Operational Evaluation of a Flight-deck Software Application

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DATAWorks
March 21-22, 2018
Traffic Aware Strategic Aircrew Requests (TASAR)

The TASAR Concept

Pilot uses **onboard automation** to optimize an aircraft’s trajectory
- Tool monitors for and proactively suggests beneficial route/altitude modifications
- Agile to changing conditions and environment (e.g., winds, weather, traffic)

Tool leverages **networked airborne connectivity** to real-time data
- Avionics connectivity for “own-ship” data
- Automatic Dependent Surveillance Broadcast (ADS-B) connectivity for traffic data
- Internet connectivity for environmental/airspace data, operational constraints, etc.

**Increase Air Traffic Control approval** of pilot’s user requests
- Tool combines flight path optimization with traffic/hazard compatibility

TASAR Objectives

1. Produce Air Traffic Control-approvable, user-optimized changes in flight to increase time on user’s business trajectory
2. Enable a near-term business case for ADS-B equipage, cockpit automation, and networked connectivity
3. Take a concrete step towards future applications of cockpit automation for significant system/user benefits
Operating Environment for Airborne Reroutes
Traffic Aware Strategic Aircrew Requests (TASAR)

Leveraging Cockpit Automation and Connectivity for Airborne Rerouting

Traffic Aware Planner (TAP): Real-Time Trajectory Optimizer

- Connected Internally
  - Aircraft State
  - Current Route
  - Aircraft Sensors

- Traffic Aware Planner (TAP):
  - Real-Time Trajectory Optimizer

Better Informed Reroute Request for Pilots

Coordinated with Dispatch

Increased Likelihood of Air Traffic Control approval

Flight Re-optimized

Approved and Flown!
## An Early Adopter Application

<table>
<thead>
<tr>
<th>TASAR Attributes</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Consistent with current operations</strong>&lt;br&gt;Requires no changes to existing FAA systems, policies, roles, training</td>
<td><strong>Near term</strong></td>
</tr>
<tr>
<td><strong>Low threshold for FAA approval</strong>&lt;br&gt;Non-safety-critical intended function</td>
<td><strong>Low Cost</strong></td>
</tr>
<tr>
<td><strong>Per-aircraft capability</strong>&lt;br&gt;Allows gradual implementation with immediate benefits</td>
<td><strong>Immediate Savings</strong></td>
</tr>
<tr>
<td><strong>Leverages aircrew availability / low workload en route</strong>&lt;br&gt;Provides more opportunities to accrue benefits&lt;br&gt;Encourages crews to become proactive about efficiency</td>
<td><strong>Accelerated ROI</strong></td>
</tr>
<tr>
<td><strong>Platform for future innovations in cockpit automation</strong>&lt;br&gt;Integrate with avionics, dispatch, data sources, data communications</td>
<td><strong>Growth Potential</strong></td>
</tr>
</tbody>
</table>
Traffic Aware Planner (TAP) Optimization Engine

Pattern-Based

Mix of Exhaustive Search and GA

Viable Solutions Only

Highly Efficient

Lateral Patterns:

- Generate All Directs
- Rank
- Best Direct
- 19 Random 1WP or 2WP
- Rank
- Keep Top 10
- 10 New (1WP or 2WP) via Mating
- Mutate a portion (exclude top 2)
- Rank

Top Ranked of 20th Generation Is Lateral Solution

Vertical Patterns:

- All Allowable Cruise Altitudes
- Rank All Candidates

Top Ranked is Vertical Solution

Combo Patterns:

- Generate All Direct/Alt
- Rank
- Best Direct/Alt
- 19 Random 1WP/Alt or 2WP/Alt
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- 10 New (1 or 2 WP/Alt) via Mating
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Traffic Aware Planner (TAP) User Interface
TASAR Benefits Estimate Tailored to Alaska Airlines

<table>
<thead>
<tr>
<th></th>
<th>Annual TASAR Fuel Benefit</th>
<th>Annual TASAR Time Benefit</th>
<th>Annual Benefit (est.) *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alaska Airlines*</td>
<td>1,040,000 gallons</td>
<td>110,700 min</td>
<td>$5.15M</td>
</tr>
<tr>
<td></td>
<td>$3,390,000/year</td>
<td>$1,759,000/year</td>
<td></td>
</tr>
</tbody>
</table>

* Excludes Alaska, Oceanic, and international operations
† Fuel, maintenance, and depreciation. Excludes crew costs.

