EDDY DISSIPATION RATE (EDR) UPLINK DEMONSTRATION AND CAPACITY AND EFFICIENCY BENEFITS QUANTIFICATION

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FAA/Delta Air Lines EDR Uplink Demo

August 2013 – July 2014

- Proof of Concept demonstration FAA and Delta Airlines
- 1-year flight demonstration period
- Goals:
  - Assess the feasibility of flight crews using electronics flight bag to display turbulence observation (Eddy Dissipation Rate-EDR) and forecast (Graphical Turbulence Guidance-GTG) information in cockpit
  - Identify and address human factors considerations
  - Quantify NAS efficiency and capacity benefits from the provision of GTG / EDR information to flight crews

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Hypothesis

- Temporal and spatial relevant turbulence information in the cockpit will enhance cabin safety, reduce unnecessary pilot initiated altitude diversions, and improve the capacity and efficiency of the NAS
  - **Better cabin management**
  - **Reduce excessive fuel burn**
  - Reduce unnecessary reallocation of airspace

Demonstration Effort

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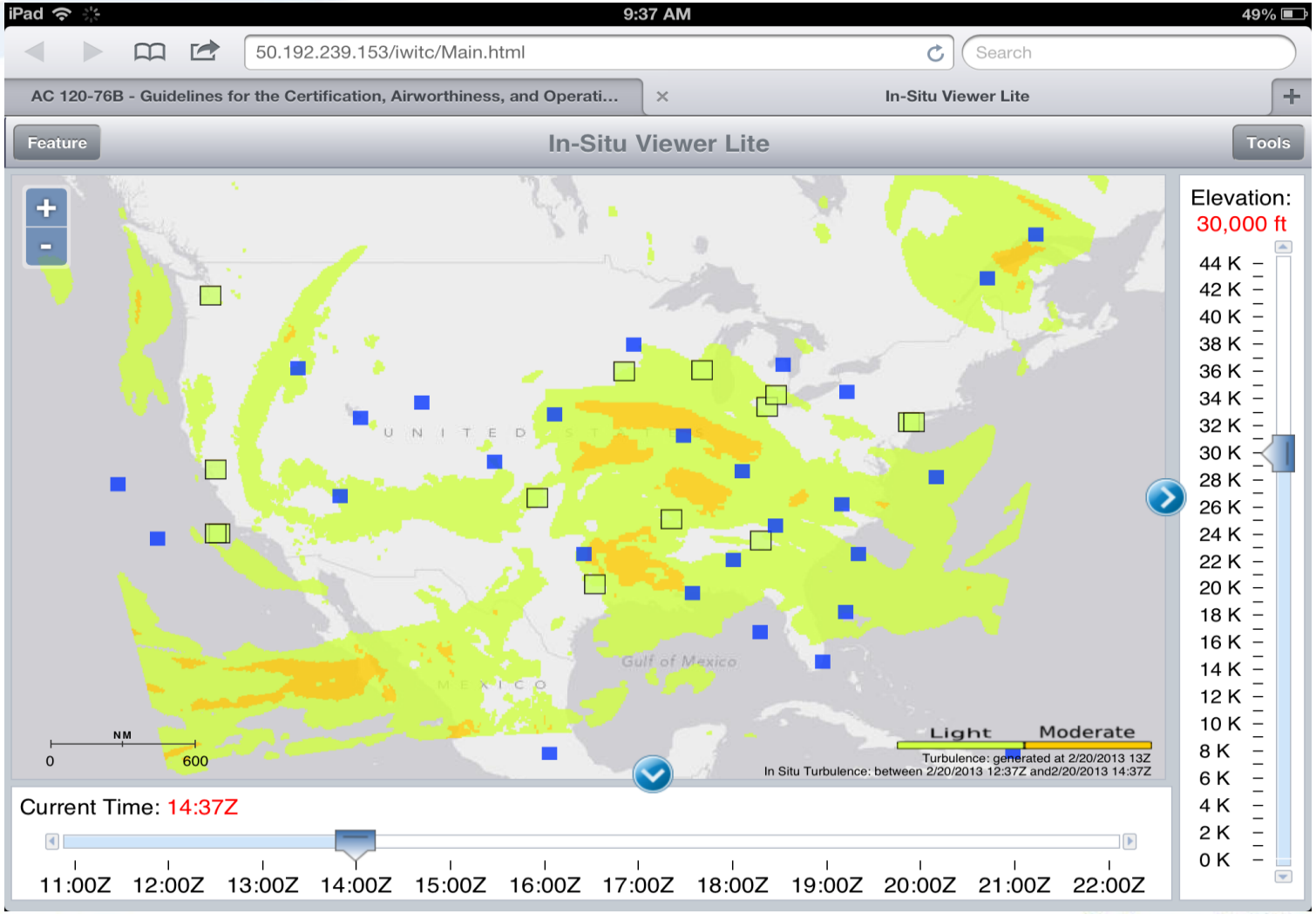
EDR Uplink Demonstration

