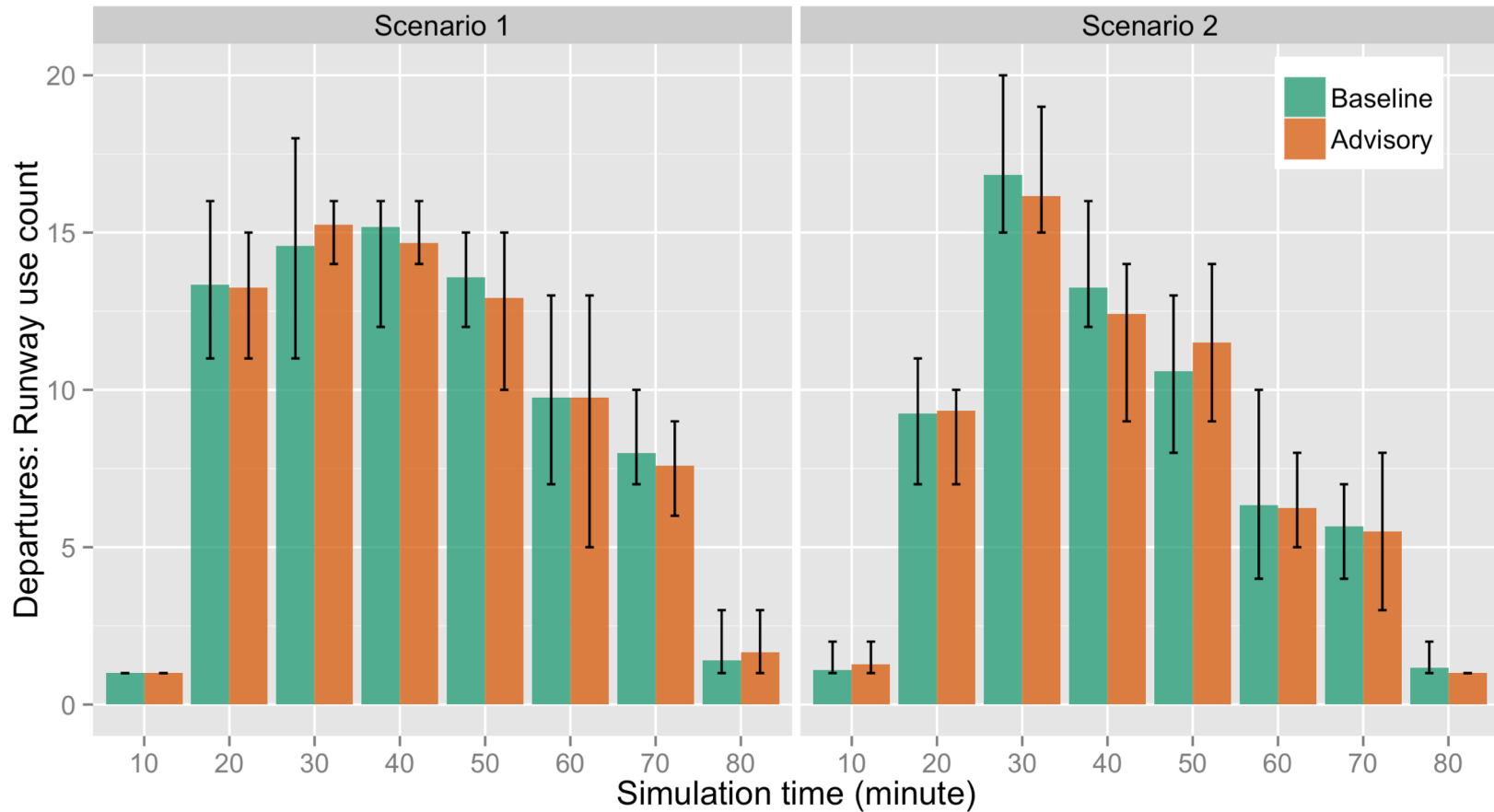




# Runway Usage



