Analysis Capabilities Developed in Support of WTIC Research

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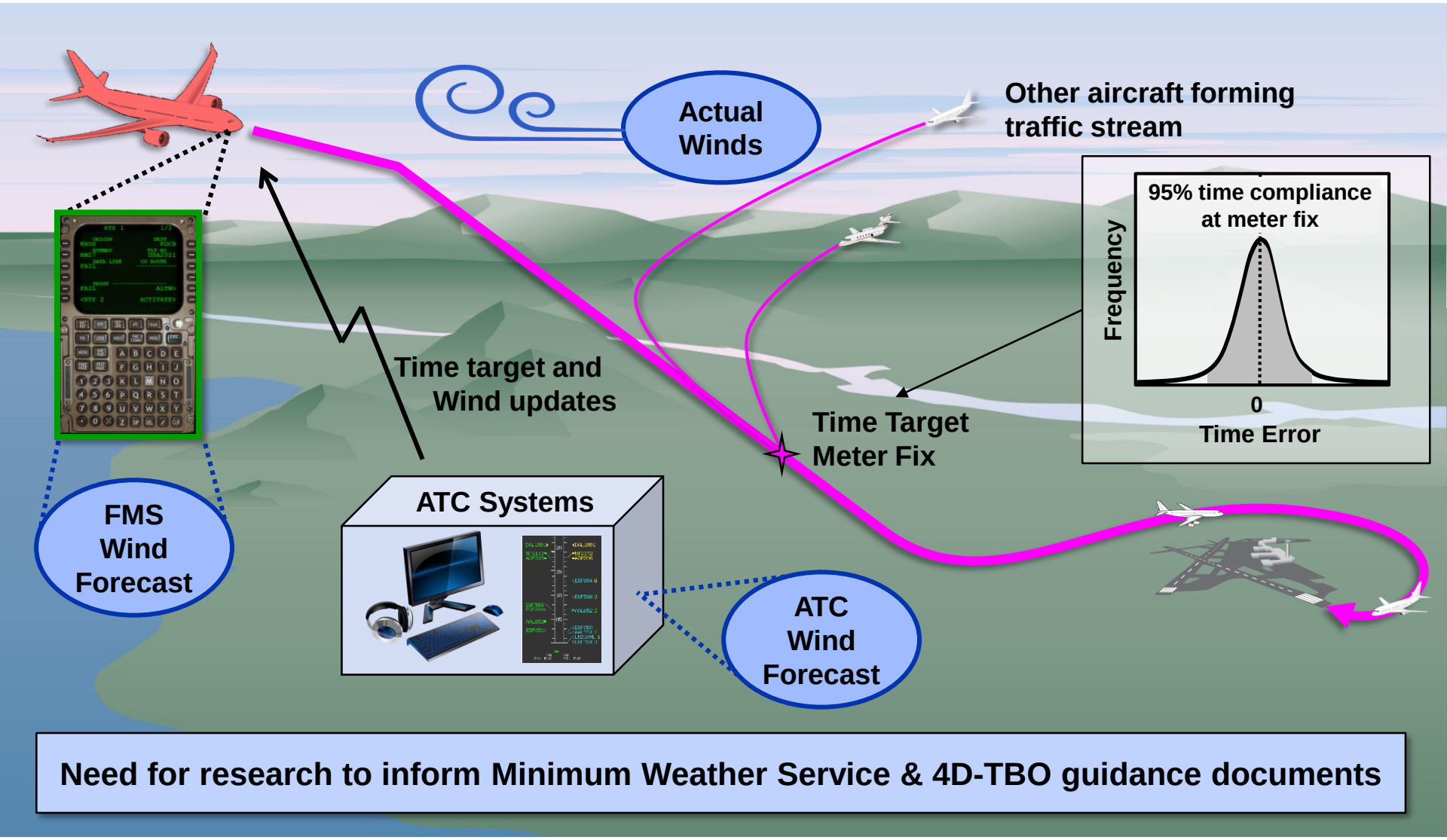
Air Traffic Control Systems Group

Friends & Partners of Aviation Weather (FPAW) Meeting
Washington, DC, August 3, 2016