- 80 Line Check Pilots
- 300 Aircraft ≅ 14.5 M Objective Reports
- 40,000+ Flights
- Web Viewer Application
  - Turbulence reports overlaid on turbulence forecast
  - Tablet in the cockpit
  - WiFi in the aircraft
- Acceptance amongst the participating pilots was outstanding

Turbulence Viewer Application



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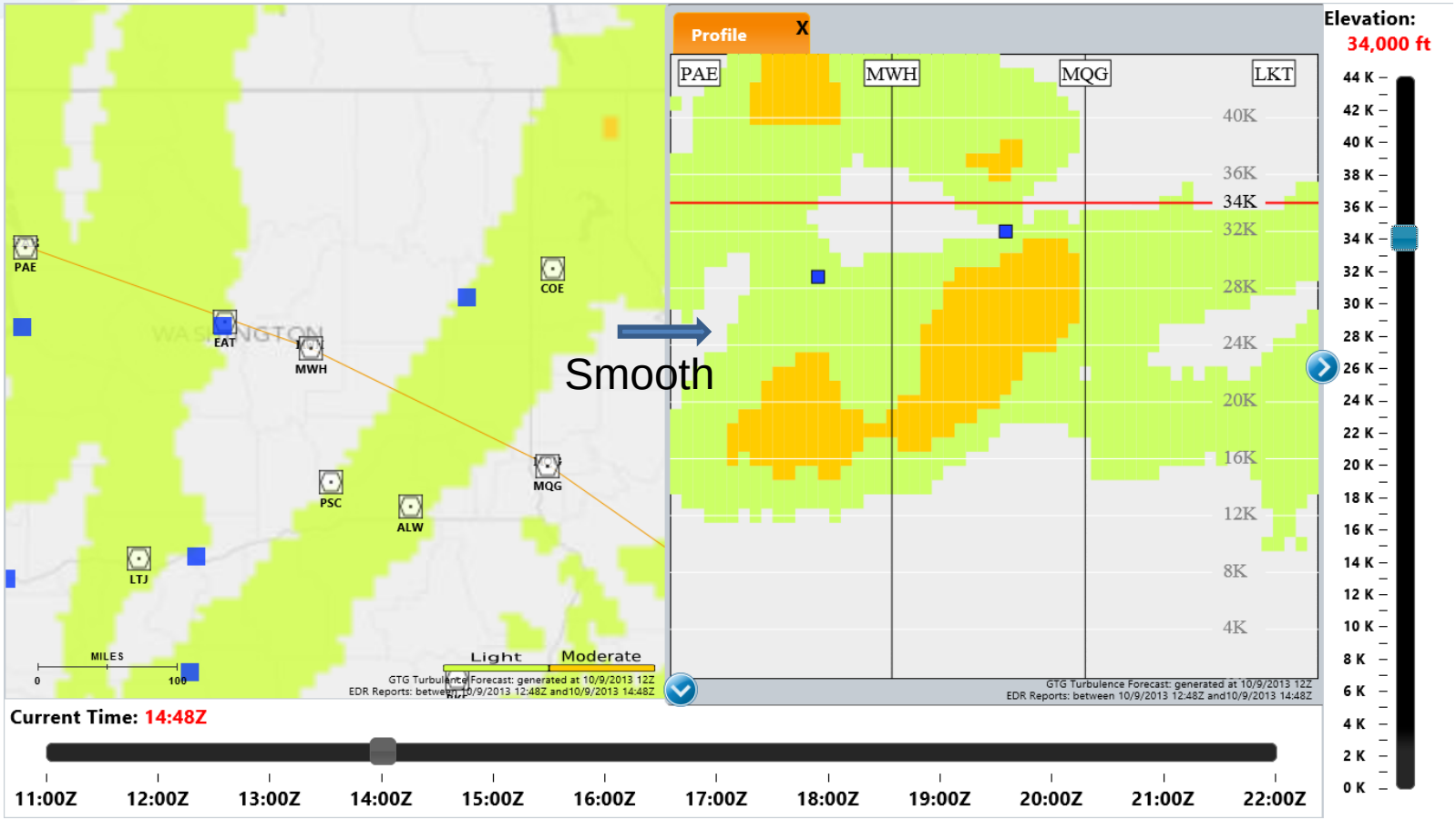
Turbulence Viewer Application
Smoother Ride Selection



