



# Progress on Joint FAA/Eurocontrol Effort to Develop an ICAO Wake Turbulence Re-Categorization

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# Outline

- Background
- Methodology
- Examples with 5 and 30 aircraft
- Summary

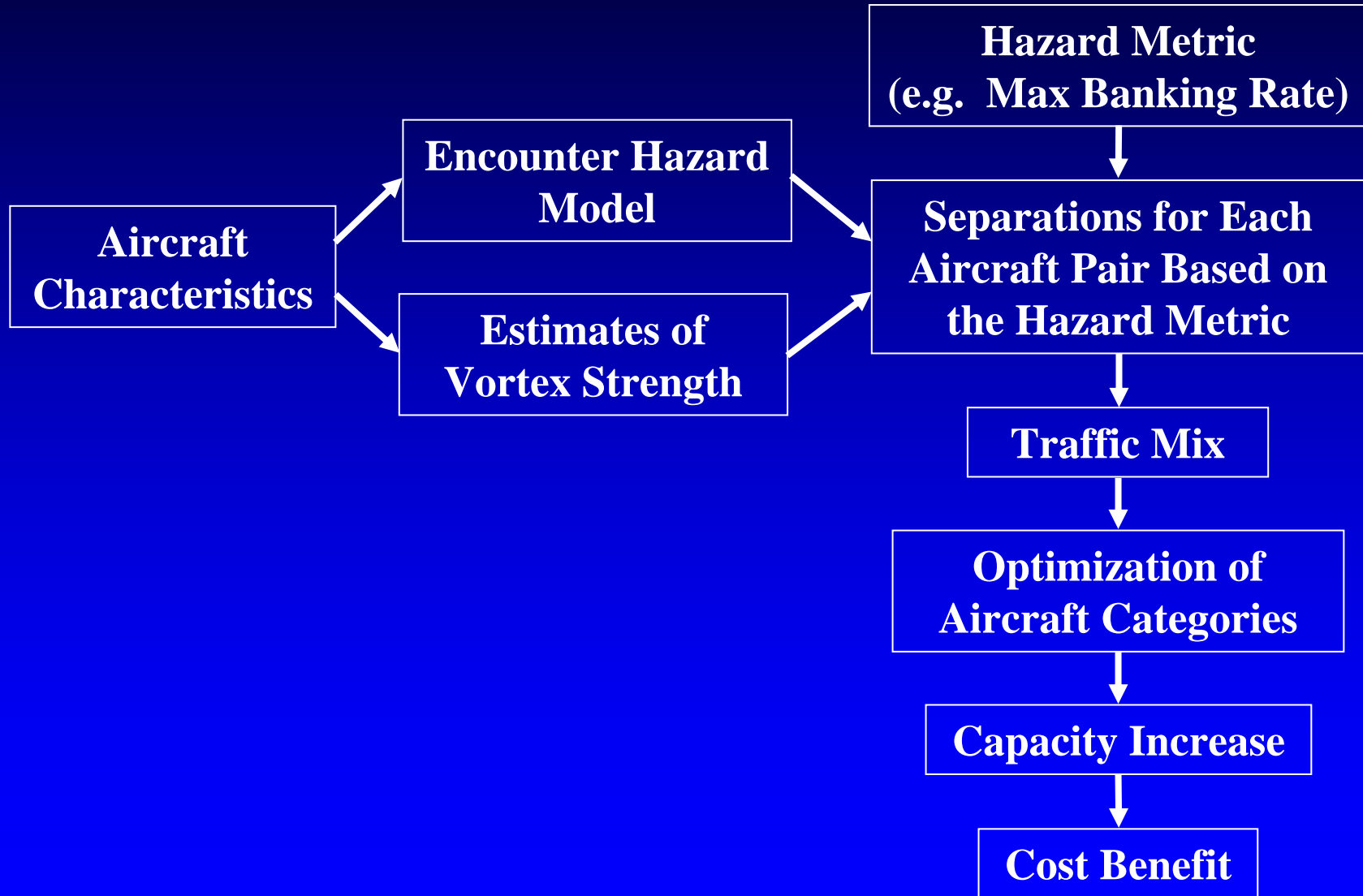
# Background (1 of 2)

- Current predictions indicate a doubling of air traffic by 2025
- Current ICAO and US separation standards are different, but both are very safe
  - Never been a fatal accident in the US due to wake vortex under IFR separations
- Recent research and improved sensors provide an opportunity to increase capacity and harmonize separation standards while providing the same or increased safety over existing standards

