Overview of Draft RTCA SC-206 “Guidance for the Usage of Data Linked Forecast and Current Wind Information in Air Traffic Management Operations” Document

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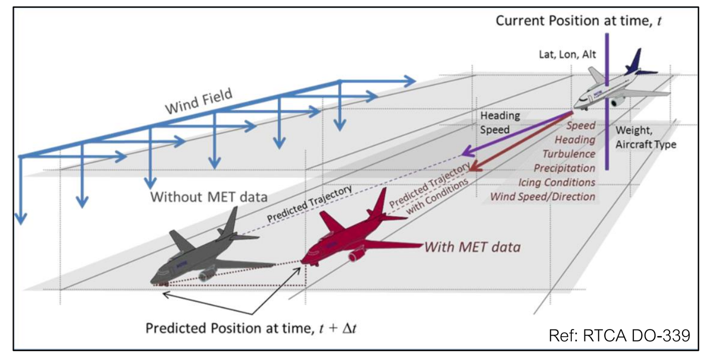
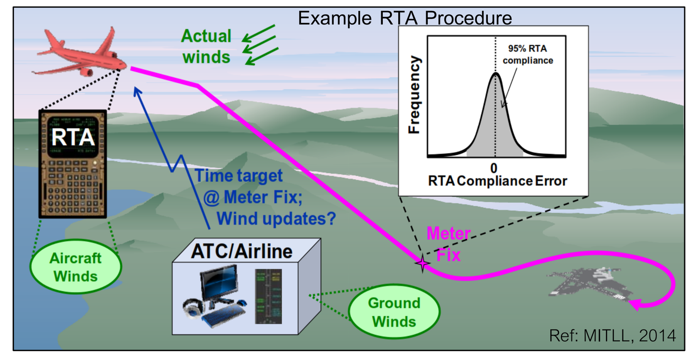
Problem Statement

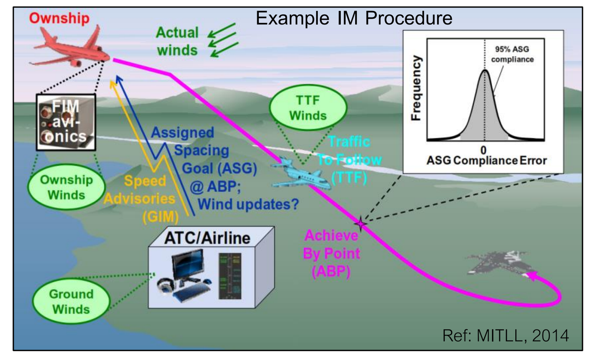
The accuracy of wind information, especially forecast wind error, has been repeatedly identified as one of the largest contributors to errors in aircraft trajectory predictions [Cole, 2000]. Wind errors impact the FAA's ground generation, controlling, and monitoring of flight clearances as well as the aircraft's execution of flight clearances. Errors in the ground and/or aircraft forecast wind information relative to truth winds actually flown through can significantly degrade the performance of ATM operations. The use of improved (high-accuracy, high-resolution, and timely) wind information will be key to minimizing trajectory errors, ensuring better and more consistent operational performance, and helping increase precision, consistency, and use of ATC and flight-deck automation tools. In addition, it will help to increase airspace and airport capacity, improve efficiency, and enhance safety in the National Airspace System.



Ref: RTCA DO-339



Ref: MITLL, 2014



Ref: MITLL, 2014

Research Overview

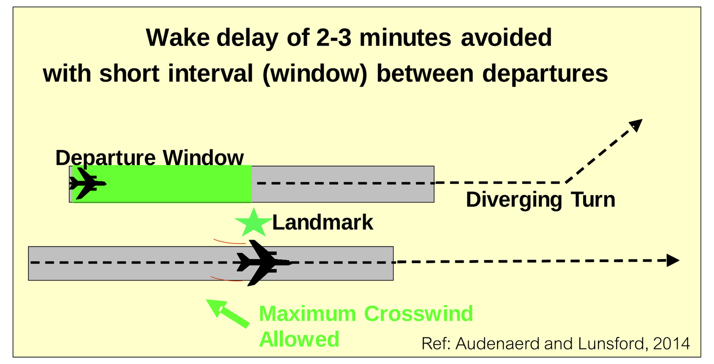
Findings and recommendations for wake mitigation operations were based on the large quantity of previous research conducted by the FAA Wake Turbulence Research Office and international organizations.

Metrics and representative simulation research scenarios specific to RTA and IM operations were used to provide the basis for generating the RTA and IM findings and recommendations for the RTCA SC-206 document. Simulation research scenarios and testable hypotheses were established based on review and input from industry stakeholders and subject matter experts.

