Weather Technology In The Cockpit (WTIC)

EDR Uplink Quantitative Benefits Analysis

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September 2014
Turbulence Workshop

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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

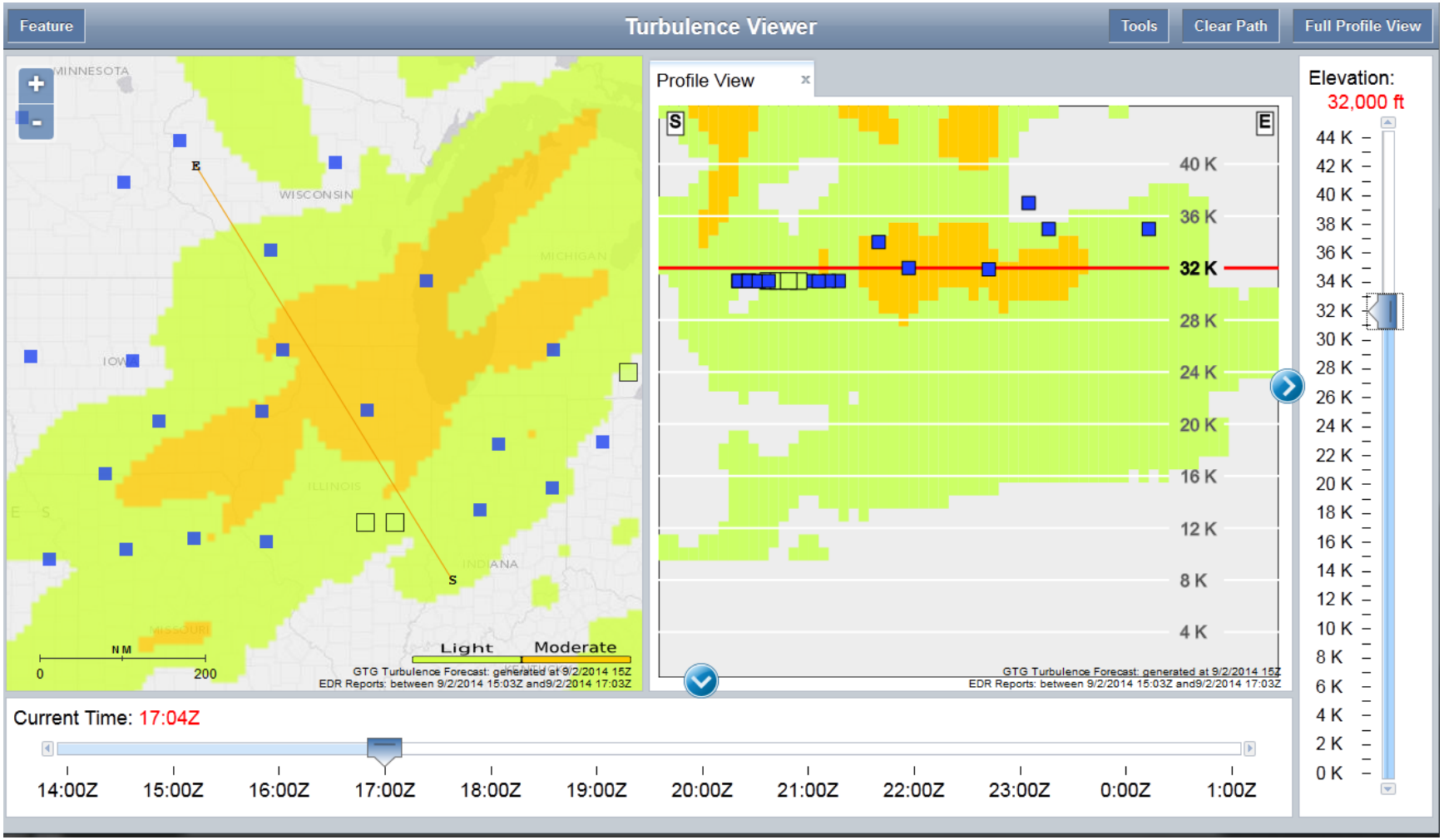
- WTIC EDR Uplink Demonstration is assessing the feasibility of using low-cost devices to display turbulence information in the cockpit for direct use by the flight crew