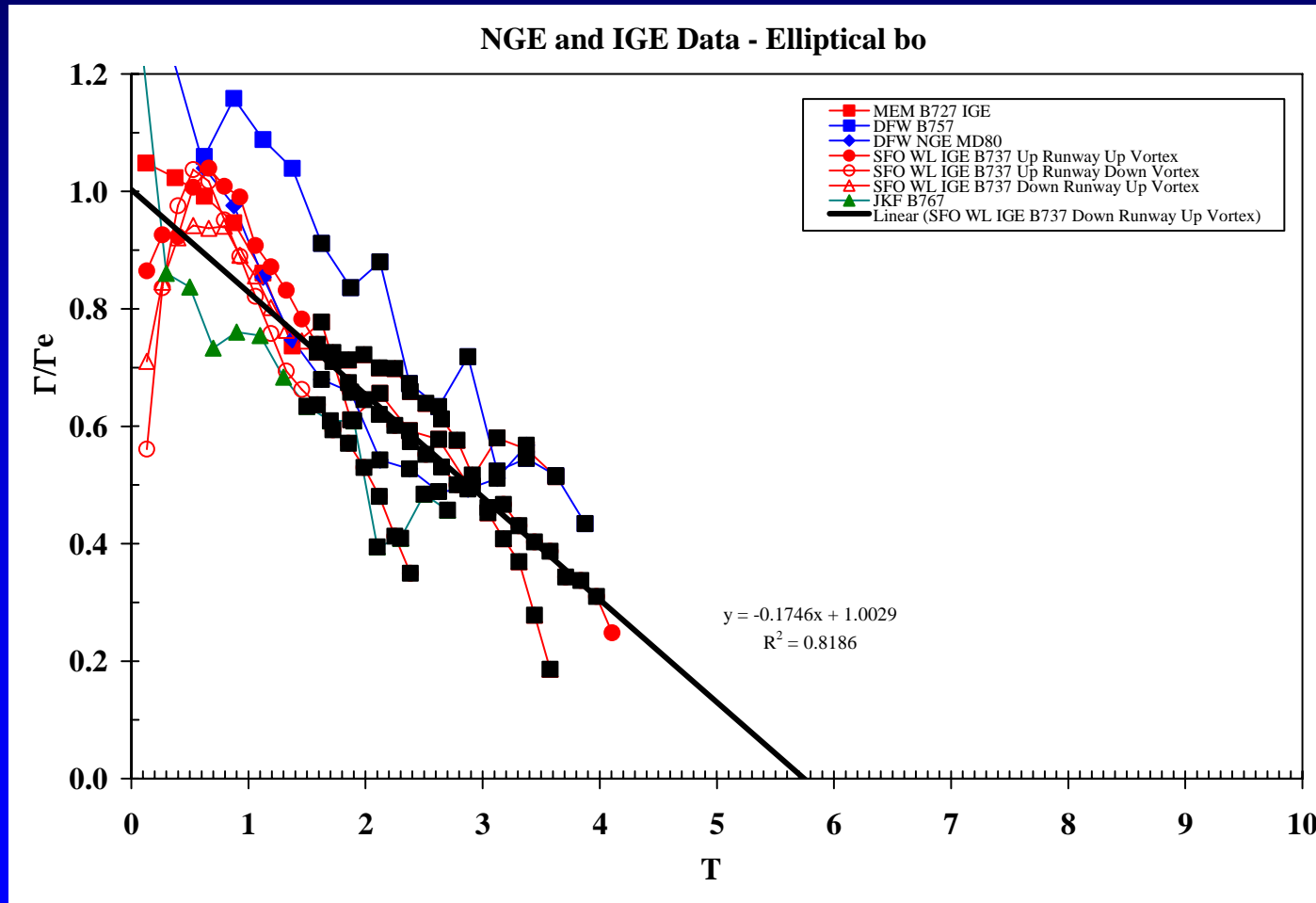
# Background (2 of 2)

- Currently, the US has 5 categories (Small, Large, B757, Heavy, A380) and ICAO has 4 categories (Light, Medium, Heavy, A380)
- Current effort is looking at 5, 6, or 7 categories as a bridge to NextGen and SESAR
  - NextGen and SESAR will incorporate dynamic pairwise separation, using individual aircraft pair separations based on current weather

