Presentation on Wake Turbulence Re-Categorization Phase I Methodology and Safety Case

February 09, 2011

WakeNet3 Europe

London

Problem Statement

- Demand for airport capacity increases every year
- Current ICAO wake separation standards are widely viewed as being outdated
- Many ANSP's globally have developed their individual variations from the ICAO standard
- International cooperation exists for addressing ICAO wake standards for the introduction of new large aircraft into service

EUROCONTROL / FAA Cooperation

- In November 2006, ICAO requested the FAA and EUROCONTROL to lead an effort to harmonize wake separation standards for all aircraft
- Study being performed under a EUROCONTROL / FAA Memorandum of Cooperation
  - 20+ Coordinated Action Plans
- Action Plan 14 deals with Wake Turbulence
  - Agree on strategy and sharing of work
  - Promote global harmonization
  - Jointly approach ICAO

Program Participants

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

Recategorization is a Three Phase Effort

- Phase 1 is Static 6 Category Separation
- Phase 2 is Static pair-wise Separation
- Phase 3 is Dynamic pair-wise Separation
- All three phases are required steps towards NextGen and SESAR

Proposed Implementation of RECAT

- Not a Big Bang Implementation
- RECAT and Today's ICAO categories are safe
- Both categorizations can co-exist
- Performance Based Transition
  - Each ANSP can transition to RECAT when needed
  - Transition Decision by one ANSP has No Impact on Adjacent ANSP
- No Required Changes to ICAO Flight Plan

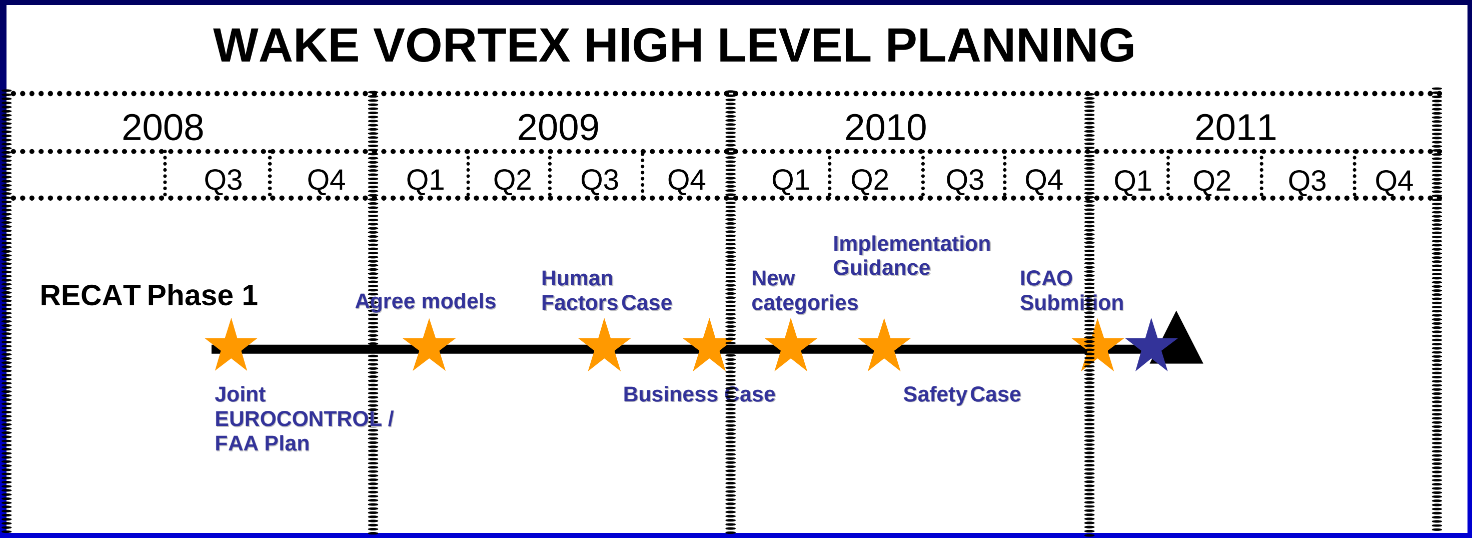
Background (1 of 2)