- 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

Turbulence Viewer

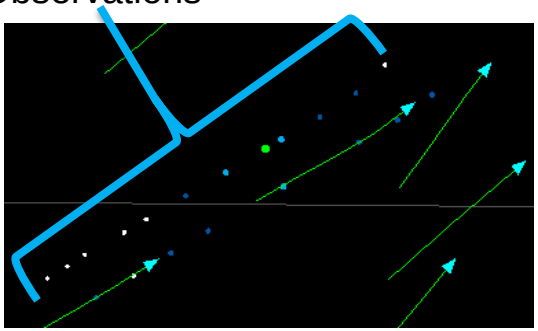
Developed and Maintained by BCI



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)

EDR Observations



- 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

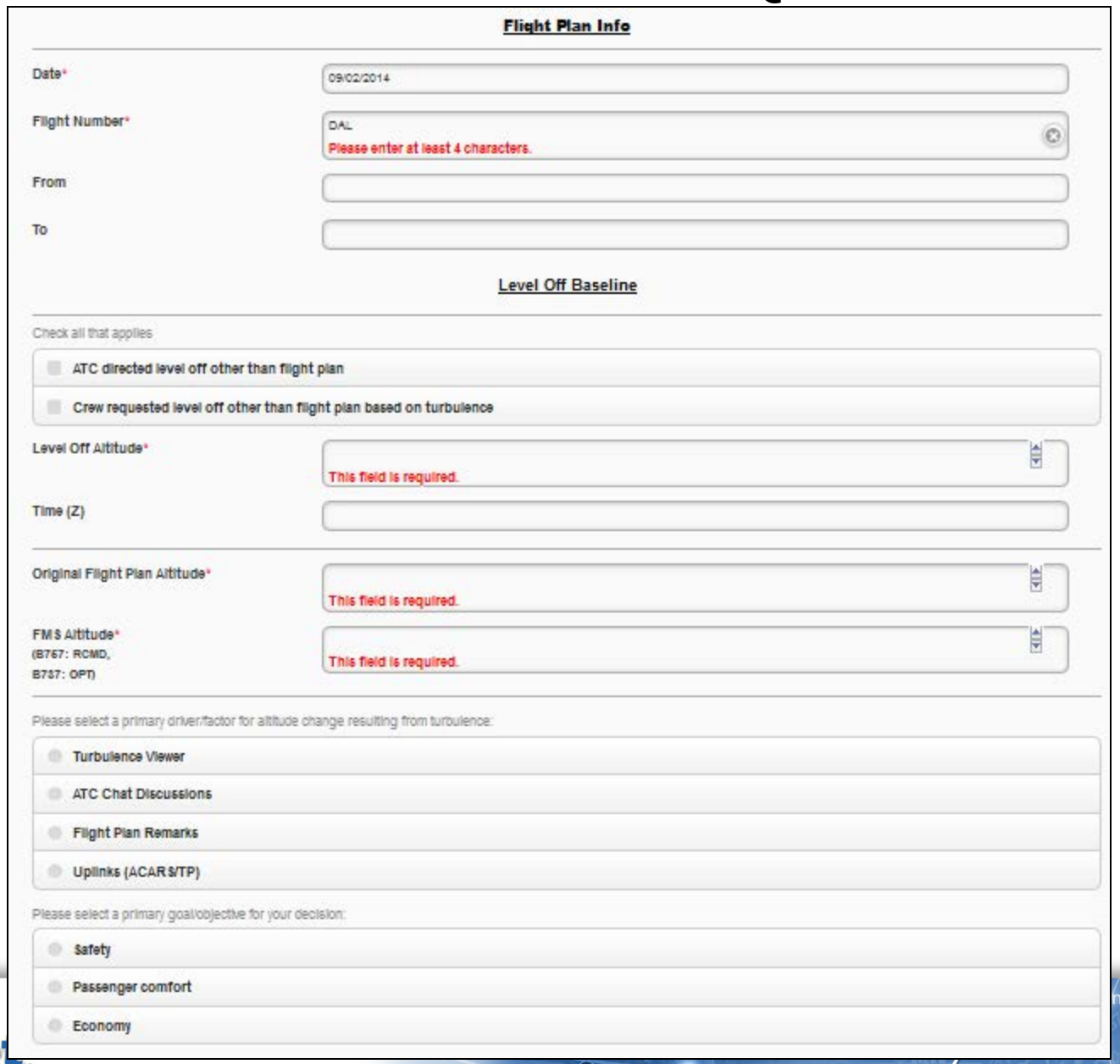
- EDR, GTG, and aircraft data mined to identify actions which could be associated with turbulence

