Presented at the 57th Air Traffic Control Association (ATCA) Annual Conference & Exposition.
Gaylord National Resort and Convention Center, Maryland, October 1-3, 2012.

Federal Aviation Administration Wake Turbulence Program - Recent Highlights

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Introduction

Aircraft-generated wake turbulence has for years been a major factor in the air-traffic-control-imposed separations between aircraft during departure, transit and arrival operations conducted at airports and air corridors of high volume. Applied research at a global level aimed to mitigate the adverse effect of wake turbulence traces back to the 1970s, although fundamental research related to the wake turbulence dates back even further [1]. The volume of research and development (R&D) documented in the literature since the 1970s has been impressive, but it is not until relatively recently that wake turbulence R&D has directly contributed to both capacity and safety improvement in terms of tangible implementations of operational changes. The contributors to the recent success (which is the subject of the current article) in wake turbulence studies are many fold, and in depth account on those factors is beyond the scope of the current paper, but interested readers are encouraged to contact the authors for further discussions. The implications as well as real term impact of the recent and ongoing wake turbulence program development are significant in supporting Federal Aviation Administration's (FAA) overall goal to revitalize air transportation system known as the Next Generation Air Transpiration System (NextGen). FAA NextGen is designed to meet the expected growth of aviation in the United States, which requires a much higher density of aircraft operating in the nation's airspace. Many of the NextGen efforts revolve around reducing the navigational uncertainty in the current system such that aircraft separation can be substantially improved/reduced from a navigation perspective. Increasing navigation improvement, in a system engineering sense, then increasingly shifts the attention to other aircraft separation factors such as safe revision of the wake turbulence spacing as an enabler to these high-density operations. Therefore, unless wake turbulence separation is appropriately addressed in the NextGen context, many of the NextGen trajectory based concepts would not be able to realize their full potentials [2].

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Since the beginning of the early 2000s, FAA wake turbulence program has been working with internal stakeholders such as the Flight Standard Service (AFS), Air Traffic Safety Oversight Service (AOV), the NextGen program office, Radio Technical Commission for Aeronautics (RTCA) and others (such as Air Line Pilots Association, International, various airport authorities and airframe manufacturers) to safely mitigate the adverse effect of wake turbulence. The current resurgence of FAA activities in wake turbulence also has both international and inter-agency elements. In those contexts, the FAA wake program is in close contact with International Civil Aviation Organization (ICAO), European Organisation for Safety of Air Navigation (EUROCONTROL), European Aviation Safety Agency (EASA), various Air Navigation Service Providers (ANSP) and research organizations. In an interagency context, the FAA wake turbulence program leverages extensively on the outcomes of past R&D elements from FAA, Volpe National Transportation Systems Center, National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), and Federally Funded Research and Development Centers (specifically, MITRE Corporation and Lincoln Laboratory)

In this article, the authors will highlight four specific ongoing efforts from the wake turbulence program.

FAA Order 7110.308

Prior to the 7110.308 Order, dependent ILS/MLS approaches with a minimum 1.5 NM diagonal separation to parallel runways were authorized for runway centerline spacing between 2500 to 4300 feet. However, when runway spacing is closer than 2500 feet, otherwise known as the Closely Spaced Parallel Runway (CSPR) geometry, wake turbulence separation consideration (also known as the wake turbulence 2500 ft rule) precluded the use of dependent instrument approaches. Consequently, the arrival rate of the runway pair is reduced to that of a single-runway.

The original design of the 2500 ft rule was to protect a *Small* aircraft on the adjacent CSPR runway from wakes of *Heavy* aircraft such as the Boeing 747. The development of the 7110.308 procedure demonstrated via multi-year and multi-sensor data collection campaign that the 2500 ft rule is overly conservative when protecting from wakes of *Large* and *Small* aircraft involved in a simultaneous, dependent approach scenario. Enabling, or retaining the use of the dependent 1.5 NM diagonal separation on CSPRs during instrument approaches with *Large* and *Small* aircraft as leaders in the pairing sequence is therefore the essence of the FAA Order 7110.308.

A diagram of the approved procedure is displayed in Figures 1 and 2. In addition to the requirement on the leading aircraft weight class types, this procedure is only approved at the specified airports and runway pairs. Details of the authorized runway pairs can be found in Change 2 (Ch2) to the 7110.308 Order, which was approved in September 2010 [3]. The number of airports that are approved to use 7110.308 is currently at 7, which are General Edward Lawrence Logan International Airport (BOS), Cleveland Hopkins International Airport (CLE), Newark Liberty International Airport (EWR), Philadelphia International Airport (PHL), Memphis International Airport (MEM), Seattle-Tacoma International Airport (SEA) and Lambert-St. Louis International Airport (STL). A 7110.308-Ch3 is currently underway, to include a revised geometry at EWR at the request of the airport facility as well as addition of SFO. Additional studies are also ongoing to extend 7110.308 to all weather conditions for as long as the airports are conducting instrument approaches, which can also occur under VMC conditions.