- 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 ANSP's use variations from ICAO categories, e.g. NATS UK utilizes 6 categories
- NextGen and SESAR will incorporate dynamic pair-wise separation, using individual aircraft pair separations based on current weather and operational parameters
  - RECAT 6 Categories is the first step to NextGen and SESAR
  - Static Pair-wise (Phase 2) is the next step

Importance of Phase I

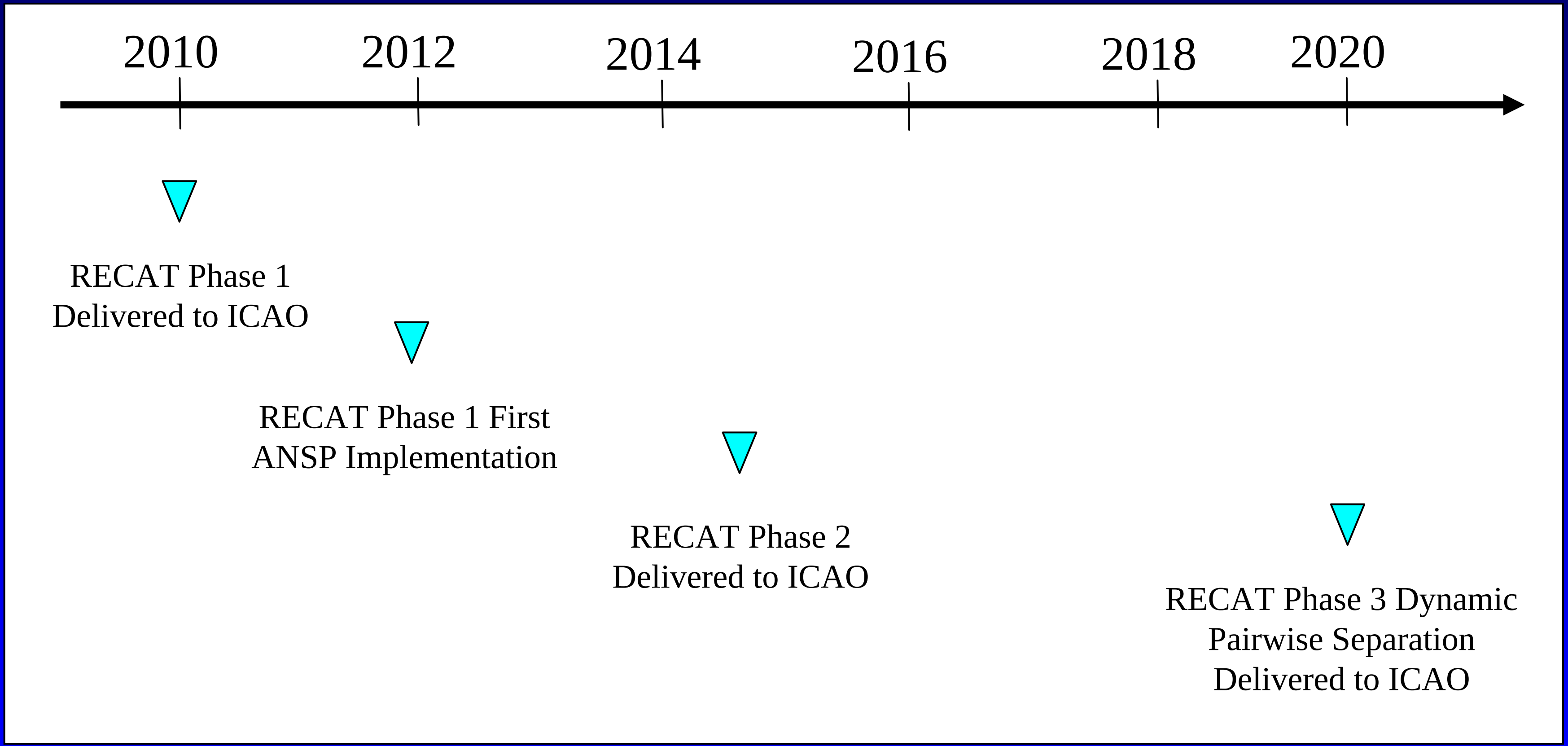


- Intense 4+ year effort
- Significant Resources Sustained on a Monthly Basis
  - R&D Funding
  - World preeminent Wake Scientists
  - Operations Expertise
  - Regulatory Expertise
  - Safety Expertise

