REDAC NAS Ops
Fall 2015 Review

NextGen - Wake Turbulence R&D

By: Jeff Tittsworth
Wake Turbulence Research Office Manager

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Topics to be Covered:

- **Purpose for Wake R&D**
- **Wake R&D Projects - Additional Accomplishments Since March 2015**
- **Planned Wake R&D:**
  - Description
  - Associated time line

Purpose for Wake R&D

Wake turbulence research and development (Wake R&D) matures wake mitigation operational concepts to the point they can be directly implemented by FAA orders. If National Airspace System (NAS) infrastructure enhancements are required, the concepts are developed to the point that they can be operationally demonstrated; and if successful, handed off to enter the FAA F&E final development and implementation process. Wake R&D supports the NextGen objective to accommodate increased demand (flights) during peak demand periods. Wake R&D provides the mechanisms for providing increased access to airport runways and airspace while maintaining or enhancing the safety of the NAS.

Wake R&D Overview

- **Prior to 2000, FAA had a long history of wake turbulence research that did not provide capacity enhancements to NAS Operations**
- **In 2002, the focus shifted to have operational impacts, which has led to significant capacity enhancements in the NAS by:**
  - Providing cost effective airport throughput capacity benefits to NAS users
    - Without requiring new runways to be built
    - Without aircraft equipage requirements
  - Setting safe, capacity efficient wake separations for new aircraft series
  - Enabling the planned capacity benefits of NextGen mid to far term capabilities (Improved Multiple Runway Ops, Separation Management)

Wake R&D Accomplishments since March

- **NextGen –Wake Turbulence R,E&D Project**
  - Completed analysis that supported EASA's determination that A320neo should have the same wake separations as the current A320
  - Began initial wake analysis of the soon to be operational Bombardier CS100/300 aircraft
  - Based on prior research, proposed wake mitigation procedure for use in aircraft maneuvers in en-route airspace – addresses situations described in recent en-route wake encounter reports.
  - Translated the Canadian NRC measurements of wakes generated by aircraft when they are cruise - into data sets that can be used in validating the outputs of wake models being applied in the en-route flight region
  - Provided assessments of the likely increased WTMD procedure availability for SFO controller use if:
    - the WTMD procedure stayed the same – just better optimization of the wind forecast algorithm for SFO
    - the WTMD procedure was changed to include a requirement that following must aircraft start its roll within "X" time after leading aircraft (wake generator) begins movement
  - Provided a sufficiently detailed WTMD Paired Departures concept/procedure/availability to allow formal consideration of proceeding with the development of changes to WTMD for the operational demonstration of WTMD Paired Departures at SFO
  - Completed the documentation, analyses, and community briefings needed to obtain approval of RNAV approach to Boston 4L runway – essential to running 7110.308A at BOS. Boston 4L RNAV added to 7110.308A in June
  - Completed the Embraer 170/190 and Boeing 757 modules for the flight data recorder potential wake encounter screening tool

Wake R&D Accomplishments since March

- **Wake Re-Categorization (RECAT) F&E Project**
  - Controllers began use of RECAT Phase I.5 wake separation standards in daily operations:
    - Charlotte (March)
    - NYC area airports and TRACON (March)
    - Chicago area airports and TRACON (June)
    - San Francisco area airports and TRACON (scheduled for September)
  - RECAT Phase II standards, supporting procedures and safety argument documentation developed and submitted for approval
- **Wake Turbulence Mitigation for Arrivals (WTMA) F&E Project**
  - FAA Order 7110.308A became effective June 2015. 7110.308A expands the 7110.308 procedure by allowing "heavy" wake category aircraft to be the lead aircraft in a dependent staggered paired instrument approach to an airport's closely spaced parallel runways (CSPRs). PHL, DTW and ATL have CSPR configurations that would accommodate the use of the "heavy lead" procedure (WTMA-P)
  - Initial assessment of the Wake Turbulence Mitigation for Arrivals – System (WTMA-S) DST concept indicated that the time periods that the cross-winds along an approach path would be sufficient to insure no wake encounter by the following aircraft in a dependent approach pair – would not merit the use of the WTMA-S ATC controller decision support tool. Evolved the WTMA-S concept to become a component of the CSPO paired approach operation concept – the following aircraft is kept ahead of the wake generated by the leading aircraft. The integrated ATC paired approach concept initially is showing sufficient operational benefit to continue its development
- **Wake Turbulence Mitigation for Departures (WTMD)**
  - WTMD Operational Demonstration Benefits Assessment report completed in May – insufficient benefit to proceed. See NextGen – Wake Turbulence R,E&D for next steps