Finally, in its current form, 7110.308 requires navigational guidance to be in the form of ILS/MLS. Efforts are ongoing to also examine the use of Global Positioning System (GPS) based navigation approaches in 7110.308. The overall effort of the project integrates well with the NextGen objective to utilize CSPR runways more efficiently.

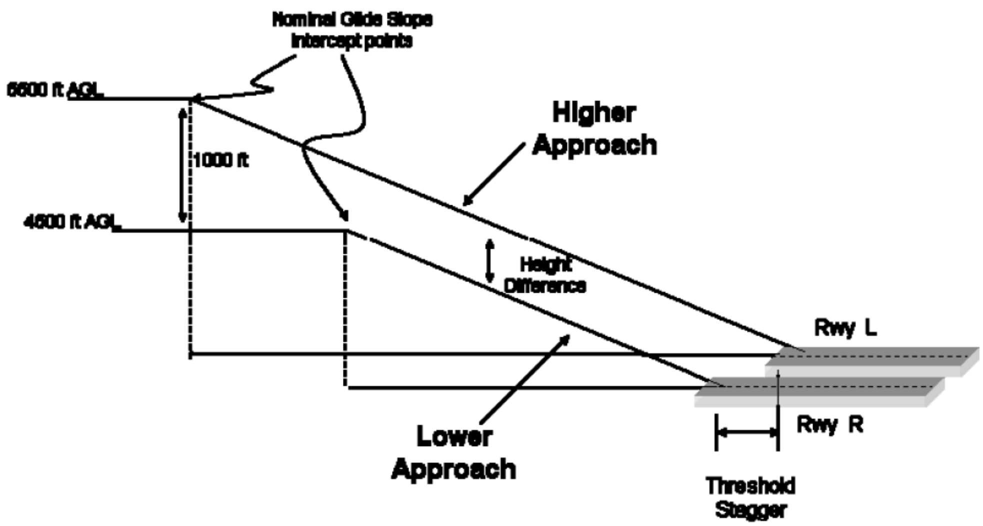

Figure 1. Side View of Example of a CSPR Approach.

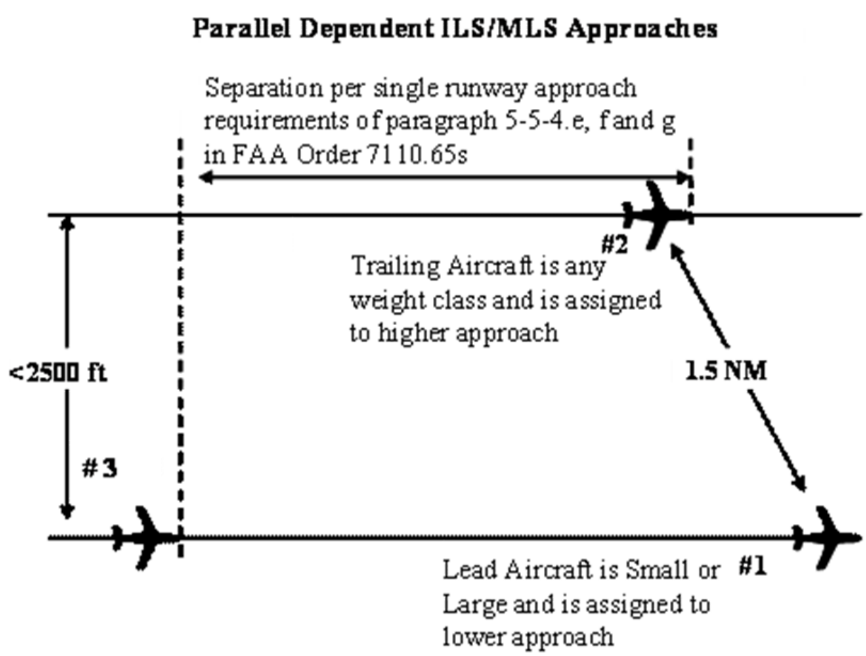

Figure 2. Top Down View of Dependent Approach Procedure.