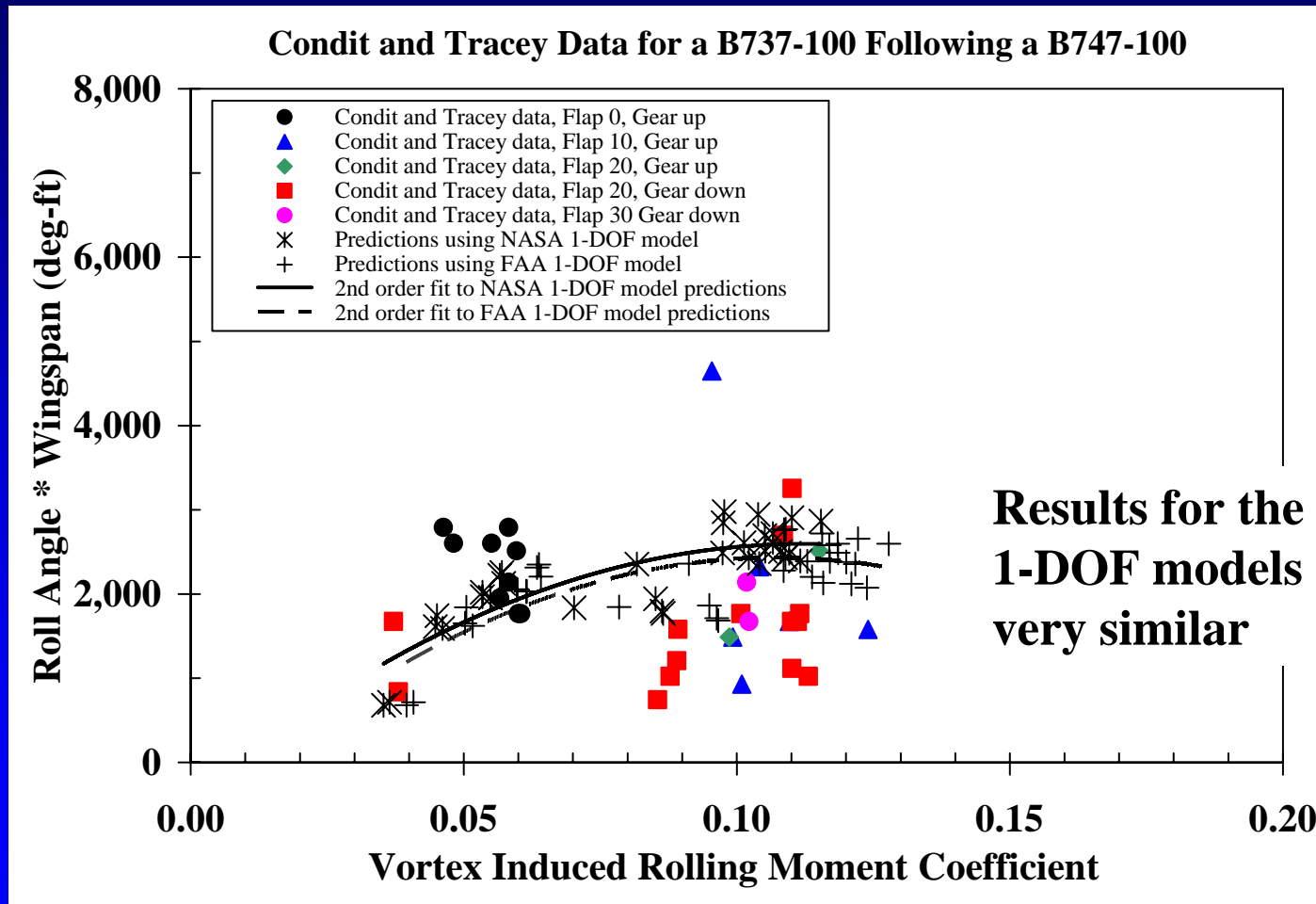
# Methodology Used In This Study



# Circulation Decay Model: Best Fit to NGE/IGE Median Data Between $T = 1.5$ and $T = 4$



# Comparison of Encounter Data With NASA and FAA 1-DOF Models



# Example With 5 Aircraft and Uniform Traffic



# Example of Grouping into Categories

- 5 aircraft grouped into 3 categories gives 6 grouping combinations
  - Call the aircraft: 1 2 3 4 5

**Start with aircraft 1,  
and form one group  
with the first aircraft**

**1      2      3      4      5**

# Example of Grouping into Categories

- 5 aircraft grouped into 3 categories gives 6 grouping combinations
  - Call the aircraft: 1 2 3 4 5

**Start with aircraft 1,  
and form one group  
with the first aircraft**

**①**

**2**

**3**

**4**

**5**

**Form a second group with the second aircraft**

# Example of Grouping into Categories

- 5 aircraft grouped into 3 categories gives 6 grouping combinations
  - Call the aircraft: 1 2 3 4 5

**Start with aircraft 1,  
and form one group  
with the first aircraft**

①

②

3

4

5

**Leave the  
remaining  
aircraft in  
the last  
group**

**Form a second group with the second aircraft**

# Example of Grouping into Categories

- 5 aircraft grouped into 3 categories gives 6 grouping combinations
  - Call the aircraft: 1 2 3 4 5

**Start with aircraft 1,  
and form one group  
with the first aircraft**

①

②

③ ④ ⑤

**Leave the  
remaining  
aircraft as  
the last  
group**

**Form a second group with the second aircraft**

**Continue forming groups, with red being one group, blue  
being a second group, and black being the third group**

# All Groupings for the Example of 5 Aircraft Into 3 Categories

- All groupings:

Look in detail at the separation matrix for this grouping (1+2, 3, 4+5):

1	2	3	4	5
1	2	3	4	5
1	2	3	4	5
1	2	3	4	5
1	2	3	4	5
1	2	3	4	5

# Separation Distance Matrix: 5 Aircraft Grouped Into 3 Categories

- Example shown is for one of the aircraft groupings (1+2, 3, and 4+5)

