Dynamic Weather Routes: Two Years of Operational Testing at American Airlines

Dave McNally, Kapil Sheth, and Chester Gong
NASA Ames Research Center
Moffett Field, California

Mike Sterenchuk
American Airlines, Integrated Operations Control
Fort Worth, Texas

Scott Sahlman, Susan Hinton, Chuhan Lee
University of California, Santa Cruz
Moffett Field, California

Fu-Tai Shih
SGT, Inc.
Moffett Field, California

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What's the Problem

• Convective weather cells, or severe thunderstorms, are leading cause of flight delay in US airspace

• Flight dispatchers file flight plans 1-2 hours prior to departure utilizing routes with conservative buffers to severe forecast weather

• Weather changes as flights progress

• No automation to help operators determine when weather avoidance routes have become stale and could be corrected to reduce delay
Take Away Message

• Continuous automatic search finds simple route corrections for significant flight time savings, airborne flights, en route airspace

• Potential savings 100,000 flying minutes, Fort Worth Center 2013, all flights, all airlines, 6.7 min/flight average

• Potential to reduce sector congestion 20% overall

• Actual savings for American Airlines is significant. More staffing, ATC friendly routes, Data Comm could yield way more savings
Outline

- DWR Automation Concept
- Convective Weather Model
- Benefits Analysis
- System Architecture
- Trial at American Airlines
- Test Results
- Future Work
How does DWR select flights and identify route corrections?
Flight Plan Route

Continuous Real Time Analysis
Airborne Flights En Route Airspace
Compute Reference Direct Route for all Flights

Savings > 5 min wind-corrected?

Flight Plan Route

Return Capture Fix
- Last fix inside limit region or
- Last fix before standard arrival route

Maneuver Start Point
- 5 min downstream or
- For climbers, first point in high altitude airspace
Auto select auxiliary waypoints (up to two) for minimum-delay weather or weather and traffic resolution

Savings > 5 min wind-corrected?
Snap To Nearby Named Fixes

Savings > 5 min wind-corrected?
Dynamic Weather Routes (DWR)

Continuous Automatic Search Finds High-Value Route Correction Opportunities, Airborne Flights, En Route Airspace

Flight Plan Route

Return Capture Fix

Dynamic Weather Route

Auxiliary Waypoints

Maneuver Start Point
Weather Model
Weather Model

Corridor Integrated Weather System (CIWS)
- 2-hour forecast, 5-min time steps, 5-min update

Convective Weather Avoidance Model (CWAM)
- CWAM (FL350, 0 min forecast)
- 100 NM (185 km)
Weather Model

Trajectory modeling and weather conflict detection accounts for movement of weather over time.

CWAM (FL350, 60 min forecast)
Sample DWR

Sample Flight A320 Houston/Denver

Flight Plan Route

Reference Direct Route

12 min potential savings
Sample Flight A320 Houston/Denver

Flight Plan Route

DWR Route

7.8 min potential savings
System Architecture

- Congested Sectors
- Special Use Airspace
- FAA Route Restrictions

CTAS
- DWR Search
- Automatic Conflict Detection & Resolution for Weather & Traffic
- Flying Time Analysis

FACET
- Congested Sectors
- Special Use Airspace
- FAA Route Restrictions

Winds, Weather, Special Use Airspace, FAA Route Restrictions

Center/TRACON Automation System (CTAS)
Future ATM Concepts Evaluation Tool (FACET)
DWR User Interface

Potential Savings: 20 min

DWR Flight List

Flight Plan Route

DWR Route Correction

Congestion on Flight Plan

Congestion on DWR
Benefits Analysis
Potential Benefits Analysis
All Airlines, All Flights, Fort Worth Center 2013

100,000 min for 15,000 flights
Fort Worth Center 2013

Potential Flight Time Savings (min)
Potential savings
Potential savings corrected for observed amendments
Trial at American Airlines
Trial at American Airlines

DWR Display

American Airlines
Integrated Operations Control, Fort Worth, Texas
Trial at American Airlines

ATC Desk, American Airlines
Integrated Operations Control, Fort Worth, Texas
Trial at American Airlines
Information Flow

NASA DWR Automation
  ↓
Airline ATC Coordinator
  ↓
Airline Dispatcher
  ↓
Pilot
  ↓
FAA Controller
  ↓
Route Clearance
How much savings do American Airlines flights get using DWR?
Estimated Actual Savings Analysis

Offline analysis, runs automatically every day

- AAL user clicks an "Accept" button on the DWR display signaling their intent to try to get a DWR reroute
- DWR users report about 90% of accepted DWR routes result in ACARS messages to flight crews
- Actual route amendments don't always match AAL accepted DWR route
- Total observed savings is often a result of more than one actual route amendment
- Assume actual route amendments up to 30 min after AAL "Accept" time correlate with DWR use
Sample Flight: Dallas to Omaha

