

Aviation ZephIR: lidar wind profiling and wake vortex detection

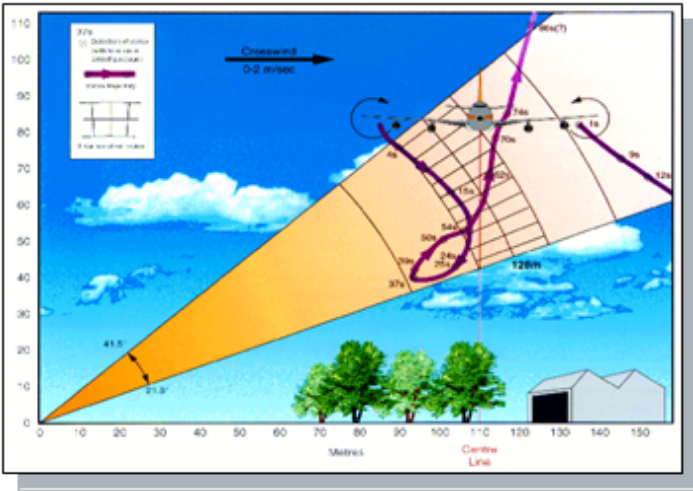
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and Dave Smith

QinetiQ Malvern

- **Reminder of what ZephIR does**
- **Aviation ZephIR: trials at UK airports**
- **Successful detection and tracking of vortices**



Airport / vortex trials with Doppler lidar



Heathrow 1994/5:

CO₂ lidar, nodding scan

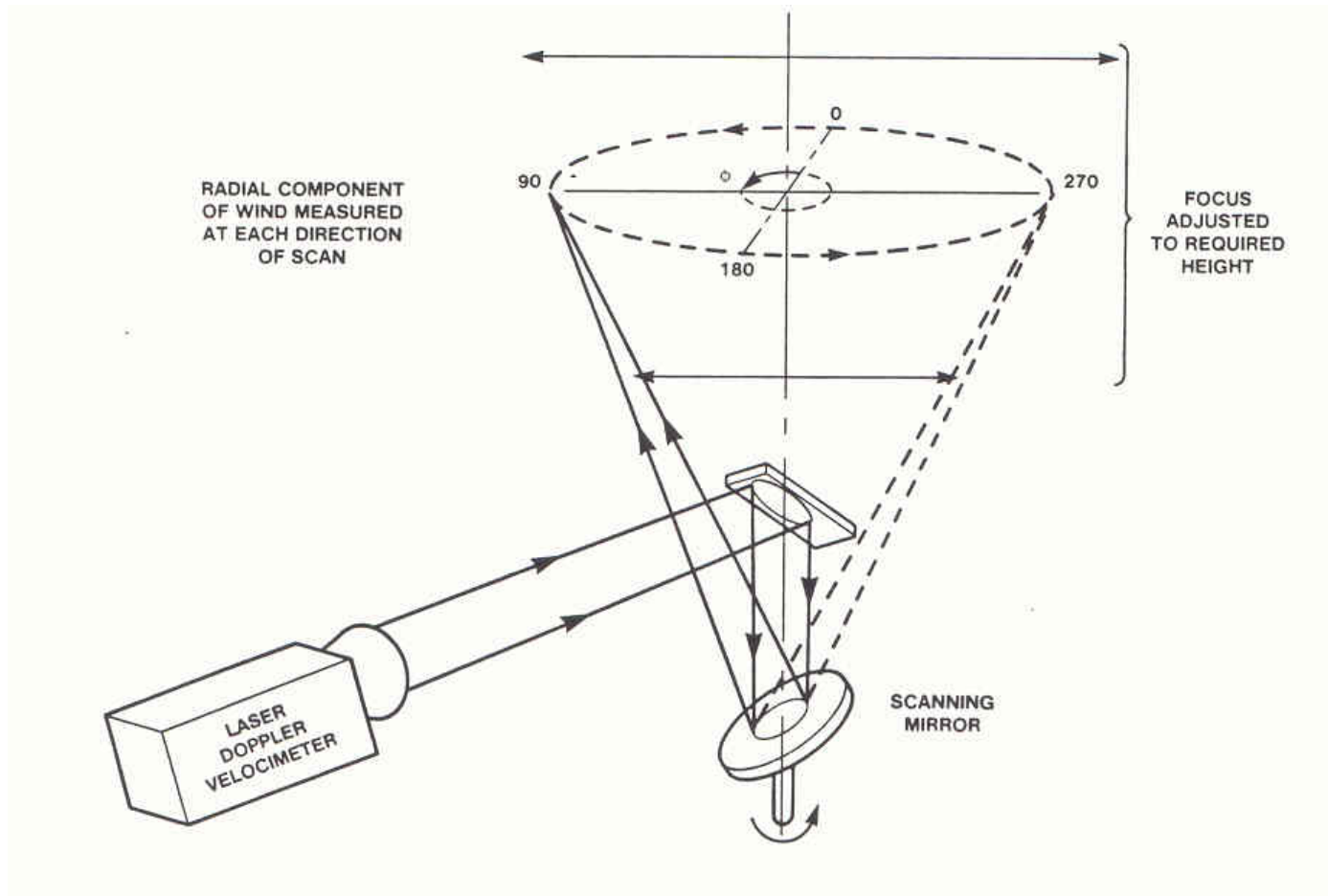
Toulouse 1998:

