Progress on ICAO Wake Turbulence Re-Categorization Effort
Outline

- Background
- Methodology
- Status
- Schedule
- Summary
Joint effort led by FAA and Eurocontrol

- Federal Aviation Administration FAA
  - ATO Air Traffic Operations
  - AVS Aviation Safety

- EUROCONTROL
  - Airspace Department
  - Performance and Methods/Safety Assessment
  - Performance and Methods/Validation

- Supporting Organizations
  - Department of Transportation Volpe Center
  - Det Norske Veritas
  - International Subject Matter Experts
Why Now

- Current status in ICAO wake separation standards are widely viewed as being outdated
- Many ANSP’s globally have developed their individual variations from the ICAO standard
- Introduction into service of new large aircraft precipitated international cooperation in addressing ICAO wake standards
- ICAO tasked the FAA and EuroControl to lead an effort to harmonize wake separation standards for all aircraft
Current predictions indicate a doubling of air traffic by 2025.

Current ICAO, US and European separation standards are different, but all are safe.
- In the US or Europe there has never been an accident caused by wake vortex under IFR separations and procedures.

Wake research and improved sensors provide an opportunity to increase capacity and harmonize separation standards while providing the same or increased safety over existing standards.
Background (2 of 2)

- ICAO effectively has 3+1 categories (Light, Medium, Heavy, A380)

- US has 6 categories (Small, Small+, Large, B757, Heavy, A380)

- Many European ANSPs use variations from ICAO categories, e.g. NATS UK utilizes 6 categories

- NextGen and SESAR will incorporate dynamic pairwise separation, using individual aircraft pair separations based on current weather and operational parameters
  - Current effort is looking at 6 categories as a bridge to NextGen and SESAR
Methodology

- Focused on representative aircraft for process efficiency
- Wake strength used as the primary hazard metric
  - Data driven wake decay used to derive the hazard metric
  - Wake decay data from both US and Europe used joint FAA and Eurocontrol measurements from both continents
  - Historically, 5-15m circulation gives good agreement with flight test encounter data
- Categories optimized for capacity increase
- Simple Relative Safety argument: No worse than today
  - Reduction in severity for smallest aircraft category
  - No increases in severity for other categories
  - Small increases in likelihood as risk is balanced in this way
1. Aircraft Characteristics

3. Data Driven Circulation Decay Fit

2. Wake Vortex Measurements (US and EU)

4. Severity Metric: Vortex Strength

5. Determine Vortex Strength Under ICAO Standards for Each Aircraft Pair

6. Safety Considerations

7. Establish the Allowed Circulation at Potential Encounter for Each Follower

8. Determine New Separations for Each Aircraft Pair

9. Optimize Aircraft Categories for Capacity Increase

10. Traffic Mix

11. Expert Review & Adjustments

12. Calculate Capacity Increase

13. Additional Safety Considerations

14. Proceed to Safety Assessment
#1 Aircraft Characteristics

- Focused on 61 aircraft comprising 80% of traffic at busiest European and US airports
- Extended to include 9000+ aircraft globally
- Publicly available data
#2 Wake Vortex Measurements

- Wake data collected in low wind conditions at several sites (US and European)
- Data collected from NGE and IGE
  - Near threshold most vulnerable area
#3 Data Driven Circulation Decay Fit

- Long lasting wakes used in circulation decay fit
  - For Safety, reasonable worst case used
- Decay fit derived through European and US collaboration
#4 Severity Metric

- Wake strength used as the primary hazard metric
  - Other considerations in support of hazard metric used to add additional conservativeness and confidence
    - Max induced rolling moment
    - Bank Angle
  - Aircraft size and resistance to vortex encounter also considered for aircraft in the top end of the ICAO Heavy category (factors that have been a part of ICAO compliant safety cases for B757-300, A380 behind A380, and discussed in previous talks this week)
Steps #5-14

- Remaining steps included in backup slides
## Example Separation Table for 6 Categories

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<th>Leader</th>
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<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
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### Aircraft by Category

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</table>

- 61 listed here, plus
- * A few examples of the > 9000+ ICAO registered aircraft assigned to these 6 categories
Summary

- Re-categorization into 6 categories can increase capacity with same or increased safety
- This re-categorization is a prerequisite to move towards NextGen/SESAR Dynamic Pair-wise separations
- Ambitious schedule for completion
  - Requires International cooperation and stakeholder participation
- Phase II Static Pairwise separation anticipated IOC 2015
- Phase III Dynamic Pairwise separation anticipated IOC 2020
Backup slides
In-Trail Wake Turbulence Separations

Leading aircraft

- Heavy >136 t
- Large 7 - 136 t
- Small < 7t

Followed by

- Heavy
- Large
- Small

Separations, miles

- 0
- 3
- 4
- 5
- 6

A320

B747

A320
ICAO In-Trail Wake Turbulence Separations

Heavy to Heavy

Leading aircraft
B747

4 NM
Separation

Trailing aircraft
A306

This is Safe

A result of the Breadth of the Heavy Category

This is Overly Conservative.