Wake Turbulence Mitigation for Departures (WTMD)

Wake Turbulence Mitigation for Departure, WTMD, is a crosswind based system that enables CSPR departures to take place without wake turbulence constraints. At the time of this writing, WTMD has just been approved by FAA AOV and yet to have an Order designation. Without WTMD, wake turbulence separation must be applied between successive departures from CSPRs when the lead aircraft is a *Heavy* or *B757*, regardless of departure runway [4]. Additionally, when thresholds are staggered (offset) by 500 feet or more aircraft departing from the offset threshold must be held 3 minutes after a departing *Heavy* or *B757* on the adjacent parallel runway. If the stagger is less than 500 feet, a 2 minute hold is applied. The aforementioned CSPR departure separation requirements are also driven by the safety concern of smaller aircraft being exposed to wake turbulence generated by *Heavy* and *B757* on the adjacent runway. However, if a persistent crosswind with sufficient magnitude were to present such that the wakes of the *Heavy* or *B757* are transported away from the adjacent runway, as graphically depicted in Figure 3 - this scenario provides the opportunity for any aircraft (including *Large* and *Small* aircraft) to depart immediately on the upwind runway when the downwind runway operates *Heavy* or *B757* departures. This removes the (up to) three minute delay, that the current CSPR departure rule would require, on the aircraft departing the up-wind runway. In order to operationalize this concept, it would be necessary to have a robust wind forecast algorithm, an understanding of transport behavior of departure wake vortices and the automation to inform controllers when wake turbulence separation is not necessary for the CSPR departures as well as what runway pairs. WTMD is the integrated system that predicts and monitors the wind and, when WTMD condition exists and is expected to persist, enables controllers to conduct CSPR departures without wake constraints. When WTMD conditions do not exist, the normal wake turbulence separation for CSPR departure is then applied.

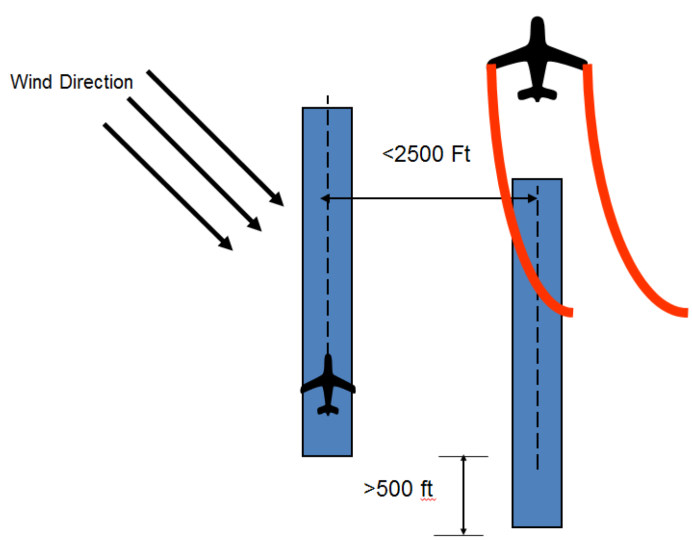

Figure 3. Scenario Addressed by the WTMD Concept.

Ten airports have been approved to conduct WTMD operations and they are BOS, Detroit Metropolitan Wayne County Airport (DTW), EWR, George Bush Intercontinental Airport (IAH), MEM, Miami International Airport (MIA), PHL, SEA, San Francisco International Airport (SFO) and STL. Currently, WTMD operational demonstration is underway at IAH and SFO, before national implementation at the rest of the airports.

The significance of the WTMD system is many faceted. Operationally, it is the first automation driven wake separation change that allows dynamic separation based on meteorology. It is also a system that improves capacity under visual meteorological conditions. Moreover, the safety of the aircraft operating on the wake free runway is enhanced even further than pre-WTMD's CSPR operation. Scientifically, it is illustrated that short term wind nowcasting has become far more matured than previously realized. The R&D that enabled WTMD also included large amount of wake turbulence measurement from *Heavy* and *B757* departures, including data collected in a joint effort with EUROCONTROL in their pursuit of a wind dependent single runway wake mitigation solution called the Crosswind Reduced Separations for Departure (CREDOS) project. In terms of inter-agency collaboration, although WTMD is a FAA NextGen deliverable, NASA partnered with the FAA with the NASA role being the development and assessment of non-operational prototype.

