The Spot and Runway Departure Advisor (SARDA) is an integrated decision support tool for airlines and air traffic control tower enabling surface collaborative decision making (CDM) and departure metering in order to enhance efficiency of surface operations at congested airports. The presentation describes the concept and architecture of the SARDA as a CDM tool, and the results from a human-in-the-loop simulation of the tool conducted in 2012 at the FutureFlight Central, the tower simulation facility. Also, presented is the current activities and future plan for SARDA development. The presentation was given at the meeting with the FAA senior advisor of the Surface Operations Office.
SARDA: An Integrated Concept for Airport Surface Operations Management

SARDA Team
NASA Ames Research Center
March 7, 2013
Spot And Runway Departure Advisor (SARDA)

- Integrated tool for airlines and Air Traffic Control Tower enabling CDM and departure metering
Spot And Runway Departure Advisor (SARDA)

- Integrated tool for airlines and Air Traffic Control Tower enabling CDM and departure metering
- Based on managing scarce resource: Runway
- Strategic or tactical departure metering
Spot And Runway Departure Advisor (SARDA)

- **Integrated** tool for airlines and Air Traffic Control Tower enabling CDM and departure metering
- Based on managing scarce resource: **Runway**
- Strategic or tactical departure metering
  - Strategic: gate/ramp hold fixed 30 or 60 mins before scheduled push-back
  - Tactical: gate/ramp hold assigned after pilot communicates push-back readiness
- Both have tactical ATCT advisories
Spot And Runway Departure Advisor (SARDA)

- **Integrated** tool for airlines and Air Traffic Control Tower enabling CDM and departure metering
- Based on managing scarce resource: Runway
- Strategic or tactical departure metering
- 4-D trajectory enabler
SARDA Strategic Gate Hold
Planning Definition

- **Planning horizon** (PH): how soon is planning done. E.g. 30 minutes
Strategic SARDA Walkthrough

Scheduled push-back
ABC101: 1502
ABC102: 1504
ABC103: 1507
Strategic SARDA Walkthrough

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

PH 30 min

Current time
Strategic SARDA Walkthrough

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

- **Strategic Planning Component (SPC)**
  - Flight restrictions (TMI)
  - Flight details
  - Airport config

- **Current time**
  - PH 30 min
  - 1400 to 1630
Strategic SARDA Walkthrough

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

**Strategic Planning Component (SPC)**
- Strategic SARDA Scheduler

**Preferences**
- Later push-back
- Swaps

Airline

PH
30 min

1400 1430 1500 1530 1600 1630

Current time
Strategic SARDA Walkthrough

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

Strategic Planning Component (SPC)

Preferences
• Later push-back
• Swaps

Airline

PH
30 min

1400 1430 1500 1530 1600 1630

Current time
Strategic SARDA Walkthrough

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

Strategic Planning Component (SPC)

Strategic SARDA Scheduler

Airline

PH
30 min

1400 1430 1500 1530 1600 1630

Current time
Strategic SARDA Walkthrough

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

Strategic Planning Component (SPC)

Tactical Advisory Component (TAC)

Tactical SARDA Scheduler

PH 30 min

1400 1430 1500 1530 1600 1630

Current time
Strategic SARDA Walkthrough

1400 | 1430 | 1500 | 1530 | 1600 | 1630

Strategic Planning Component (SPC)

Tactical Advisory Component (TAC)

Tactical SARDA Scheduler

Agreed push-back times

1500 PH 30 min

Current time

ABC101
ABC102
ABC103
Strategic SARDA Walkthrough

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

Strategic Planning Component (SPC)

Agreed push-back times

Tactical Advisory Component (TAC)

Tactical SARDA Scheduler

10 sec update of all aircraft positions

PH
30 min

1400 1430 1500 1530 1600 1630

Current time
Strategic SARDA Walkthrough

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

**Agreed push-back times**

**Tactical Advisory Component (TAC)**

**Strategic Planning Component (SPC)**

**10 sec update of all aircraft positions**

**ATCT Advisories**

Current time: 1530
Strategic SARDA Walkthrough

**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 Scheduler

**ATCT Advisories**
Strategic SARDA Walkthrough

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

**Strategic Planning Component (SPC)**
- Agreed push-back times

**Tactical Advisory Component (TAC)**
- Tactical SARDA Scheduler

10 sec update of all aircraft positions

**ATCT Advisories**

Current time: 1530
**Strategic SARDA Walkthrough**

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

10sec update of all aircraft positions

- Agreed push-back times
- Strategic Planning Component (SPC)
- Tactical Advisory Component (TAC)