Estimated Average Benefits Per Flight

2.89 min/flight
27.8 gallons/flight

Annualized average across all flights, even those that did not benefit

Historical trajectories used as a baseline for estimating benefits

1,606 Alaska flights analyzed

Flight Tested in the National Airspace System

**Goal:** Increase operational readiness for partner airline activities

**Objectives:**
1. Verify TAP software operates effectively on partner airlines hardware
2. Verify processing of external data
3. Assess the methodology to characterize TAP computed outcomes
4. Assess acceptability of TASAR requests
5. Assess usability and acceptability of TAP Human Machine Interface
6. Assess effect on Crew Resource Management

Operational Evaluation with Alaska Airlines

• TAP installed on three Alaska aircraft to evaluate its performance in operational use

• Validate the utility and benefits of TAP in an airline operational environment

• Accelerate technology transfer to the commercial sector

• Increase maturity of TASAR to enable air-ground integration in 2018-2020
**Flight Test vs. Operational Evaluation**

<table>
<thead>
<tr>
<th>Flight Test</th>
<th>Operational Evaluation</th>
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<tbody>
<tr>
<td>Conducted by NASA or contractor</td>
<td>NASA in partnership with commercial airline</td>
</tr>
<tr>
<td>Relevant environment</td>
<td>Operational environment</td>
</tr>
<tr>
<td>Design of Experiments</td>
<td>Observational data</td>
</tr>
<tr>
<td>Smaller dataset with fewer users and flight profiles</td>
<td>Larger dataset with more users and flight profiles</td>
</tr>
<tr>
<td>In-depth user feedback</td>
<td>Limited user feedback</td>
</tr>
<tr>
<td>No missing data</td>
<td>Missing data</td>
</tr>
<tr>
<td>Less time</td>
<td>More time</td>
</tr>
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</table>
NASA and Alaska Airlines are partners for the purpose of evaluating the TAP software in operational use

Objective: To quantify operational performance by assessing

- Achieved fuel and time benefits
- TAP usability by pilots
- Dispatch coordination outcomes
- ATC approval statistics
## Analysis by Operational Stage

### Stage 0: Establish connectivity between TAP and avionics
- Avionics data format and rate
  - Computational performance in flight
  - Trajectory prediction accuracy
  - Verify airborne internet data
  - Identify and fix software issues

### Stage 1: TAP running without display
- Identify and fix remaining software issues
  - Verify communications between software engine and display
  - Quantitative analysis

### Stage 2: Operational Evaluation by select group of pilots
- Limited software testing if needed
  - Quantitative analysis

### Stage 3: Full Operational Evaluations

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<th>Stage 0</th>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
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Data Sources

- TAP recorded data
- Avionics data
- Pilot and Dispatcher questionnaires
- Alaska flight plans
- Flight data
- Aircraft operating costs

Additional text:

Alaska flight plans

FAA Form 7233-1 (8-82)

CLOSE VFR FLIGHT PLAN WITH _____________________ FSS ON ARRIVAL

TAP recorded data

Avionics data

Pilot and Dispatcher questionnaires

Alaska flight plans

Flight data

Aircraft operating costs

14
Achieved Fuel and Time Benefits

A. Predicted fuel and time to destination prior to first TAP reroute request

B. Flown fuel and time along TAP-advised reroute + predicted descent

Achieved benefit is fuel and time at destination from B minus fuel and time at destination from A.
Overview of Benefits Analysis

1. Identify route and altitude changes
2. Identify pilot interactions with TAP display
3. Match route and altitude changes with TAP reroute advisories
   - 4. Identify last TAP ownership prediction prior to executed change
   - 5. Apply error distribution to TAP ownership prediction
   - 6. Identify first ownership state to obtain fuel and time
   - 7. Identify last ownership state prior to final descent with stable prediction
4. Predicted fuel and time prior to TAP reroute
5. Flown fuel and time along TAP reroute
8. Calculate cost savings
9. Benefits aggregation and reporting
Benefits Analysis

Assessing achieved benefits is challenging due to

- Air Traffic Control actions
- Uncertain atmospheric conditions
- Fuel and time measurement error
Thank You