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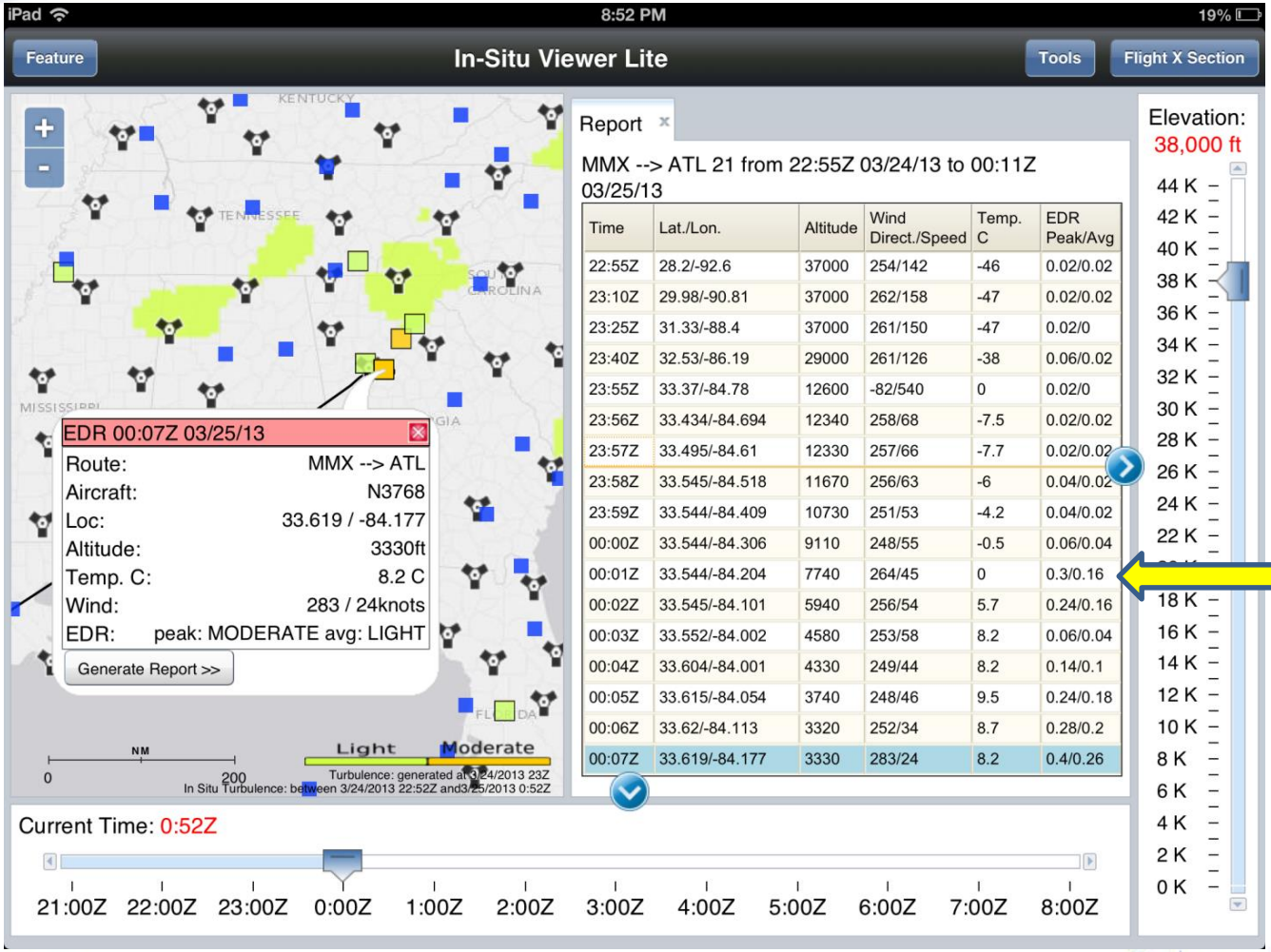
Turbulence Viewer Application
Cabin Management on Approach