Planned Wake R&D

- **What comes after RECAT Phase II** (Operational FY16)
  - RECAT Phase II standards are distance based wake separation minima between categories of aircraft
    - Phase II aircraft categories are selected from a 100+ by 100+ matrix of separations for aircraft pairs. The matrix covers the aircraft types that make up 99% of operations in the United States.
    - Phase I standards provided great benefit to MEM, CVG, ATL, JFK, ORD and not so great benefit to IAH, SFO, etc.
    - Phase II allows airports to optimize the Phase II standard categories to reflect the aircraft fleet mix operating at their airport and gain the maximum arrival and departure throughput to their runways.
  - RECAT Phase 2.5 is underway (Operational FY17)
    - Some aircraft to aircraft minimum separation distances in Phase II are know to be too conservative but further analysis is required to set the minimums
    - RECAT Phase 2.5 will complete these analyses and update the Phase II Order and the airport Phase II category optimization tool
  - RECAT Phase III is in beginning stage of definition (Operational FY20)
    - At a minimum – elimination of wake separation categories – static minimum separation directly from 100+ by 100+ matrix
    - Addition of weather effects and individual aircraft performance factors depends on remaining capacity benefit this complexity will produce
    - NEXTOR II is investigating this complexity versus benefit trade-off

RECAT Phase II Implementation Concept 3

	A380	B744	A346	B773	B772	A343	A333	A332	MD11	B763	A306	B753	B752	B739	B738	...
A380	2.5	5.91	5.9	[illegible]	[illegible]	[illegible]	[illegible]	5.91	5.93	[illegible]	[illegible]	7	[illegible]	7	7	...
B744	1.85	4	4	4	[illegible]	[illegible]	[illegible]	[illegible]	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.93	...
A346	1.85	3.82	3.83	[illegible]	[illegible]	[illegible]	3.84	3.84	3.81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.79	...
B773	1.85	3.52	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.46	4.46	...
B772	1.85	3.46	3.5	3.5	3.58	3.57	3.56	3.57	3.4	3.53	3.57	4.65	4.68	4.62	4.63	...
A343	1.85	3.26	3.33	3.33	3.47	3.45	3.44	3.45	3.16	3.37	3.46	4.72	4.78	4.65	4.67	...
A333	1.85	3.23	3.3	3.3	3.46	3.44	3.43	3.44	3.13	3.35	[illegible]	4.74	4.8	4.67	4.69	...
A332	[illegible]	3.19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.85	[illegible]	4.72	...
MD11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.55	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.14	...
B763	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.91	...
A306	1.85	2.01	1.96	[illegible]	1.93	1.92	1.91	1.92	2.1	1.92	1.92	2.54	2.53	2.54	2.54	...
B753	1.85	2.01	1.96	1.96	1.81	1.83	1.85	1.83	2.1	1.92	1.82	1.9	1.92	1.9	1.88	...
B752	1.85	2.01	1.96	1.96	1.81	1.83	1.85	1.83	2.1	[illegible]	1.82	1.92	1.95	1.9	1.88	...
B739	1.85	2.01	1.96	[illegible]	[illegible]	1.83	[illegible]	[illegible]	[illegible]	[illegible]	1.82	1.82	1.75	1.9	1.88	...
B738	1.85	2.01	1.96	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.82	1.75	1.9	1.88	...
B737	1.85	2.01	1.96	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.82	1.75	1.9	1.88	...
B736	1.85	2.01	1.96	1.96	1.81	1.83	1.85	1.83	2.1	1.92	1.82	1.82	1.75	1.9	1.88	...
A319	1.85	2.01	1.96	1.96	1.81	1.83	1.85	1.83	2.1	1.92	1.82	1.82	1.75	1.9	1.88	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

