Analysis Capabilities Developed in Support of WTIC Research

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Motivation: Wind Impacts on 4D-Trajectory Based Operations

FMS = Flight Management System
4D-TBO = 4D-Trajectory Based Operations
Charter

- Support WTIC objective to develop a minimum weather service

- Perform analyses to determine wind information specifications and potential FMS wind-related enhancements that enable current and selected NextGen operations to meet performance objectives in various wind conditions

- Various capabilities developed to support this charter

Identify NextGen Operations Impacted by Wind Forecasts

Develop Modeling Framework

Work with Stakeholders
  - Identify performance objectives

Conduct Analysis
  - Develop analysis infrastructure
  - Develop Trade Spaces of Performance vs data source, accuracy, update rate, etc.
  - Assess datalink implications

Develop Recommendations for Minimum Wind Information and Datalink Requirements

Technical reports, RTCA activities, etc.
Lincoln/WTIC Winds Program History

WTIC Winds Panel - 4
TGR 08/03/16
Lincoln/WTIC Winds Program History

- Developed WIAF concept
- Applied to simple RTA ops
- Incorporated FMS variants
- Explored simple FMS scenarios
- High fidelity RTA ops assessment
- Operational wind product assessment
- RTCA support
- Development of more flexible analysis infrastructure to support RTCA SC-206

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Aircraft Operations Modeling System (ATOMS)

FMS RTA Capability/Tolerance

Wind forecast error

Hi (25 kts RMS)
Medium (15 kts RMS)
Low (5 kts RMS)
Case Study: Establishing Wind Information Needs and Associated ConOps/Datalink Needs to Support a Given Level of Required 4D-TBO Performance

1. Define scenarios of interest
2. Identify performance trade-space
3. Select target performance level
4. Do feasible combinations of performance drivers meet target level of performance?
   - Yes (wind error limit)
   - No
5. Do feasible combinations of wind forecast model and look-ahead time meet error limit?
   - Yes
6. Define procedure/ConOps/datalink needs to get required wind info accuracy to aircraft

4D-TBO from cruise at FL290-390 to meter fix at 12,000 ft

Wind information needed to support any studied aircraft/FMS combination

Identified need for enhanced automation and/or wind model

On average:
- GFS: cannot support 5 kts RMSE
- RAP: <2.1 hrs lookahead
- HRRR: <3.0 hrs lookahead

Wind Model Forecast Error (Vs. HRRR6-hr Truth)

Low (5 kts RMS)
Medium (15 kts RMS)
Hi (25 kts RMS)

FMS RTA Capability/Tolerance

95% RTA Compliance (secs)

1) Any combination with 5 kts RMS wind error
2) A-FMS/Tol 6 only with 15 kts RMS wind error
3) No FMS/operation with 25 kts RMS wind error
Current Infrastructure Development

- Integration of WIAF, ATOMS & MAFID (Meteorological and Flight Information Database)
  - Allows identification of scenarios based on operational flights meeting desired criteria
  - Simulate flights with truth atmosphere data based on MDCRS measurements

**MDCRS = Meteorological Data Collection and Reporting System**
Leveraging Aircraft *In-Situ* Atmospheric Measurements

- To maximize the realism of the conditions, now can use aircraft-derived meteorological data reports from MDCRS-equipped aircraft
- Simulated aircraft reproduced actual flights

MDCRS = Meteorological Data Collection and Reporting System
Latest RTA Analysis

- Key research questions:

1. What is the impact to RTA performance of increasing the number of Descent Forecast Levels (DFLs) in a B757 FMS from four to nine?

2. What is the impact to RTA performance of optimized wind altitude selection for B757 FMS descent wind definitions?
Latest RTA Analysis: Effect of Enhancing FMS Descent Forecasts

- Airlines currently often use simple wind selection procedures to determine what (if any) forecast information to load into the FMS
- FMS can only accept a limited set of forecast data at discrete points
  - E.g., Four Descent Forecast Levels (DFLs)

DFL = Descent Forecast Level
Effect of Enhancing FMS Descent Forecast
Research Questions

1. What is the impact to RTA performance of increasing the number of DFLs in a B757 FMS from four to nine?

Operational B757 Pegasus FMS
(4 DFLs, wind only)

Enhanced B757 Pegasus FMS
(9 DFLs, wind & temp)

DFL = Descent Forecast Level
Effect of Enhancing FMS Descent Forecast Research Questions

2. What is the impact to RTA performance of optimized wind altitude selection for B757 FMS descent wind definitions?

![Graph showing different altitude selection profiles]

- Headwind optimized profile
- Magnitude optimized profile
- Equidistant altitude selection profile

9 DFLs
4 DFLs
Summary

• Analysis capabilities critical to support WTIC mission

• Range of tools developed at Lincoln to assess impacts of atmospheric forecast accuracy on 4D-TBO performance

• Application of tools being leveraged in range of areas, e.g., RTCA guidance documents

• On-going work:
  – Use of aircraft-derived winds (e.g., via Mode S EHS)
  – RTA to lower altitude meter fixes

• Interested to explore collaborations with other stakeholders who could benefit from access to tools
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Backups
KDEN Simulations (No Forecast Data)
KDEN Simulations
(Cruise and 4 Magn-opt DFLs w/ 3hr fcst)
Results
All Qualified Flights, Wind Magnitude Optimized

Within +/-10sec: 94.2 %
Within +/-10sec: 95.6 %
Within +/-10sec: 96.4 %
Within +/- 10sec: 24.5%