<b>Follower=&gt;</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>Leader 1:</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>
<b>Leader 2:</b>	<b>4</b>	<b>4</b>	<b>6</b>	<b>6</b>	<b>7</b>
<b>Leader 3:</b>	<b>3</b>	<b>4</b>	<b>6</b>	<b>6</b>	<b>7</b>
<b>Leader 4:</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>6</b>
<b>Leader 5:</b>	<b>3</b>	<b>4</b>	<b>4</b>	<b>5</b>	<b>5</b>

# Separation Distance Matrix: 5 Aircraft Grouped Into 3 Categories

- Replace the original separation between aircraft pairs with the maximum separation within a category

For example, in this grouping, replace all values with the maximum value of 5

<b>Follower=&gt;</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>Leader 1:</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>
<b>Leader 2:</b>	<b>4</b>	<b>4</b>	<b>6</b>	<b>6</b>	<b>7</b>
<b>Leader 3:</b>	<b>3</b>	<b>4</b>	<b>6</b>	<b>6</b>	<b>7</b>
<b>Leader 4:</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>6</b>
<b>Leader 5:</b>	<b>3</b>	<b>4</b>	<b>4</b>	<b>5</b>	<b>5</b>

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<b>Leader 2:</b>	<b>5</b>	<b>5</b>	<b>6</b>	<b>6</b>	<b>7</b>
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<b>Leader 5:</b>	<b>3</b>	<b>4</b>	<b>4</b>	<b>5</b>	<b>5</b>

Note that we always take the worst case in the group.



# Separation Distance Matrix: 5 Aircraft Grouped Into 3 Categories

- Replace the original separation between aircraft pairs with the maximum separation within a category

Leave this group at 6

<b>Follower=&gt;</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>Leader 1:</b>	<b>5</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>
<b>Leader 2:</b>	<b>5</b>	<b>5</b>	<b>6</b>	<b>6</b>	<b>7</b>
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<b>Leader 5:</b>	<b>3</b>	<b>4</b>	<b>4</b>	<b>5</b>	<b>5</b>

# Separation Distance Matrix: 5 Aircraft Grouped Into 3 Categories

- Replace the original separation between aircraft pairs with the maximum separation within a category

Replace this group with  
the maximum value of 8

<b>Follower=&gt;</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>Leader 1:</b>	<b>5</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>
<b>Leader 2:</b>	<b>5</b>	<b>5</b>	<b>6</b>	<b>6</b>	<b>7</b>
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<b>Leader 1:</b>	<b>5</b>	<b>5</b>	<b>6</b>	<b>8</b>	<b>8</b>
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<b>Leader 5:</b>	<b>3</b>	<b>4</b>	<b>4</b>	<b>5</b>	<b>5</b>

# Separation Distance Matrix: 5 Aircraft Grouped Into 3 Categories

- Replace the original separation between aircraft pairs with the maximum separation within a category

Repeat with other groups

<b>Follower=&gt;</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>Leader 1:</b>	<b>5</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>
<b>Leader 2:</b>	<b>5</b>	<b>5</b>	<b>6</b>	<b>6</b>	<b>7</b>
<b>Leader 3:</b>	<b>3</b>	<b>4</b>	<b>6</b>	<b>6</b>	<b>7</b>
<b>Leader 4:</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>6</b>
<b>Leader 5:</b>	<b>3</b>	<b>4</b>	<b>4</b>	<b>5</b>	<b>5</b>

# Separation Distance Matrix: 5 Aircraft Grouped Into 3 Categories

- Replace the original separation between aircraft pairs with the maximum separation within a category