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

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

Various combinations as well as specific details provide different scenarios and opportunities for a benefits analysis

Key Data: Turbulence Viewer Questionnaire



Flight Plan Info

Date*: 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.

FMS Altitude* (B767: RCMD, B737: OPT): This field is required.

Please select a primary driver/factor for altitude change resulting from turbulence:

- Turbulence Viewer
- ATC Chat Discussions
- Flight Plan Remarks
- Uplinks (ACARS/TP)

Please select a primary goal/objective for your decision:

- Safety
- Passenger comfort
- Economy

Demonstration Data Collection (Aug '13 – July '14)

Questionnaire Data

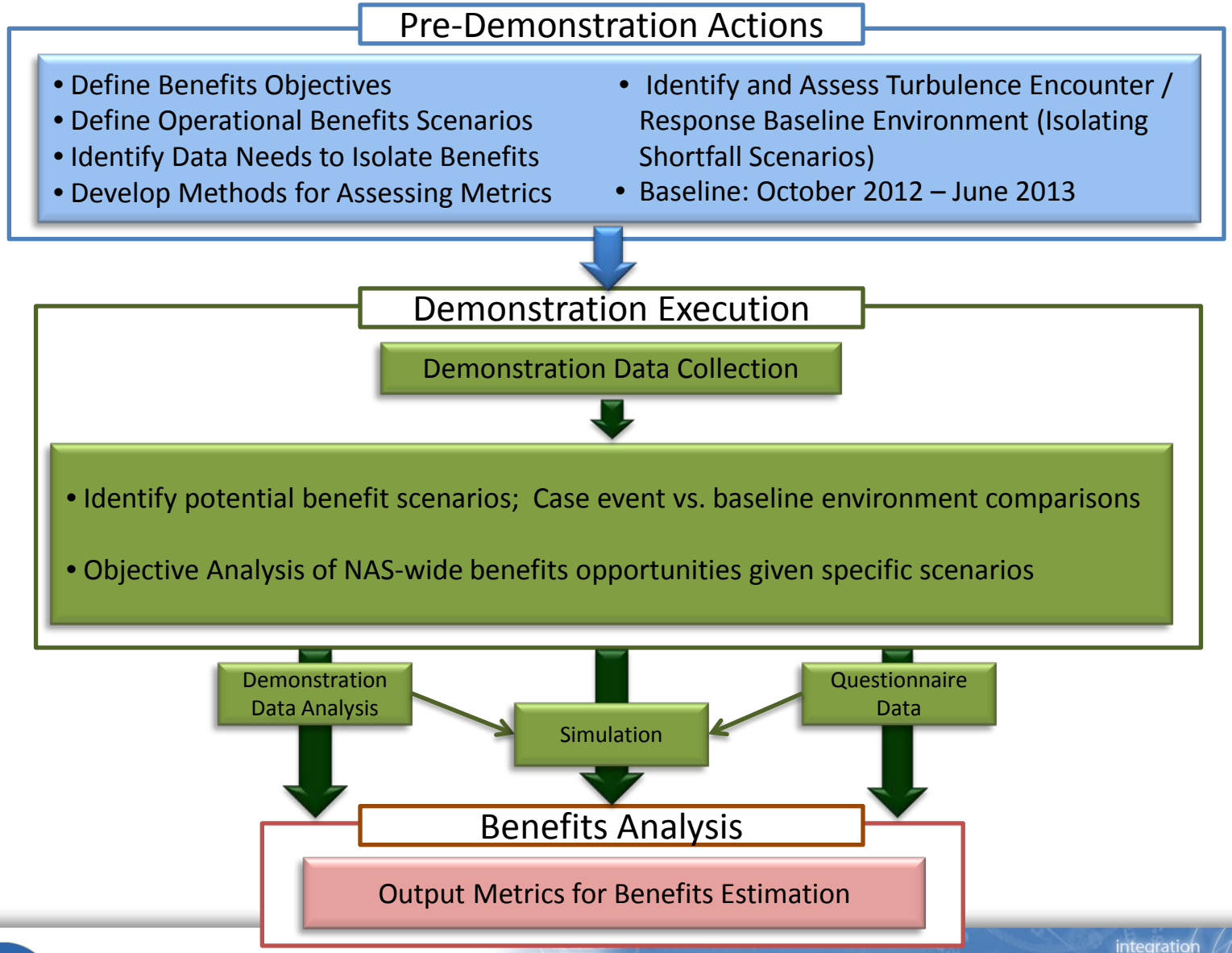
Evaluating questionnaires during demonstration period