Motivation: Wind Impacts on 4D-Trajectory Based Operations

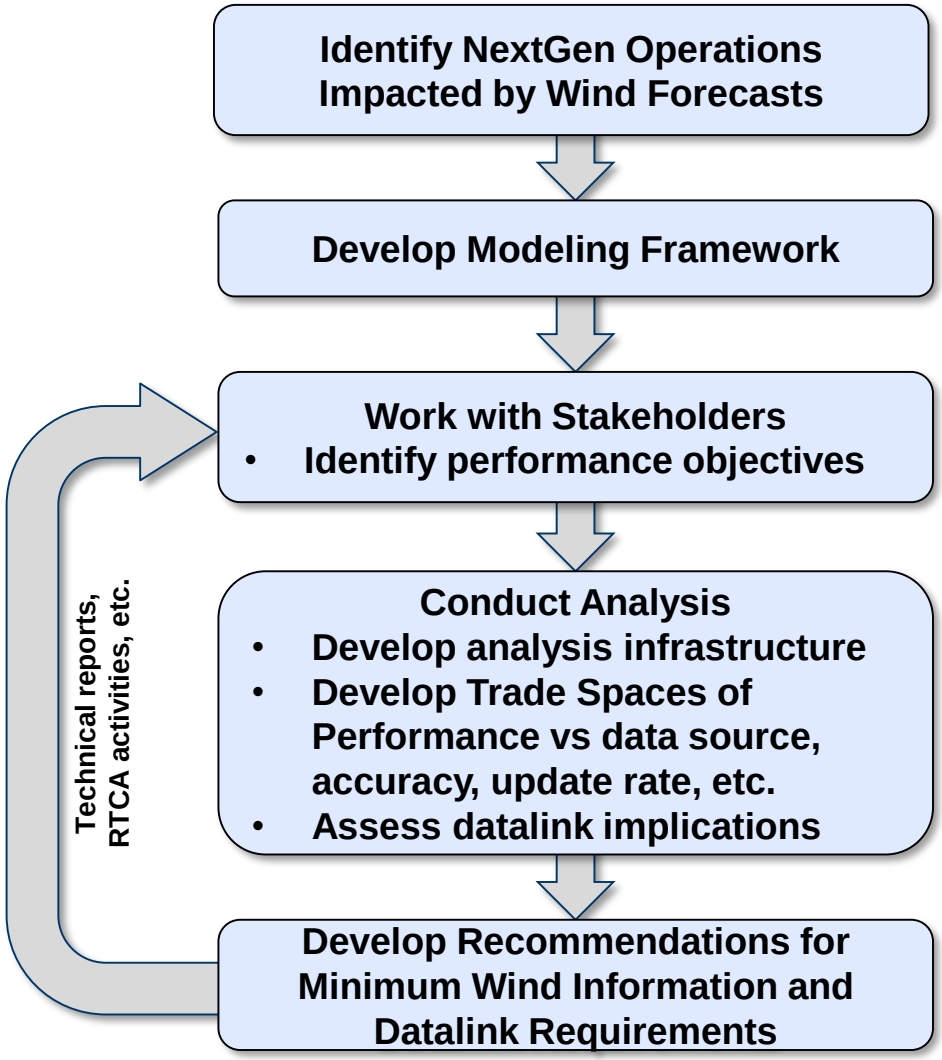


Need for research to inform Minimum Weather Service & 4D-TBO guidance documents

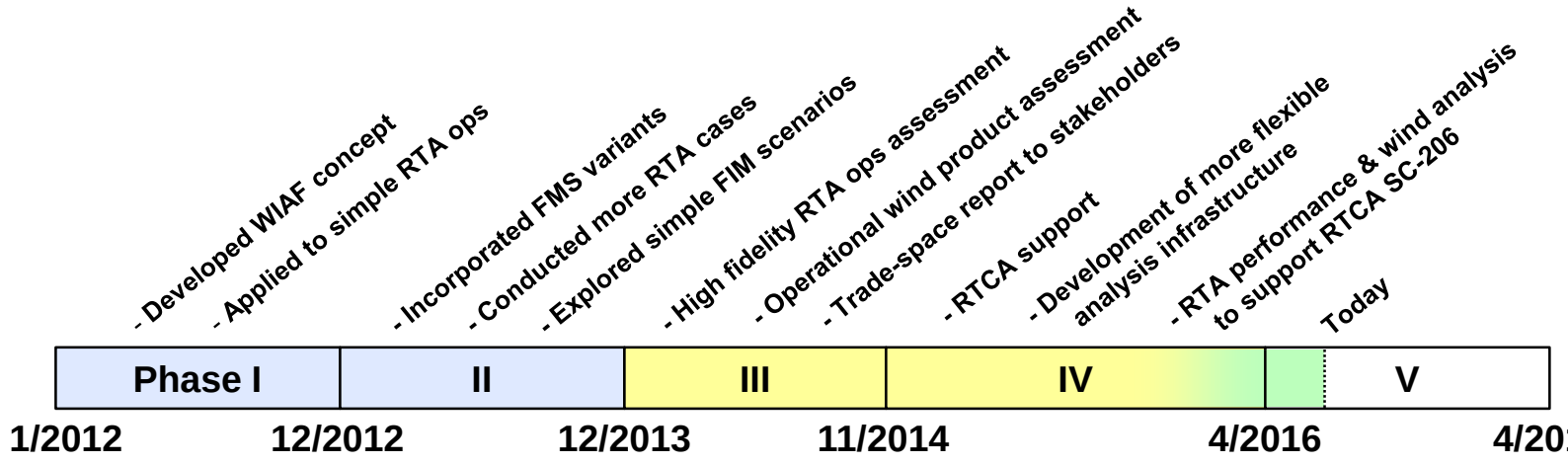
FMS = Flight Management System
4D-TBO = 4D-Trajectory Based Operations