**ATCT Advisories**

- Tactical SARDA Scheduler

**Timeline:**
- 1400
- 1430
- 1500
- 1530
- 1600
- 1630

**Current time**
Strategic SARDA 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, \textit{without affecting complying aircraft}
Tactical SARDA Walkthrough

- Intended for airports with single majority carrier (CLT)
- Can work with airline or ramp control
- SARDA has flight plan
- Push-back time continuously updated based on current airport situation and airline input
- CLT version: When pilot calls “ready for push back”
  - Ramp Controller inputs in SARDA display, SARDA gives hold or release. If hold, gives hold time
  - Advisories for ATCT
SARDA Components and Uses

• Airline (and/or ramp) collaboration
  – Move delays from runway queue to gate
  – Fuel and emission reductions
  – Potentially better connections

• Ground controller advisory
  – Compliance to SARDA for early push-back

• Local controller advisory
  – Improve predictability for downstream (TRACON) integration of departure aircraft
  – Improve predictability of arrival aircraft movement on taxiways
Tactical SARDA HITL tests

- Conducted in May-June 2012
- SARDA implemented in SDSS
- East side DFW (17R departures and 17C arrivals)
- 2 controllers (Ground and Local)
- Pseudo-pilots
- Tactical gate hold through CDM (Idealized to reduce delays)
- No perimeter taxiway
- Ground Controller and Local Controller advisory – through EFS
Tactical SARDA HITL

- Run traffic with SARDA advisories, and without SARDA (aka “Baseline”)
- 2 traffic levels - medium (1.2x) and heavy (1.5x)
- 3 weeks, 2 controllers per week, 48 runs
- Departure peaks in some scenarios
- Separation requirements for RNAV
- Traffic Management Initiatives (TMI) in all runs
Simulation Caveats

- “Advisories” had to be followed
- Ramp area
  - Gate management not implemented
  - De-conflicted ramp movement under development
SARDA Controller Display

Ground Controller Display

Local Controller Display
Results

• Did we succeed in gate holding?
• Was there any loss in runway usage due to holding?
• What are the benefits?
• Aircraft “waiting” in the system:

At every 1 minute, number of departure aircraft that
– Have pushed back and
– Have not taken off within unimpeded taxi time

• Expectation: lower for advisory
Gate Holding

At every 1 minute, number of departure aircraft that have pushed back but not have not taken off
At every 1 minute, number of departure aircraft that have pushed back but not have not taken off
At every 1 minute, number of departure aircraft that have pushed back but not have not taken off
Gate Holding

No more than 6 aircraft “waiting” on the surface with advisory.

At every 1 minute, number of departure aircraft that have pushed back but not have not taken off.
Results

✓ Did we succeed in gate holding?
- Was there any loss in runway usage due to holding?
- What are the benefits?
Runway Usage Comparison

- Cumulative runway usage
  - Number of departure take-offs and arrival crossings until a particular time
  - Calculated every 5 minutes

- Expectation: No reduction in runway usage with advisory
Number of departure take-offs and arrival crossings till a particular time
Runway Usage Comparison

Cumulative runway usage - scenario m1

Number of departure take-offs and arrival crossings until a particular time
Number of departure take-offs and arrival crossings *till* a particular time
Runway Usage Comparison

Cumulative runway usage - scenario m1

Cumulative runway usage - scenario m2

Cumulative runway usage - scenario h3

Cumulative runway usage - scenario h4

Number of departure take-offs and arrival crossings till a particular time
Runway Usage Comparison

No reduction in runway usage with SARDA advisory

Number of departure take-offs and arrival crossings till a particular time
Results

✔ Did we succeed in gate holding?
✔ Was there any loss in runway usage due to holding?
  • What are the benefits?
Results

- Did we succeed in gate holding?
- Was there any loss in runway usage due to holding?
- What are the benefits?
  - Delay
  - Fuel
Delay

• Delay definition
  – (Observed time – unimpeded time)
  – Unimpeded taxi time: time to travel on that route (gate-spot-queue combination) at 17 knots without stops
  – Unimpeded definition different from ASPM

• Taxiing delay: Delay in ramp, taxiways, queues and runway
Taxiing Delay for Departures (ramp, taxiway, queue)

- Mean over all aircraft for that scenario
- 3 min reduction in medium (45%)
- 5.5 min reduction in heavy (60%)
Taxiing Delay for Departures (ramp, taxiway, queue)

Mean and percentile over all aircraft for that scenario
Taxi Delay - Distribution