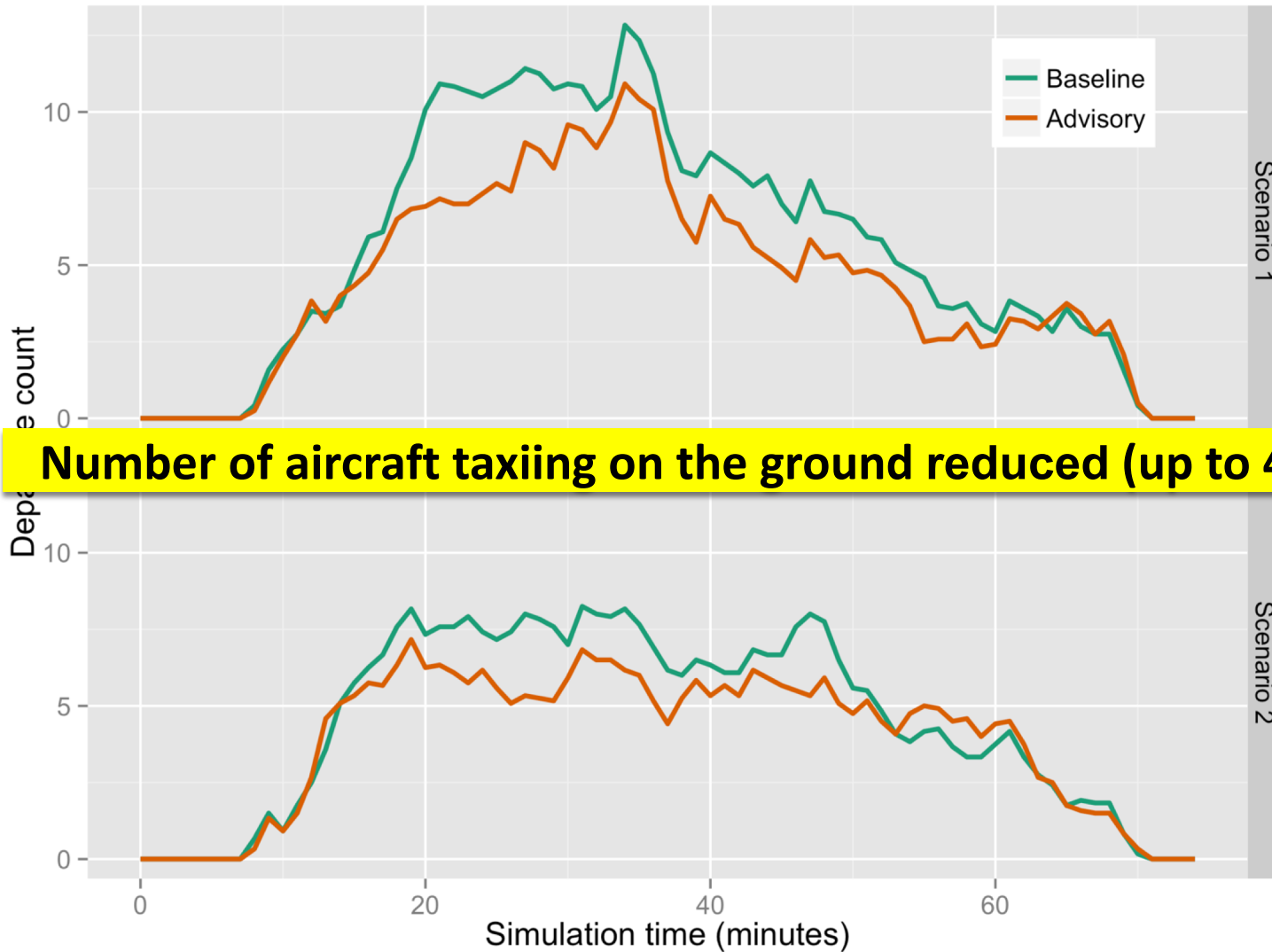
**No observable reduction in runway usage with advisory**