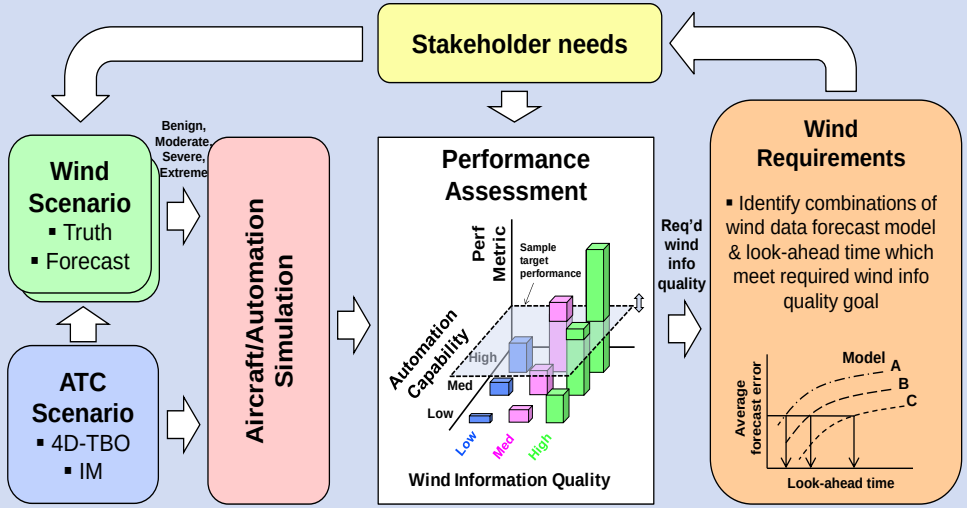
Charter

- **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**



Lincoln/WTIC Winds Program History

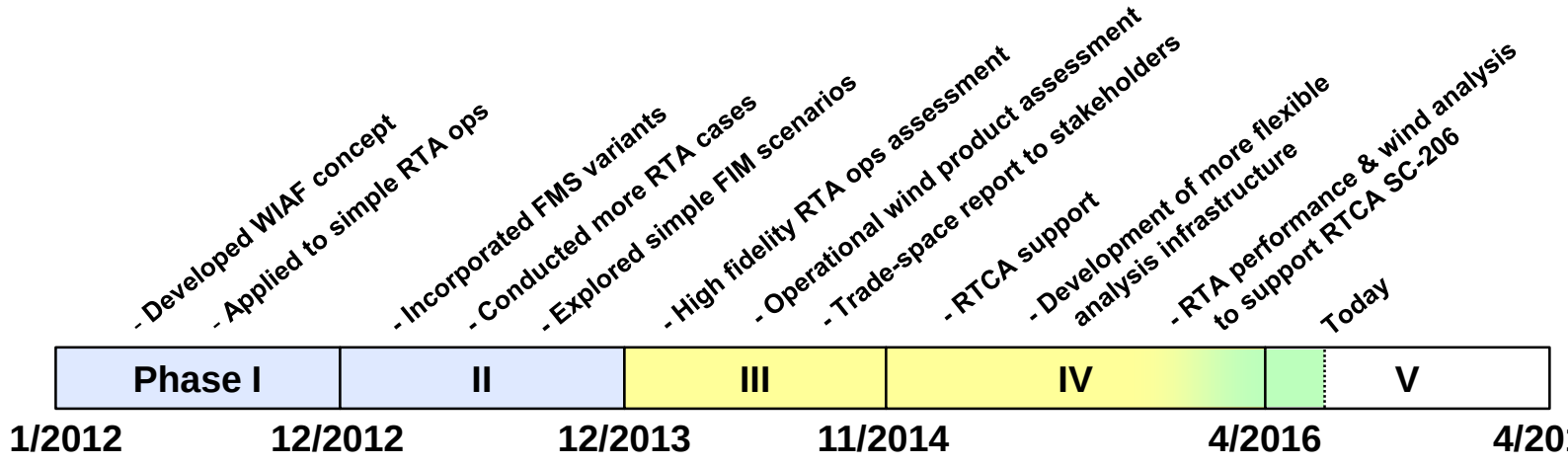


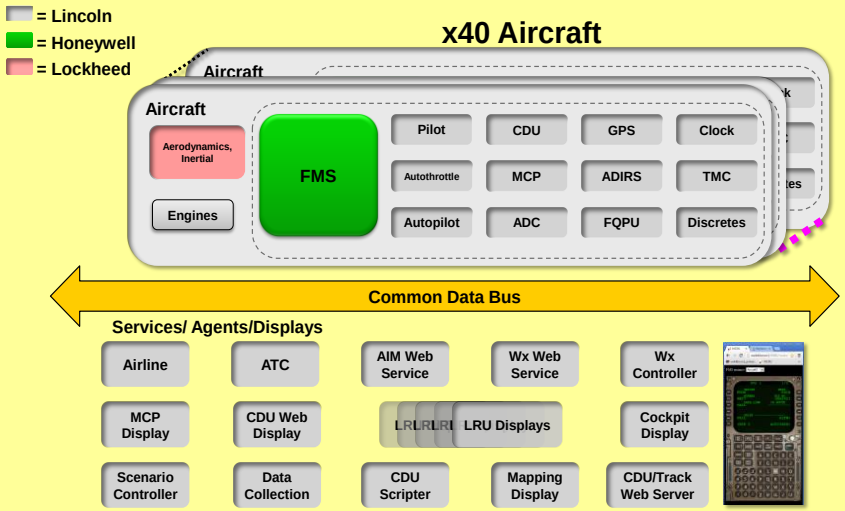


Wind Information Analysis Framework (WIAF)

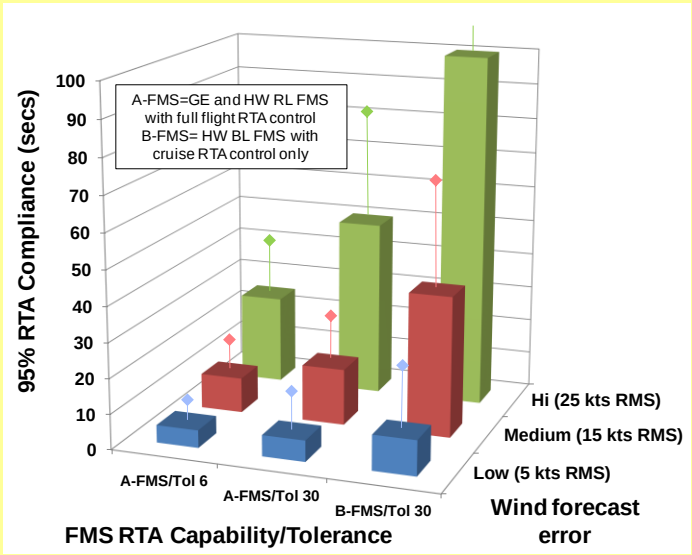
Scenario Variable	Overall Impact on Performance	Worse Performance From…*	Better Performance From…*
FMS RTA capability	Major	Open-Loop in Descent	Full Closed-Loop Control
FMS RTA tolerance	Major	Wider RTA tolerance	Tighter RTA tolerance
Wind forecast error magnitude	Major	Hi forecast error	Lo forecast error
Wind forecast error location relative to meter fix	Medium	Near forecast error	Far forecast error
Truth wind variability	Medium (correlates with error magnitude)	Hi var truth wind	Lo var truth wind
Cruise flight level	Medium	High cruise level	Low cruise level
Waypoint (wind forecast point) density	Minor	Few cruise wind WPs	Many cruise wind WPs

Lincoln/WTIC Winds Program History





AircrafT Operations Modeling System (ATOMS)