Requirements and Scope of the Effort

- Safety: As safe or safer than today
- Transparency: Openly available tools and data
- Optimization:
  - Provides new categories and separations optimized to current fleet mixes and evaluated for potential future fleet mixes
  - Focuses on 61 representative aircraft types
- Applies to Arrival and Departure
  - Distance and time based separation provided for approach and departure
- Increase capacity

Next Phases



2010
2012
2014
2016
2018
2020
RECAT Phase 1 Delivered to ICAO
RECAT Phase 1 First ANSP Implementation
RECAT Phase 2 Delivered to ICAO
RECAT Phase 3 Dynamic Pairwise Separation Delivered to ICAO

Current ICAO Matrix

		Follower			
		A380	Heavy	Medium	Light
Leader	A380		6NM	7NM	8NM
	Heavy		4NM	5NM	6NM
	Medium				5NM
	Light				

RECAT Separation Table

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

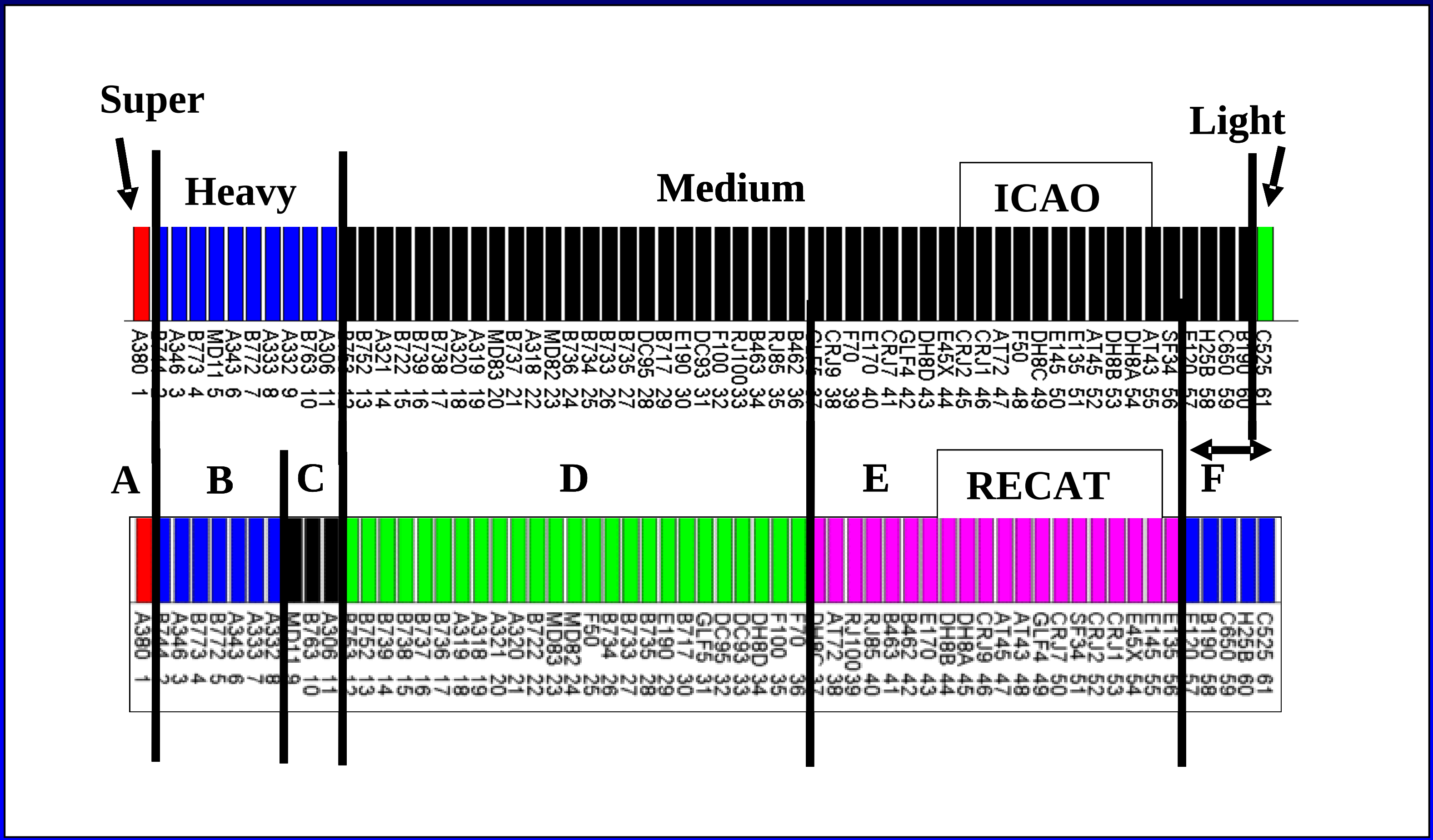
RECAT Separation Matrix

Proposed 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

(green)	Separation was increased for some or all aircraft pairs
(teal)	Separation was decreased for some or all aircraft pairs
(white)	Separation remained the same for some or all aircraft pairs
MRS	Minimum Radar Separation (3NM, or 2.5 NM when existing requirements are met)

Categories: ICAO vs. RECAT (61 aircraft types)



Selected Aircraft by Category

A	B	C	D	E	F
A380	B744	MD11	B753	DH8C	E120
AN-225	A346	B763	B752	AT72	B190
	B773	A306	B739	RJ100	C650
	B772		B738	RJ85	H25B
	A343		B737	B463	C525
	A333		B736	B462	
	A332		A319	E170	
			A318	DH8B	
			A321	DH8A	
			A320	CRJ9	
			B722	AT45	
			MD83	AT43	