- 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:

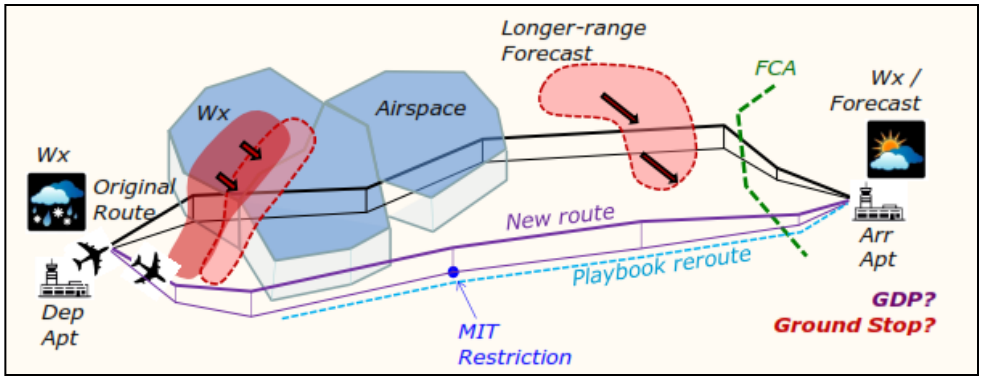
- Viewer allowed me to see forecasted Turb moving south. I was able to stay at 380
- Maintained a smooth altitude to avoid light/mod turbulence presented by the viewer. Maintained F350 as opposed to climbing to FMS recommended and flight plan Alt of F390
- Viewer allow(ed) us to stay at optimum altitude and avoid an unnecessary descent.
- Viewer allowed us to see only a small pocket of chop. We stayed at optimum.