Secure the Cabin

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Turbulence Decision Making Factors During Demonstration

- Pre-Flight – All available sources
- En-route Altitude Changes
  - Source
    - ATC “Chat Room” 17%
    - Turbulence Viewer 81%
  - Flights off Optimum Altitude 28%
- Additional benefits
  - Reduced Radio Calls 44%
  - Decreased Workloads 37%
    - ATC / Pilots

EDR Uplink Capacity and Efficiency Benefits Assessment

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- Temporal and spatial relevant turbulence information in the cockpit will enhance cabin safety, reduce unnecessary pilot initiated altitude diversions, and improve the capacity and efficiency of the NAS
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  - **Reduce unnecessary reallocation of airspace**

Quantification Effort

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Demonstration Data Collection Periods

- **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)
  - All Delta Air Lines EDR reporting flights

- **Demonstration period with viewer** (August 2013 – July 2014)
  - Delta Air Line flights with viewer
  - Delta Air Line flights submitting questionnaires
    - Subset of Demonstration Period as a whole
    - Includes key questionnaire data submitted by pilots regarding usability of and advantages / disadvantages of viewer tool

- Data collected throughout the Baseline and Demonstration periods included:
  - EDR
  - PIREPs
  - GTG (Analysis/Forecast)
  - Convective Weather Diagnostic Data
  - Aircraft Data (equipment, altitude, etc.)
  - Flight Track Data (actual vs. planned)

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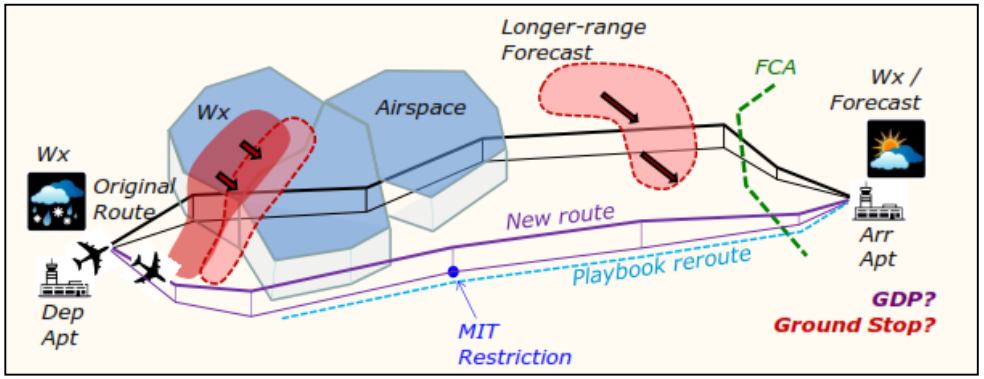
Modeling Airspace Utility Benefits