CO₂ lidar, nodding scan

**Birmingham and
Heathrow 2007 - 2009:
ZephIR, conical scan**

Conical-scan laser Doppler velocimeter (LDV):

CO₂ LDV was 1980s / 90s workhorse; ZephIR uses same principle



ZephIR™: a fibre-optic lidar wind profiler

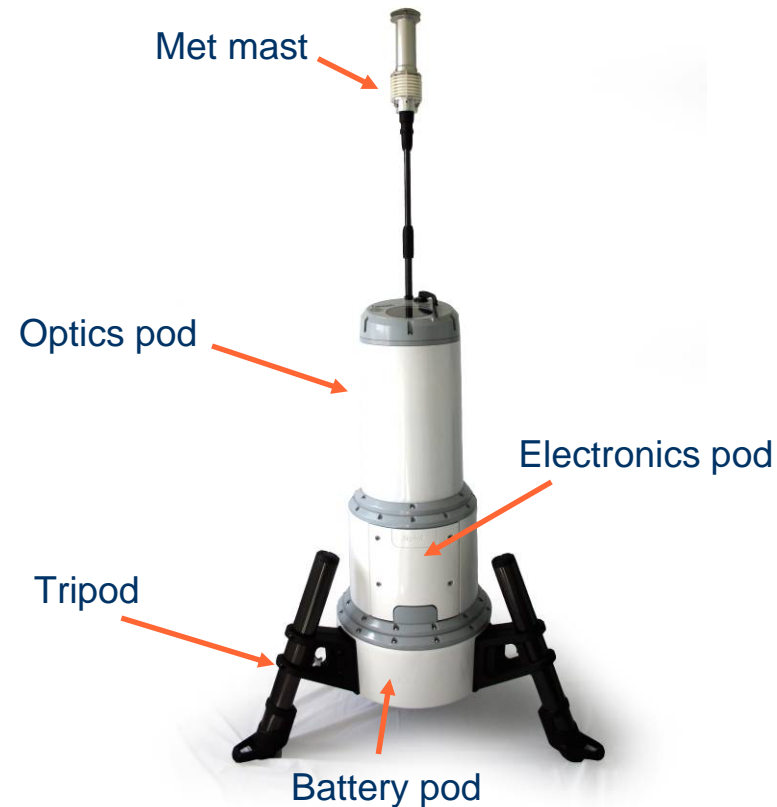
Builds up wind profile by measuring wind speed at chosen heights, 10 m - 200 m

