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Wake vortex safety at NLR

Gerben van Baren, Lennaert Speijker, Peter van der Geest

vanbaren@nlr-atsi.nl

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- Overview of wake vortex safety activities at NLR
- Encounter severity metric ‘equivalent roll rate’

NLR Wake vortex activities (1)
Involvement in EC projects

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- **Involvement in EC projects, in various roles:**
  - Coordinator of networks (WakeNet Europe 1 & 2)
  - Coordinator of R&D projects (WAVENC, S-Wake, ATC-Wake)
  - Work-package manager (CREDOS, I-Wake, FAR-Wake, Awiator)
  - Wakenet3 leader of the task group Safety requirements & Regulatory framework

NLR Wake vortex activities (2)
WakeNet3-Europe activities

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- **Coordination of Area Wake Vortex Safety**
  - Establishment of several WV safety related deliverables (Coordination Area Safety Report 1 on the state of art of wake turbulence safety assessment)
- **Link with Rulemaking authorities**
  - (e.g. EASA, FAA, SRC, CAA UK, CAA Netherlands, FOCA, DGAC)
- **Link with Amsterdam Stakeholder Working Group**
  - (e.g. AAS, LVNL, Dutch ALPA, CAA Netherlands)
- **Host/organizer of specific workshop on**
  - Wake Vortex regulation & safety requirements
- **Host/co-organizer of specific workshop on**
  - Incident monitoring and accident analysis
- **Representation of Wake Vortex theme at Aerodays 2011**
  - CREDOS (technical presentation & press conference)

NLR Wake vortex activities (3)
Wake Vortex Advisory System development

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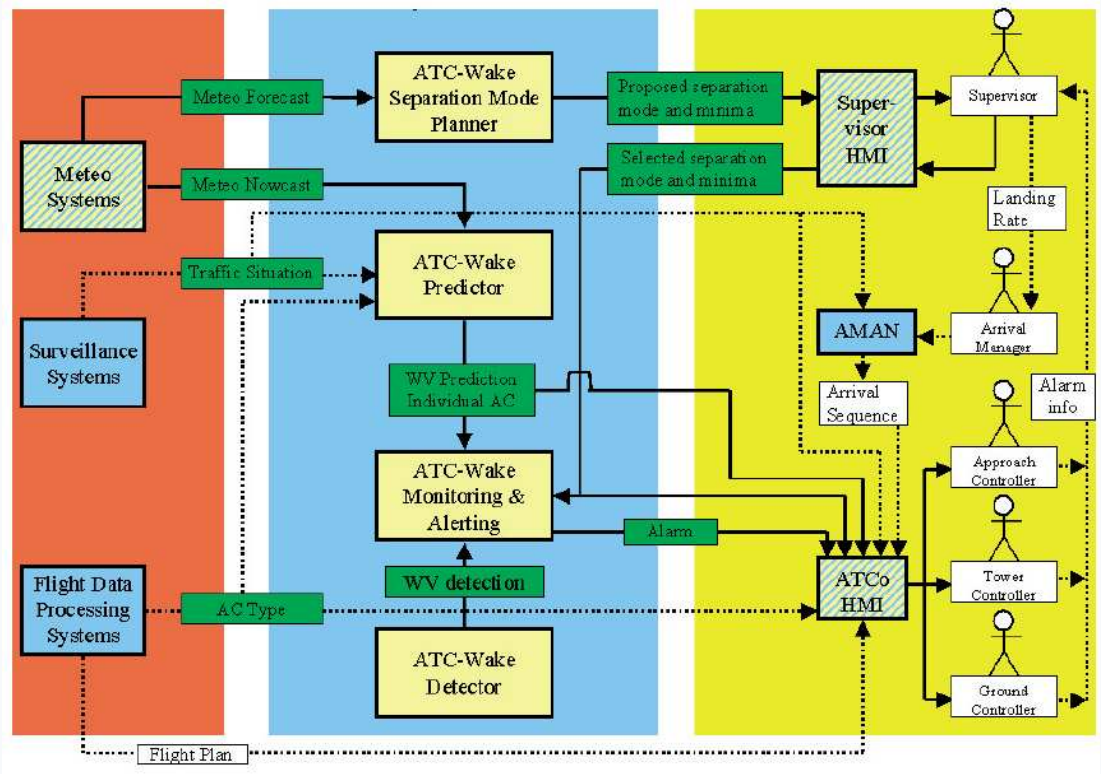
- **ATC-Wake**