# Surface Congestion



## Number of departures in movement area



# Taxi Times



$\text{taxi-out\_time} = \text{actual\_off\_time} - \text{actual\_out\_time}$

$\text{taxi-in\_time} = \text{actual\_in\_time} - \text{actual\_on\_time}$

## Arrivals

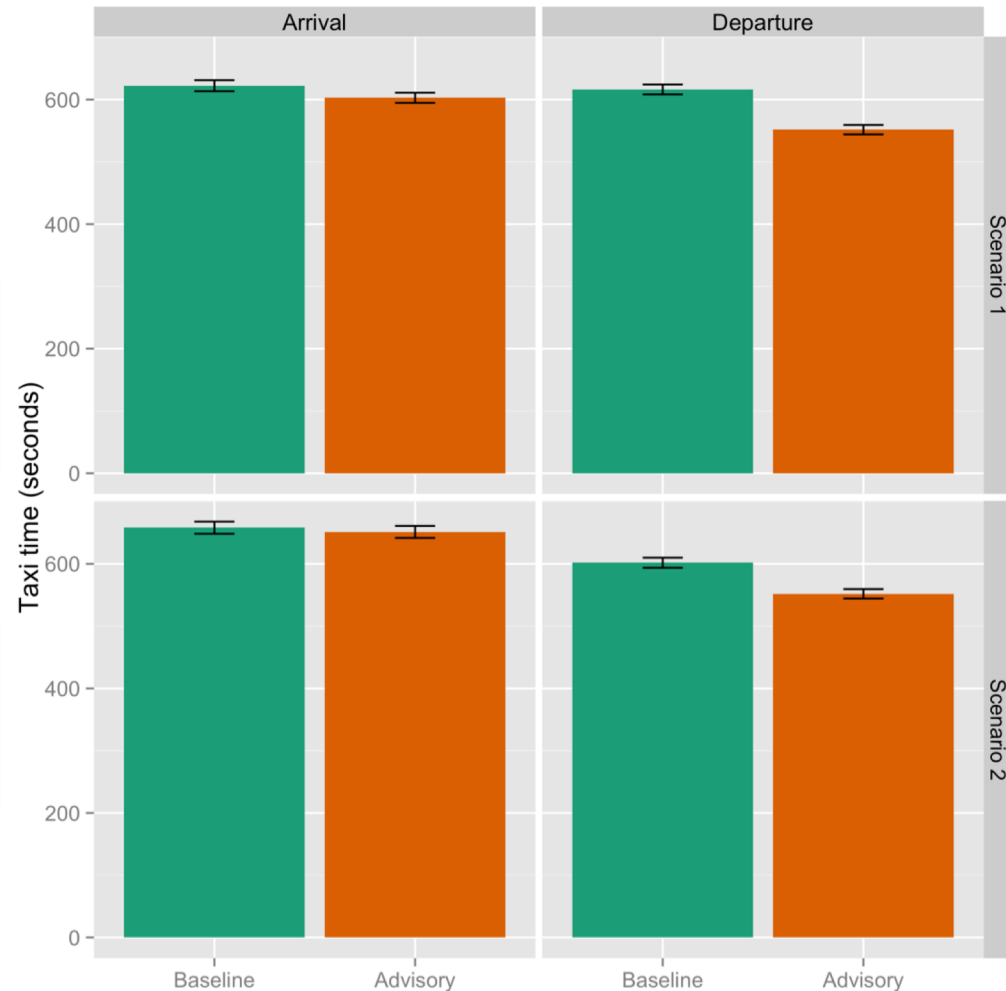
0.3 min reduction in Scenario 1 (3.1%)

0.1 min reduction in Scenario 2 (1.0%)

## Departures

1.1 min reduction in Scenario 1 (10.5%)

0.8 min reduction in Scenario 2 (8.3%)



# Fuel & Emissions Calculation



## Assumptions:

- Engines are off if aircraft is held at the gate
- Engine thrust level: 7% during the entire taxi phase
- Both engines are running while taxiing

AC Type	Assumed AC Model	Assumed Engine Type	EI HC (g/kg)	EI CO (g/kg)	EI NOx (g/kg)	Fuel Flow (kg/sec)
Heavy	B772	Trent 892	1.59	29.62	8.88	0.57
B757	B752	RB211-535E4	0.56	19.40	7.33	0.34
Large	A319	CFM56-5A5	3.47	41.92	7.15	0.19