Case Study: Establishing Wind Information Needs and Associated ConOps/Datalink Needs to Support a Given Level of Required 4D-TBO Performance

Identified need for enhanced automation and/or wind model

1. Define scenarios of interest

2. Identify performance trade-space

3. Select target performance level

"or"

4. Do feasible combinations of performance drivers meet target level of performance?

No

Yes (wind error limit)

5. Do feasible combinations of wind forecast model and look-ahead time meet error limit?

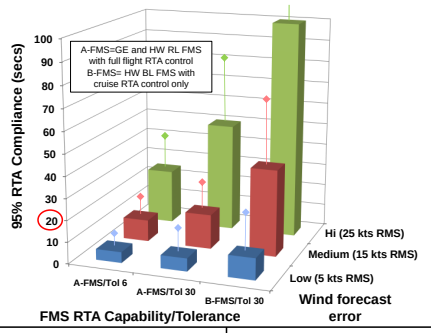
No

Yes

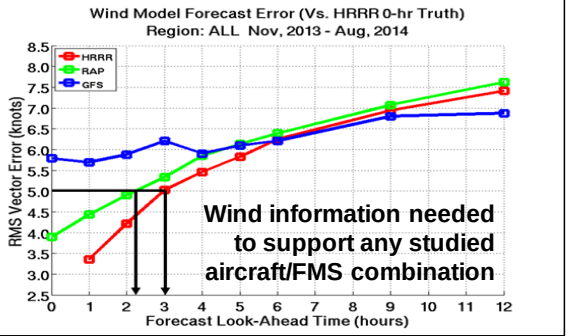
6. Define procedure/ConOps/datalink needs to get required wind info accuracy to aircraft

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

±10 secs 95% of time (slice through trade-space at 20 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



