



NLR Air Transport Safety Institute

Research & Consultancy

Wake vortex severity criteria *The search for a single metric*

The potential of equivalent roll rate

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WakeNet3_Europe, specific workshop

Wake Vortex Encounter Severity Criteria

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Contents

- Characteristics of WV severity metric
- What is used today, pro's and cons
- What is equivalent roll rate
- Example application
- Conclusion & Recommendations



Good characteristics of Metric

- Strong relation between encounter severity and metric (discriminative power)
- Aircraft independent
- Meaningful
- Easy to be determined for a large range of aircraft, without need for access to proprietary data
- Applicable in an absolute sense
- Thresholds easy to validate

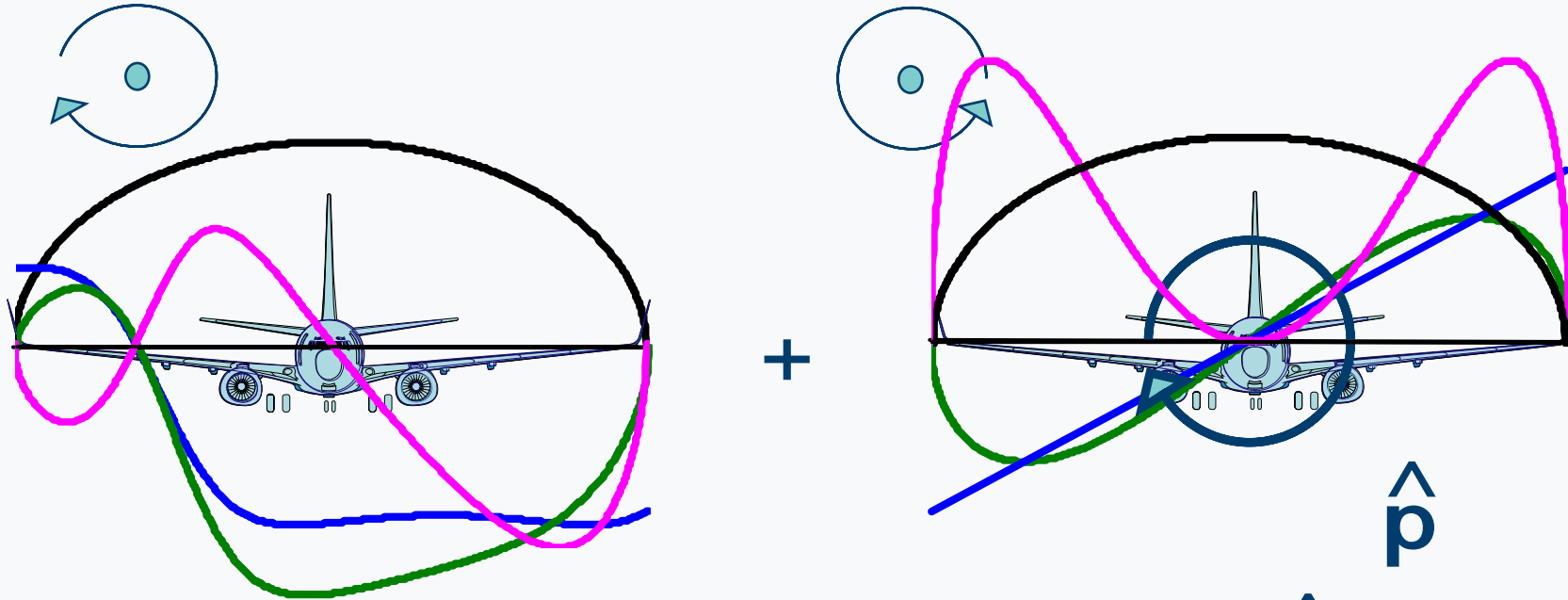
What is used today (basically)

- Wake Vortex Circulation (Γ), [m²/s]
- Rolling Moment (L), [Nm]
- Dimensionless Rolling Moment Coefficient (C_θ), [-]
- Roll Control Ratio $\frac{C_l}{C_{l\delta_a} \delta_{a_{\max}}}$, [-]
- Roll response (e.g. Tatnall), [deg]

