Speed Profiles Analysis
Supporting the FAA Wake Initiatives

FOQA and Threaded Track Data

MITRE – Lisa Spinoso and Clark Lunsford

Volpe National Transportation Systems Center (Volpe) – Steve Mackey, Melanie Soares and Hadi Wassaf

WakeNet-Europe 2014
May 13-14, 2014
EUROCONTROL Experimental Centre (EEC)
Brétigny-sur-Orge, France

Approved for Public Release; Distribution Unlimited. 14-1657
Acknowledgements

The authors would like to recognize the following for their continued support throughout this effort:

– Jeffrey Tittsworth – AJV-2A, FAA Wake Turbulence Research Program Manager

– Steve Barnes – Former Manager AFS-440, Flight Standards Service - Flight Technologies and Procedures Division

Speed Profile Objective

- Provide improved information for actual approach and departure speeds observed in different aircraft types
  - Book Speeds ➔ Observed Speeds

- Better knowledge of operational speeds by aircraft type will enable more accurate determination of
  - Wake generation strength
  - Wake encounter severity
  - Separation in time (Time-To-Fly)

- For use of expanding number of FAA related wake initiatives. Applications for two specific initiatives highlighted
  - Wake Recategorization (RECAT)
  - Wake Turbulence Mitigation for Arrivals Procedures (WTMA-P)
Recap on RECAT
Wake Recategorization (RECAT)

RECAT is a 3 phase international effort to incrementally safely optimize wake turbulence separation

- **Phase I:** Establishes six new wake classes with the goal of increasing capacity while maintaining or improving safety, based on analysis of 61 of the most common aircraft types at major US and EU airports

- **Phase II:** Aims to determine pairwise leader/follower wake separation minima for individual aircraft types, based on analysis of 115 of the most common aircraft types at 95 airports globally
  - An aircraft speed profile has a strong influence on the wake strength and wake encounter severity for individual aircraft types

- **Phase III:** Addresses dynamic conditions as they apply to pairwise separation

Current US Wake Categories

<table>
<thead>
<tr>
<th>Leading Aircraft</th>
<th>Trailing Aircraft</th>
</tr>
</thead>
<tbody>
<tr>
<td>A380 Heavy B757 Large Small</td>
<td>A380 Heavy B757 Large Small</td>
</tr>
<tr>
<td>A380 MRS 6 7 7 8</td>
<td>A380 MRS 6 7 7 8</td>
</tr>
<tr>
<td>Heavy MRS 4 5 5 6</td>
<td>Heavy MRS 4 5 5 6</td>
</tr>
<tr>
<td>B757 MRS 4 4 4 5</td>
<td>B757 MRS 4 4 4 5</td>
</tr>
<tr>
<td>Large MRS MRS MRS MRS 4</td>
<td>Large MRS MRS MRS MRS 4</td>
</tr>
<tr>
<td>Small MRS MRS MRS MRS MRS</td>
<td>Small MRS MRS MRS MRS MRS</td>
</tr>
</tbody>
</table>

© 2014 The MITRE Corporation. All rights reserved.

US: United States of America
EU: European
MEM: Memphis International Airport
SDF: Louisville International Airport
CVG: Cincinnati/Northern Kentucky International Airport
Approach Speed Profiles
RECAT Phase I used publicly available approach speeds, adjustment for 85% max landing weight and a nominal deceleration profile.
True Airspeed Profile using FOQA and RECAT Phase I
(Continental ASDE-X Airports)

31 aircraft types represent approx. 70% of U.S. operations

Example: CRJ2

© 2014 The MITRE Corporation. All rights reserved.
True Airspeed Profile using FOQA and RECAT Phase I
(Continental ASDE-X Airports)

- FOQA 95%
- FOQA 75%
- FOQA 50%
- FOQA 25%
- FOQA 5%
- RECAT I

130+ aircraft types
at 34 different airports
using 5 million+ tracks

Example: CRJ2
RECAT Speed Profiles by Aircraft Type

RECAT Phase 1 ➢ FOQA Data ➢ Threaded Track Data

Example: CRJ2

True Airspeed Profile using FOQA and RECAT Phase I
(Continental ASDE-X Airports)

130+ different aircraft types can be chosen.
Data can be displayed in 4 different ways:
IAS, TAS, GS, and Time to Fly

Threaded Track: Dark Colors
FOQA: Light Colors
RECAT: Black Dashed Line

Speed profiles can also be displayed by airport, wake category and meteorological & wind conditions
Sample Results and Discoveries

Approach Speed Sensitivity Analysis
Deceleration of Jets vs. Turboprops
Time-to-Fly
Application to WTMA-P
Gross Landing Weight
Approach Speed Sensitivity Analysis

- There has been further investigation on the variance of final approach speed by
  - Airport elevation
  - Runway length
  - Arrival Rate
  - Annual airport operations
  - Aircraft weight & length
  - Temperature
  - IMC/VMC
  - Wind, etc.

- FAA is undergoing a sensitivity analysis on how airport altitude and special operations effect the variance in final approach speed.

Average and Standard Deviation of Approach Speeds by Airport ordered by Altitude

© 2014 The MITRE Corporation. All rights reserved.
A Comparison of Deceleration Profiles for Jets and Turboprops

The turboprop waits as long as feasible to slow to their landing speed to fit into the pace of the arrival stream and to not cause problems for the trailing jets.