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

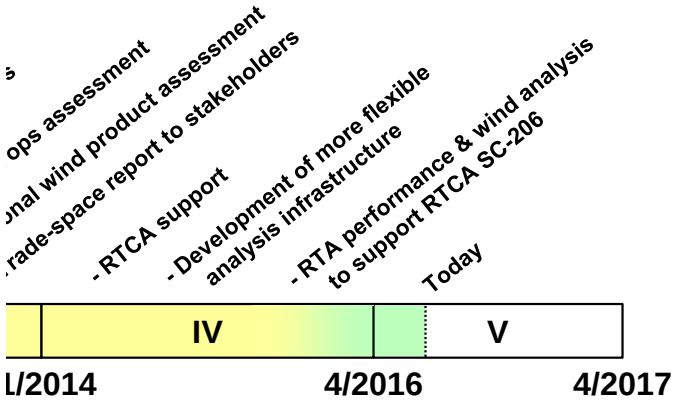

Project Report ATC-422

Wind Information Requirements for NextGen Applications

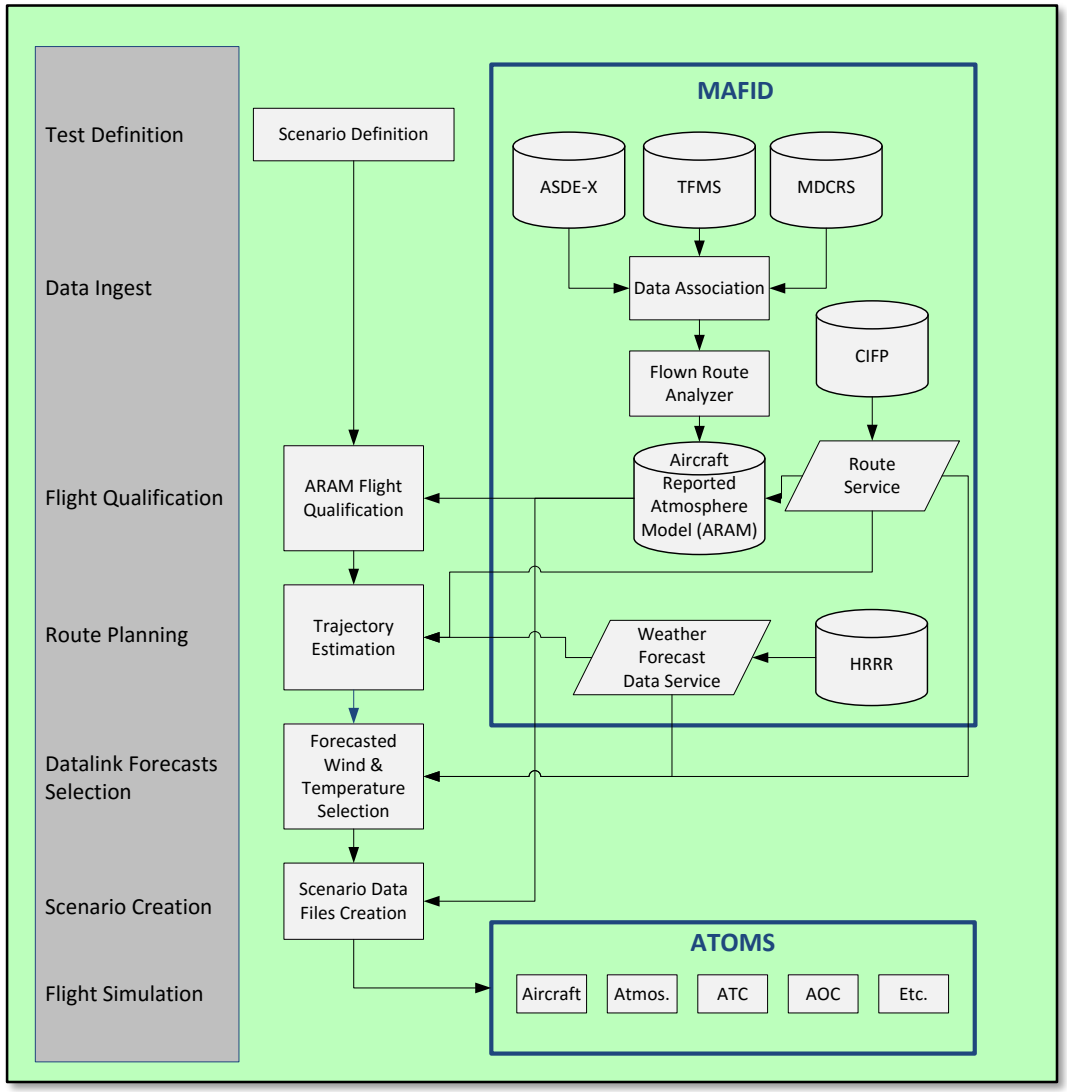
Phase 3 Final Report

Lincoln Laboratory

Current Infrastructure Development



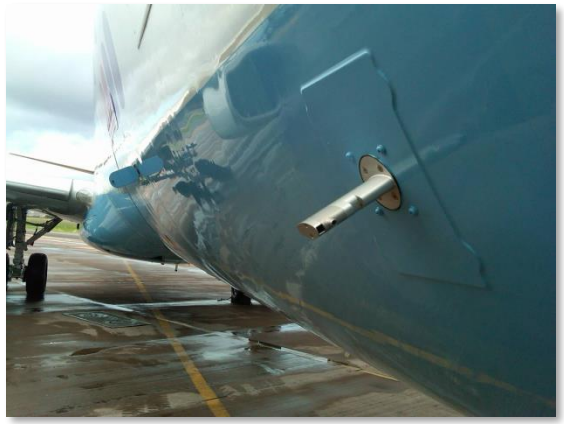
- **Integration of WIAF, ATOMS & MAFID (Meteorological and Flight Information Database)**
  - **Allows identification of scenarios based on operational flights meeting desired criteria**
  - **Simulate flights with truth atmosphere data based on MDCRS measurements**

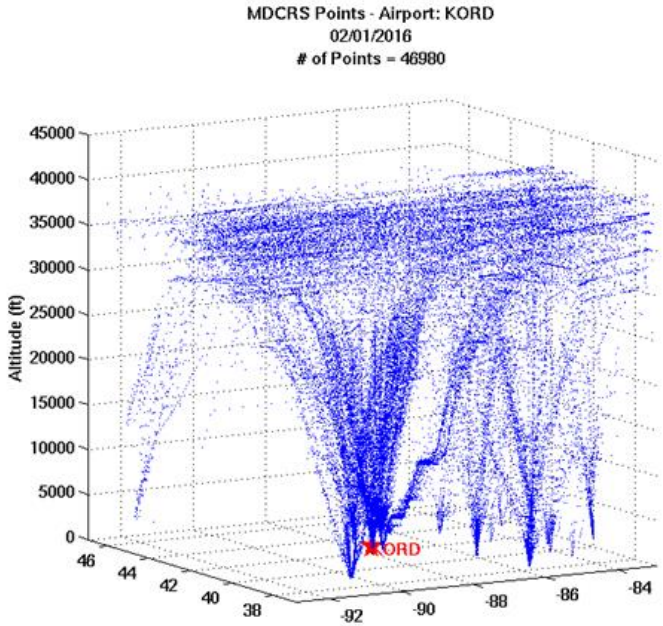


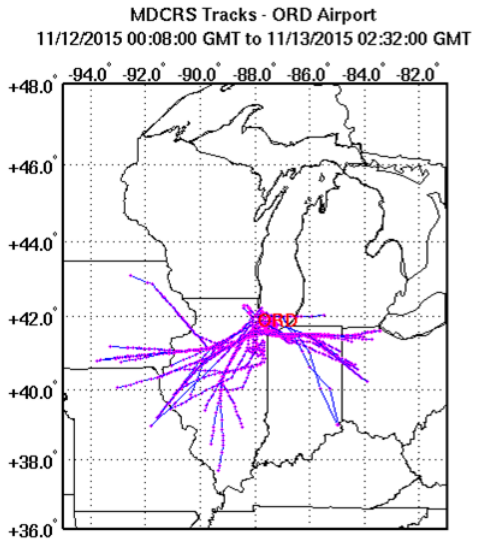
MDCRS = Meteorological Data Collection and Reporting System

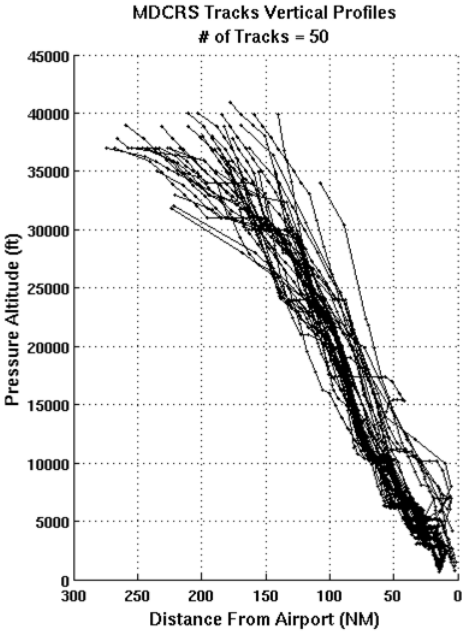
Leveraging Aircraft *In-Situ* Atmospheric Measurements