Measures horizontal wind speed & wind direction, vertical wind speed, turbulence

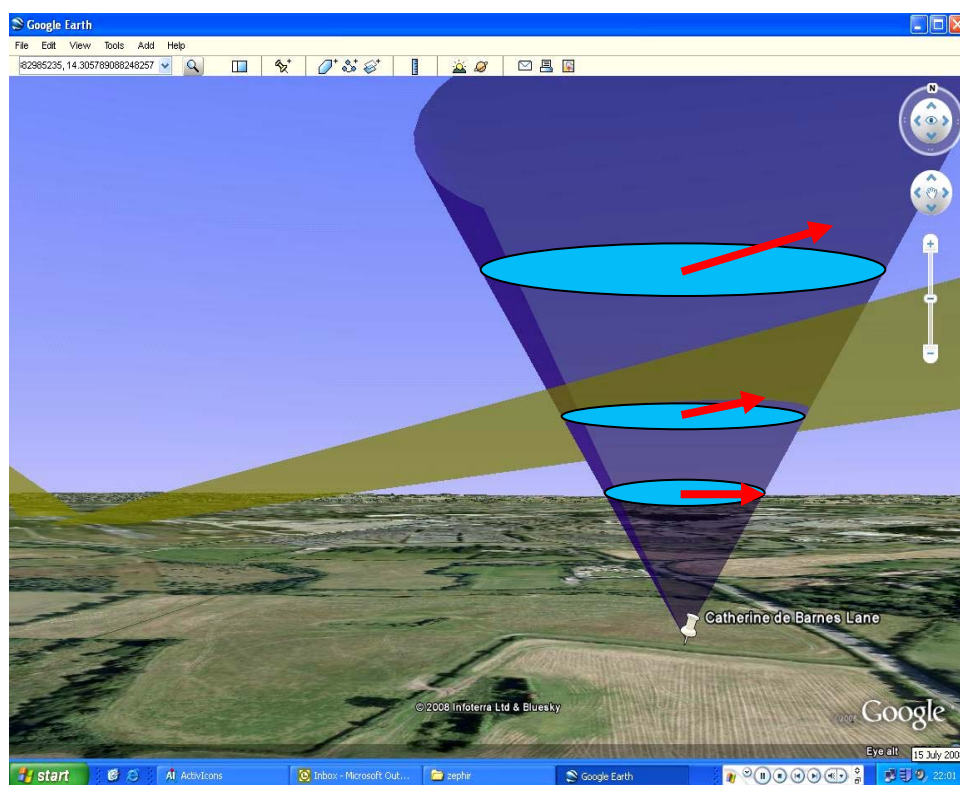
Overall height 1.5 m, mass 130 kg. Assembled and operational in under 1 hour

Independently assessed and compared with conventional anemometers and sodars

An accepted, validated benchmark for remote anemometry in the wind power industry



Aviation ZephIR: the ZephIR development for wind shear and wake vortex detection



3 trials at Birmingham Airport and 3 at Heathrow:

- Easily installed beneath the approach path
- Measured wind profile and shear at heights up to 150 m

