Weather Technology In The Cockpit (WTIC)

EDR Uplink Quantitative Benefits Analysis

Mike Robinson
AvMet Applications, Inc.

September 2014
Turbulence Workshop
Motivation

• Lack of timely, accurate turbulence information for use in flight operations results in impacts to NAS flight safety, to effective capacity utilization, and to flight efficiency (fuel burn/emissions)

• User concerns:
  – **Crew/Dispatch:** Multiple (sometimes conflicting) data sources, PIREP subjectivity, cabin management, tolerance for risk; Data “timeliness” an issue
  – **ATC:** No access to real-time turbulence data in work area, ride reports passed from controller to controller during shift change, “blocked” out altitudes can persist for hours
  – **Flight Attendants:** Cabin management / uncooperative passengers, obligation to continue duties when seatbelt sign is on
“EDR Uplink” Demonstration
Pilot Use of Real-time Turbulence Viewer in Cockpit

- WTIC EDR Uplink Demonstration is assessing the feasibility of using low-cost devices to display turbulence information in the cockpit for direct use by the flight crew

- Goals:
  1. Identify the feasibility of providing and displaying the EDR/GTG information to crews on the flight deck through existing WIFI link
  2. Identify and address human factors considerations associated with providing the EDR/GTG data to flight crews
  3. **Quantify the efficiency and capacity benefits to the NAS of providing the EDR/GTG data directly to flight deck**

- Cooperative effort with DAL
  - 40 DAL 737 and 28 DAL 757 Line Check Airmen (LCA) pilots provided Turbulence viewers on IPads (737) or Microsoft Surface Tablet (757)
  - LCAs fill out detailed usage surveys (on tablets) after each flight
  - Data collection period: August 2013 – July 2014
Experiment Data

• Data collected throughout the baseline period and demonstration period included:
  - EDR
  - PIREP
  - GTG (Analysis/Forecast)
  - NCWD
  - Aircraft data (equipment, altitude, etc.)
  - Flight Data (actual vs. planned)

• Baseline period (October 2012 – June 2013)
  - Baseline data used to establish pre-demonstration and pre-viewer flight crew behaviors in / around areas of clear-air turbulence (e.g., not convectively-induced)

• Demonstration period (August 2013 – July 2014)
  - Additional, key data during demonstration included questionnaire data submitted by pilots who have the viewer onboard
Data Analysis

- EDR, GTG, and aircraft data mined to identify actions which could be associated with turbulence

- General data captured identified various scenarios associated with altitude changes associated with clear air turbulence:

<table>
<thead>
<tr>
<th>Actionable Item</th>
<th>Flight encounters turbulence</th>
<th>Flight does not encounter turbulence</th>
<th>Flights in the vicinity report / discuss turbulence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Considerations</td>
<td>Severity, duration of turbulence experience, turbulence forecast data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flight Response</td>
<td>Change/No change in altitude/sector</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equipment</td>
<td>Viewer equipped, EDR equipped, aircraft type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NAS Impact</td>
<td>Location / workload</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other Information</td>
<td>PIREPs, Questionnaire data, severe weather proximity</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Various combinations as well as specific details provide different scenarios and opportunities for a benefits analysis.
Key Data: Turbulence Viewer Questionnaire

Flight Plan Info

Data*
09/02/2014

Flight Number*
DAL
Please enter at least 4 characters.

From
To

Level Off Baseline

Check all that applies:

- ATC directed level off other than flight plan
- Crew requested level off other than flight plan based on turbulence

Level Off Altitude*
This field is required.

Time (Z)

Original Flight Plan Altitude*
This field is required.

FM $ Altitude*
(8767: RCMD,
8737: OPT)
This field is required.