			MD82	GLF4	
			F50	CRJ7	
			B734	SF34	
			B733	CRJ2	
			B735	CRJ1	
			E190	E45X	
			B717	E145	
			GLF5	E135	
			DC95		
			DC93		
			DH8D		
			F100		

- Selected aircraft listed here, plus all 9000+ ICAO registered aircraft were successfully assigned to these 6 categories

Project Assumptions (1/2)

- All Current ICAO Separations are Acceptably Safe
- Results to be Applicable for Approach and Departure and under all weather conditions
- No required changes on the flight deck
- Minimum modifications on the ground (if any)
- Minimum changes in procedures
- Multiple aircraft parameters considered, in addition to weight (wingspan, speed, lift force distribution)

Project Assumptions (2/2)

- Methodology developed to categorize future aircraft types
- Reasonable worst case wake strength from airport operational data
  - Analysis performed at threshold, where wake encounters are most critical
- Optimization based on traffic mixes from 4 European and 5 US congested airports
- Capacity gain will
  - Provide benefit at constrained airports as well as other airports world wide
  - More than justify minimum changes to procedures and on the ground
- Not another R&D project. Used airport operational measurements and presently available knowledge

Traffic Samples

- 4 European airports:
  - Heathrow (EGLL)
  - Amsterdam (EHAM)
  - Frankfurt (EDDF)
  - Paris “Charles de Gaulle”(LFPG)
- 5 U.S. airports:
  - Atlanta (KATL)
  - Newark (KEWR)
  - John F. Kennedy (KJFK)
  - Chicago O’Hare (KORD)
  - San Francisco (KSFO)
- Representative traffic mix of 61 aircraft types (85% of the traffic)