# Fuel Savings



## Average Fuel Savings:

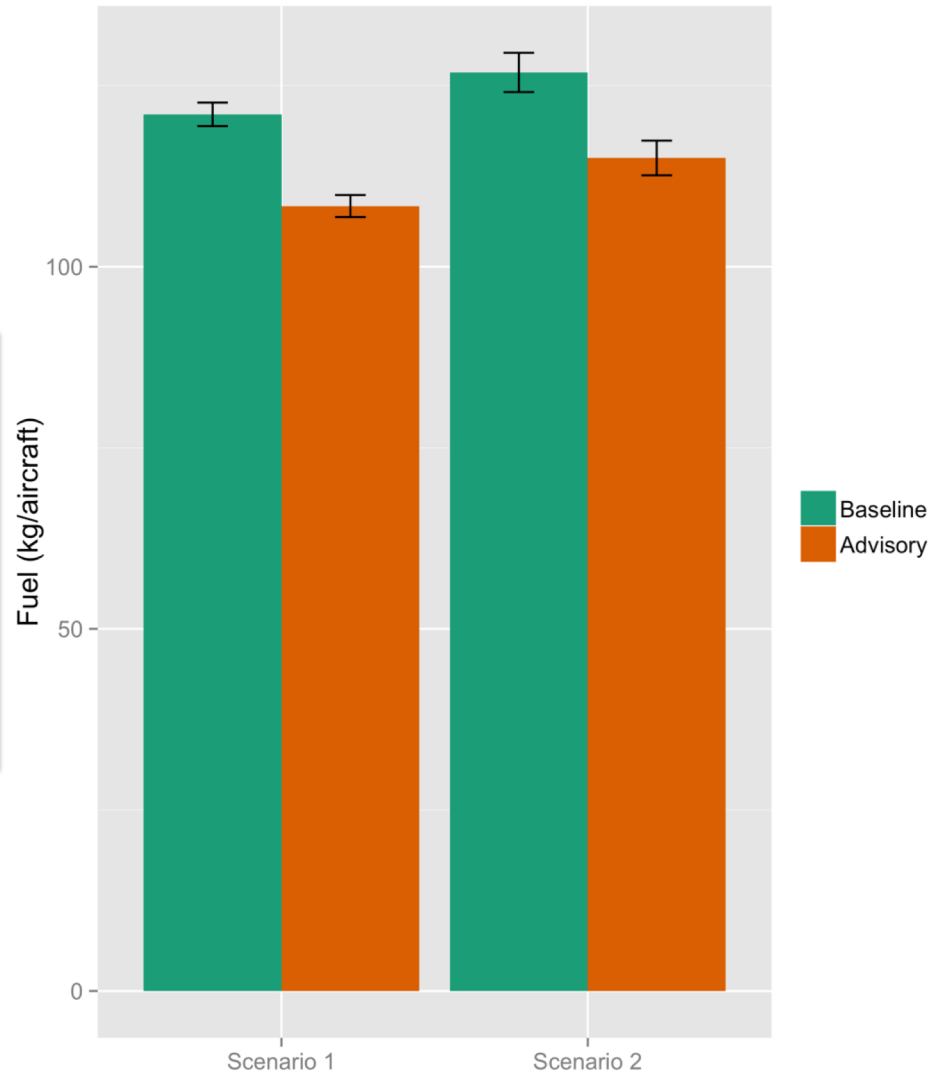
12.7 kg/flight saved in Scenario 1 (10.5%)

11.8 kg/flight saved in Scenario 2 (9.3%)