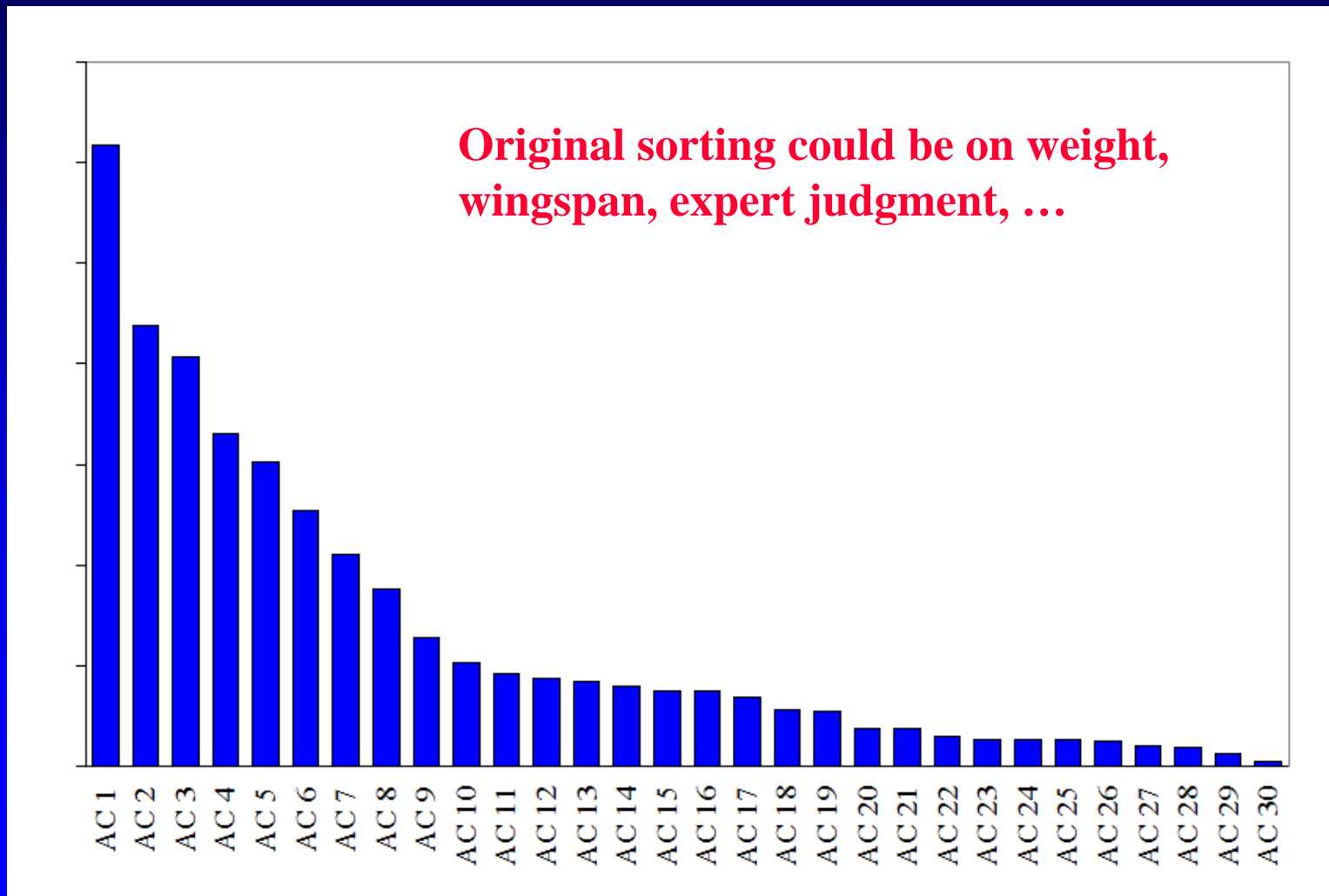
<b>Follower=&gt;</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>Leader 1:</b>	<b>5</b>	<b>5</b>	<b>6</b>	<b>8</b>	<b>8</b>
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<b>Leader 5:</b>	<b>4</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>6</b>

# Optimization

- Next, compute the total separation required to accommodate all aircraft pairs for each aircraft grouping combination
  - In this example, add up all 25 times
- Look at all possible groupings
  - The grouping combination with the minimum total separation is the optimal categorization