- **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

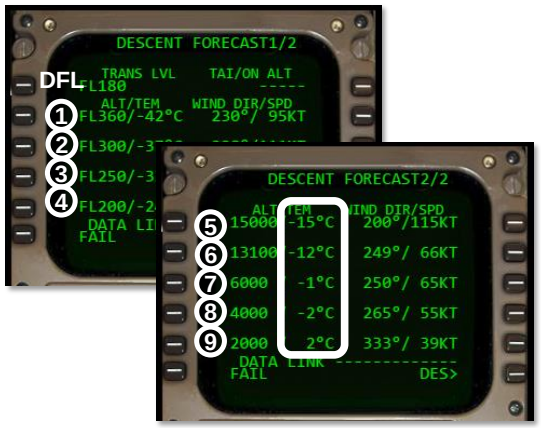
- **Key research questions:**

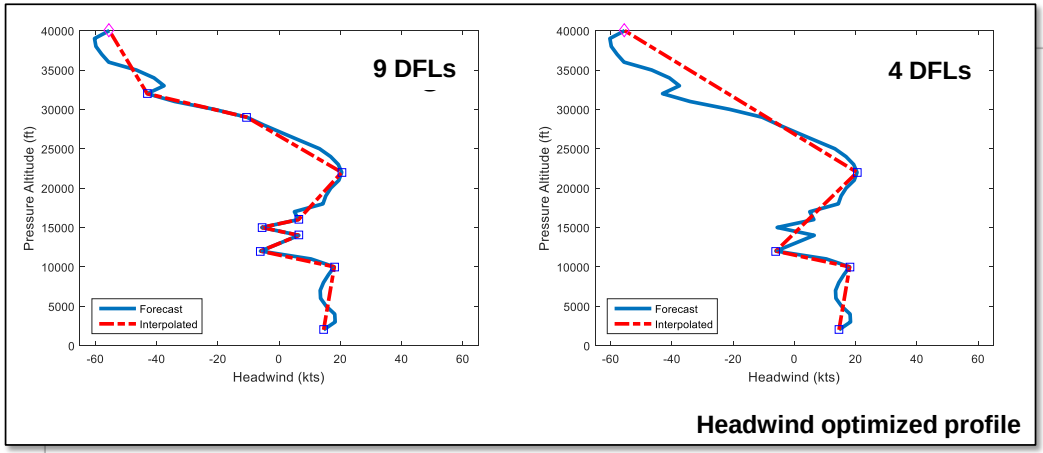
1. **What is the impact to RTA performance of increasing the number of Descent Forecast Levels (DFLs) in a B757 FMS from four to nine?**

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

Operational B757 Pegasus FMS
(4 DFLs, wind only)

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





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)

Boeing 757, Honeywell Pegasus FMS

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?**

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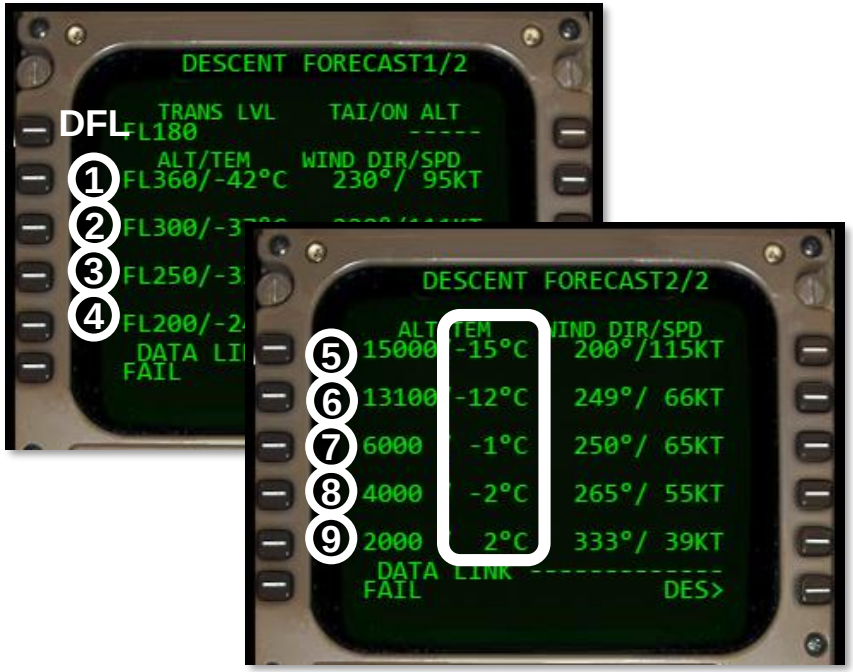
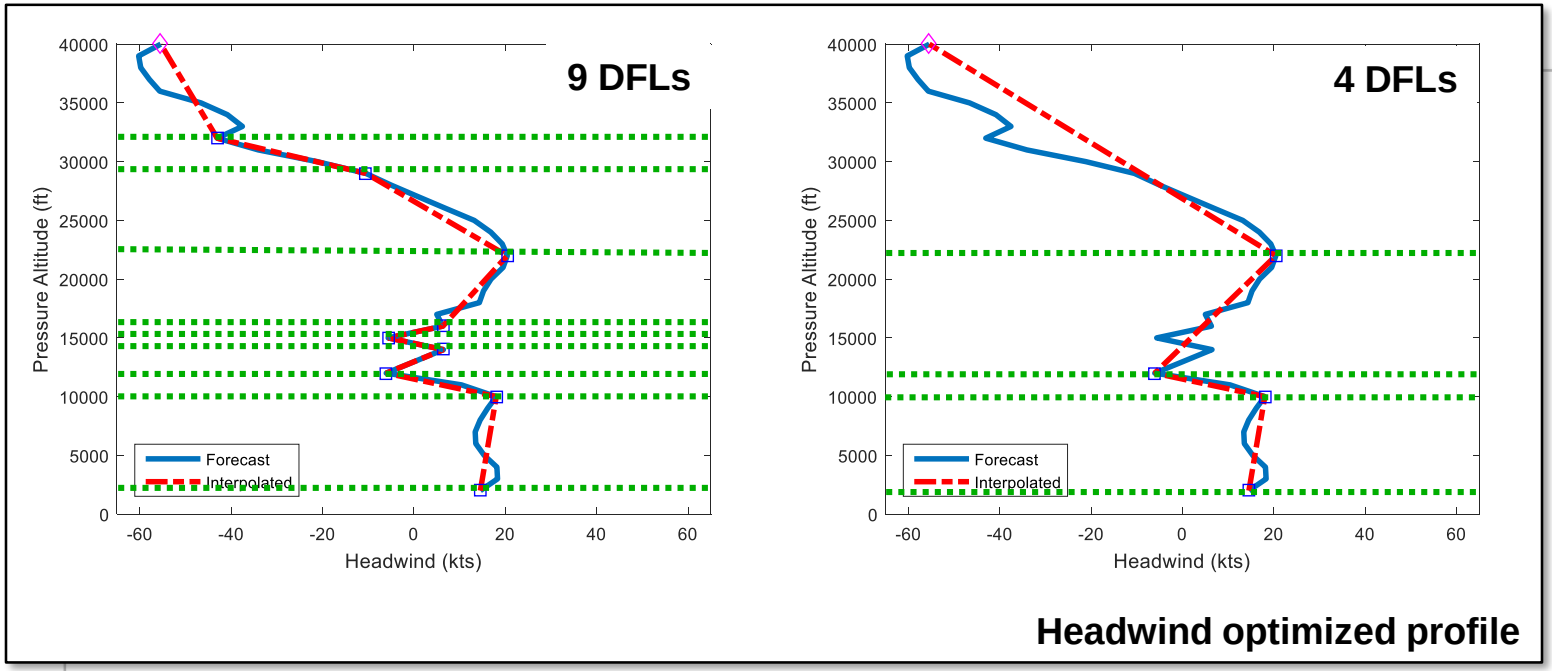