Wake Turbulence Mitigation

The goal of wake turbulence mitigation applications is to safely increase capacity and/or enhance operational safety and efficiency in a cost-effective manner. These applications use MET information, especially winds, in various ways to ensure wake turbulence will not present undue hazard to trailing aircraft at reduced separation. Correct wind information is key to determining when to enable or halt wind-based wake applications. The quality of wake vortex predictions strongly depends on the quality of available input parameters. For vortex transport, accuracy of wind data plays the most important role. ASOS provides frequently updated surface level wind information, but the best winds aloft information available to the applications is hourly forecasts several hours into the future. The latency of these forecasts can be an hour plus by the time they are received; thus, requiring uncertainty buffers to be applied that directly impact availability of the applications.

Improved MET information, particularly near real-time crosswinds with sufficient temporal, vertical, and horizontal sampling density, is needed to increase availability of wake mitigation applications for departures and arrivals (e.g., WTMD, PD, and WTMA). In addition, aircraft observations of near real-time winds, on the order of minutes from observation to use, from aircraft operating into/out of airports are needed to provide a more accurate characterization of winds at the airport and on specific airborne paths as well as to determine how winds are transitioning from one forecast update to the next.



Ref: Audenaerd and Lunsford, 2014

The current research focus is on system solutions, which use forecast and near real-time wind information in determining time periods when each wake application can be used, when use should be suspended, and what distance or time-based wake separations will need to be applied. The FAA is initially focusing on ground-systems where DSTs process available forecast and near real-time wind information and indicate when each wake solution will be available. For some wake solutions, wake separations applied between aircraft will vary depending on the wind.

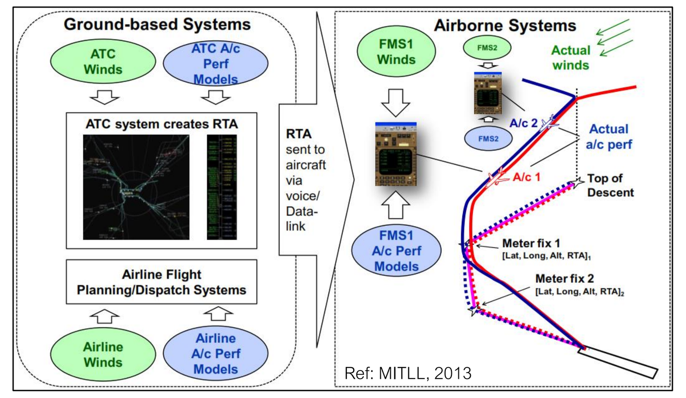
Required Time of Arrival

4D TBO is an ATM concept where planned trajectories in both space and time are agreed upon by all parties prior to execution, and meaningful changes to estimated trajectories are shared amongst all affected parties. RTA is a capability, the time when an aircraft is required to cross a fix, and is an enabler of 4D TBO.

RTA operations occur when ATC provides the aircraft an RTA clearance and the flight crew agrees the aircraft can be flown to arrive at a fix within a specified CTW (CT +/- tolerance). After accepting ATC's clearance, the flight crew typically employs TOAC capability of an FMS to adjust the speed and vertical profile to arrive at the fix within the RTA target window (RTA +/- tolerance). The FMS continuously updates its estimated trajectory based on current sensed conditions and forecasted environment for the remainder of the route, up to the fix. If the ETA at the fix is outside the RTA target window, a new speed and vertical profile will be applied. The solution sought considers efficient and safe operation as well as the impact of altitude and speed constraints defined along the route.

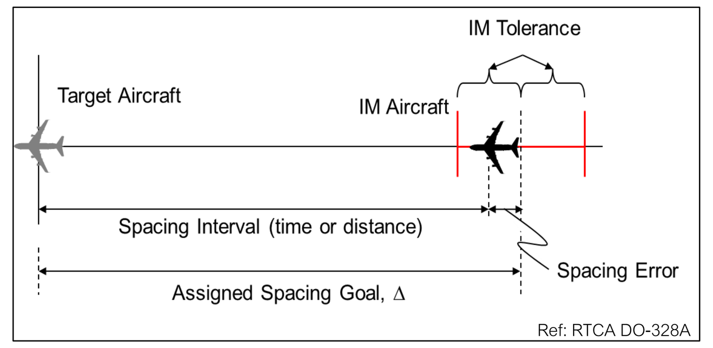
Wind information is used by ATC to develop time targets for RTA and by aircraft avionics to manage the aircraft trajectory to the RTA. The temporal accuracy of a predicted trajectory is subject to the accuracy of the aircraft performance model, the future adherence to planned speeds along the route, and the accuracy of forecasted MET conditions along the route when the aircraft is predicted to pass through a specific region.