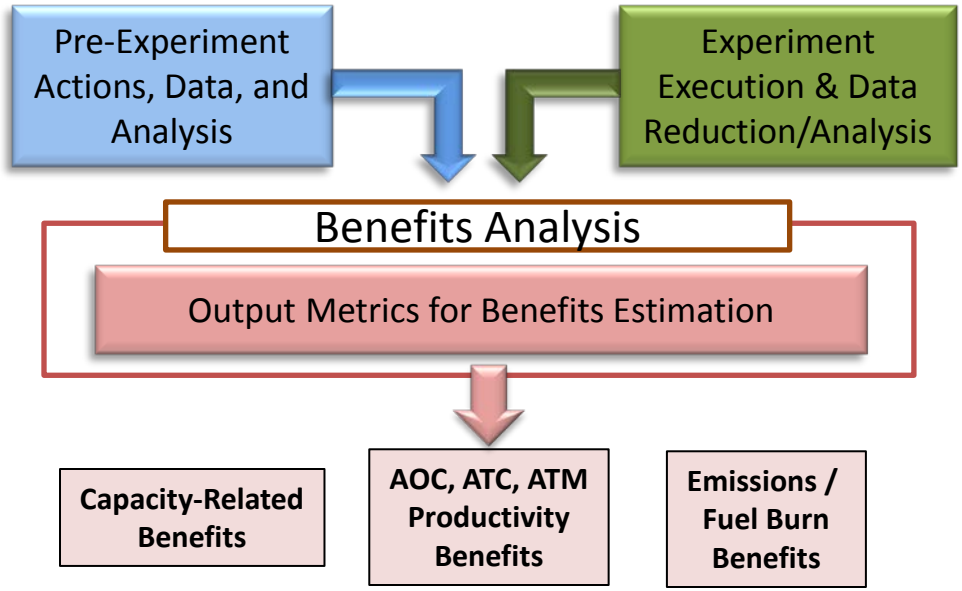
Benefits Analysis Framework



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



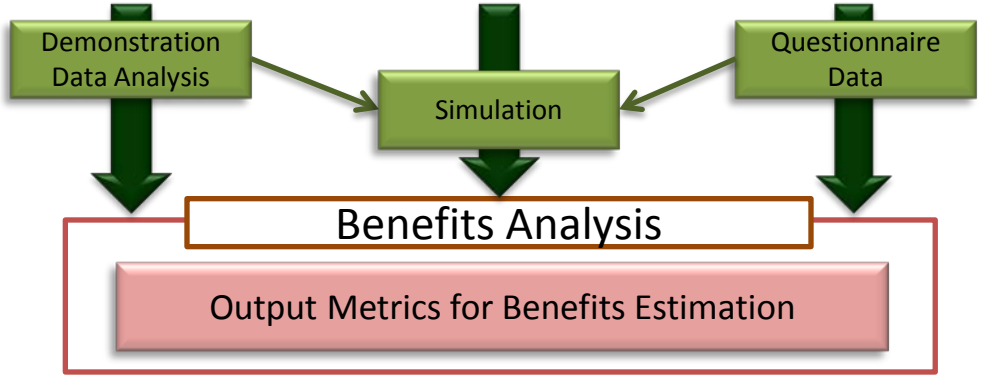


DART-focused Benefits Areas for Turbulence Viewer Experiment

- 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

Reduction in flights changing altitude for less than moderate turbulence	DART	Observations / Questionnaire
Reduction in flights changing altitude for moderate turbulence	DART	Observations / Questionnaire