~100x100 separation matrix

- **Category A-F is optimized for ANSP fleet mix , the remainder aircraft make up 7th category, G**

RECAT Phase I separation matrix

		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

- **Separations for Category G is a conservative 8.0 nm. Aircraft in this category are uncommon to the airport, so 8.0 nm should not affect capacity.**

RECAT Phase II 7-category separation matrix

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

EWR – Top 20 Changes From ’11 to ’13

- 151 Aircraft Types Comprise 99% 2011 EWR Movements
- Top 20 Aircraft Type Changes Represent 45% Movement Change

ACType	2011	2013	2013-2011
DH8D	17698	4974	-12724
E145	26527	38277	11750
DH8C	1440	11044	9604
E45X	13904	5173	-8731
A320	7349	15199	7850
B735	6923	60	-6863
DH8B	7702	1246	-6456
B738	21623	16830	-4793
A319	3314	7670	4356
B753	3587	1111	-2476
B734	2381	280	-2101
DH8A	1806	3880	2074
CRJ9	2286	510	-1776
A321	7	1655	1648
B763	1726	3303	1577
B762	1997	478	-1519
MD88	1585	123	-1462
B752	16942	15494	-1448
B772	5295	3848	-1447
E170	9465	10865	1400

Dynamic Separation Concepts Overview

NEXTOR

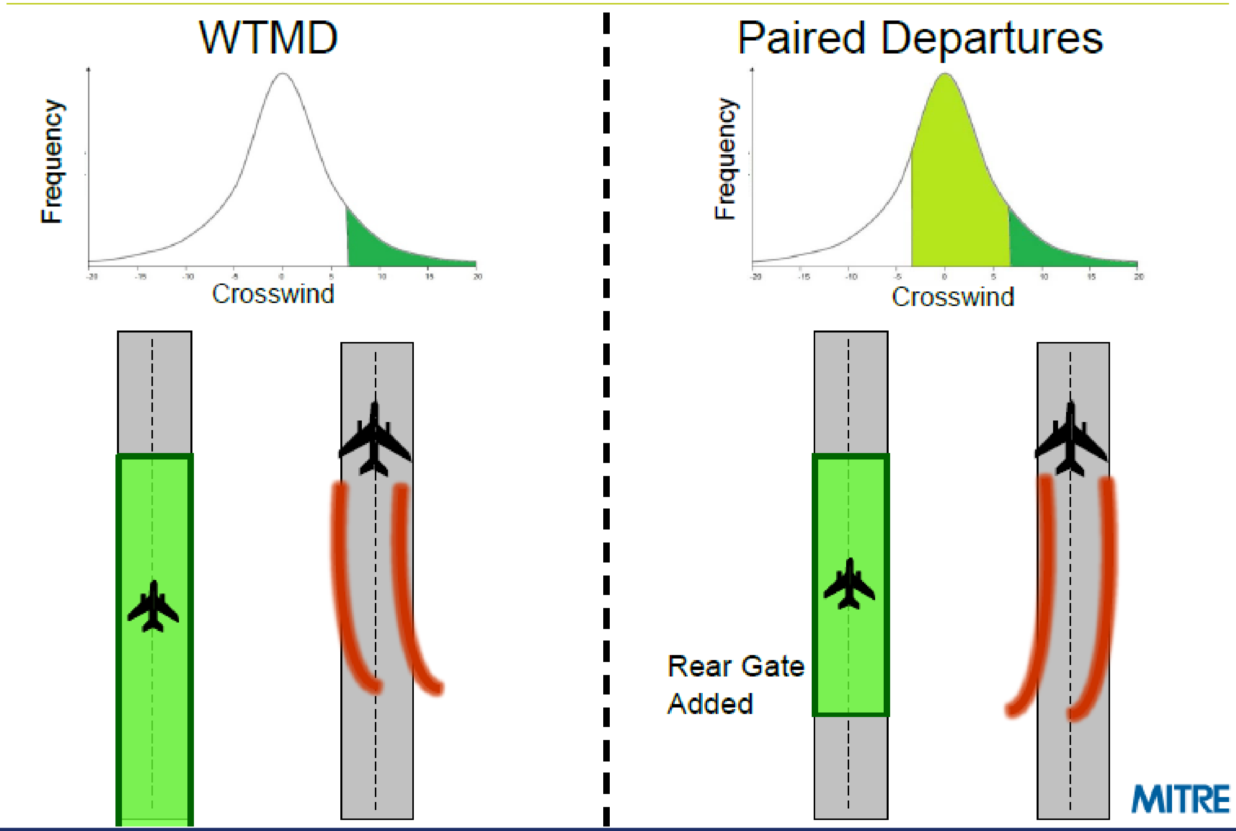
	DEPARTURES	ARRIVALS
SINGLE RUNWAY	• RECAT 3	• RECAT 3 • Time Based Separation (TBS) • On-Board Sensor Criticality Parameters
MULTI-RUNWAY	• WTMD (.316) • WTMD-Paired Departures	• WTMA-S • Interval Management – Paired Approaches • SOIA • Curved Approaches