The research focus was to examine the effects of three trades spaces (forecast source, number of DFLs, and speed constraints) on the ability of RTA systems to achieve specified CTs relative to the performance standard (+/-10 seconds, 95%) when attempting to achieve a CT assigned during cruise and associated with a fix well into the descent. To evaluate the effects of the trades spaces on RTA performance, an approach was taken that performed simulations replicating actual flights utilizing recorded wind and temperature data to reproduce the atmospheric conditions experienced on each flight.



Ref: MITLL, 2013

Interval Management

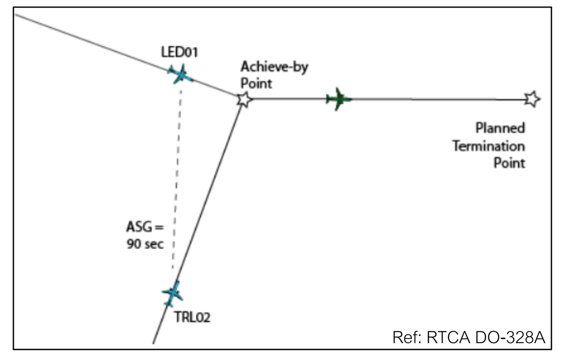


Ref: RTCA DO-328A

IM is an ADS-B-enabled suite of applications that use ground and flight-deck capabilities and procedures to support flight crew-managed relative spacing of aircraft to improve inter-aircraft spacing precision, increase throughput, and reduce delays in capacity-constrained airspace. ATC determines IM availability and instructs the flight crew of an IM Aircraft to achieve and/or maintain a spacing (in time or distance) relative to a TA. FIM equipment on the IM Aircraft provides speed commands to achieve the ASG and/or maintain relative spacing to the TA.

Accurate and timely wind information is key for ATC's ground automation tools to determine if IM operations are feasible, calculate ASGs, generate trajectories, calculate ETAs at constraint points, and determine the sequence and STAs based on minimum spacing at constraint points. Winds are also used by the IM Aircraft's flight-deck automation tools to generate 4DTs for both aircraft and to provide IM speeds to meet the ASG. Changes in current and forecast winds can cause an update to the schedule, which may result in changes to ASGs, ABPs, and PTPs or cancelling IM altogether. Without accurate and timely wind information, the spacing accuracy of an IM operation may be limited or may require more frequent speed changes to achieve and maintain the ASG.

Three IM performance analyses were designed to study the incremental performance improvements in IM operations when improved wind information is available to FIM equipment over the baseline wind information in RTCA DO-328A and RTCA DO-361. They included evaluating IM spacing performance for single-runway arrival and approach IM operations with the ABP at the FAF, the impact of inconsistent wind information on IM spacing performance, and the impact of using TA's forecast wind information in FIM equipment for IM operations on non-coincident routes.



Ref: RTCA DO-328A

Findings & Recommendations

Wake Turbulence Mitigation Findings

- Use of forecast and current wind information requires application of uncertainty buffers and setting conservative wind thresholds to guard against incorrect wind forecasts in absence of near real-time knowledge of winds, which significantly reduces availability of wind-based wake mitigation applications.
- Wake mitigation applications would benefit from forecast and near real-time wind information for altitudes and flight paths of aircraft involved in wake operations.
- Mixed equipage with 10% or greater aircraft broadcasting along path wind data may provide substantial enhancement in local wind field estimation.
- Latency associated with existing availability of aircraft-derived wind observations to ATC automation tools does not provide near real-time access.

Wake Turbulence Mitigation Recommendations

- Near real-time AbO data should be made available from aircraft as described in RTCA DO-364. The desired atmospheric characterization, which would only result from aggregating observations from multiple aircraft, is:

Data Element	Airport & Terminal Area	En Route
Wind Speed Wind Direction Static Pressure Static Temperature Eddy Dissipation Rate Humidity/Water Vapor	Every 50 ft of altitude Every 1 NM in level flight	Every 500 ft of altitude Every 5 NM in level flight

- The transmission modes described in RTCA DO-364 should be used when providing these reports. For example, AbO broadcast and/or request-reply communications in the terminal area could support wake turbulence mitigation applications associated with aircraft arrival and departure operations.
- Develop near real-time mesoscale forecasts that incorporate AbO winds.