Metric evaluation

	<i>Circulation</i>	<i>Rolling Moment</i>	<i>RM coefficient</i>	<i>RC ratio</i>	<i>Response</i>
Discriminative power	0	+	+	++	+
Independency	-	-	+	+	0
Meaningful	-	-	0	++	++
Computable	++	0	0	-	0
Absolute	-	-	0	++	++
Validation	0	-	0	++	0

Equivalent roll rate



$$= 0 \Rightarrow P_{\text{equivalent}} = \hat{p}b/2V$$

- angle of attack distribution
- nominal lift distribution
- induced lift distribution distribution
- rolling moment distribution distribution

Parameters in Peq Calculation

Given a wake vortex circulation field, parameters are

- Wing Area
- Span
- Velocity
- Lift-curve slope (aircraft dependent, but easy to estimate)
- Liftdistribution (aircraft dependent, elliptic assumption, insensitive parameter due to calculation method)

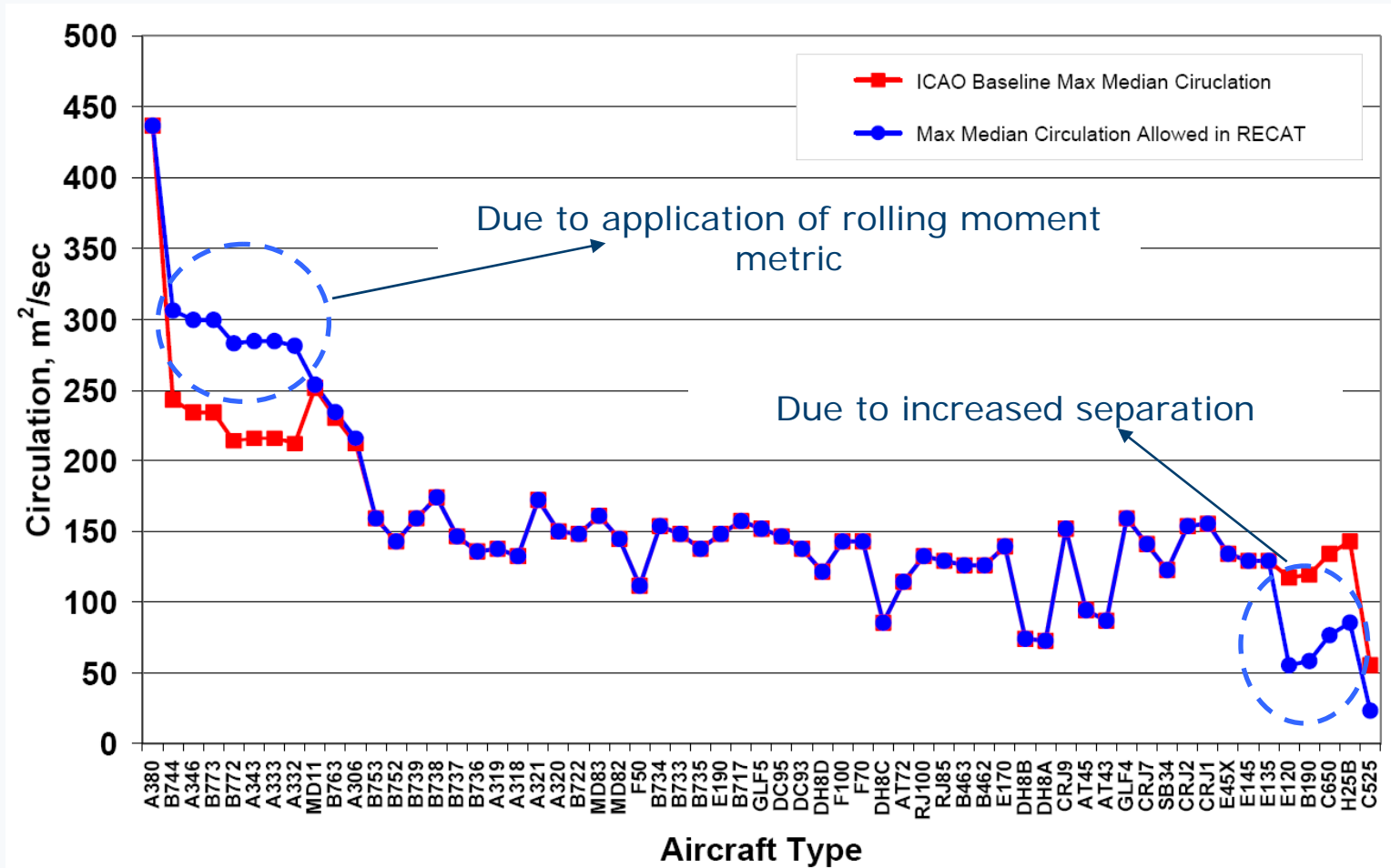
Characteristics of P_{eq}