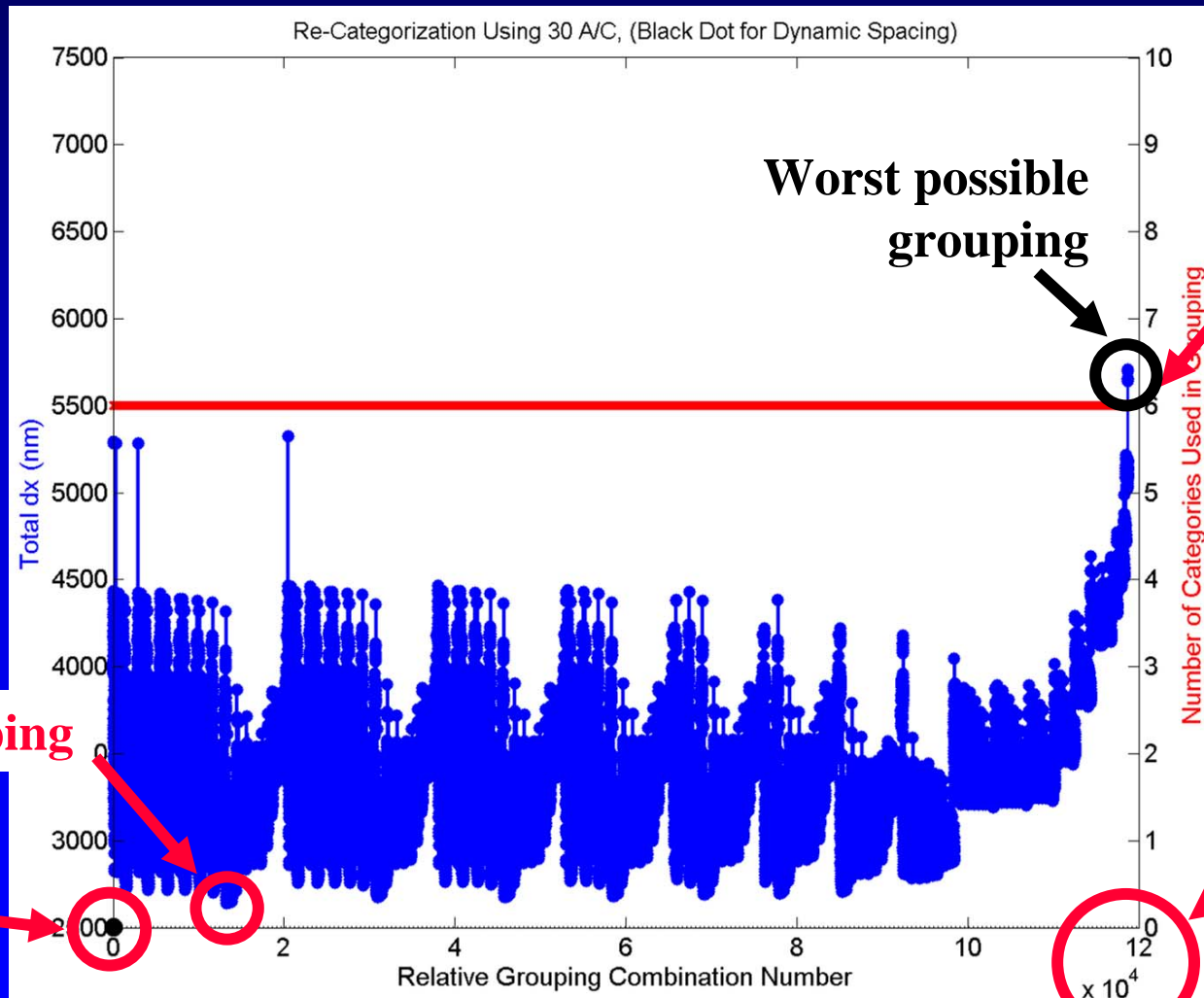
# Example With 30 Aircraft and Non-Uniform Traffic