Required Time of Arrival Findings

- Aircraft tend to arrive at the RTA fix late relative to the assigned RTA.
- Standard deviation of RTA TE:
  - Decreases with increasing number of DFLs
  - Was nearly half that of speed constrained cases for flights without speed constraints
- The provision of forecast information at cruise levels had a significant effect on performance, reducing all standard deviations by over 66%.
- With 2+ DFLs, both biases and standard deviations approach the lowest values for any greater number of DFLs used in simulations.
- For flights with speed constraints, performance is improved as a function of forecast source. Performance increases when using HRRR as compared to using GFS and when using truth as compared to using HRRR.
- For flights with speed constraints, performance could not be met under conditions tested.
- Flights without speed constraints, were principally 100% compliant using 2+ DFLs regardless of forecast source used.

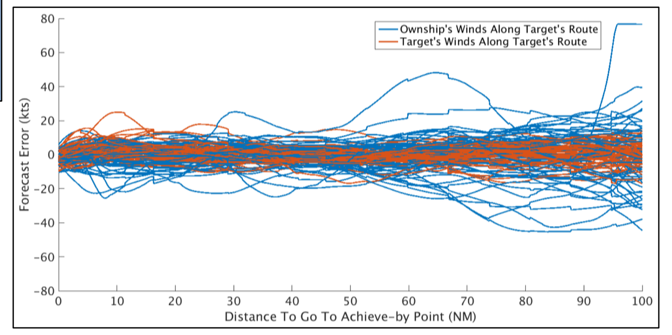
Inputs		Compliant (%) With Speed Constraints (N=276)			Compliant (%) Without Speed Constraints (N=54)		
No Forecast		24.5			47.2		
Cruise Forecast	# DFLs	Forecast Source: GFS	HRRR	Truth	Forecast Source: GFS	HRRR	Truth
Yes	0	65.5	63.4	64.9	83.3	83.3	87.0
Yes	1	82.2	82.0	84.0	98.2	90.7	96.3
Yes	2	85.8	86.9	91.6	100.0	100.0	100.0
Yes	3	86.1	88.4	89.5	100.0	100.0	98.2
Yes	4	86.6	88.7	90.6	98.2	100.0	98.2
Yes	5	89.5	90.2	93.8	98.2	100.0	100.0
Yes	6	87.3	88.7	93.1	98.2	100.0	98.2
Yes	7	86.5	89.1	92.7	100.0	100.0	98.2
Yes	8	88.6	91.2	94.9	98.2	98.2	100.0
Yes	9	87.6	90.6	94.6	100.0	98.2	100.0

Required Time of Arrival Recommendations

- Apply RTA fix prior to location of speed constraint on route.
- Time constraints should be given higher priority over speed constraints.
- Use most demonstratively accurate forecast source possible. If choosing between GFS and HRRR, use HRRR.
  - Create or identify more accurate forecast sources.
- Provide wind forecasts at cruise waypoints.
- For flights without speed constraints on routes, use at least 2 DFLs for nominal performance.
- For flights with speed constraints on routes, use 5 or more DFLs.

Interval Management Findings

- For single-runway operations using 3-hr wind forecast, operationally significant differences in performance were not observed due to using TA's forecast winds, increasing the number of altitudes forecast winds are available, providing forecast winds along IM Aircraft's route versus a single point, or using a more accurate forecast.
- For single-runway operations using wind forecasts with varying ages, the number of wind conditions where spacing performance exceeds the IM tolerance saw an operationally significant increase when using 6-hr forecast or randomly chosen forecast age.
- Inconsistency in wind forecast leads to greater variability in IM performance at tails of spacing performance distribution, but was not operationally significant when forecast winds of sufficient quality were provided.
- For non-coincident routes at Boston, forecast errors when using IM Aircraft's forecast winds are much larger than when using TA's forecast winds to predict winds along TA's route. Larger forecast errors correlate with larger errors in spacing performance, and the magnitude of the errors suggest there will be an operationally significant impact on non-coincident route operations.



Simple IM Operations Recommendations

- For federated systems, errors in forecast wind made available to FIM equipment should be less than errors typical to 6-hr RAP forecast.
- Forecast winds for at least 4 appropriately-selected altitudes should be provided to FIM equipment per RTCA DO-361.

Complex IM Operations Recommendation

- Forecast wind information specific to TA's route should be available to FIM equipment.

RTCA Final Review and Comment & Acknowledgements

- RTCA FRAC period: January 9 – February 8, 2017; Contact Karan Hofmann at RTCA, www.RTCA.org, to request document and submit comments

- FAA's Weather Technology in the Cockpit (WTIC) Program, Steve Abelman and Gary Pokodner
- RTCA SC-206 Sub-Group 7 co-chairs: Ernie Dash and Michael McPartland
- The MITRE Corporation for leading the wake mitigation research documentation and the IM simulations for the RTCA SC-206 document
- MIT Lincoln Laboratory for leading RTA simulations and wake mitigation wind forecast analysis documentation for the RTCA SC-206 document