Please select a primary driver/actor for attitude change resulting from turbulence:

- Turbulence Viewer
- ATC Chat Discussions
- Flight Plan Remarks
- Uplinks (ACAR & TP)

Please select a primary goal/objective for your decision:

- Safety
- Passenger comfort
- Economy
Demonstration Data Collection (Aug ‘13 – July ‘14)

Evaluating questionnaires during demonstration period

- 758 questionnaires submitted
  - 462 (61%) selected “Turbulence Viewer” as primary driver for altitude change or remaining on cruise altitude
    » 145 (31%) selected “Economy” of “Safety” as the primary reason
    » 312 (68%) selected “Passenger Comfort” as the primary reason
  - 267 (58%) noted altitude changes

Comments submitted include:

- Viewer allowed me to see forecasted Turb moving south. I was able to stay at 380

- Maintained a smooth altitude to avoid light/mod turbulence presented by the viewer. Maintained F350 as opposed to climbing to FMS recommended and flight plan Alt of F390

- Viewer allow(ed) us to stay at optimum altitude and avoid an unnecessary descent.

- Viewer allowed us to see only a small pocket of chop. We stayed at optimum.
Benefits Analysis Framework

Pre-Demonstration Actions

- Define Benefits Objectives
- Define Operational Benefits Scenarios
- Identify Data Needs to Isolate Benefits
- Develop Methods for Assessing Metrics
- Identify and Assess Turbulence Encounter / Response Baseline Environment (Isolating Shortfall Scenarios)
- Baseline: October 2012 – June 2013

Demonstration Execution

Demonstration Data Collection

- Identify potential benefit scenarios; Case event vs. baseline environment comparisons
- Objective Analysis of NAS-wide benefits opportunities given specific scenarios

Benefits Analysis

Output Metrics for Benefits Estimation

Pre-Demonstration Actions:

- Demonstration Data Collection
  - Demonstration Data Analysis
  - Simulation
  - Questionnaire Data

Benefits Analysis:

Output Metrics for Benefits Estimation
Turbulence Viewer Quantitative Benefits Analysis

- Dynamic Airspace Routing Tool (DART) – a weather-aware “superfast-time” ATM simulation model – has ability to:
  - Automatically generate most-economical reroutes using weather diagnostic/forecast blend (including EDR/GTG here);
  - Combine reroutes and/or ground delays (and cancellations where needed);
  - Apply user-specified cost parameters for a benefits analysis, reroute strategies, and risk tolerance factors; and
  - Apply actual and simulated TMIs within the modeling environment

- DART will be used to recreate and evaluate primary benefits scenarios identified from Turbulence Viewer experiment

Output Metrics for Benefits Estimation

- Capacity-Related Benefits
- AOC, ATC, ATM Productivity Benefits
- Emissions / Fuel Burn Benefits
DART-focused Benefits Areas for Turbulence Viewer Experiment

- Primary operational impact identified as a result of the EDR/GTG information in cockpit is a reduction in unnecessary altitude changes prior to or during a turbulence encounter

- Benefits may be extracted which include:

1) Reduction in ATC workload
   - Communications
   - Sector changes
   - Flight amendments
   - Requests for ride reports

2) Reduction in fuel burn / emissions
   - Magnitude of altitude change
   - Frequency of altitude change

3) Capacity utilization efficiency
   - Reduction in ATM actions
   - Reduction in NAS Delay / Airline Operating Cost & Passenger Value Time

Completed DART simulations for a 6 month period
- January - June 2014
- 1,322 simulations
- Separated results by region and time of day
- Categorized days by varying coverage of turbulence
Benefits Quantification Simulation Studies

- Identified simulation scenarios based on questionnaire responses collected during demonstration and/or observed data from demonstration
- Benefits quantification determined from questionnaire responses, demonstration data, and simulations