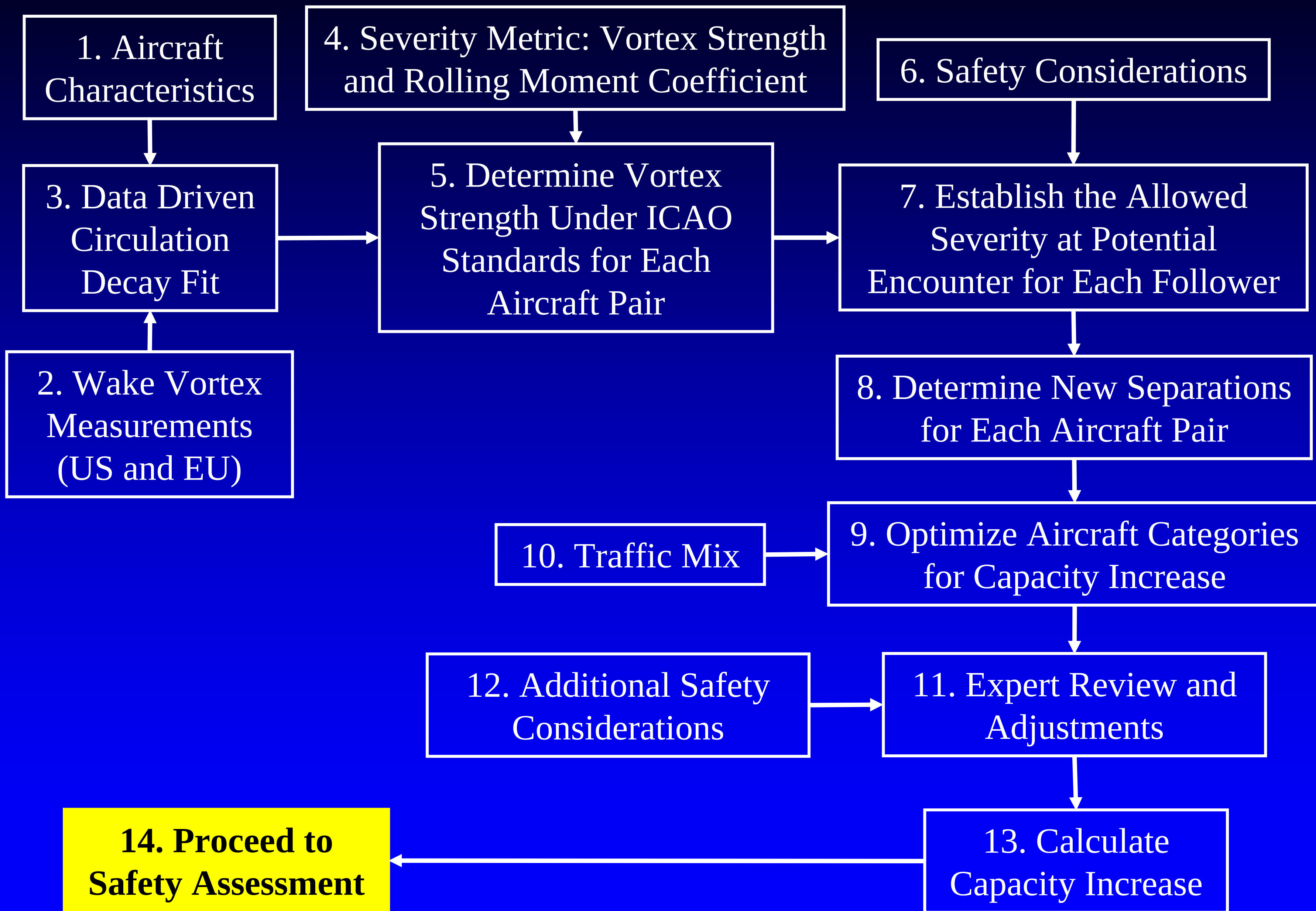
Operational Percentage in US and Europe

US Avg Peak		European Peak	
A306	0.69%	A306	2.53%
A318	0.06%	A318	0.79%
A319	2.87%	A319	6.18%
A320	7.17%	A320	9.86%
A321	0.25%	A321	5.96%
A332	0.39%	A332	0.21%
A333	0.18%	A333	1.55%
A343	0.31%	A343	0.80%
A346	0.43%	A346	0.28%
AT43	0.00%	AT43	0.11%
AT72	0.80%	AT72	0.06%
B190	0.00%	B190	0.04%
B712	4.28%	B712	0.00%
B722	0.18%	B722	0.00%
B733	3.00%	B733	11.76%
B734	0.38%	B734	4.52%
B735	2.36%	B735	5.21%
B736	0.00%	B736	0.77%
B737	2.85%	B737	1.71%
B738	4.53%	B738	7.12%
B739	0.23%	B739	1.58%
B744	2.74%	B744	2.84%
B752	10.30%	B752	0.46%
B753	0.39%	B753	0.14%
B763	3.25%	B763	1.60%
B772	1.81%	B772	0.90%
B773	0.15%	B773	0.17%
C525	0.02%	C525	0.11%
C650	0.02%	C650	0.04%
CRJ1	0.82%	CRJ1	0.00%
CRJ2	11.21%	CRJ2	1.58%
CRJ7	6.74%	CRJ7	0.89%