This difference in approach speed management impacts the time it takes the turboprop to fly specific wake separations and also influences its wake severity metric

- All key factors in determining safe wake separations.
Time-To-Fly

Example: CRJ2

- Used to calculate the time it takes for a trailing aircraft to fly various wake separation distances to limit severity of wake presented to the trailing aircraft to current ICAO levels.
- Result feeds directly into the calculation of pair-wise wake-safe separations for RECAT Phase II being performed by the FAA.

Time-to-Fly Profile using FOQA and RECAT Phase I
(Continental ASDE-X Airports)

- TT 95%
- TT 75%
- TT 50%
- TT 25%
- TT 5%
- FOQA 95%
- FOQA 75%
- FOQA 50%
- FOQA 25%
- FOQA 5%
- RECAT I
WTMA-P application of Threaded Track

Wake Turbulence Mitigation for Arrivals Procedures (WTMA-P)

- Concept permits reduced inter-aircraft radar separation during dependent parallel precision approaches
  - Based on geometry of approach path and approved for specific aircraft types as leader and follower.
  - Extension of 7110.308 to include heavier aircraft than FAA Large and Small as leaders where possible.

- Previous analysis used “book speeds” at threshold crossing and a nominal Out of Ground Effect ground speed for all aircraft

- For improved fidelity of the analysis, WTMA-P assessment incorporated Threaded Track speed profiles
  - Observed approach speeds are typically higher than book speeds

- Applied these profiles to both Near/In and Out of Ground Effect wake proximity frequency and severity analysis (out to 14 NM)
  - Evaluated for both the single runway baseline and WTMA-P operations on closely spaced parallel runways

- Also used observed speeds to determine nominal compression values between leader and follower aircraft

© 2014 The MITRE Corporation. All rights reserved.
Aircraft weight is an important factor in determining the strength of the wake that is generated by an aircraft.

- Weight information is not generally available in recorded air traffic data

Analysis of average landing weights through ASIAS helped the RECAT Team to appropriately represent landing weight in Phase II separation calculations.
Gross Landing Weight

Actual Landing Weight
Gross Landing Weight/Max Landing Weight

Gross Landing Weight/Max Landing Weight (%)
Initial Departure Speed Profiles
Sensitivity Analysis
Departure Characteristics to Consider

- How fast is the leader at wake generation point 1 (for initial wake strength)
- How fast is follower at wake encounter point 2 (for wake encounter reaction)
- How far down track (distance 3) is leader aircraft
- How long (time 4) has wake aged (decayed)
Initial Comparison of Departure Speed Profiles

Determined lift-off point and time for the departure speed profile

Need to determine operational ranges and dependence on primary factors
- Aircraft type, weight, power settings, temperature, airport specific, etc.
Threaded Track Validation with FOQA Data

*True Airspeed, Time-to-Fly, Height Above Takeoff Initial Cut*

- Created an interactive workbook to investigate departure Threaded Track and FOQA data.
  - TAS, Time-to-Fly, Height Above Takeoff
  - FOQA data provided is not as granular as Threaded Track data.

- Threaded Track departure dataset captured a year’s worth of surveillance data
  - 5 million+ tracks
  - 34 major airports
  - 125 aircraft types

Filters
- Airport
- Aircraft Type
- Temperature
- Weight
- Altitude

© 2014 The MITRE Corporation. All rights reserved.
Next Steps for Departure Analysis

- Departure speed and Time-to-Fly validation by aircraft type

- Departure speed sensitivity analysis
  - Variations by airport, field elevation, departure rate, temperature, weight, runway length, etc.

- Document the departure speeds for RECAT Phase II methodology report
Thank You

- **Objective**
  - Provide improved information for actual approach and departure speeds observed in different aircraft types

Book Speeds ➔ Observed Speeds
This is the copyright work of The MITRE Corporation and was produced for the U.S. Government under Contract Number DTFAWA-10-C-00080 and is subject to Federal Aviation Administration Acquisition Management System Clause 3.5-13, Rights in Data-General, Alt. III and Alt. IV (Oct. 1996). No other use other than that granted to the U.S. Government, or to those acting on behalf of the U.S. Government, under that Clause is authorized without the express written permission of The MITRE Corporation. For further information, please contact The MITRE Corporation, Contract Office, 7515 Colshire Drive, McLean, VA 22102, (703) 983-6000.

The contents of this material reflect the views of the author and/or the Director of the Center for Advanced Aviation System Development, and do not necessarily reflect the views of the Federal Aviation Administration (FAA) or Department of Transportation (DOT). Neither the FAA nor the DOT makes any warranty or guarantee, or promise, expressed or implied, concerning the content or accuracy of the views expressed herein.

©2014 The MITRE Corporation. The Government retains a nonexclusive, royalty-free right to publish or reproduce this document, or to allow others to do so, for “Government Purposes Only.”

Approved for Public Release; Distribution Unlimited. 14-1657

<table>
<thead>
<tr>
<th>Fiscal Year:</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outcome Number:</td>
<td>02</td>
</tr>
<tr>
<td>PBWP Reference:</td>
<td>2-2.B1-1</td>
</tr>
</tbody>
</table>