Vortex Encounter Severity Assessment

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Introduction (1)
What is VESA?

- VESA is a software tool developed by Airbus
- VESA is based on fast-time, high-fidelity aircraft simulations
- VESA’s objectives:
  - Computation of the Wake Vortex Encounter (WVE) severity
  - Comparison of WVE hazard for specific follower aircraft behind different generator aircraft

VESA can be used to assess the adequacy of separation standards for new and larger aircraft

VESA was selected by A380 Wake Vortex Steering Group (FAA, JAA, Eurocontrol, ICAO) as part of the methodology for WVE risk assessment behind A380

Introduction (2)
Overall Methodology

Two step methodology for wake vortex risk assessment:
- Determination of vortex encounter probability and encounter conditions
  Tool: ASAT (FAA)
- Determination of encounter severity
  Tool: VESA (Airbus)

Input
- Geographic location (airport)
- Flight phase
- Traffic mix
- Meteorological conditions
- Etc, etc, ....

Output
- Probability to exceed certain hazard levels
- Comparison of WVE severity of specific generator/follower a/c combinations
Introduction (3)

VESA/ASAT Coupling

Step 1

Frequency of aircraft/vortex proximities

Wake Vortex Encounters
Flights through area of interest

Step 2

Severity Probability
Probability of severe encounters (landing approach: GA probability)

Probability reduction = benefit of VESA

Total probability of severe encounters:

\[ P_{\text{severe}} = P_{\text{ASAT}} \cdot P_{\text{VESA}} \]

Introduction (4)

Scenario

Vortex parameters

- \( \Gamma \): Vortex strength
- \( b_v \): Vortex span
- \( r_c \): Vortex core radius

Encounter geometry

- \( y_{\text{EF}} \): Min. distance between vortex and encountering a/c trajectory
- \( H_{\text{EF}} \): Encounter height
- \( \Delta \gamma_{\text{VW}} \): Encounter angles
- \( \Delta \psi_{\text{VW}} \): encountering a/c glide path

Vortex velocity profile

\( \Gamma_{\text{VW}} \)

Wake vortex system
Introduction (5)
Capabilities of VESA:

Three analysis types of VESA:

1. Sensitivity Analysis (SA)
   - Critical vortex strength

2. Worst-Case Search (WCS)
   - Worst-case encounter conditions
   - Critical vortex strength

3. Assessment of the encounter severity by Monte Carlo Simulations (MCS)

VESA Models (1)
Simulation Setup

WVE Flight Simulation

WVE S/W Package
- Leader A/C
- Wake Vortex Model
- Follower A/C
- Aero Interaction Model

Pilot Model

Follower A/C

Flight Simulation

Hazard Criteria
VESA Models (2)
Hazard Criteria

- Necessary to assess WVE severity in offline simulations
- Relate severity of WVE, which is perceived by the pilot, to objectively measurable data

MCS with VESA (1)
What is MCS?

- Definition: Monte Carlo* Simulation (MCS) randomly generates values for uncertain variables to simulate a model
- AIM: To automatically analyse the effect of varying inputs on outputs of a modelled system

Probability distributions for uncertain variables

<table>
<thead>
<tr>
<th>Probability distributions</th>
<th>Input</th>
<th>No. of samples N</th>
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<tbody>
<tr>
<td></td>
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<td>Distribution</td>
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<tr>
<td></td>
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<td>of N sets of values for variables</td>
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<td>Statistical evaluation of N simulations</td>
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<td>N simulations under different conditions</td>
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</tbody>
</table>

WVE Simulation

Result

Probability to exceed severity level

1) The term "Monte Carlo" comes from the city in Monaco. Its main attraction are casinos, which run games that exploit the random behaviour
MCS with VESA (2)
Time History and Criterion Plot

- Example of 1000 samples
- Plot permits post analysis: clicking on any symbol or curve highlights corresponding symbols and curves of test case

MCS with VESA (3)
Comparison of WVE Severity

Follower a/c behind Generator a/c A

MCS 1

Probability to exceed severity limit \( P \)

Follower a/c behind Generator a/c B

MCS 2

Follower behind Gen. A
Follower behind Gen. B

Comparison

\[ 1-P \] \[ 1-P \]
Post Analysis

After MCS, VESA permits post analysis of individual MCS samples:

- **THOR flight simulator:**
  - VESA flight simulation models and those used in THOR flight simulation are the same
  - "flying" the WVE
  - Visualising the vortices

- **3D animation tool:**
  - Visualisation of vortices and aircraft trajectory
  - Provides impression of aircraft motion from different perspectives

Conclusions

- A combination of ASAT and VESA was selected by A380 WV Steering Group (FAA, Eurocontrol, JAA, ICAO) to assess WVE severity behind A380 and other aircraft in a comparative way
- Preliminary computations with VESA for the VFW614-ATD behind different generator aircraft provided reasonable results and confirmed observations during simulator tests
- A combination of an air space simulation tool (such as ASAT) and VESA has the potential to be used to determine safe aircraft separation distances in the future
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