US Avg Peak		European Peak	
CRJ9	1.51%	CRJ9	0.17%
DC93	0.14%	DC93	0.00%
DC95	0.26%	DC95	0.00%
DH8A	0.00%	DH8A	0.00%
DH8B	0.06%	DH8B	0.00%
DH8C	0.00%	DH8C	1.10%
DH8D	0.97%	DH8D	0.87%
E120	1.46%	E120	0.00%
E135	2.14%	E135	0.29%
E145	8.48%	E145	0.65%
E170	2.37%	E170	1.26%
E190	1.33%	E190	0.00%
E45X	0.88%	E45X	0.00%
GLF4	0.08%	GLF4	0.06%
GLF5	0.05%	GLF5	0.04%
MD11	0.38%	MD11	1.30%
MD82	3.29%	MD82	0.58%
MD83/88	8.07%	MD83	0.02%
SF34	0.00%	SF34	0.01%
US Only Aircraft			
H25B	0.12%		
		European Only	
		AT45	0.05%
		A380	0.00%
		RJ85	1.13%
		RJ1H	0.08%
		B462	0.58%
		B463	2.75%
		F50	2.91%
		F70	7.81%
		F100	6.38%

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
- Also used rolling moment coefficient as a metric
- Categories optimized for capacity increase
- Simple Relative Safety argument: Same or better than today


1. Aircraft Characteristics
4. Severity Metric: Vortex Strength and Rolling Moment Coefficient
6. Safety Considerations
3. Data Driven Circulation Decay Fit
5. Determine Vortex Strength Under ICAO Standards for Each Aircraft Pair
7. Establish the Allowed Severity at Potential Encounter for Each Follower
2. Wake Vortex Measurements (US and EU)
8. Determine New Separations for Each Aircraft Pair
10. Traffic Mix
9. Optimize Aircraft Categories for Capacity Increase
12. Additional Safety Considerations
11. Expert Review and Adjustments
14. Proceed to Safety Assessment
13. Calculate Capacity Increase

#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 maintained for groupings
- Optimized set of categories found for maximum capacity (minimum total separation)
  - RECAT problem is to optimize 61 aircraft into 6 categories
  - RECAT problem has 5,461,512 possible groupings

#10 Traffic Mix

- Traffic mix was used in the optimization
- Traffic mixes for the U.S. determined from five 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
  - Confirmed analyzing traffic mixes at world wide capacity constrained airports
- Pair-wise statistics derived by assuming probability of occurrence of each aircraft is independent