Using Dynamic Airspace Routing Tool (DART)

- Dynamic Airspace Routing Tool (DART) – a weather-aware "superfast-time" NAS simulation model – has ability to:
  - Generate most-economical reroutes using weather diagnostic/forecast blend (including EDR/GTG)
  - Combine reroutes and/or ground delays (and cancellations where needed)
  - Apply user-specified cost parameters for benefits analysis, reroute strategies, and risk tolerance factors
  - Apply actual and simulated Traffic Management Initiatives (TMI) within the modeling environment

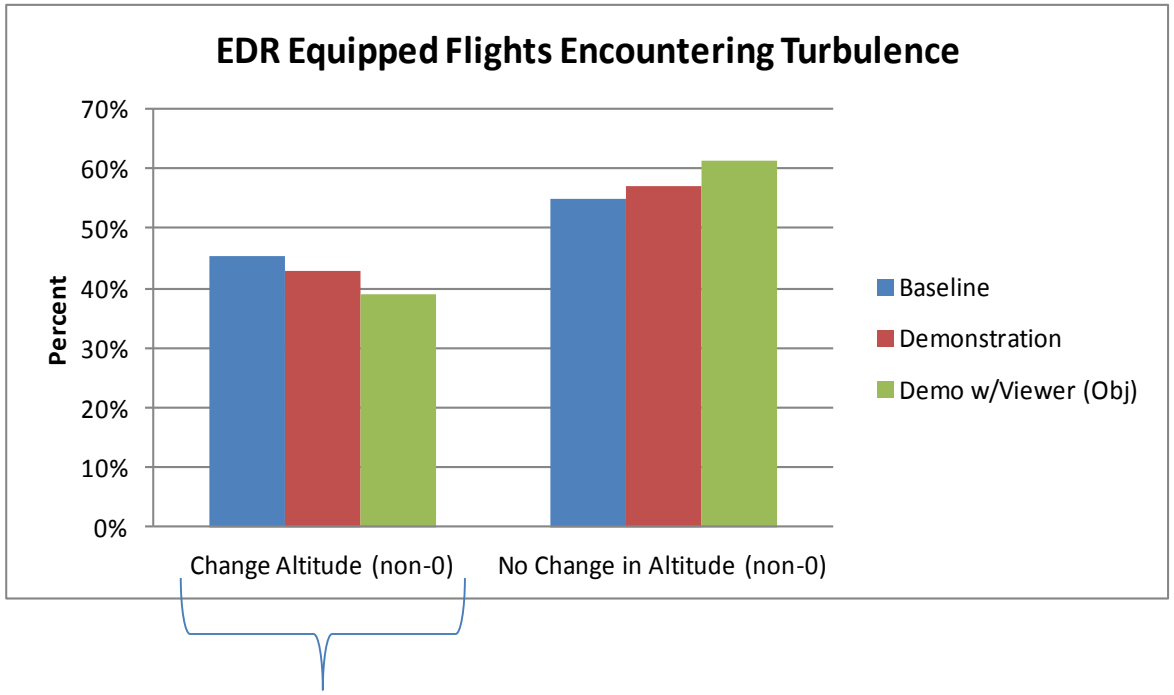


Completed NAS simulations for a 6-month period:
- January - June 2014
- ~1,400 simulations
- Separated results by region
- Categorized days by varying coverage of turbulence

- Vertical deviations modeled to account for altitude changes in vicinity of Clear Air Turbulence
  - **Sector MAP values driving factor** in evaluating airspace availability in NAS simulation given turbulence encounters / actions
    - MAP values (i.e., capacity) decreased as result of weather
    - Objective findings applied to ½ impacted sectors
  - In this manner, airspace capacity is a factor contributing to delays

Objective Data Analysis Findings

- Definitions for flights established and re-established at cruise (above FL280) to better isolate altitude changes as a result of experienced turbulence
- Differences between Baseline, Demonstration, and Demo-with-viewer indicated:
  - Flights with viewer tended to not change altitude as much as those without viewer
  - Flights with viewer changed altitude less frequently when encountering higher EDR turbulence values