- **SESAR P12.2.2 'Runway WV Detection, Prediction & decision support tools'**
  - for Thales (as subcontractor) & DFS (as associate partner)

NLR Wake vortex activities (4)
Safety Case development

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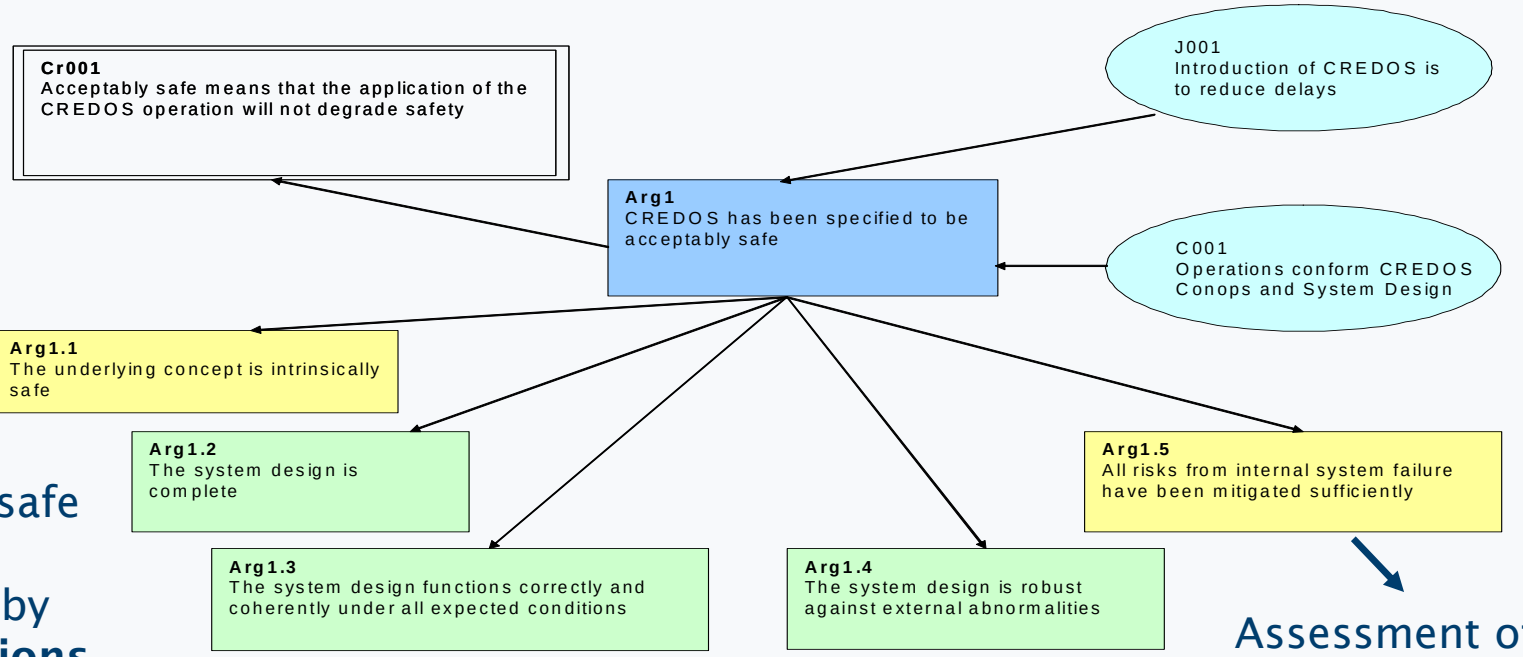
- **CREDOS Preliminary Safety Case**



Intrinsically safe can be supported by **risk simulations**

Assessment of system failure usually supported by **FHA/PSSA**

- **Safety Case for WT Separation of Large Aircraft**
  - Providing support to EASA