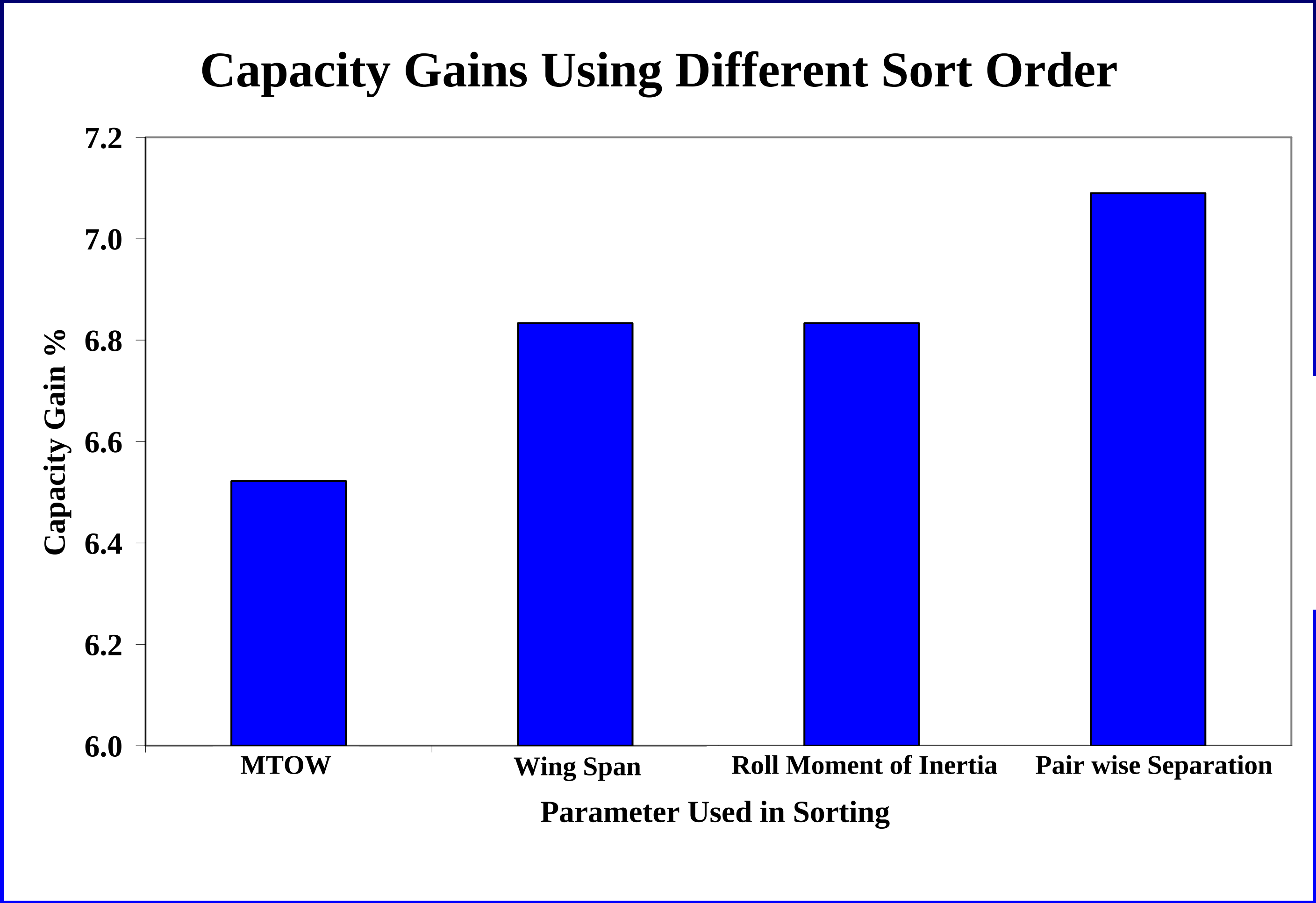
Aircraft Traffic Mix

- If the probabilities of occurrence of each aircraft and each aircraft pair are uniformly distributed, there is no weighting needed
- If there is a non-uniform traffic mix, the separation between a pair of aircraft is weighted by the likelihood of that pair
- If the probabilities of occurrence of aircraft pairs are not available, the separation between a pair of aircraft is weighted by the product of the likelihood of each aircraft in that pair

Optimizations

- Optimization performed for average US peak traffic and average EU peak traffic
- Blending of US optimization and EU optimization performed
- Looked at optimizing based on maximum take off weight, wingspan, rolling moment of inertia, and pair-wise separation