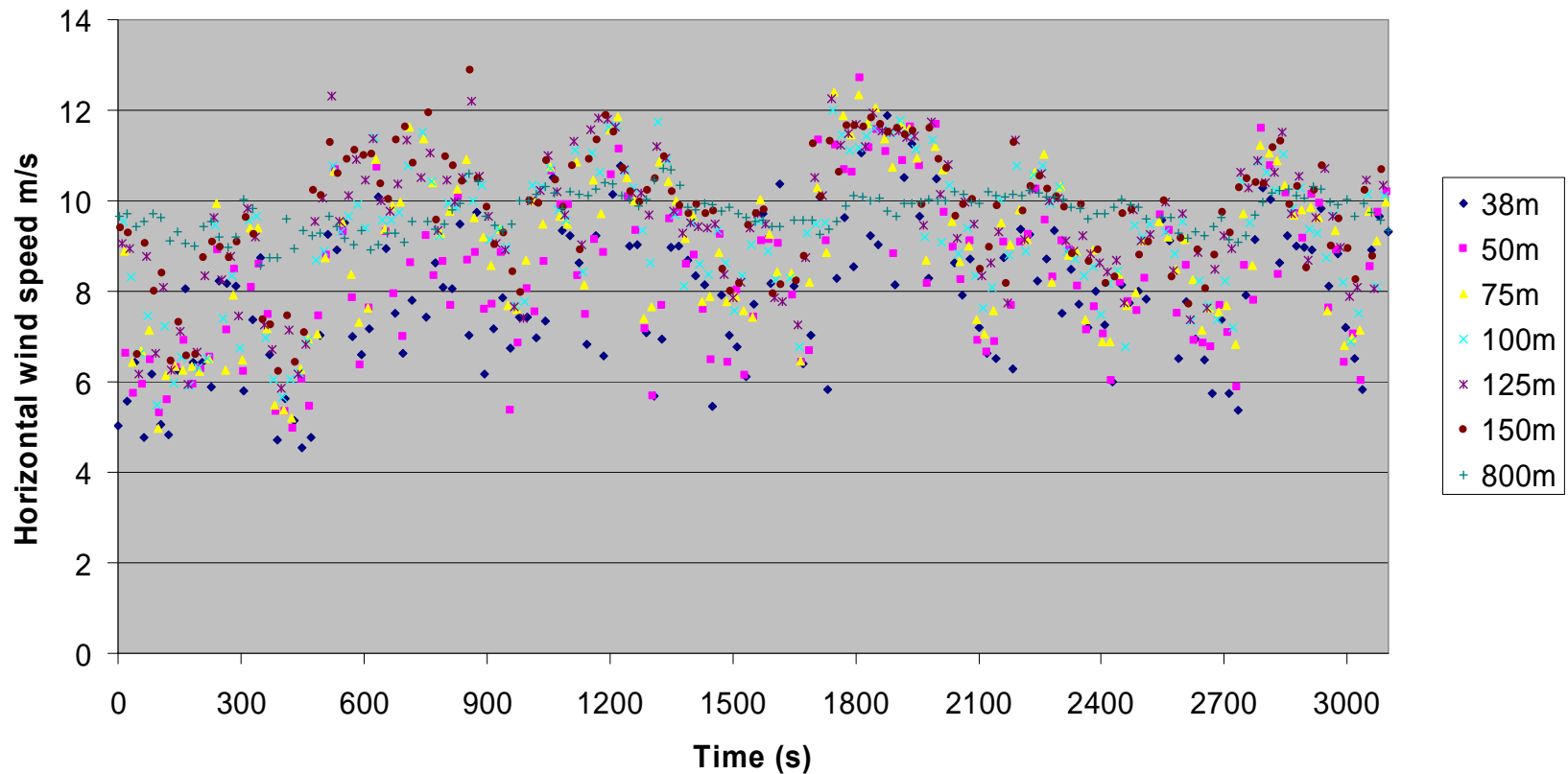
PLUS

- Recorded *wake turbulence* from several hundred aircraft arrivals

Conical scan intersecting glide slope at BHX

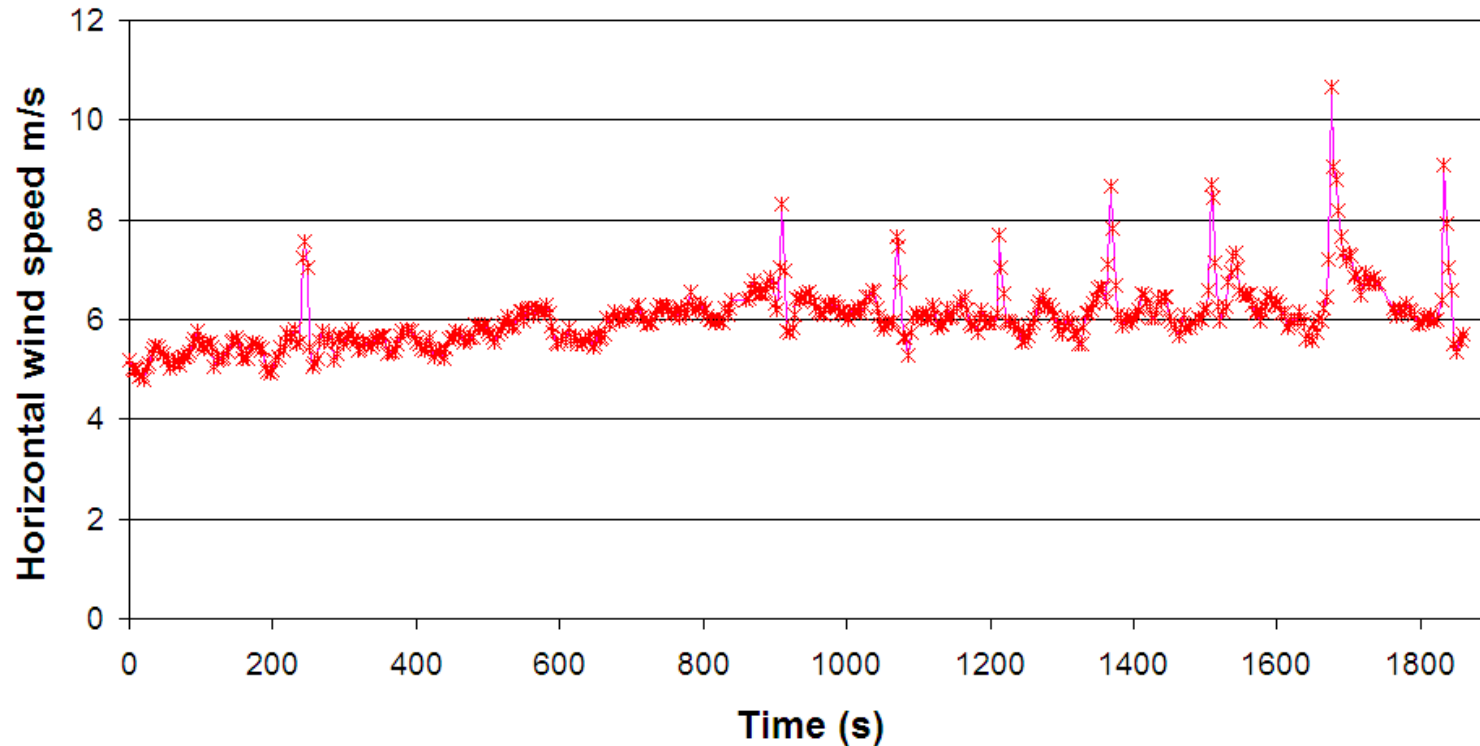
Aviation ZephIR: Standard profile, 25 m to 150 m altitude