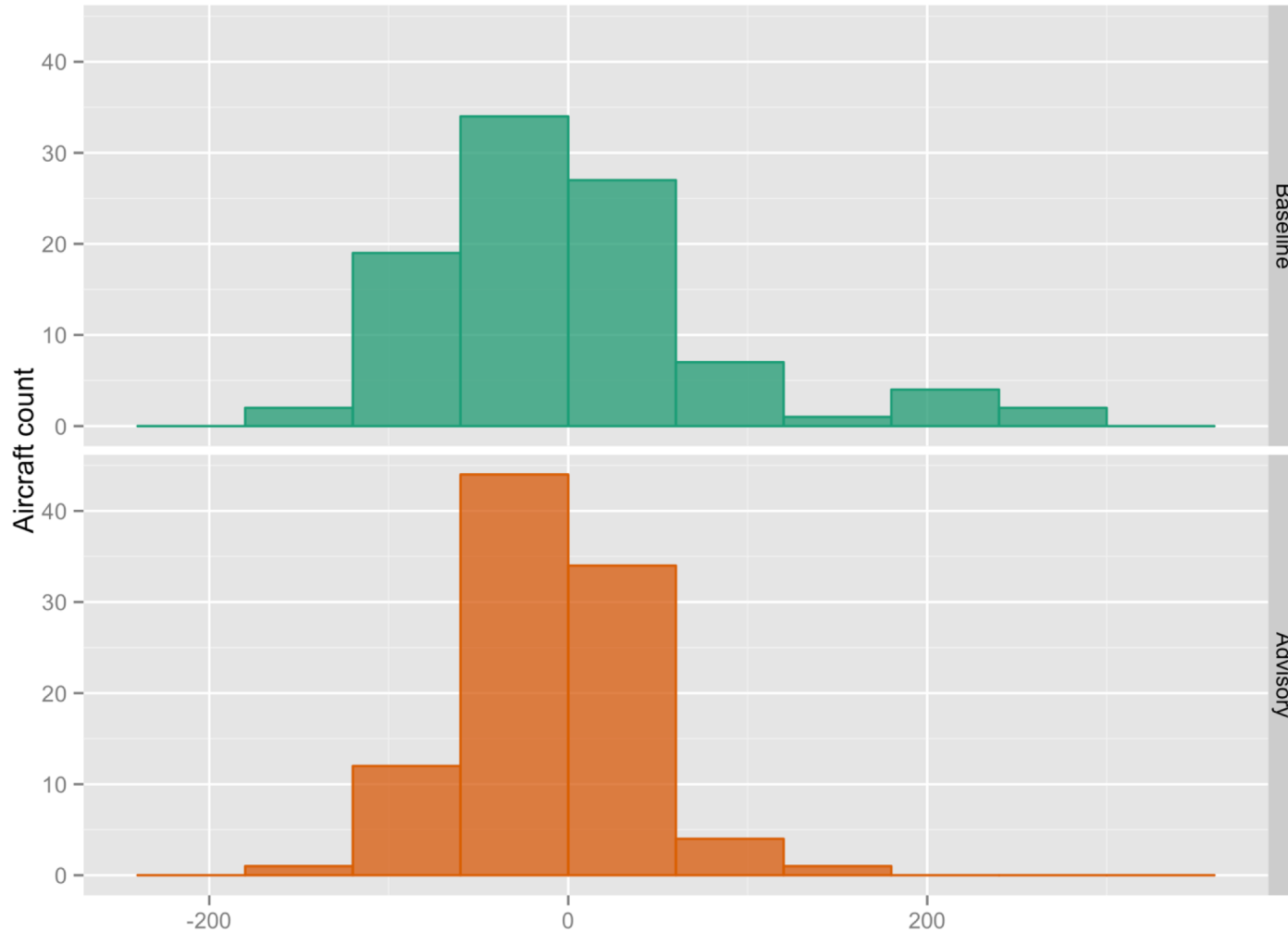
## Total Fuel Savings:

1.3 tonnes saved in Scenario 1 (12%)

1.1 tonnes saved in Scenario 2 (10.4%)



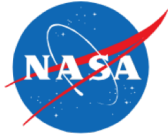
# TMI Conformance



**Advisory runs resulted in smaller variances in the TMI deviations than Baseline runs**

# Summary – Ramp Tool HITL Performance

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- Aircraft were held at the gate longer with advisories.
- No significant differences in runway usage.
- Number of aircraft taxiing on the ground was reduced (up to 4).
- Taxi-out times were reduced (8-10%).
- Fuel savings for departures:
  - 1.3 tonnes in Scenario 1,
  - 1.1 tonnes in Scenario 2
- Better TMI conformance with advisories.

# Summary and Next Step

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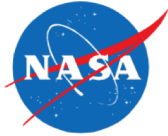


- SARDA provides an optimal schedule of departure aircraft for efficient surface operations.
- A prototype tower controller tool evaluated via HITL simulations showed promising results in taxi delay reduction and fuel saving for DFW.
- SARDA was applied to airline ramp operations to provide pushback advisories.
- HITL results of CLT ramp tower tool showed reduction in taxi time, queue size, and fuel savings.
- Currently, collaborating with American Airlines for field testing.



# Thank you!

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For more information go to:  
**[www.aiviationsystems.arc.nasa.gov](http://www.aiviationsystems.arc.nasa.gov)**



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# Backup Slides



# SARDA Ramp Tool System Architecture