Planned Wake R&D

- **Development of Wake Related ATC Decision Support Tools**
  - WTMD Paired Departures
    - Assessment from WTMD operational demonstrations at IAH, SFO and MEM was that it was reliable in its designation of time periods that departures did not have to delay 2 to 3 minutes after a “heavy” departed on an adjacent runway. However time periods were too infrequent and too short for WTMD to be of benefit to ATC operations.
    - R&D focus is now on raising the time periods and the length of time periods where the WTMD immediate departure procedure can be used by ATC
    - MIT-LL and Volpe developed new parameter set for the WTMD wind forecast algorithm for use in SFO – based on wind profile data collected at SFO. NAS NCP and associated modified safety risk management document being developed to renew the SFO WTMD ops demo using new parameters – projected availability increased from current15% to 24%
    - In parallel, a change to the WTMD procedure (WTMD-PD) is being developed that would require the “following” departing aircraft on CSPRs to begin moving before the leading aircraft reached a certain point on its runway. This fly- ahead of the wake procedure change allows less stringent parameters on the crosswind for the use of WTMD-PD immediate departure. Availability of the WTMD-PD procedure for ATC use is projected to be 40 to 50% of the operational day

WTMD vs. Paired Departures

- **PD maintains WTMD level of safety, while significantly increasing availability of wake mitigating procedure**
- **Takes advantage of the pairing that is built into SFO ops**