Capacity Gains for Different Sorting

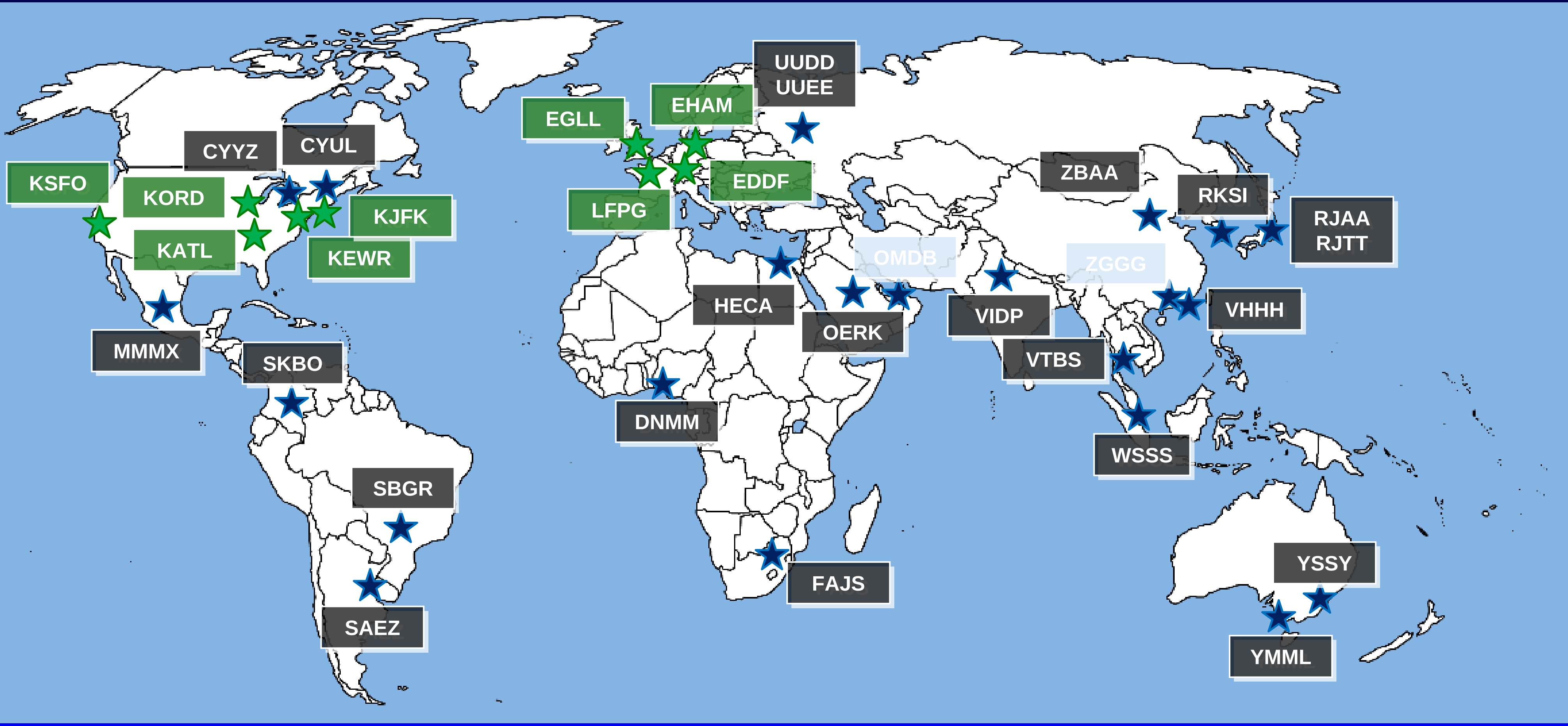


For ease, we used wing span sorting

Additional Airports Checked

- Additional airports were checked world-wide to ensure that the blended optimization worked beyond Europe and the US

Airport Traffic Analyzed in RECAT To Provide Worldwide Coverage



- Airports selected for detailed analysis (Green)
- Additional airports analyzed to confirm benefits (Black)

29

#13 Calculate Capacity Increase

- Percentage of capacity increase computed relative to baseline
  - Baseline computed using current separations
  - Capacity increase computed using RECAT categories and separations

Application of Methodology to All ICAO Aircraft Types

- 61 representative aircraft types were used in developing the categories and separations
- Methodology was then applied to all 9000+ ICAO aircraft types

Estimated Benefits

- Capacity gain
- Traffic mix and local procedures influence the benefits
- Estimated capacity gain for Europe (constrained airports) is on average 4%
- Estimated capacity gain for U.S (constrained airports) is on average 7%
- Similar estimated capacity gains for other world wide (capacity constrained) airports

Summary

- Joint Effort by FAA/EUROCONTROL as requested by ICAO
- Harmonization
- Capacity benefit local and network wide (Congested airports have impact worldwide)
- Maintain or Improve Today's Safety
- Methodology developed for categorizing current and future aircraft types
- Approach and Departure separations, Distance and Time Based
- Used Present and future traffic mix
- Openly available tools, methods and aircraft data
- Solution supported by ICAO compliant safety case
- Path to SESAR and NextGen goals require Phase I and Phase II elements of RECAT to achieve maximum benefits

Research Needs for Phase 2 and Beyond

- What capacity increase is needed to adopt a categorization scheme
  - Globally
    - Regionally
      - Locally
- What evaluation of associated procedures is required for capacity impact
  - Airport unique procedures
- Unique separations at individual airports
  - Vary from day to day
  - Vary by time of day
  - Impact of the dynamic separation on controllers and pilots