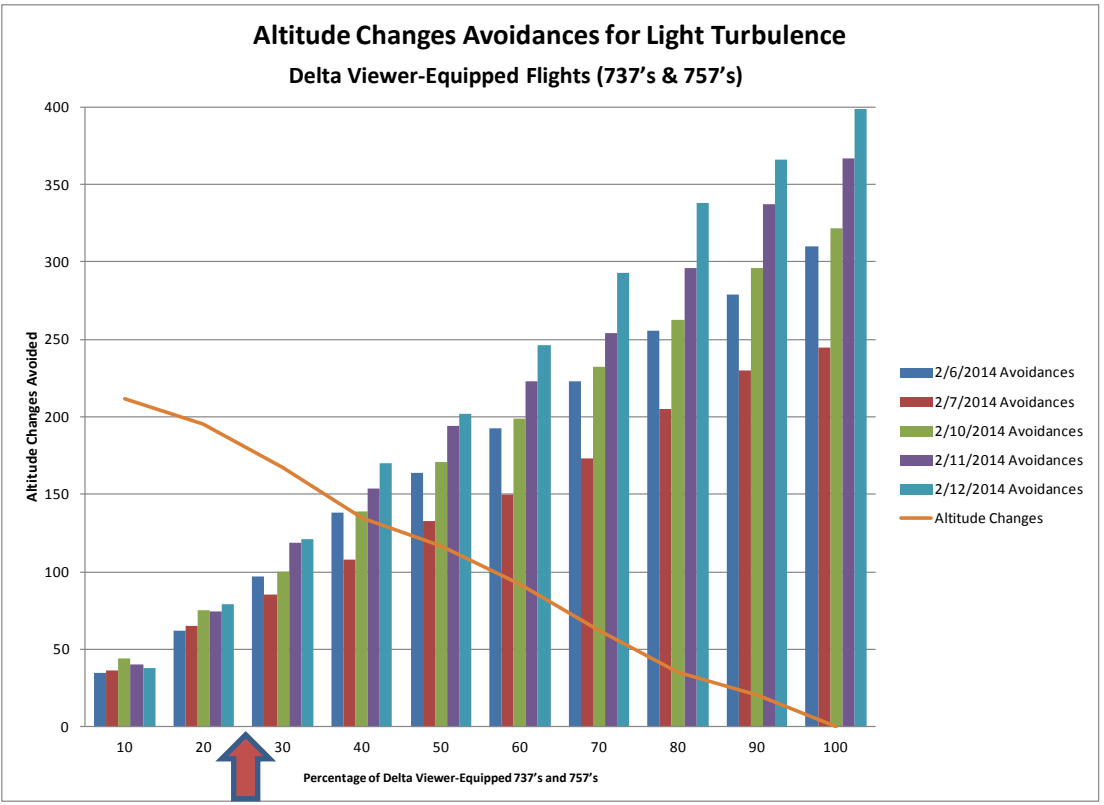
	Benefits Analysis	Simulation	Basis	Notes
1	Reduction in fuel usage / emissions from less flights changing off optimal planned altitude for turbulence	DART	Observations / Questionnaire	Magnitude of altitude changes determined from observations, percentages and results derivations applied to simulation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

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 avoidances 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 decreases 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)

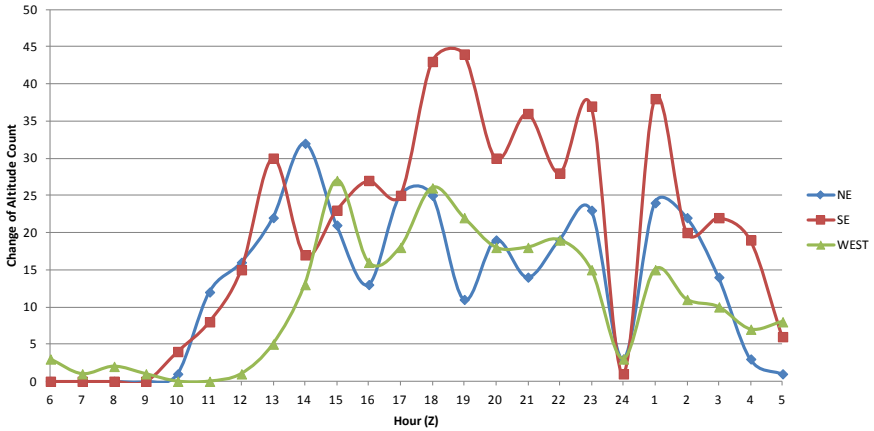
With demonstration LCA participation, on any given day, could have ~26% of DAL B737/757 fleet viewer-equipped (68 LCA's operating 266 aircraft)

Turbulence Viewer Benefits – Simulation Test (3 of 3)