NLR Wake vortex activities (5)
WV safety R&D tools

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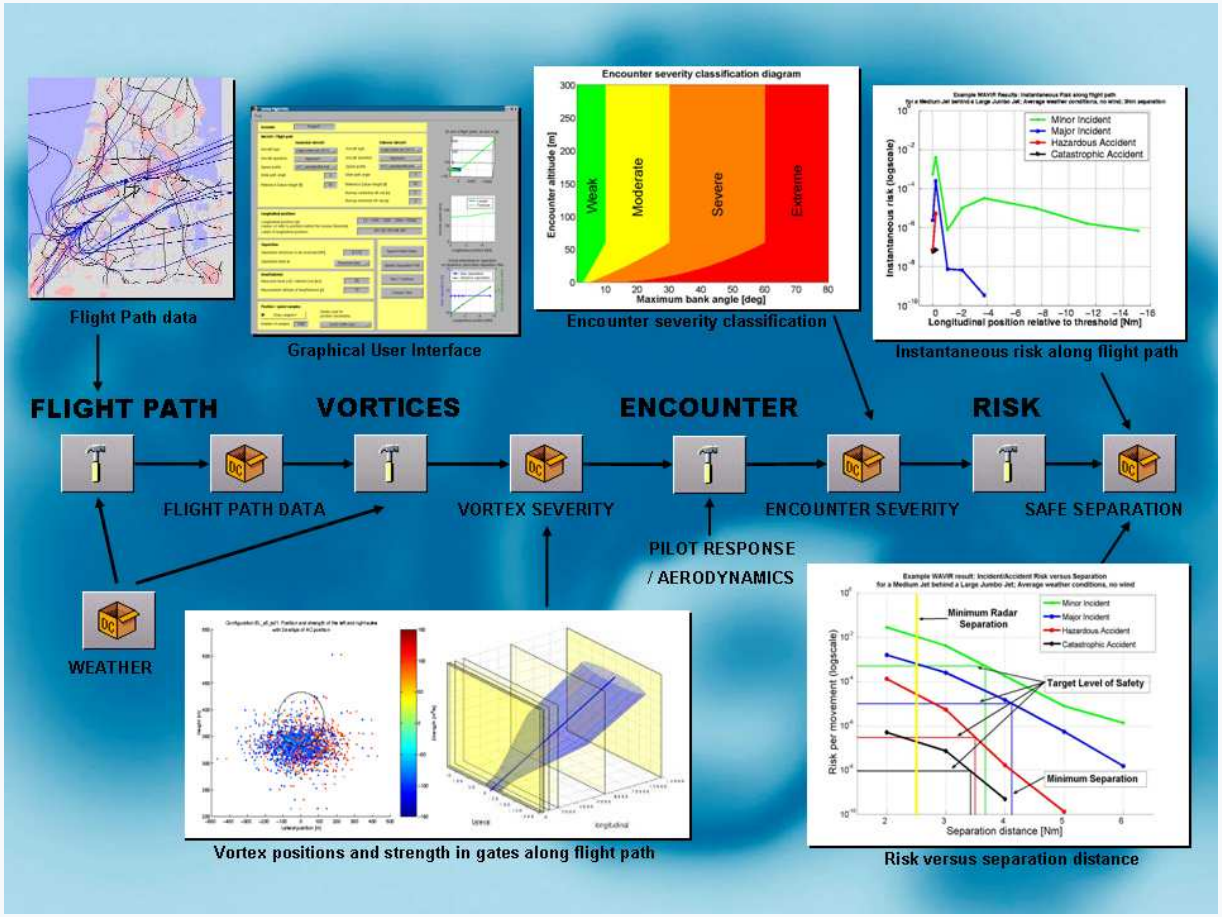
- **WAVENDA *Wake Vortex Detection Algorithm***
- **WAVIR *Wake Vortex Induced Risk assessment***



NLR Wake vortex activities (6)
WV risk simulation (WAVIR) & analysis

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- **DFS**
  - Safety analysis of wake vortex risks related to HALS/DTOP
- **EC projects:**
  - S-Wake, I-Wake, Awiator, ATC-Wake
- **Swiss CAA FOCA:**
  - Second Opinion on a WV risk assessment study regarding segregated operations at Zürich runways 14 & 16
- **Dutch ANSP LVNL:**
  - Relative worst-case analysis of wake vortex induced risk of 700ft vertical separation
    - *as part of LVNL's project to reduce vertical separation between Medium generator and Light follower in Rotterdam TMA*
  - Relative worst-case analysis of encounter severity in the wake of an A380 in converging missed approach paths
    - *as part of LVNL's safety case on the introduction of the A380 to Schiphol airport*

- **Modular set-up: possible to 'plug in' various inputs:**
  - aircraft types
  - flight path models (approach, missed approach, take-off)
  - characterisations of weather conditions
  - wake vortex evolution models
  - wake encounter models