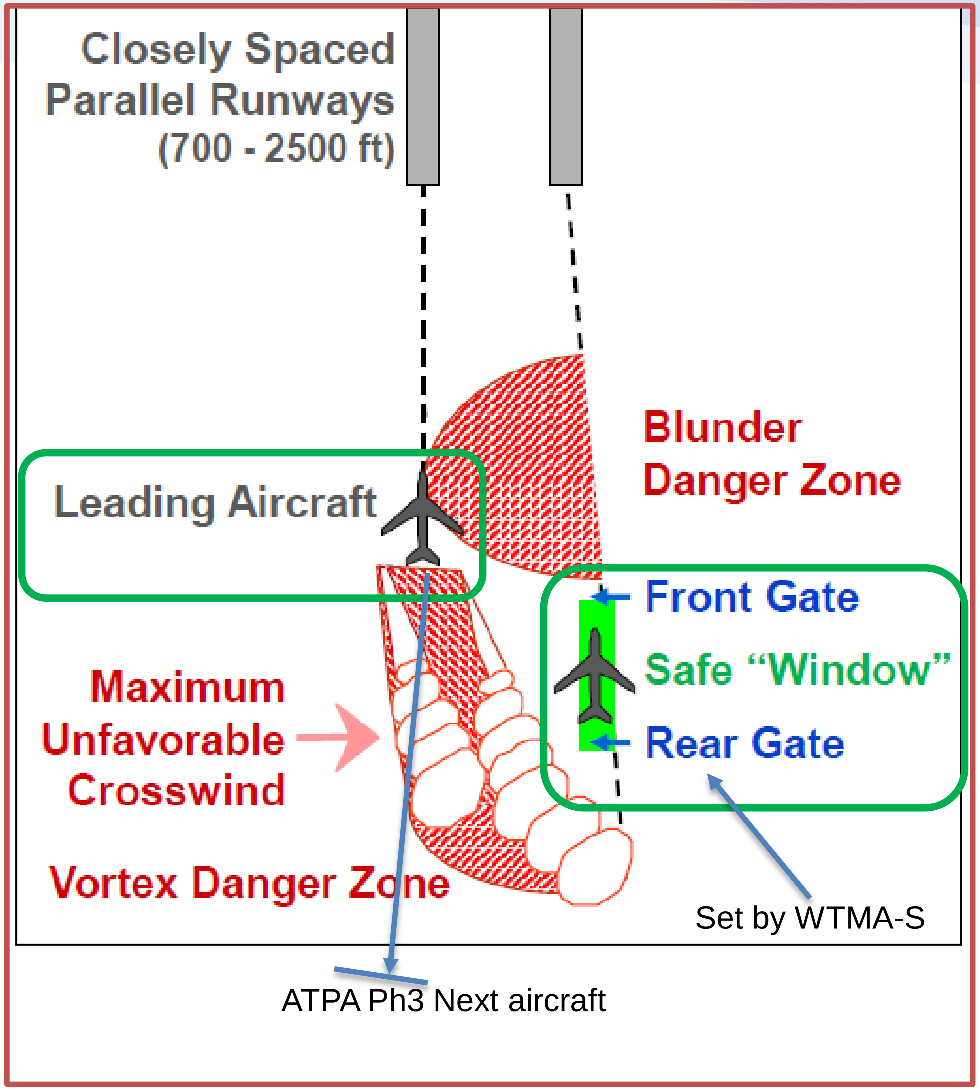


Planned Wake R&D

- **Development of Wake Related ATC Decision Support Tools**
  - WTMA (Wake) and Paired Arrivals (CSPO)
    - The "procedures only" WTMA product (WTMA-P) included in FAA Order 7110.308A has been approved for use at PHL. Its use will require PHL to incorporate use of their CSPRs for instrument arrivals as part of their overall ATC operation at PHL. WTMA-P has also been approved for use at DTW – contingent on a RNAV approach being developed and approved for the CSPR that currently does not have ILS. Work on developing that approach for WTMA-P is now underway. ATL is also being considered for WTMA-P.
    - WTMA-S was originally a DST concept that allowed the use of WTMA-P at airports whose CSPR configurations did not meet the restrictions of 7110.308A. WTMA-S would predict when the crosswind on the CSPR approaches would be sufficient to keep the wake of the lead aircraft on the dependent staggered approach from the path of the following aircraft.
    - CAASD, with inputs from MIT-LL and Volpe, did a survey of NextGen Core airports that likely would use WTMA-S and provided an assessment that WTMA-S would be available for ATC very infrequently – due to its very stringent crosswind requirements to insure no wake travel into the following aircraft's approach corridor
    - The NextGen CSPO project is developing a paired approach (PA) concept that places the following aircraft in close stagger to the leading aircraft on the adjacent CSPR and flying ahead of the wake of the leading aircraft's wake. Integrating WTMA-S with PA – and providing ATC a DST for the procedure is showing encouraging initial estimates for procedure availability. R&D is continuing.