DFL = Descent Forecast Level

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?



Headwind optimized profile

Magnitude optimized profile

Equidistant altitude selection profile

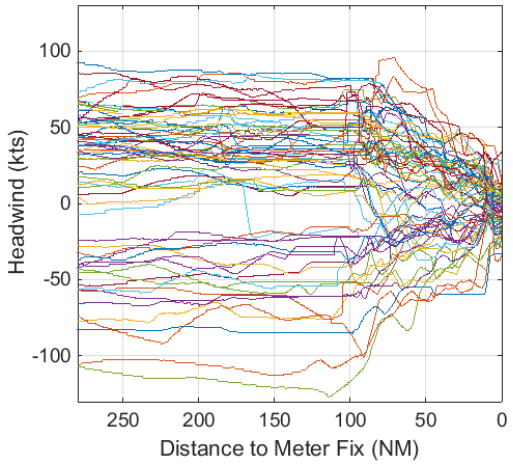
Summary

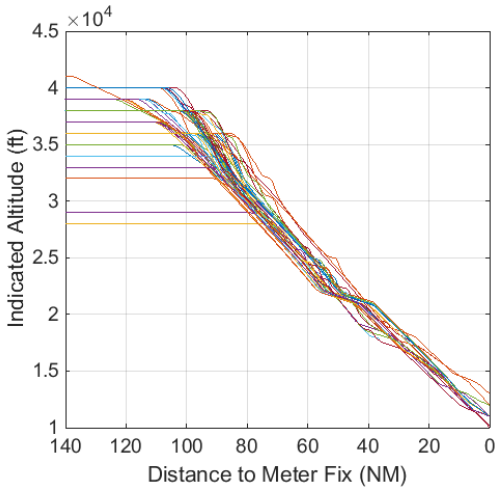
- **Analysis capabilities critical to support WTIC mission**
- **Range of tools developed at Lincoln to assess impacts of atmospheric forecast accuracy on 4D-TBO performance**
- **Application of tools being leveraged in range of areas, e.g., RTCA guidance documents**
- **On-going work:**
  - **Use of 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**

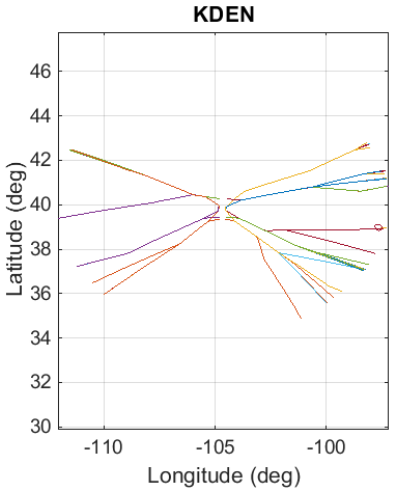
This material is based upon work supported by the Federal Aviation Administration under Air Force Contract No. FA8721-05-C-0002 and/or FA8702-15-D-0001. Any opinions, findings, conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the Federal Aviation Administration.

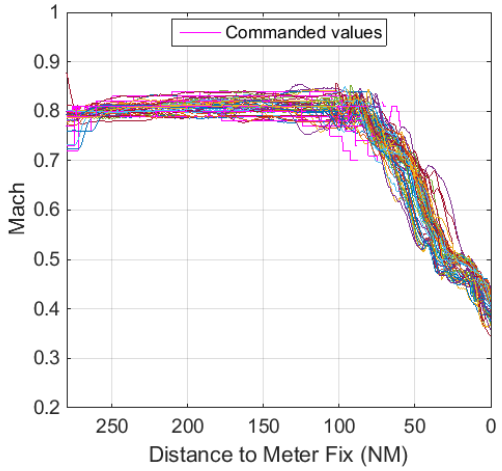
Backups

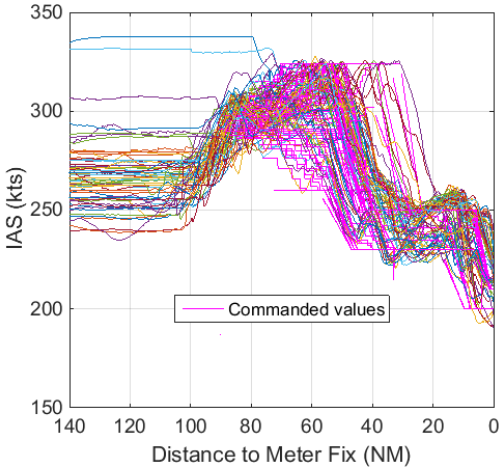
KDEN Simulations (No Forecast Data)