Flight Plan Route

AA Accepted DWR Route
10.4 min potential savings

CAUTION: NO WEATHER CONFLICT DETECTION BELOW FL250
Sample Flight: Dallas to Omaha

- Return Capture Fix
- Actual Flight Track
- Flight Plan Route
- Auxiliary Waypoint
- AAL Accepted DWR Route
  10.4 min attempted savings
- Maneuver Start Point

Scale: 100 NM
Sample Flight: Dallas to Omaha

First amendment, $t_0 + 13$ min
Direct PNH, 0.5 min savings

AAL Accepted DWR Route
10.4 min attempted savings

Accept time = $t_0$
Sample Flight: Dallas to Omaha

First amendment, $t_0 + 13$ min
Direct PNH, 0.5 min savings

Second amendment, $t_0 + 24$ min
Direct GCK, 4.8 min savings

Accept time = $t_0$

AAL Accepted DWR Route
10.4 min attempted savings

100 NM
Sample Flight: Dallas to Omaha

First amendment, $t_0 + 13$ min
Direct PNH, 0.5 min savings

Second amendment, $t_0 + 24$ min
Direct GCK, 4.8 min savings

Third amendment, $t_0 + 49$ min
Direct GCK037015, direct LNK
3.8 min savings

AAL Accepted DWR Route
10.4 min attempted savings

Accept time = $t_0$

5.3 min Estimated Actual Savings

100 NM
Sample Flight: Dallas to New Orleans

Flight Plan
Route
AA Accepted DWR
30.0 min potential savings

31.5 min Estimated Actual Savings

Accept time = $t_0$

First amendment, $t_0 + 5$ min direct RZC, 0.0 min savings

Second amendment, $t_0 + 10$ min direct MSY, 31.5 min savings
Actual savings significant, but small compared to what could be saved

More staffing, ATC friendly route corrections, and Data Comm could result in way more savings
How much more savings does AAL get when they're using DWR vs not using DWR?

DFW/DAL Departures, 29 days in 2014 with High Potential DWR Savings

<table>
<thead>
<tr>
<th>Advised Savings</th>
<th>DWR Used</th>
<th>DWR Not Used</th>
<th>DWR Not Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,102 min</td>
<td>114 AAL flights</td>
<td>4,315 min</td>
<td>412 AAL flights</td>
</tr>
</tbody>
</table>

Actual Savings/DWR Advised Savings (%)

When DWR is staffed flights get 20% more savings
Do weather cells that require deviation occur on the DWR trajectory after Accept time?

Sometimes. But, required deviation usually small, less than 20 NM.

Work ongoing to improve logic that rejects DWR solutions with narrow weather gaps and conflicts.
What happens to sector congestion if all flights fly DWR routes?

- Analyze top 30 days in terms of DWR potential savings, July 2012 to Sept 2014
- Two FACET simulation runs for each day
  1) All traffic on Center flight plan routes
  2) All 7,098 DWR flights on DWR routes, other traffic on Center flight plan routes
- Compare time duration in congested sectors
What happens to sector congestion if all flights fly DWR routes?

Proposed DWRs for 7,098 Flights, Top 30 days Aug 2012 to Sept 2014

<table>
<thead>
<tr>
<th>Flight Plan</th>
<th>Time in congested sectors (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow</td>
<td>14,000</td>
</tr>
<tr>
<td>Red</td>
<td>10,000</td>
</tr>
<tr>
<td>Red + Yellow</td>
<td>18,000</td>
</tr>
</tbody>
</table>

20% reduction in congestion due to DWR routes.
38% reduction in congestion due to DWR routes.

Red + Yellow Congestion Status
Future Work

• Better balance of potential flight time savings with ATC acceptability
  – Familiar routings
  – Avoid congested airspace and dense merging streams
  – Reduce coordination

• Common routes for multiple flights, better suited to FAA users, corrections to playbook routes

• Data Comm and web-based connectivity for streamlined coordination
Take Away Message

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POC: dave.mcnally@nasa.gov
Backup Slides
DWR Compatibility with Data Comm

Press buttons to load, communicate, visualize, execute

Reference: McNally, Gong, Sahlman, ICNS2015
Nowcast Gaps

180 Accepted AA flights over 9 high-value, high-use days

Minimum gap width (nmi)

Elapsed time from Accept time (min)

DWR System Gap Rejection Parameters

- 25 nmi Gap
- 50 nmi Offset (up to 7/24/14)
- 50 nmi Gap
- 75 nmi Offset (after 7/24/14)
Nowcast Conflicts

180 Accepted AA flights over 9 high-value, high-use days

Minimum deviation to avoid conflict (nmi)

4 conflicts, all on one day, real-time processing error, no flights rerouted
Direct Route Example

Strong head winds sometimes create opportunities for big savings

MD83 Dallas/Chicago
9 min Potential Savings