A380 wake vortex status
WakeNet3 - Europe
Southampton, May 2011
A380 wake vortex flight test campaign - (1)

- First campaign from May 2005 to December 2007
- Second campaign November and December 2010

**TOTAL:**

- 91 flights (all aircraft)
- 388 flight hours
- 627 ground-based LIDAR runs
- Airborne LIDAR measurements in cruise
- 167 wake encounters in cruise
- 1308 wake encounters during approach
- 1475 total wake encounters
This is the largest campaign ever conducted to investigate all aspects of the wake vortex characteristics of one specific aircraft.
Current status (1)

- Cruise: no limitation compared to other aircraft. Obtained thanks to back to back encounters behind A380 and B747, complemented by airborne Lidar.

- In approach, all separations are based on Lidar: penalty of 2 NM for all aircraft categories. This penalty includes a rounding up to nearest mile, and an uncertainty allowance of 1 NM.

- Back to back encounter tests performed by Airbus in 2007. Raw data and pilots impression show no difference between A380 and A340-600.

- Decision made by the Steering Group in January 2009 to continue the study of the encounters. 3 Working Groups created: Technical, Flight Test and Safety Case.
Current status (2)

- Final report of the Technical WG given in September 2010. No global consensus:
  - EASA and Eurocontrol: almost all points have been cleared and agreement on feasibility of use of encounters to adjust separations.
  - FAA: several issues and in summary not convinced that encounters could allow reduced separations.

- The SG decided that the Technical WG will now be “dormant” and the Flight Test WG (FTWG) will take over.

- New flight test campaign end 2010. Data are presently being analyzed.
Second flight test campaign

-Campaign performed between 24\textsuperscript{th} Nov and 2\textsuperscript{nd} Dec 2010.

-All flights performed to get more data on encounters at various distances behind A380 and another Heavy (A340-600) using back to back tests technique.

- Five flights, with participation of Members of the FTWG:
  - Three flights A320 (Medium) behind A380 and A340-600.
  - One flight A340-300 (Heavy) behind A380 and A340-600
  - One flight A320 behind A380 to quantify thrust / glide slope effect.

- One of the flight was added by Airbus in order to have an idea of the difference of the vortex effect in normal law and with the autopilot, as the test encounters have been performed in roll direct law. In fact, it was one of the flight A320 behind A380 and A340-600 split in two parts.
Encounter test principle (1)

Encounter test consists of physically flying an aircraft through the wake of another to measure specific parameters, thus determining the actual separation to apply.

The follower aircraft flies encounters alternatively behind A380 and a suitable reference aircraft, with both wake generators flying side by side.
Many parameters recorded with focus on the following flight parameters:

- Altitude loss
- Vertical acceleration
- Roll rate
- Roll acceleration

Flight mechanic equations show that the roll acceleration is directly proportional to the roll moment created by the vortex and therefore represents its strength.
Flight test procedure
Comparison flight tests

A346 and A380 as wake generator
Constant track, speed and altitude

A346
A380
A320, A340-300

A380 and A346 wakes
made visible by oil injection

Follow relative flight path

A320, A340 as encounterer
usually horizontally through the wakes
at 10°-15° lateral encounter angle

Figure referenced to wake generating aircraft
Comment on the encounter tests

- Previous campaigns have shown that tests in normal law minimize the effect of the encounter. This is why it has been decided to perform all the tests in degraded law, stick free, in order to directly measure only the effect of the vortex.

- Degraded law used is called “alternate”, with direct roll control (stick free = roll surfaces at zero) and aircraft is laterally unstable. Pitch control is normal (stabilized) as all the tests demonstrated that effect in pitch is small.

- As the effect is amplified in roll during the tests, Airbus has decided to perform some encounters in normal law behind a “standard” Heavy, the A340-600, at different distances, in order to have an idea of the effect of the vortex in real life.
Preliminary raw data - Flight F4

A343 (AP Off, Alt2 law) behind A380 and A346

- Maximum absolute roll acceleration during WVE: \[|\frac{dp}{dt}|_{\text{max}}\]

\[|\frac{dp}{dt}|_{\text{max}}\] versus Separation Distance (data points, means and standard deviations)
Detailed analysis

- Analysis is performed first with a screening method developed by Airbus to validate the test points, including a very precise determination of the distance to the centre of the vortex.

- Another method created by Airbus called DWIM (Direct Wake Impact Method) is then applied to analyse all the data recognized as valid.

- It has been found that for a given rolling moment, the circulation could be different.
• Wake induced rolling moment versus circulation
  ‣ Despite a larger circulation, the impact of the A380 vortex can be identical to that of an A340-600.
Tests performed with the A320 behind A340-600 at 5 and 6 NM, out of ground effect, in normal law, stick free (more than 10 encounters at each distance), show that there is no real reduction of the severity when increasing the distance:

- 5 NM: max bank angle upset 30.4°, max roll rate 20.3°/s
- 6 NM: max bank angle upset 38.4°, max roll rate 17.6°/s
- No improvement for average values: max bank angle upset at 19.8° at 5 NM versus 22.1° at 6 NM.
Airbus comment:
Results given for a B707 generator. Other information from the report seems to show that the size of the generator (B747 versus B707) has no significant effect on the results.
Airbus and Boeing results in free air are similar:

- Large bank angle: 25 to 30°, behind A340-600 or B707.
- Only small decrease (if any) of this angle when increasing the distance.
- Only small decrease of roll rate with increased distance for both types.
- No information on roll acceleration for Boeing aircraft, but we can reasonably assume that it is similar to Airbus: only slow decrease with distance.
“Conclusions

...5. Data indicated that the wake generated in ground effect (1/4 to 1/2 span above the ground) does not form hazardous, tight vortices. Thus, wake turbulence is relatively weak near the runway in the landing flare or take off rotation area.”

P. M. Condit and P. W. Tracy (1970)
Airbus agrees with Boeing conclusion.

We have today several transport aircraft taking off and landing every second throughout the world (order of magnitude is one billion in ten years). If vortices close to the ground were as strong as those found in free air, we would have had several accidents. It is not the case, so the vortex in ground effect can only be weak as expressed by Boeing.

The explanation may not be obvious, but it is a fact.
Conclusions

- Data processing for the encounters flight test campaign of end 2010 is in progress.

- Specific encounters in normal law performed behind an A340-600, in free air, show rather strong encounters with only a slow decrease with increasing distance.

- These results are fully in line with Boeing results (1969 campaign).

- We also agree with Boeing that in ground effect the vortex can only be weak.