~6% decrease in altitude changes when encountering EDR>0 for all flights reporting EDR

- Potential benefits exist where flights remain on altitude by comparing overall percentages of EDR reporting flights
- Comparing overall %'s of altitude changes when reporting a non-0 turbulence:
  - ~45% Baseline
  - ~43% EDR Demonstration
  - ~39% with viewer

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Results Summary

Baseline/Demo vs. Viewer Equipped

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

Sample High-level **Objective** Findings

Comparing overall percentages:

- **~6% decrease in altitude changes** when encountering EDR >0 for all flights reporting EDR

Higher tolerance for higher EDR ranges

- Reduction in altitude changes in the higher EDR range
  - e.g., 14% increase in flights remaining at altitude for higher EDR ranges (≥0.1)

Benefits

1) **Reduction in fuel burn / emissions**
   - Frequency of altitude change

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

3) **Capacity utilization efficiency**
   - Reduction in ATM actions
   - Reduction in NAS Delay

- **Subjective** response data collected throughout demonstration period via viewer questionnaire
- 77 Line Check Airmen (815 reports) on subset of Delta fleet using tablet device reported:
  - 79% reported decisions were influenced by “viewer”
  - 64% reported that the “viewer” was primary driver for altitude change decision
  - 53% reported radio calls were reduced as a result of using viewer

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Simulating and Measuring Effects of Capacity Degradation

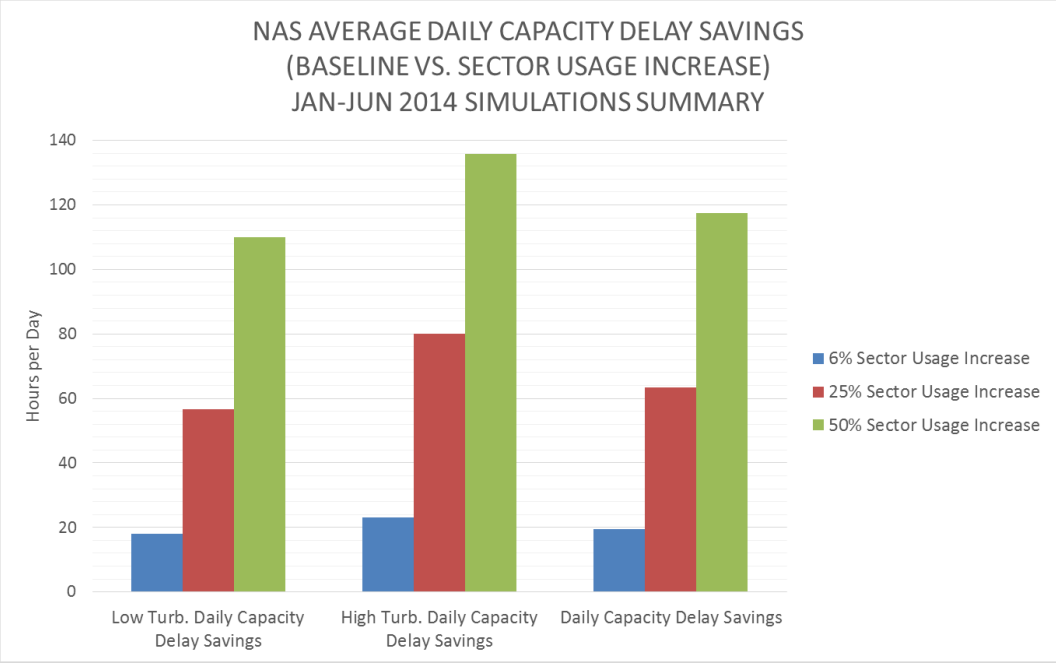
- DART computes arrival delay (sum of multiple components) per flight:
  1) **Ground Delays:**
     - Departure delay due to departure airport capacity constraints with/without weather
     - Departure delays due to TMIs
     - Departure delay due to airspace capacity constraints (simulator will not send an aircraft into an overloaded sector)
  2) **Airborne Delays**:
     - Airborne delay due to airborne reroutes
     - Arrival delay due to sequencing and spacing on approach to destination airport