Equivalent Roll Rate P_{eq} :

- Easy to calculate for any aircraft
- Meaningful parameter, and directly related to:
 - induced rolling moment
 - initial acceleration; $\dot{p}_0 = p_{eq} / \tau_R$
 - roll response; $\varphi(t) = p_{eq} (t + \tau_R (e^{-t/\tau_R} - 1))$
- Applicable in an absolute sense (TBD)
- Single, A/C independent, threshold could be potentially valid

Application to RECAT

RECAT: relative assessment, with basically “WV circulation” as metric



ICAO and RECAT separation

ICAO

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

RECAT

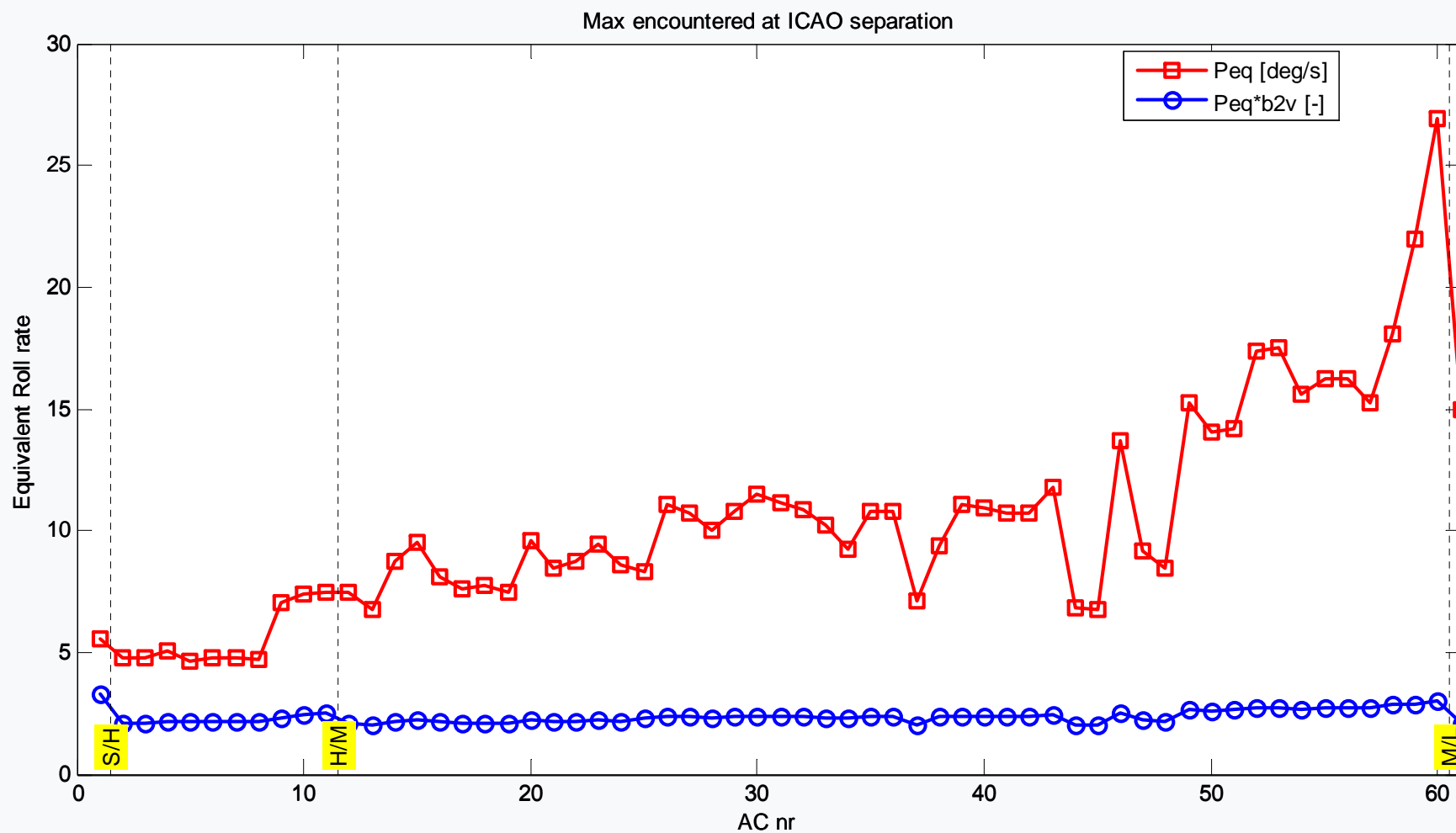
		Follower					
		A	B	C	D	E	F
Leader	A		5.0NM ⁻¹	6.0NM	7.0NM	7.0NM	8.0NM ⁺¹
	B		3.0NM ⁻¹	4.0NM	5.0NM	5.0NM	7.0NM ^{+1, +2}
	C		-1.5	-1.5	3.5NM ^{-1.5}	3.5NM ^{-1.5}	6.0NM ⁺¹
	D						5.0NM ⁺¹
	E						4.0NM ^{+1.5, -1}
	F						-2.5