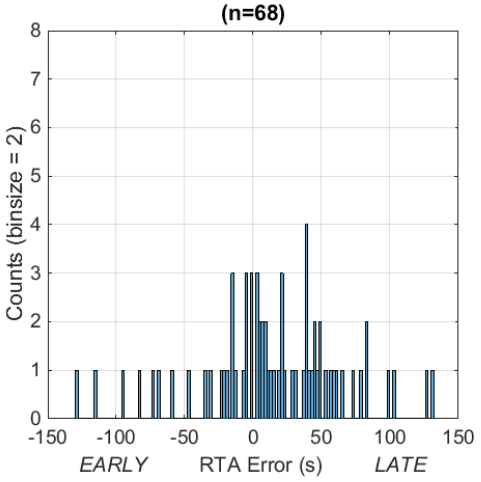




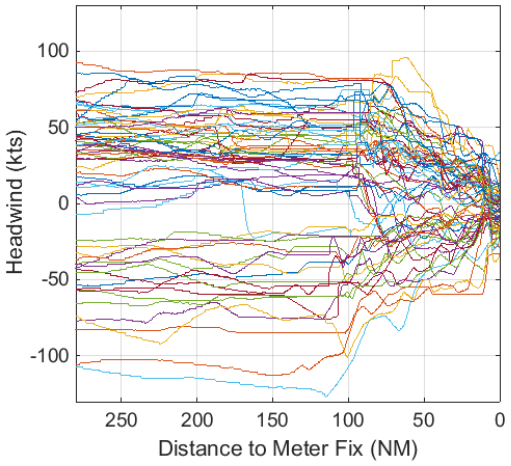


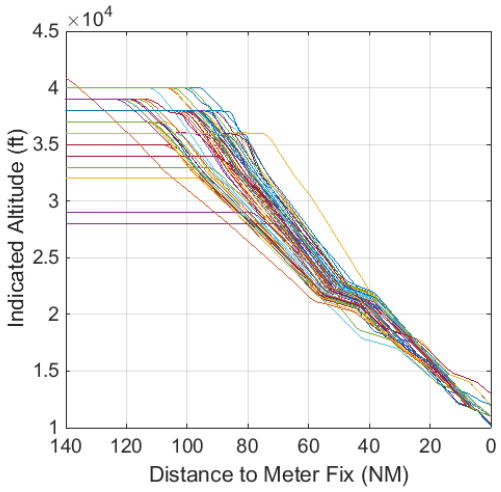


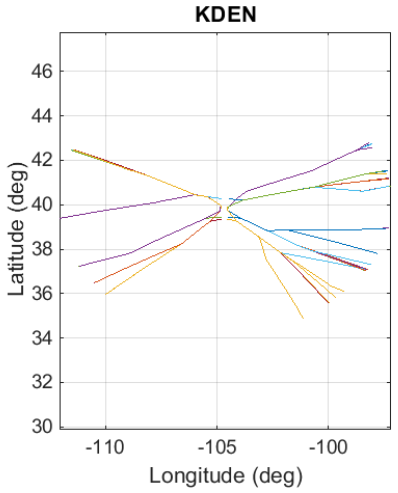


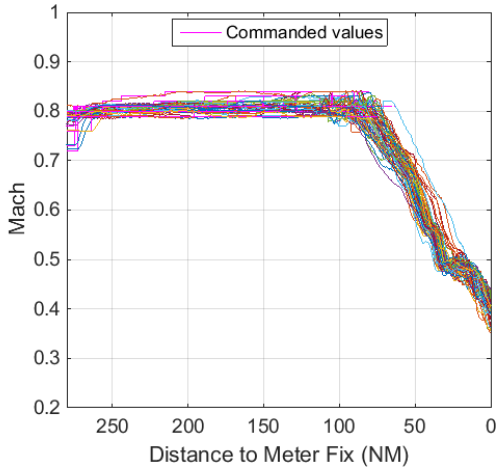


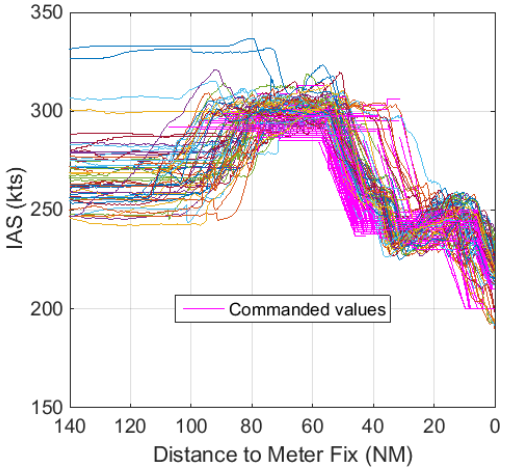
KDEN Simulations (Cruise and 4 Magn-opt DFLs w/ 3hr fcst)

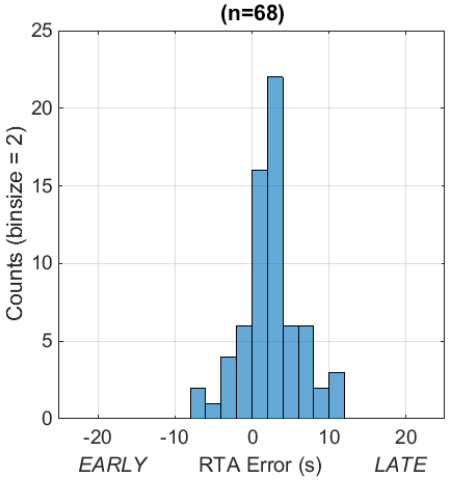












Results

All Qualified Flights, Wind Magnitude Optimized