Total delay, scenario - h3

Baseline

Total delay (min)
Taxi Delay - Distribution

Large variation in delay in baseline
Fuel Consumption

22% reduction in medium
34% reduction in heavy
Fuel Consumption

Daily operations: 6 peak periods of 50 aircraft each

At $3/gallon, annual savings: 6 million USD

Extra fuel per aircraft

- Advisory
- Baseline

<table>
<thead>
<tr>
<th>Aircraft Type</th>
<th>Extra Fuel (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium 1</td>
<td>100</td>
</tr>
<tr>
<td>Medium 2</td>
<td>150</td>
</tr>
<tr>
<td>Heavy 3</td>
<td>250</td>
</tr>
<tr>
<td>Heavy 4</td>
<td>200</td>
</tr>
</tbody>
</table>
Results

✓ Did we succeed in gate holding?
✓ Was there any loss in runway usage due to holding?

• What are the benefits?
  – Delay
  – Fuel
  – TMI (Traffic Management Initiatives)
TMI

• Details
  – Each TMI aircraft has a scheduled take-off time (displayed in Electronic Flight Strips)
  – Aircraft should take off within 1 minute before or 1 minute after this time
  – If cannot be done, release as close to time as possible (no new TMI time issued)

• Compliance?

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Baseline</th>
<th>Advisory</th>
</tr>
</thead>
<tbody>
<tr>
<td>m1</td>
<td>93%</td>
<td>100%</td>
</tr>
<tr>
<td>m2</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>h3</td>
<td>86%</td>
<td>100%</td>
</tr>
<tr>
<td>h4</td>
<td>93%</td>
<td>100%</td>
</tr>
</tbody>
</table>
TMI

Less variation in TMI aircrafts’ delays in advisory
Results

- Did we succeed in gate holding?
- Was there any loss in runway usage due to holding?

- What are the benefits?
  - Delay
  - Fuel
  - TMI (Traffic Management Initiatives)

- Effect on arrivals
Arrival Delay

No effect on arrival aircraft
Results

✓ Did we succeed in gate holding?
✓ Was there any loss in runway usage due to holding?

• What are the benefits?
  – Delay
  – Fuel
  – TMI (Traffic Management Initiatives)

• Effect on arrivals

• Reduction in overall delay
Departure Delay

Statistically significant effect of advisory on departure delay
Results

- Did we succeed in gate holding?
- Was there any loss in runway usage due to holding?

- What are the benefits?
  - Delay
  - Fuel
  - TMI (Traffic Management Initiatives)

- Effect on arrivals
- Reduction in overall delay
- Increased predictability
Beyond 2012 HITL

• Idealized push back holds – what happens under push back uncertainty
  – Real-time automated simulations
  – Even with increasing uncertainty in gate push-back (± 3 mins), there is little increase in taxiing delay
  – For the 2 scenarios tested, loss in runway usage with ± 3 mins push-back uncertainty not substantial
Spot And Runway Departure Advisor (SARDA)

- Integrated tool for airlines and Air Traffic Control Tower enabling CDM and departure metering
- Based on managing scarce resource: Runway
- Strategic or tactical departure metering
- 4-D trajectory enabler
  - Currently 3 advisories: gate/ramp, spot and runway
  - SARDA can provide times for more “nodes” – full datalink based movements
Current Activities

- NRA teams are wrapping up studies of implementing SARDA concepts at airports: PHL, LAX, CLT, JFK, and BOS
- Preparation for the next HITL in 2014
  - Developing a second airport model (adaptation), Charlotte
  - Expanding SARDA scheduler to provide full airport scheduling
  - Developing ramp controller interface (GUIs)
  - Enhancing simulation facility to host multiple & concurrent participants (ramp and tower controllers)
Upcoming Activities

• 2014 Charlotte ramp control HITL
  – Simulation characteristics
    • Two hour long scenario, to capture arrival-departure push
    • Includes turnaround traffic
  – Ramp side
    • Staffing: 4-ramp controllers + 1-supervisor
    • Participants: airline operator personnel
    • Using Electronic Flight Strips (EFS) and other GUI to interact with SARDA and manage traffic
  – Tower side
    • Staffing: 1-ground + 1-local controller
    • Participants: 1-ground controller + 1-local controller (pool of participant is TBD)
    • Using Electronic Flight Strips (EFS) and other GUI to interact with SARDA and control traffic

• Future Work
  – Strategic SARDA with airline interface
  – Accepts changes to miles-in-trail restrictions in real-time.