Wake Turbulence Mitigation for Arrivals (WTMA)

Wake Turbulence Mitigation for Arrival, or WTMA, is an ongoing R&D effort. WTMA R&D uses the overall 7110.308 concept and explores the circumstances under which reduced wake spacing for staggered dependent instrument approaches to CSPR can be safety extended to include *B757* and *Heavy* aircraft as leaders. Research is ongoing to examine both purely procedural and wind based versions of WTMA, with the latter option requiring further development of the wind forecast algorithm used in WTMD to extend the spatial and temporal coverage. Common to both versions of the WTMA is the continual wind and wake vortex data collections with *Heavy* and *B757* as the special focus, which are ongoing.

Wake Turbulence Recategorization

Wake Turbulence Recategorization, or ReCat for short, is a three-phase effort aimed to safely and efficiently revise international single runway wake turbulence separation standards. Currently the FAA and ICAO single runway wake turbulence separation for arrival operations are both maximum takeoff weight based, each involving categories having a rather wide range of weight and wingspan, and differs most significantly on the boundary between FAA *Large-Small* vs. ICAO *Medium-Light*. Phase I of the ReCat effort, or ReCat I, is a joint FAA and EUROCONTROL study to revise the ICAO single runway wake separation that addresses both capacity and safety improvements. FAA and EUROCONTROL shared operational experience, wake turbulence data and analysis expertise throughout the course of the collaboration.

The fundamental departure that ReCat represents over the current separation scheme is that, instead of using the traditional maximum takeoff weight based separation standard, uses a separation matrix devised by the ReCat I group and based on wake vortex physics and aircraft dynamics parameters. The result of the phase I study, finalized in 2011, recommended a six category system common to both arrival and departure operations, a safety case supporting those recommendations, and a methodology to assign all 9000+ ICAO registered aircraft to those categories and a methodology to categorize new aircraft over the horizon.

As a specific example of why ReCat I can be safely applied, consider Figure 4 which shows the current ICAO separation standards of 4 NM for a *Heavy* behind a *Heavy*. This separation standard applies to both one of the lightest of the *Heavy* (B767) following one of the heaviest of the *Heavy* (B747), shown in the top drawing in Figure 4, as well for one of the heaviest of the *Heavy* (B747) following one of the lightest of the *Heavy* (B767-300), shown in the bottom drawing in Figure 4. Under the current ICAO separation standards, both scenarios in Figure 4 are safe, but, clearly, if the top scenario in Figure 4 were safe, the bottom scenario is overly conservative. Under Phase 1 of the re-categorization, the separations of the heavier *Heavy* behind the lighter *Heavy* are being reduced. This reduction in separation is shown in Figure 5. The top drawing in Figure 4 is safe under the current ICAO wake turbulence separation standards. The bottom drawing is equally safe. The boundary changes do not always result in spacing reduction for all pairings. While the new boundaries in ReCat I result in some separation reduction and many cases where there is no separation changes, separation is increased as a safety measure for the *Small* / *Light* as followers. The ReCat I separation and the associated category classifications are represented in Figures 6 and 7.

The status of the ReCat I effort includes the selection of MEM as the key-site in the United States and scheduled for near-term implementation of the ReCat I recommendation. And currently the ReCat project is embarking on its phase II study, with the intended deliverable to be a separation matrix for static pairwise spacing with each combination of leader and follower optimized for wake separation. In that sense, separation category boundaries are then removed, resulting what may be considered as a de-categorization. Finally, it is noteworthy to point out that, ReCat III, aimed to deliver a weather based pair-wise separation, maps directly to FAA NextGen's ultimate dynamic pair-wise separation.

In light of the aforementioned various wake solution development being based on the current separation standard, an obvious activity in the near future would be to harmonize the operational details for 7110.308, WTMD and WTMA with ReCat.

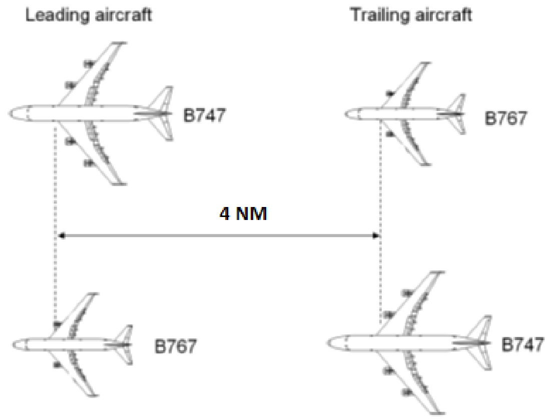

Figure 4. Two Scenarios of the Current ICAO In-Trail Wake Turbulence Separation Standards for a *Heavy* behind a *Heavy*.