B747

A306
ICAO In-Trail Wake Turbulence Separations

Upper Heavy to Lower Heavy

Leading aircraft

B747

4 NM

Separation

Trailing aircraft

A306

This is Safe

Lower Heavy to Upper Heavy

A306

2.5 NM

Separation

B747

This is Equally Safe
ICAO In-Trail Wake Turbulence Separations

Lower Heavy to Upper Medium

3.5 NM
Separation

Trailing aircraft

A306

A320

This is as Safe as Today

Lower Medium to Lower Medium

3.5 NM
Separation

A306

DH8

This is as Safe as Today
#5 Determine Vortex Strength Under ICAO Standards for Each Aircraft Pair

For each aircraft pair:

- Used generator aircraft characteristics to determine initial wake strength
- Used follower characteristics to determine time interval between generator and follower for ICAO separation
- Used circulation decay fit to determine wake strength at current ICAO separation standard
Current ICAO separation standards are considered to be safe.

Safety of smaller aircraft enhanced by reducing allowed circulation 25% below that with ICAO separations.
#7 Establish the Allowed Circulation at Potential Encounter for Each Follower

- Not to exceed circulation values observed today under ICAO standards
- Additional conservativeness added for lightest, most vulnerable aircraft
#8 Determine New Separations for Each Aircraft Pair

- Computed new minimum separate matrix for each aircraft pair using the allowed circulation values (from #7)
#9 Optimize Aircraft Categories for Capacity Increase

- Aircraft grouped into categories and total separation distance computed
  - Separation for each aircraft pair changed to maximum within a category

- All possible groupings computed
  - Initial sorted list used for groupings

- Optimized categories are those with the minimum total separation distance
Traffic mix was used for the optimization.

Traffic mixes for the U.S. determined from six U.S. airports and for Europe determined from four European airports:
- US: Atlanta (ATL), Chicago (ORD), Newark (EWR), New York JFK (JFK), and San Francisco (SFO)
- Europe: Amsterdam (AMS), Frankfurt (FRA), London Heathrow (LHR), and Paris Charles de Gaulle (CDG)

These traffic mixes are assumed to be representative of the larger fleet mix.

Pair-wise statistics derived by assuming probability of occurrence of each aircraft is independent.
#11 Expert Review and Adjustments

- Adjusted the categories by blending the US and EU optimized categories
- Added further conservatism by
  - Adding separation for smallest category in trail
  - Manually moving aircraft
#12 Calculate Capacity Increase

- Percentage of capacity increase computed relative to baseline
  - Baseline computed using today’s separations
  - Capacity increase computed using new categories
Add additional separation for smallest category of aircraft in trail as SMEs determine for additional conservatism.
#14 Proceed to Safety Assessment

- Develop Safety Case and Safety Analysis Report for the proposed recommendation to ICAO
#1 Aircraft Characteristics

- 61 Aircraft Types based on number of operations in European and US Airports
  - Requests for data made to each manufacturer
  - Data from open sources

- The Following Aircraft Characteristics Required For Wake Strength – Primary Safety Criteria:

<table>
<thead>
<tr>
<th>AC_TYPE</th>
<th>MTW(lb)</th>
<th>MLW(lb)</th>
<th>Span(ft)</th>
<th>Approach_speed @0.85MLW(kts)</th>
<th>EU_Traffic_mix (Op_Day)</th>
<th>EU_Traffic_mix (Peak_Op_Hr)</th>
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#1 Aircraft Characteristics (concluded)

- Additional safety criteria used to communicate risk in terms familiar to stakeholders (Bank Angle, % Roll Control Authority, etc)
- These additional criteria also supported the metric ‘as safe as or safer than today’
- The Following Aircraft Characteristics Required For Secondary Safety Criteria:

<table>
<thead>
<tr>
<th>AC_TYPE</th>
<th>Wingarea(ft^2)</th>
<th>Aspect_ratio</th>
<th>Taper_ratio</th>
<th>CL_alpha(/rad)</th>
<th>Cl_p(/rad)</th>
<th>lxx(sl-ft^2)@0.85MLW</th>
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