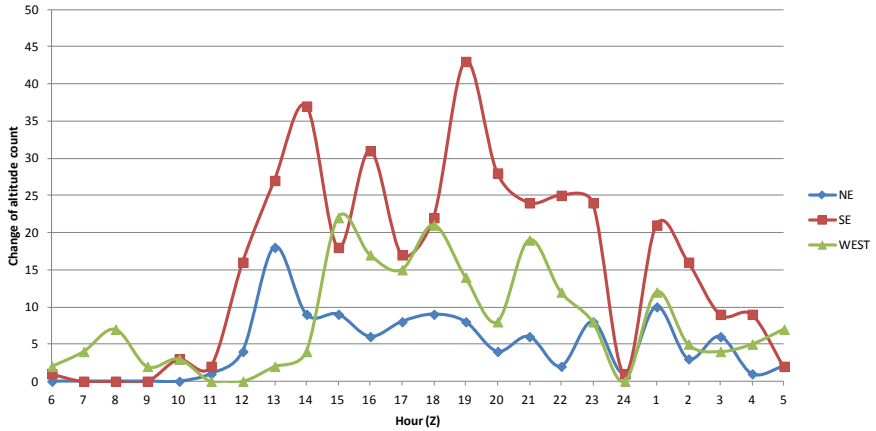
- Location of altitude changes within NAS used as identifiers for sector capacity issues
- Results for location of altitude changes from simulations
  - Parsed by general location
  - Parsed by time of day

2/12/2014 Data

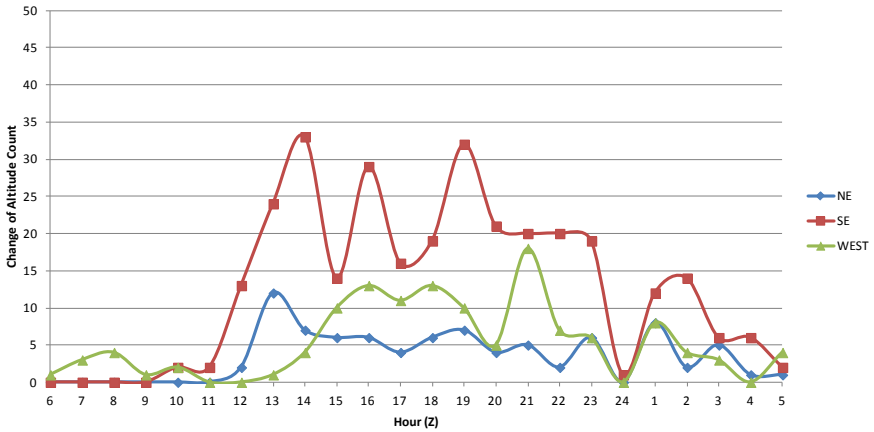
0% Viewer-Equipped



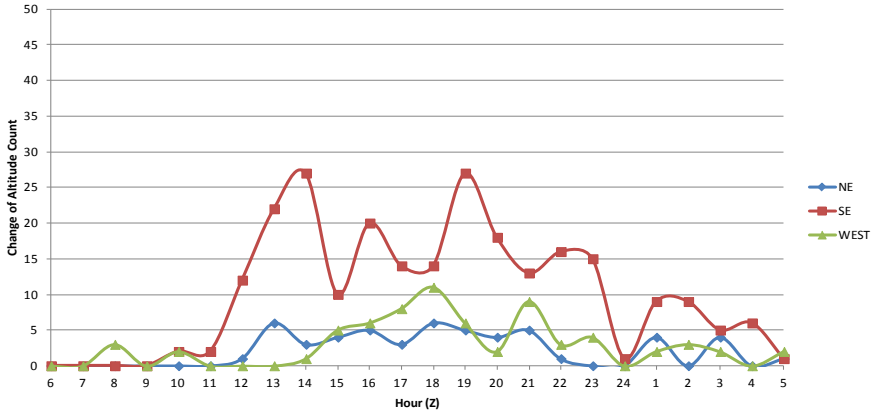
20% Viewer-Equipped



60% Viewer-Equipped



100% Viewer-Equipped



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

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.