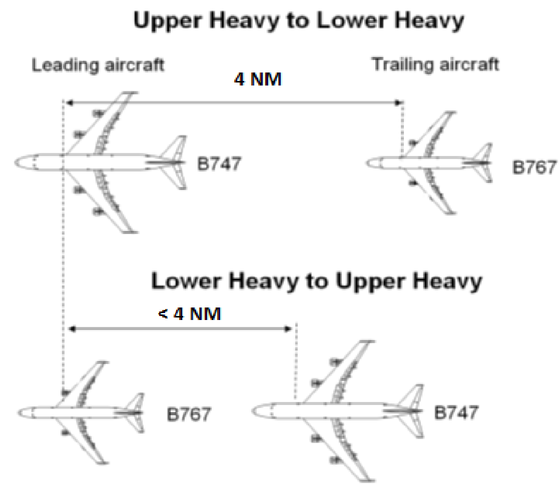

Figure 5. Two Scenarios Under ReCat I for In-Trail Wake Turbulence Separation Standards for an ICAO *Heavy* behind a *Heavy*. The Top Drawing is Safe Under the Current ICAO Wake Turbulence Separation Standards. The Bottom Drawing is Equally Safe.

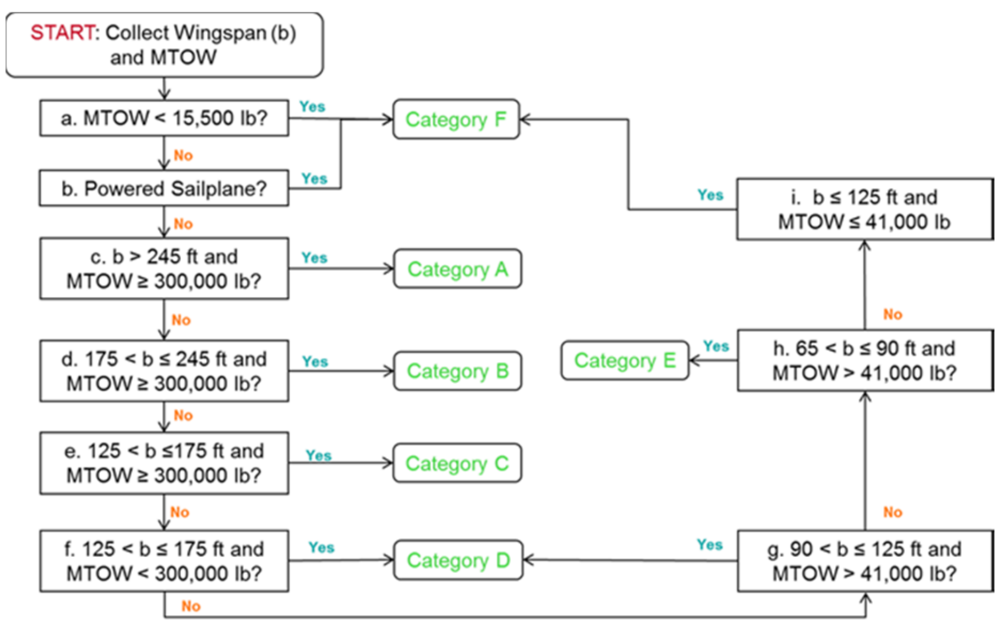

Figure 6. The Generalized ReCat I Categorization Scheme.

		Follower					
		A	B	C	D	E	F
Leader	A	MRS	5.0	6.0	7.0	7.0	8.0
	B	MRS	3.0	4.0	5.0	5.0	7.0
	C	MRS	MRS	MRS	3.5	3.5	6.0
	D	MRS	MRS	MRS	MRS	MRS	5.0
	E	MRS	MRS	MRS	MRS	MRS	4.0
	F	MRS	MRS	MRS	MRS	MRS	MRS

Separation Was Increased for Some of All Aircraft Pairs

Separation Was Decreased for Some of All Aircraft Pairs

Separation Remained the Same for Some of All Aircraft Pairs

MRS Minimum Radar Separation (3 NM, or 2.5 NM When Existing Requirements Are Met)

Figure 7. Separation Matrix for ReCat I Relative to Current ICAO Standard.

Closing Remarks

A brief account of the current wake turbulence program activity is presented herein. A suite of wake mitigation solutions to improve both capacity and safety are being developed, and more importantly, are being implemented. This paper highlights four specific examples from the current wake turbulence program portfolio, which are 7110.308, WTMD, WTMA and ReCat. All of these solutions directly support NextGen's objective for capacity enhancement goals. The program acknowledges all of the past R&Ds in the field leading to the current successes, and continues to seek constructive feedbacks from the stakeholders.

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