WTMA-S Paired Approach Design

- “Dependent” like approach to runways spaced > 700’
- Capacity nearly 80% of VMC
- Controller merges following aircraft into the “safe window”
- WTMA-S Wind Forecast Algorithm processing determines:
  - When crosswinds will be OK to begin using front door/back door procedure
  - How far back (time/distance) is the rear gate from the front gate.
  - When the procedure (as displayed by ATPA-P3) needs to revert to Re-Cat aircraft-to-aircraft separations – 15 minute warning in advance



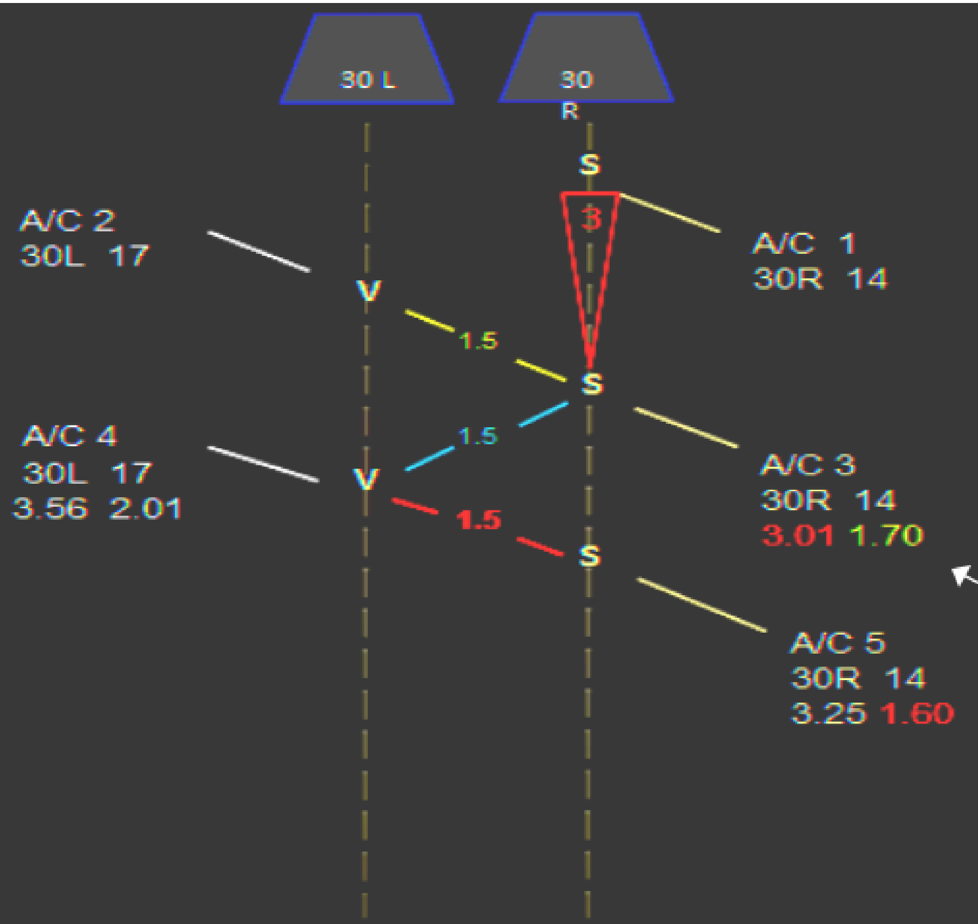
Part of slide courtesy of MITRE CAASD

Planned Wake R&D

- **Development of Wake Related ATC Decision Support Tools**
  - Automated Terminal Proximity Alert (ATPA, ATPA-Phase 1, ATPA-Phase 2)
    - ATPA was developed to assist controllers in monitoring aircraft closing rates on arrival streams to an airport's runway. It was based on a controller tool developed in Europe. When implemented at MSP, its use resulted in:
      - There are 23 percent fewer go-arounds
      - Total excess time flown due to a go-around is 19 percent lower
      - The time between go-around events has increased from 12.3 days to 21.3 days
    - ATPA-Phase 1 is ATPA adapted to display to and monitor for the controller the new RECAT wake separations between aircraft on approach to a single runway. It is a DST that is available for use nationally on the STARS or CARTS platforms.
    - ATPA-Phase 2 uses the same controller display mechanisms as ATPA-Phase 1, but expands it to include separation monitoring for dependent approach operations on parallel runways. If an airport is using 7110.65, WTMA-P or other 7110.308A dependent staggered approach procedures it will support the controller in the use of those procedures
    - An operational demonstration of ATPA-Phase 2 is planned for FY16/17
    - ATPA-Phase 2 is being considered as the display vehicle for the combined WTMA-S Paired Approach DST – initially termed ATPA-Phase 3.

ATPA Phase 2

The in-trail distance from the preceding aircraft is displayed on the *left* side of line 3 in the Full Data Block (FDB)



The diagonal distance from the preceding aircraft is displayed on the *right* side of line 3

Planned Wake R&D

- **Development of Wake Related ATC Decision Support Tools**
  - Dynamic ATC Wake Mitigation Separation DSTs
    - WTMD-PD and WTMA-S/PA under development are examples of wake DSTs that enable controllers to apply wake separations based on changing predicted and observed crosswinds at the airport.