Separation Reduction

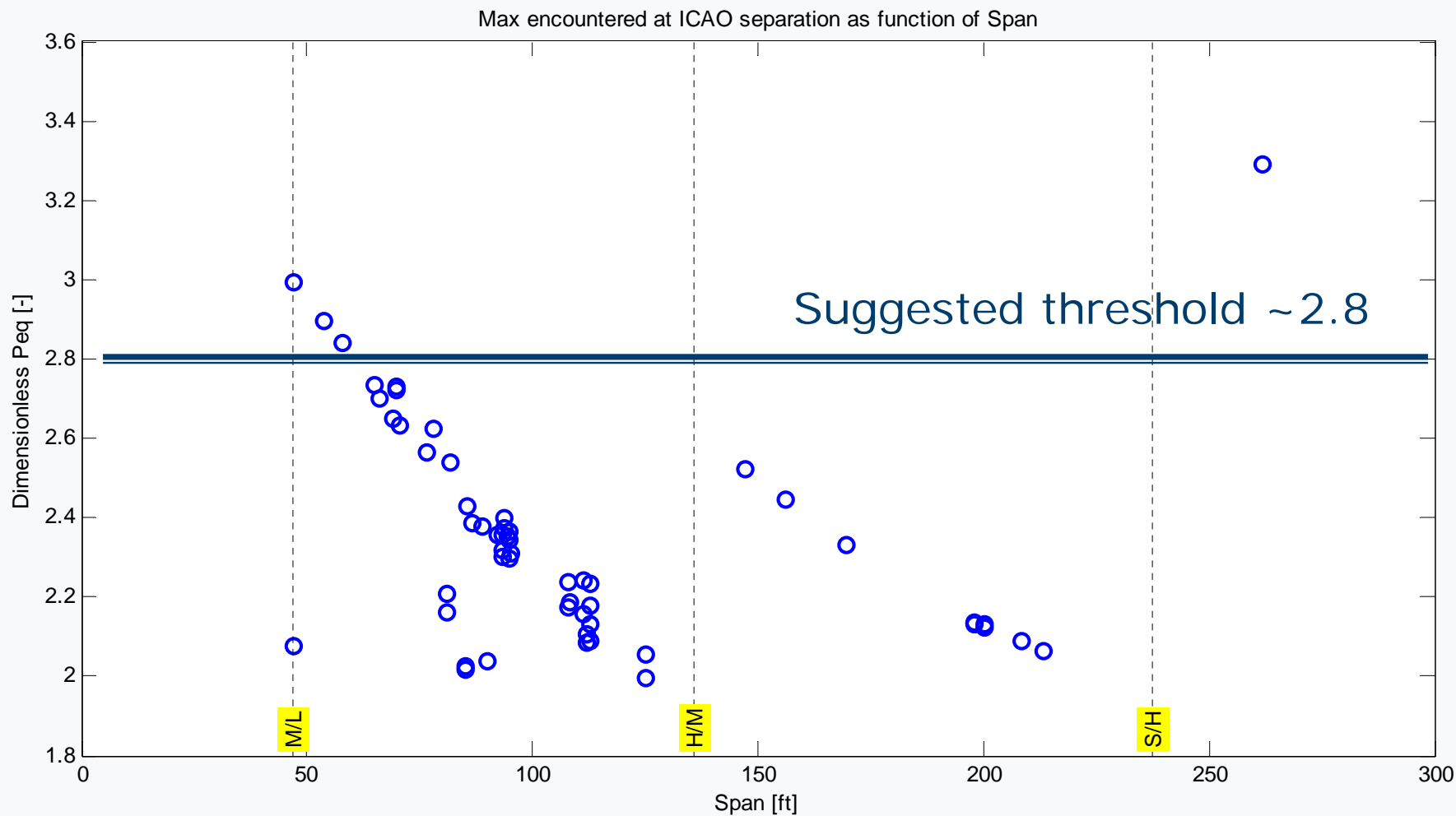
Separation Increase



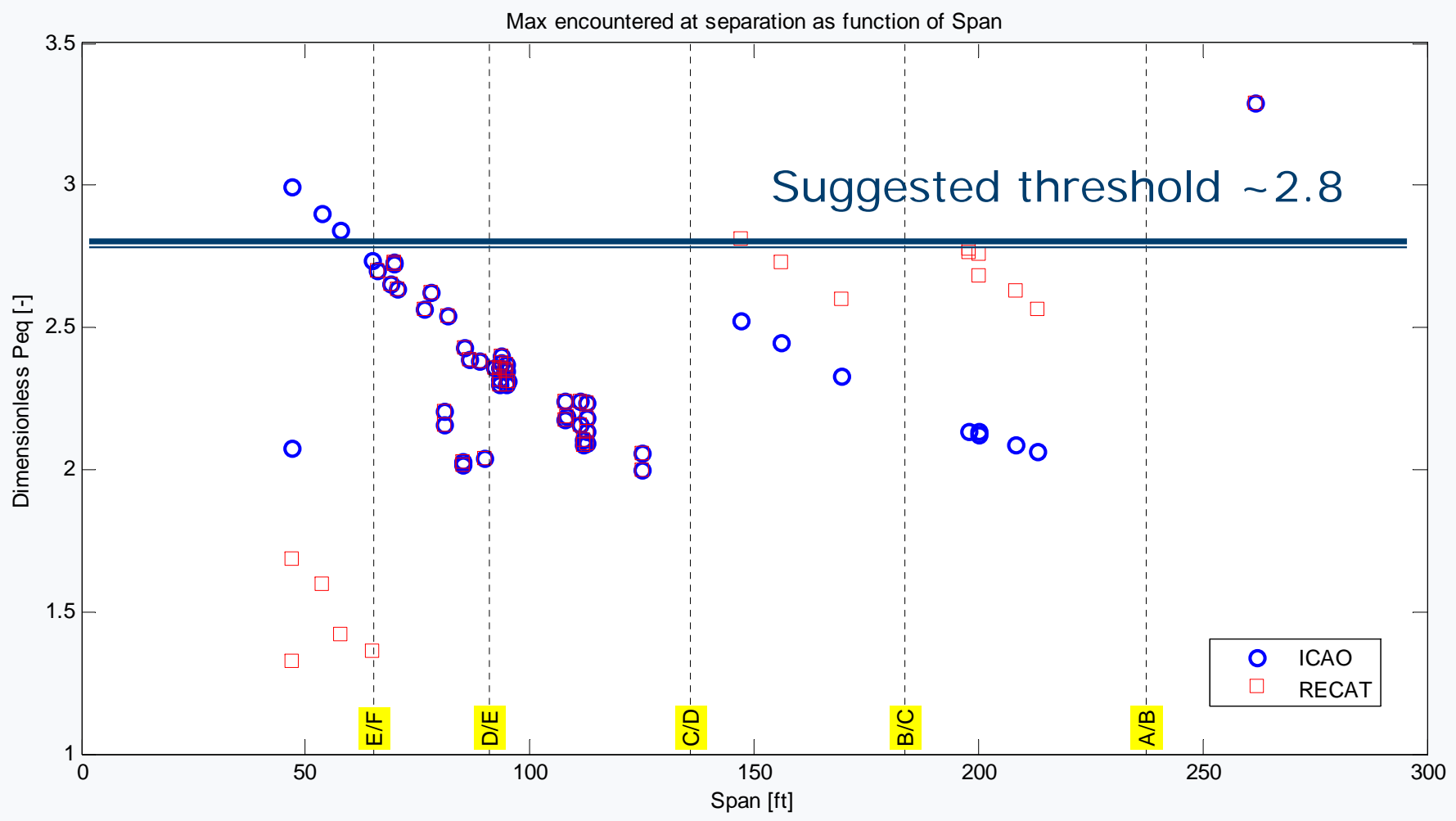
Max Peq under ICAO



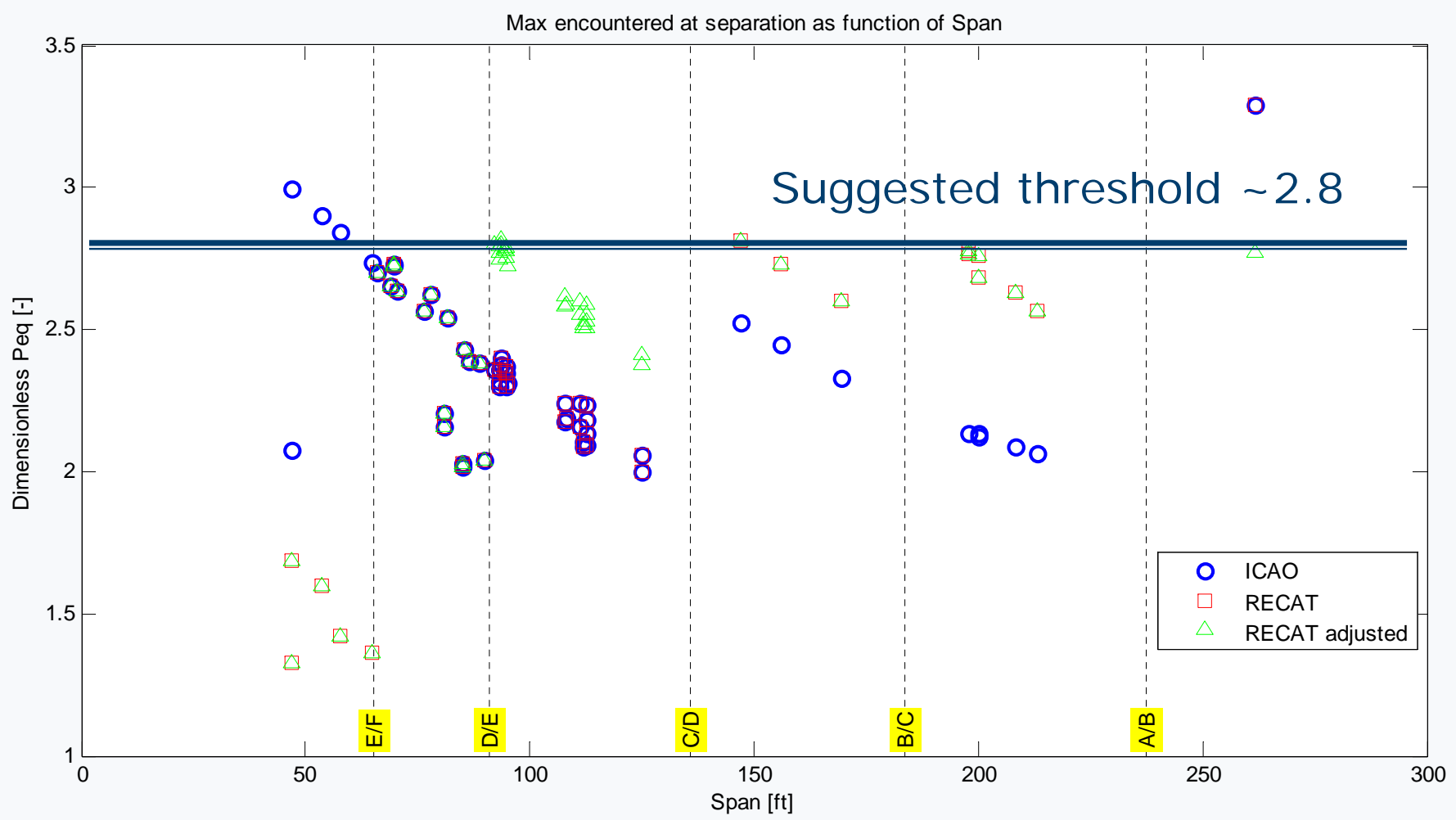
Peq max @ ICAO separation



Peq max @ RECAT separation



Peq max @ adjusted RECAT separation



ICAO and adjusted RECAT separation

ICAO

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

RECAT

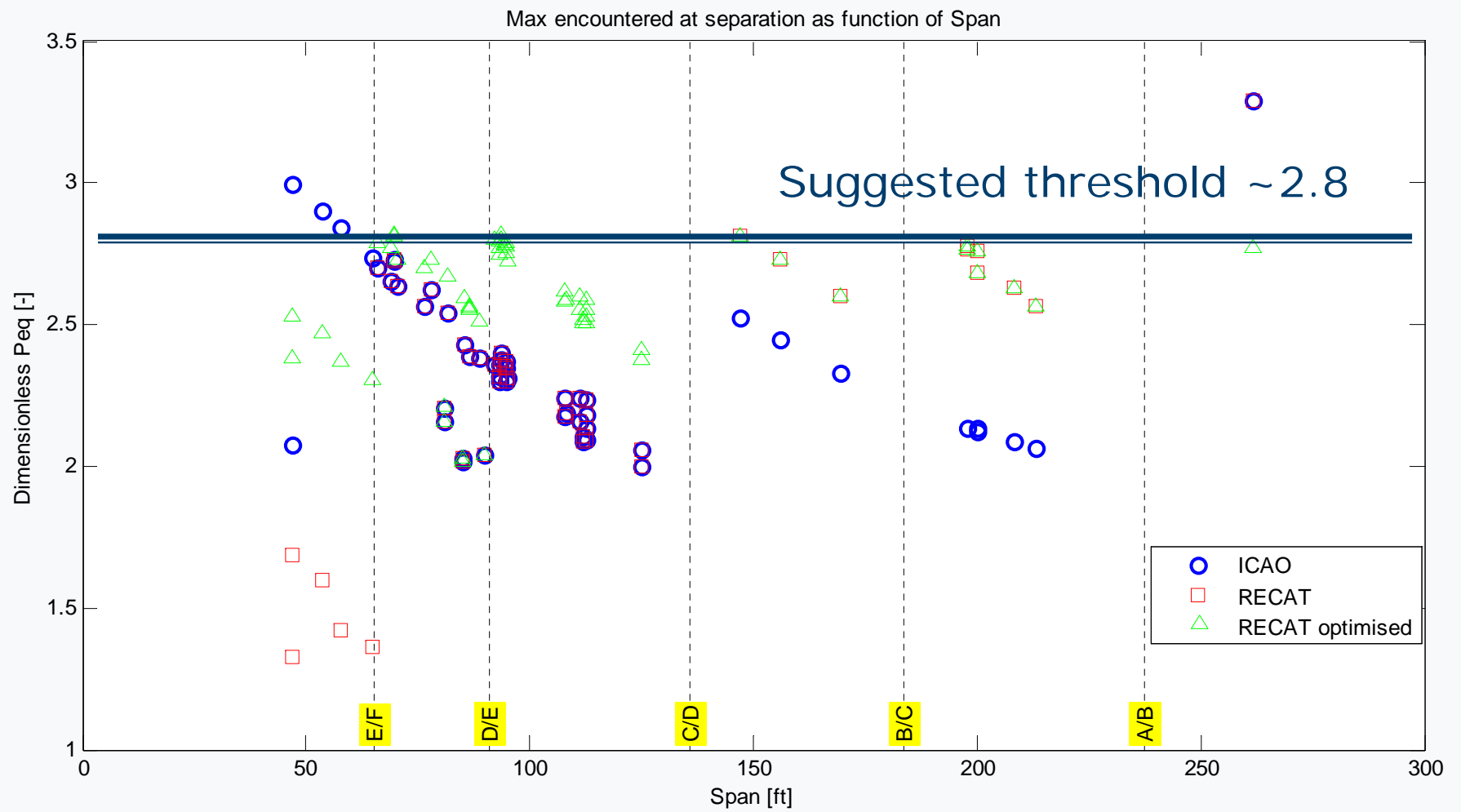