# Original Sorting for 30 Aircraft Example





# All Possible Groupings for 6 Categories With 30 Aircraft and Non-Uniform Traffic Mix



6 categories

Best grouping

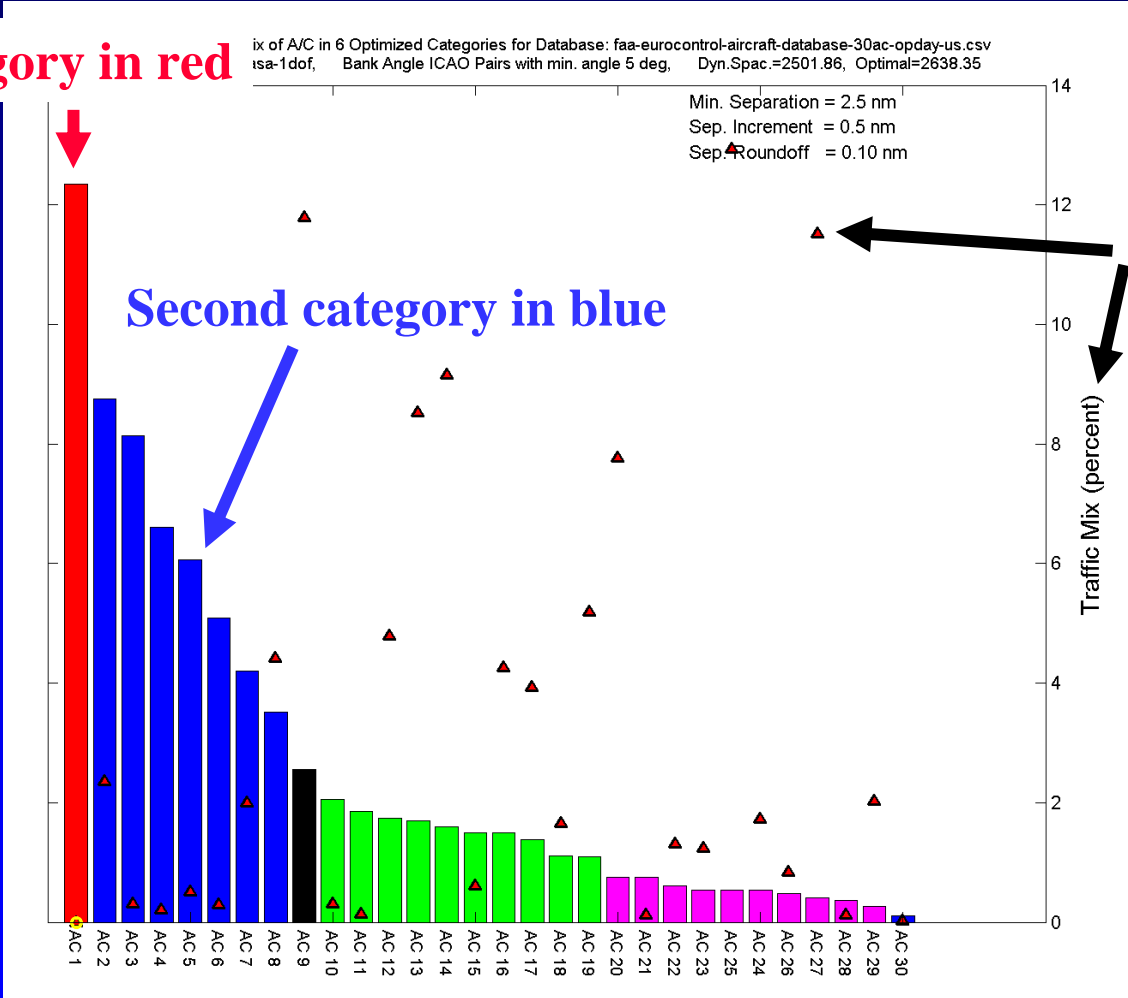
Dynamic pair-wise spacing

120,000 possible groupings

# Example of 6 Optimized Categories With 30 Aircraft: Non-Uniform Traffic Mix

(Bars with the same color represent the same categories)