<table>
<thead>
<tr>
<th>Benefits Analysis</th>
<th>Simulation</th>
<th>Basis</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Reduction in fuel usage / emissions from less flights changing off optimal planned altitude for turbulence</td>
<td>DART</td>
<td>Observations / Questionnaire</td>
<td>Magnitude of altitude changes determined from observations, percentages and results derivations applied to simulation results</td>
</tr>
<tr>
<td>2 Reduction in ATC communication workload (i.e., sector changes, flight amendments, ride reports/requests) from flights changing altitude</td>
<td>DART / ATC Workload Model</td>
<td>Questionnaire</td>
<td>Changes in altitude require communications with ATC and others. Reductions in ride reports / requests as well are possible based upon viewer input.</td>
</tr>
<tr>
<td>3 Reduction in “unnecessary” altitude changes</td>
<td>-</td>
<td>Questionnaire</td>
<td>Direct response from questionnaire</td>
</tr>
<tr>
<td>4 Improved capacity utilization</td>
<td>DART</td>
<td>Observations / Questionnaire</td>
<td>Identify location of altitude changes per simulation modeling, evaluate ATM decisions based on frequency, location, and timing; Assess associated change in delay/cost</td>
</tr>
</tbody>
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Reduction in flights changing altitude for less than moderate turbulence

Reduction in flights changing altitude for moderate turbulence
Turbulence Viewer Benefits – Simulation Test (1 of 3)

• Conducted 104 DART simulations for 1 week of GTG data (weekdays only)
  - Incrementally increased percentage of 737s and 757s with viewer
    - ~800 737/757 flights
  - Defined behavior of flights with viewer as:
    - Encounters with light turbulence = No change altitude
    - Encounters with moderate turbulence = Change altitude

• Simulation data collected included number of:
  - Viewer-equipped 737s & 757s
  - Altitude changes by:
    - Viewer-equipped flights & NAS
    - Cause (i.e., light vs. moderate turbulence)
    - Latitude / Longitude
  - Altitude changes avoided due to viewer
Turbulence Viewer Benefits – Simulation Test (2 of 3)

- Conducted 104 simulations for 1 week of GTG data (weekdays only)
  - Incrementally increased percentage of 737s and 757s with viewer
  - Defined behavior of flights with viewer as:
    - Encounters with light turbulence = No change altitude
    - Encounters with moderate turbulence = Change altitude

- Results show an increase in altitude change avoidance caused by less than moderate turbulence for viewer-equipped aircraft
  - Averages/day:
    - 71 20% w/ viewer
    - 142 40% w/ viewer
    - 202 60% w/ viewer
    - 272 80% w/ viewer
    - 329 100% w/ viewer

- Reductions for viewer-equipped flights also decrease as more flights are equipped with a viewer

- Per model rules, moderate turbulence areas are unavoidable and require altitude changes
  - Average ~ 55/day (Delta 737/757)

With demonstration LCA participation, on any given day, could have ~26% of DAL B737/757 fleet viewer-equipped (68 LCA’s operating 266 aircraft)
Turbulence Viewer Benefits – Simulation Test (3 of 3)

- Location of altitude changes within NAS used as identifiers for sector capacity issues
- Results for location of altitude changes from simulations
  - Parsed by general location
  - Parsed by time of day

- All Delta flights (737/757)
- Light/Moderate Turbulence Altitude Changes

2/12/2014 Data

0% Viewer-Equipped

20% Viewer-Equipped

60% Viewer-Equipped

100% Viewer-Equipped
Summary

- Intensive, collaborative effort undertaken to evaluate multi-faceted challenges and potential benefits of direct pilot access to real-time turbulence data for enhanced decision-making

- AvMet supporting FAA effort to assess potential capacity utilization and operational efficiency benefits attributed to alternative turbulence impact management decisions via enhanced cockpit data access

- Analyzing objective weather and flight behavior data in conjunction with turbulence viewer surveys from DAL pilots to inform high fidelity simulation experiments for quantifying efficiency-related benefits

- Preliminary NAS-wide results keying on primary mode of cockpit viewer benefits show significant opportunities for improved operations

- AvMet working data analysis and simulation data reduction / evaluation now; Final results to FAA end of October.