		Follower					
		A	B	C	D	E	F
Leader	A	3.5NM(+1)	5.0N ₋₁	6.0NM	7.0NM	7.0NM	8.0NM ⁺¹
	B		3.0N ₋₁	4.0NM	4.5NM(-.5)	5.0NM	7.0N ^{+1, +2}
	C		-1.5	-1.5	3.5 _{-1.5}	3.5 _{-1.5}	6.0NM ⁺¹
	D						5.0NM ⁺¹
	E						4.0N ₋₁ ^{+1.5}
	F						-2.5

Separation Reduction

Separation Increase



Peq max @ optimised RECAT separation



ICAO and optimised RECAT separation

ICAO

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

RECAT

		Follower					
		A	B	C	D	E	F
Leader	A	3.5NM(+1)	4.5NM(-1.5)	5.5NM(-.5)	6.5NM(-.5)	6.5NM(-.5)	7NM (0,-1)
	B		3.0N -1	4.0NM	4.5NM(-.5)	5.0NM	6NM (0,+1)
	C		-1.5	-1.5	3.5 -1.5	3.5 -1.5	5.5NM(-.5,+5)
	D						4.5NM(-.5,+5)
	E						3.5NM(-1.5,+1)
	F						-2.5

Separation Reduction

Separation Increase



Conclusions

Equivalent roll rate appears to have very good potential for a WV severity metric:

- Strong correlation with severity
- Only dependent on a few aircraft parameters
- Has a physical meaning and therefore easy interpretable
- Easy to compute
- Provides an absolute measure (to be validated)

Preliminary research suggests:

$P_{eq} < 2.8$ provides equivalent safety as ICAO separation

Preliminary application to RECAT

- provides suggestions for optimisation in RECAT categories
 - A380 behind A380 may need +1 NM separation
 - Cat D behind B could be reduced -.5 NM
 - CAT B-F behind A380 could be reduced slightly (.5 [C-E] to 1.5 [B])
 - CAT F separation increase (wrt ICAO) can be reduced .5 to 1 NM



Recommendation

Equivalent Roll Rate with upper bound of 2.8 needs further validation.

Recommended to:

- Give it some thought, and maybe..
- Re-process existing data to verify Equivalent roll rate concept and associated threshold
- Piloted simulations with various aircraft type to validate concept