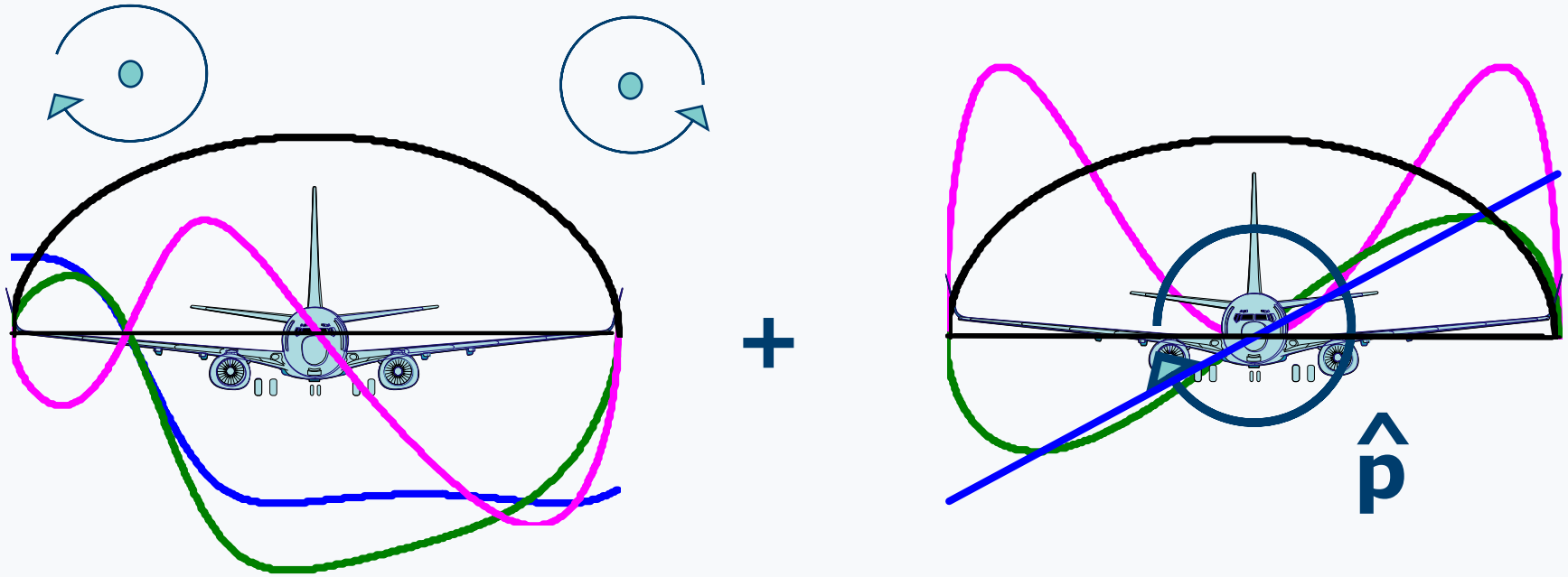
- **Producing various WV risk indicators (outputs)**
  - WV strength (circulation, core size, lifetime, position probabilities)
  - Roll control ratio
  - Tatnall's one DoF maximum bank angle
  - Induced (maximum) rolling moment
  - Induced load factor
  - Equivalent roll rate

- **Safe separation determined for given criteria on WV risk indicators**

WAVIR developments: Equivalent roll rate

- **Looking for as simple as possible but effective WVE severity parameter**
- **Equivalent roll rate:**
  - Roll rate equivalent to the wake induced roll moment, without pilot intervention
  - Equivalent roll rate is the roll rate in the equilibrium situation where WV induced rolling moment and aircraft roll rate induced rolling moment are in balance. Therefore, no information on roll inertia is required.
  - Estimated roll damping is a by-product of the equivalent roll rate calculation, and depends on the assumed basic lift distribution. Because the computed WV induced rolling moment depends on the same assumed lift distribution, the resulting equivalent roll rate is rather insensitive to the actual lift distribution and the associated actual roll damping. Variations in lift distribution have shown to have only minor impact on the calculated equivalent roll rate.

Equivalent roll rate



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

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

Equivalent roll rate classification

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- **Classification for equivalent roll rate can be linked to roll angle classification**
  - roll angle ~ equivalent roll rate x pilot reaction time

- **ICAO doc 9426:**

Severe:	roll angle > 30 deg
Moderate:	10 deg < roll angle < 30 deg
Slight:	roll angle < 10 deg