    - Another example is the time based weather conditions wake separation DST implemented by NATS this spring at London Heathrow. Heathrow has a constant headwind on approach – static distance standards caused more separation than required for wake safety. Using controller display technology developed for ATPA in the USA, Mode-S wind reports from aircraft on approach and prediction algorithms developed by the NATS Met office, the NATS/LM DST has decreased headwind caused arrival delays at Heathrow by 50%. FAA will evaluate its application as a wake single runway solution for the US airports. (starting FY16)
    - RECAT Phase III providing individualized wake separation to each aircraft pairing using a variation of ATPA-Phase 1 is an example of a wake DST that allows controllers to dynamically change separations between aircraft based on sequence. ATPA-Phase 2 and 3 being upgraded to use the RECAT Phase III aircraft pairing separations are other examples of DST's enabling dynamic wake separation by sequence
    - NEXTOR II is conducting a high level assessment of the additional capacity benefit that could be achieved by changing ATC wake separation criteria dynamically based on flight conditions and sequencing - in addition to examples mentioned above. (Work continuing in FY16). Going further in developing ATC dynamic wake DSTs in addition to the above examples may not be worth the cost in their development and operation

EU Mandate for TBS by 2024

NATS

Time-Based Separation (TBS) consists in the separation of aircraft in sequence on the approach to a runway using time intervals instead of distances

- It may be applied during final approach by allowing equivalent distance information to be displayed to the controller taking account of prevailing wind conditions
- Radar separation minima and Wake Turbulence Separation parameters shall be integrated in a TBS support tool providing guidance to the air traffic controller to enable time-based spacing of aircraft during final approach that considers the effect of the headwind

http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:JOL_2014_190_R_0005

Rank	Airport	Location
1	London Heathrow Airport	London
3	Frankfurt Airport	Frankfurt
5	Amsterdam Airport Schiphol	Amsterdam
6	Adolfo Suárez Madrid–Barajas Airport	Madrid
7	Munich Airport	Munich
8	Leonardo da Vinci-Fiumicino Airport	Rome
9	London Gatwick Airport	London
13	Paris-Orly Airport	Paris
15	Copenhagen Airport, Kastrup	Copenhagen
16	Zürich Airport	Zürich
17	Oslo Gardermoen International Airport	Oslo
20	Vienna International Airport	Vienna
22	Manchester Airport	Manchester
24	Düsseldorf International Airport	Düsseldorf
25	Dublin Airport	Dublin
28	Malpensa Airport	Milan