One category in red

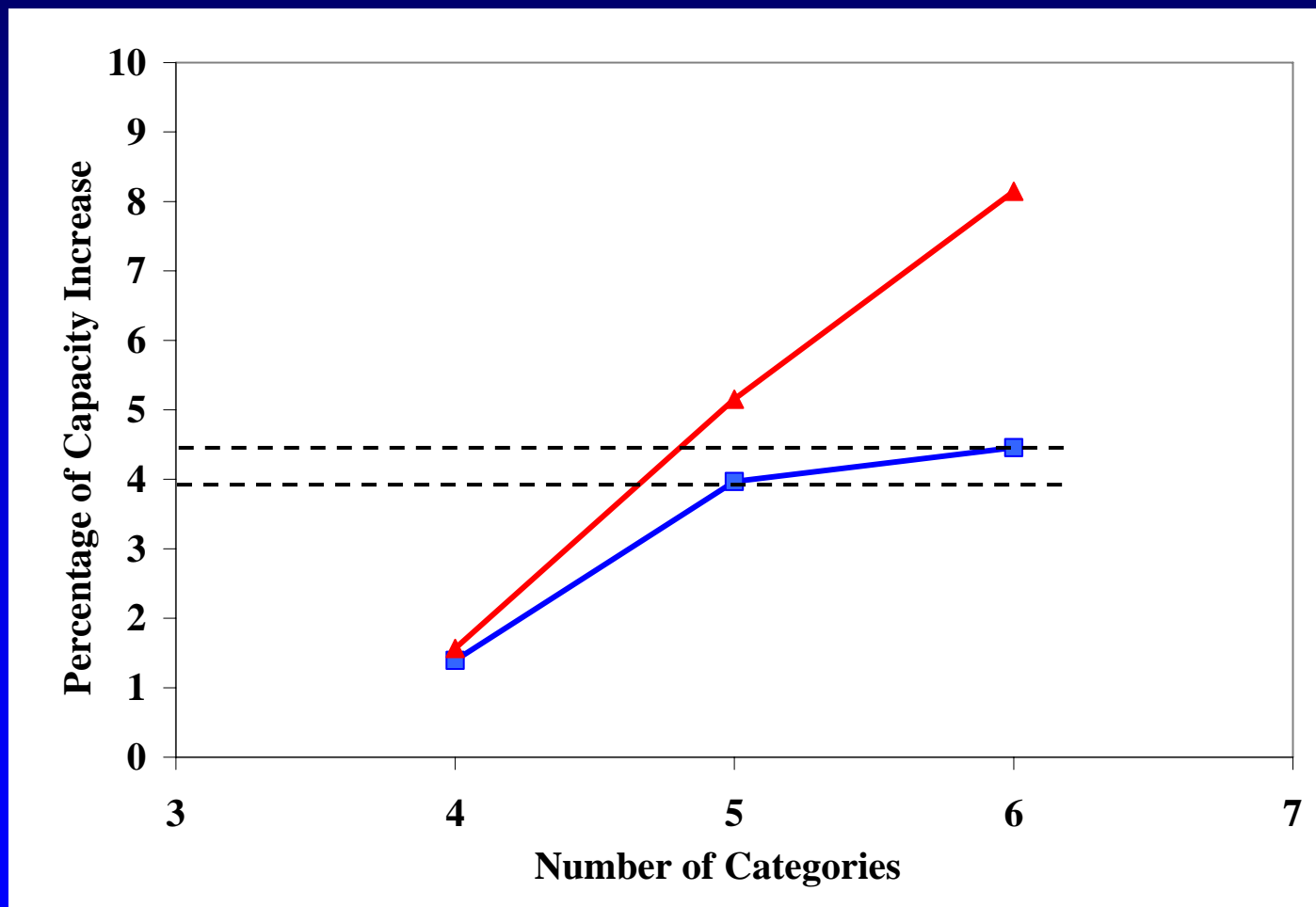


Non-Uniform  
Traffic mix

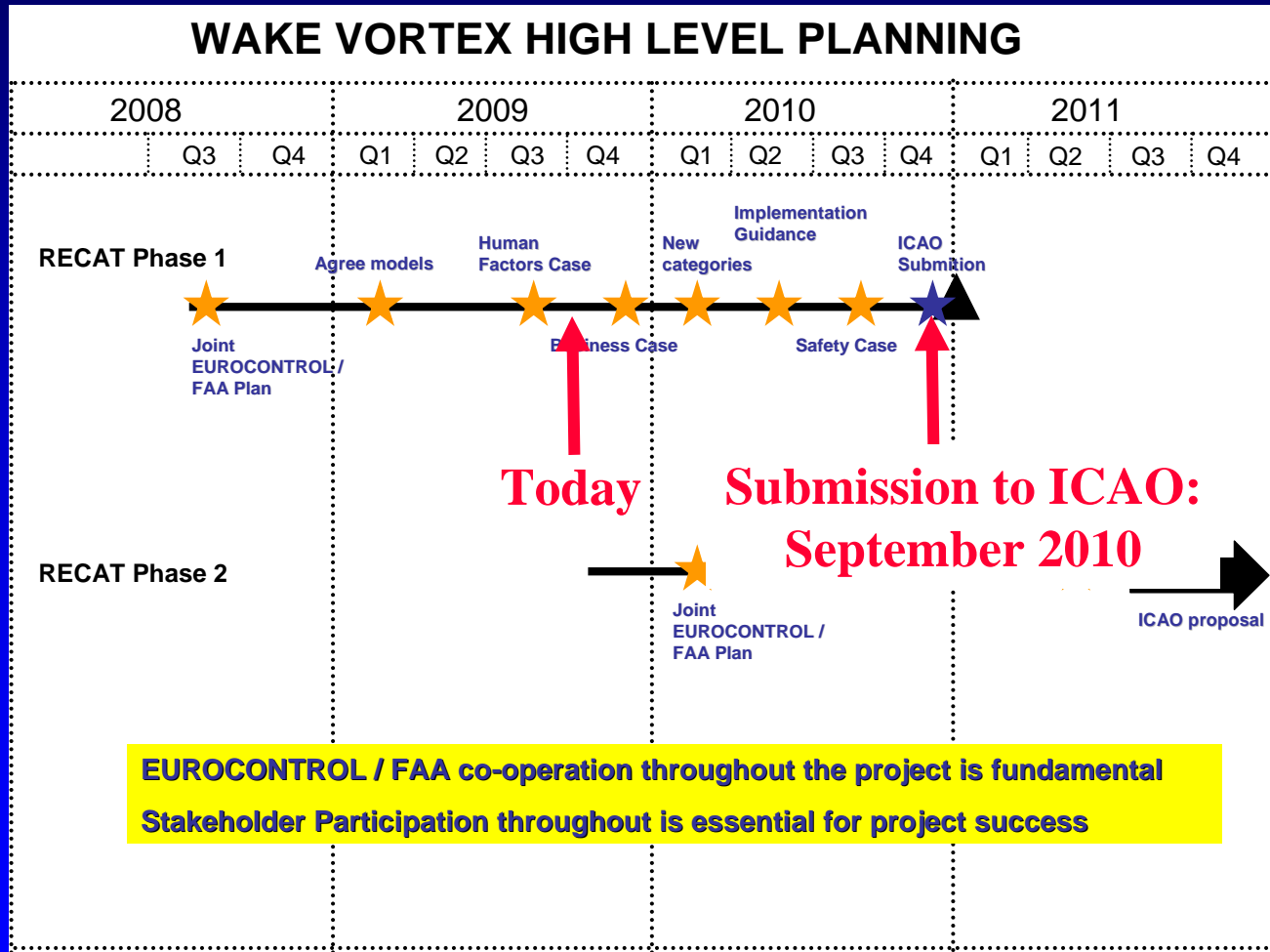
# Metrics

- Multiple metrics being explored
  - Bank angle
  - Vortex circulations encountered at today's separations
  - Others
- Will show one example of varying the minimum bank angle
  - Arbitrarily raise the minimum bank angle to 3 or 5 degrees for 4, 5, or 6 categories

# Percentage Capacity Increase Over the Current ICAO Separations For Minimum Bank Angles of 3 (blue) and 5 (red) Degrees



# Tentative Schedule for Completion of the Re-Categorization Study



# Summary

- Re-categorization into 6 categories can increase capacity by 3 to 5 percent with same or increased safety
- This re-categorization is a bridge between current categories and NextGen/SESAR
- Ambitious schedule for completion
  - Requires EUROCONTROL/FAA cooperation and stakeholder participation