Advantages of equivalent roll rate

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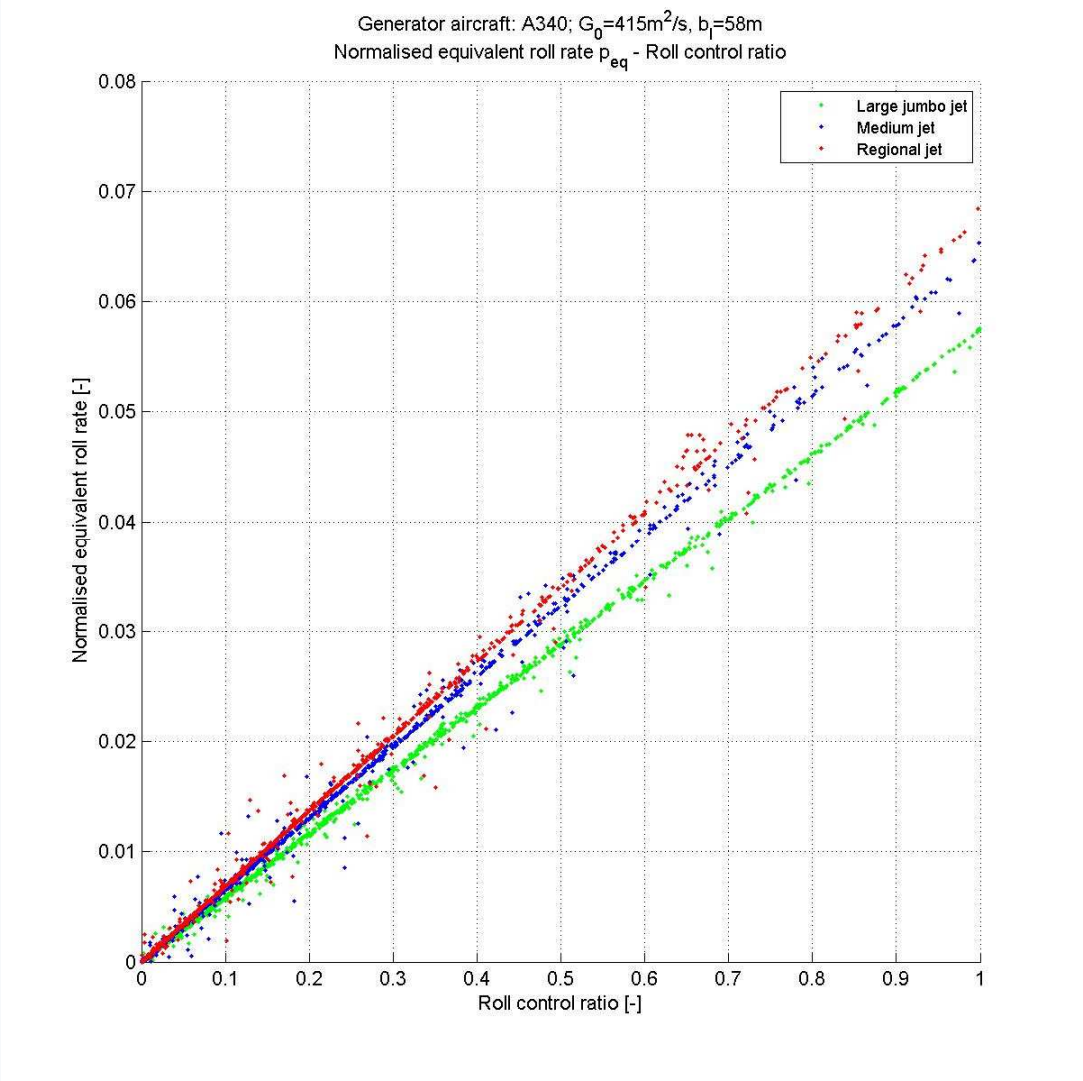
- **Application of equivalent roll rate does not require aircraft characteristics other than wingspan**
  - E.g., RCR strongly dependent on accuracy with which maximum roll control power can be determined:
    - difficult to acquire this data for a large variety of aircraft in practice
    - max. roll control power can be strongly dependent on flight condition
    - roll control systems can be complex due to combinations of inner & outer ailerons and flight spoilers
    - difficult to obtain for Fly-By-Wire systems
- **Allows severity assessment of intersection with wake vortices at any interception angle**
- **More directly related to pilot's experience**
- **Showing good correlation with RCR**

Correlation RCR & Equivalent roll rate



Conclusions

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- Wake vortex safety assessment requires attention for various aspects:
  - Safety Case development
  - FHA/PSSA
  - Risk simulations
  - Link to stakeholders / regulators
- Any severity parameter should be both effective and as simple as possible to become an accepted standard
- Without an accepted standard, any WV safety assessment is vulnerable to endless discussion and reluctant decision making
- NLR has used equivalent roll rate alongside RCR and bank angle in several WV projects, resulting in comparable severity assessment results
- Further research into the viability of the equivalent roll rate is required.