http://en.wikipedia.org/wiki/List_of_the_busiest_airports_in_Europe

Planned Wake R&D

- **Development of Wake Mitigation Separations for New Aircraft Designs**
  - Passenger/cargo aircraft
    - Airbus 320Neo – first delivery late CY15 (FAA assessment complete)
    - Bombardier CS100 – first delivery early CY16 (FAA assessment underway)
    - Bombardier CS300 – first delivery late CY16 (FAA assessment underway)
    - Boeing 737 Max – first delivery 3rd Quarter CY17
    - Embraer E-2 Series – first delivery 4th Quarter CY18
    - Boeing 777X – first delivery late CY19/early CY20 (may require Boeing to conduct flight tests for wake standards setting)
  - Unmanned Aircraft System (UAS)
    - Develop ATC procedure concepts for UAS wake mitigation separation for the likely scenarios of UAS operations in the NAS.
    - Once the policy is established for how the categories of UAS will integrate into the NAS, Wake R&D will adapt developed procedures to insure wake safety
- **Analysis of Airports for Characteristics that Allow Reduction of Required Wake Separations Between Aircraft** (continuing in FY16)
  - Assess ATL for WTMA-P applicability
  - Review existing runway intersection wake separation standards and based on wake transport and decay data collected, develop modifications for increased throughput if feasible in terms of safety. Additional data collection near runway intersections may be required.
  - Development of wake mitigation criteria for design of RNAV/GBAS/EoR approaches

Planned Wake R&D

- **Develop Statistical Wake Encounter Frequency/Severity Risk Assessment Capability**
  - Determine Wake Encounter Likelihood and Severity in the NAS (present/future)
    - Analyze NASA's ASRS reports, air carrier reports (continuing)
    - Collect statistic wake encounter data from archived air carrier flight data recorder data sets (continuing)
    - Complete pilot reaction – wake assessment studies (FY16/17 – depends on AVS Wake CSTA priority)
    - Use NEXTOR II/CSSI statistics based tools to evaluate potential wake hot spots with new ATC procedures, air routing, trajectory based operations, interval management initiatives (as requested)
  - Fully characterize relationship between wake lifetime/hazard potential and environmental situation (to define throughput increasing opportunity for RECAT Phase III) (begin FY17)
  - Utilize analysis tools and additional human factor studies to better define acceptable separations for light aircraft behind large/heavy aircraft. (FY16 – depends on AVS Wake CSTA priority)

Planned Wake R&D

- **Develop Wake Models, Data Bases and Data Sources**
  - Mature the NEXTOR II probabilistic wake encounter model for use in en-route, terminal area and arrival/departure procedure/routes encounter probabilities analyses
    - Update/validate included NASA fast time wake model for en-route, terminal area (continues into FY16)
    - Relative comparisons of between current and proposed procedures/routes (as requested)
  - Upgrade the LIDAR Wake Track processing to better characterize wakes as they decay over time (new upgrade to be evaluated in FY16)
  - Acquire and evaluate new to market wind and other wake atmospheric factors measuring systems (continuing activity)
    - Continue to enhance the measurement applications of "portable" lower cost LIDAR wind profilers (Gallion and Leosphere)
    - Evaluate the capabilities of the new generation multi-beam cross correlation low cost (< $100K) non-scanning multi-beam cross correlation LIDAR wind profilers
  - Research what other weather measurements besides winds and EDR (calculated) can be used in the prediction of how aircraft wakes will transit and decay. (potential FY16 start)
  - Through RTCA collaboration, develop means of obtaining aircraft observed real-time weather data for use in ATC wake separation DSTs (WTMD-PD, WTMA-S/PA, WTMSR)

Work not in the FAA Wake R&D Agenda

- **R&D to Develop Pilot Based Wake Mitigation Procedures/DSTs**
  - Determining capacity/safety benefit of pilots providing tactical wake separation (what is the plus/minus of the “wake free zone” being displayed to the pilot)
  - Determining the role of ATC when aircraft has wake visualization capability
  - Determining whether the wake location visualization cockpit capability is a pilot insurance policy (redundant to the primary ATC wake separation/mitigation mechanism) or a coming safety requirement