- Two key metrics were used to evaluate benefits of turbulence information in cockpit:
  - **Total Arrival Delay**
    - Ground Delays + Airborne Delays
    - Sums ASQP flights only
    - DART output is daily average Total Arrival Delay per day
  - **Daily Airspace Capacity Delay Savings**
    - Component of Total Arrival Delay
    - Average difference between the “Departure delay due to airspace capacity constraints with/without weather” for baseline runs and simulated benefits

Turbulence Capacity Utilization Benefits Results

Capacity-Related Benefits

- Metrics for baseline period compared to increased sector usage
  - Simulations identified previously underutilized sectors in increments identified in study (i.e., baseline sectors identified as impacted and thus 'avoided' by flights)
  - DART simulated results for Low, High, and All turbulence coverage days



- Simulation results indicate a modest increase in both metrics when additional % of sectors are utilized
- Results increase to ~118 hours of capacity delay savings per day due to increased sector usage
- Following factors applied to estimated cost savings:

Economic Impact Category
Direct Operating Cost, On-Ground, At-Gate
Direct Operating Cost, airborne
Passenger Value of Time

Cost Associated with Air Traffic Impact

(from: *FAA, 2014: Economic Information for Investment Analysis, Prepared for Operations Research / ATO-F)*

Average Daily Simulated Savings	6% Sector Usage Increase	25% Sector Usage Increase	50% Sector Usage Increase
TOTAL Daily Cost Savings Estimate	**$190,000**	**$600,000**	**$1.1 M**
TOTAL Annual Cost Savings Estimate	**$69 M**	**$219 M**	**$414 M**

Estimating ATC Workload Benefits

Associated with Improved Turbulence Awareness in Cockpit

- ATC task times associated with controlling a flight are a function of the nature of the task

AOC, ATC, ATM Productivity Benefits

Benefits per Center per Day
(min/max minutes)

Center	Simulated Benefits Based on Objective Data
ZMA	8 / 15
ZAU	8 / 14
ZLA	7 / 13
ZFW	7 / 12
ZHU	6 / 12
ZSE	5 / 8
ZJX	4 / 8
ZOA	4 / 8
ZTL	4 / 7
ZDV	4 / 7
ZAB	4 / 6
ZID	4 / 6
ZNY	4 / 6
ZDC	3 / 6
ZOB	3 / 5
ZKC	2 / 4
ZME	2 / 4
ZMP	2 / 4
ZBW	2 / 3
ZLC	1 / 2

- Simulated reductions from baseline in altitude changes per Center applied to ATC workload times per:
  - TRB published report on Air Traffic Controller Staffing in the En Route Domain
- Task times associated with a flight transitioning from one altitude to another are approximately 14.6 seconds
  - Used as ‘minimum’ ATC task time
- When a traffic separation situation occurs, the task time increases to approximately 27.6 seconds
  - Used as conservative ‘maximum’ ATC task time - could be cumulative with minimum time

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WTIC EDR Uplink Demonstration Conclusions

- Objective analysis identified positive behavior as a result of turbulence information in cockpit
- Objective analysis results were applied in simulation environment to translate reductions in altitude changes to fuel burn/emissions, ATC workload, and capacity savings
- Simulation environment evaluated benefits as result of additional reductions in changes in altitude
- Conclusions
  - Number of flights changing altitude for low turbulence significantly reduced
  - Reduction in flights changing altitude results in reduced controller workload
  - Sector capacities were maintained
  - Arrival delays were reduced
- Additional benefits from turbulence information in cockpit could further reduce unnecessary changes in altitude through:
  - Pilot and turbulence impact training
  - Recognition of product benefits and risks
  - Aircraft specific EDR thresholds
  - Aircraft cabin management as related to specific EDR thresholds

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Questions
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