Wind profile (horizontal speed) LHR 27R 20/08/08 1515



Aviation ZephIR: Wind speed on Heathrow glideslope at 90 m

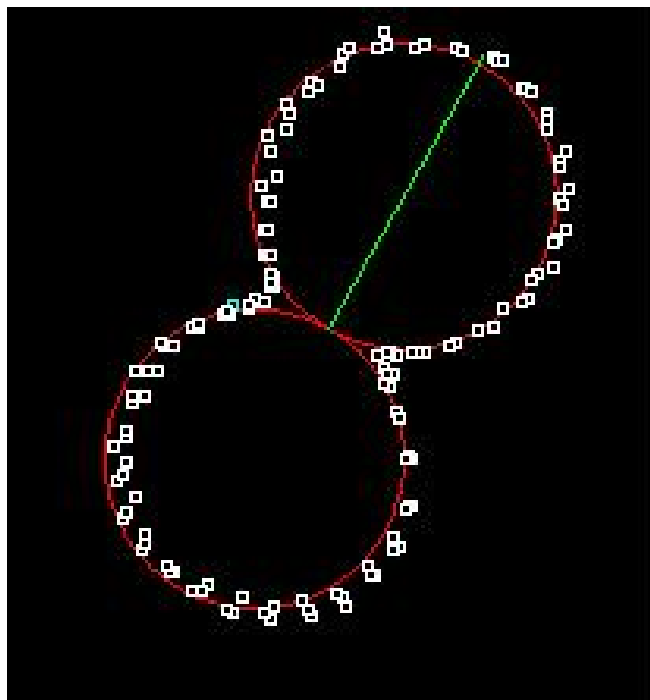
ZephIR lidar data for London Heathrow runway 27L
30 minute period (05:47 to 06:18 on August 21 2008)



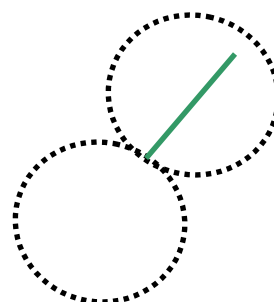
Aviation ZephIR: Pilot's view of LHR approach



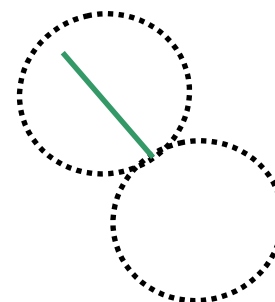
Wind measurement by ZephIR: interpreting “figures of 8”



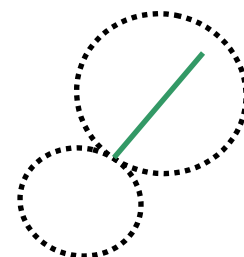
Undisturbed air:
a smooth “Figure of eight”



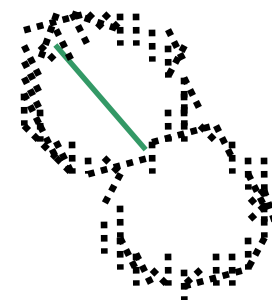
NE wind



NW wind

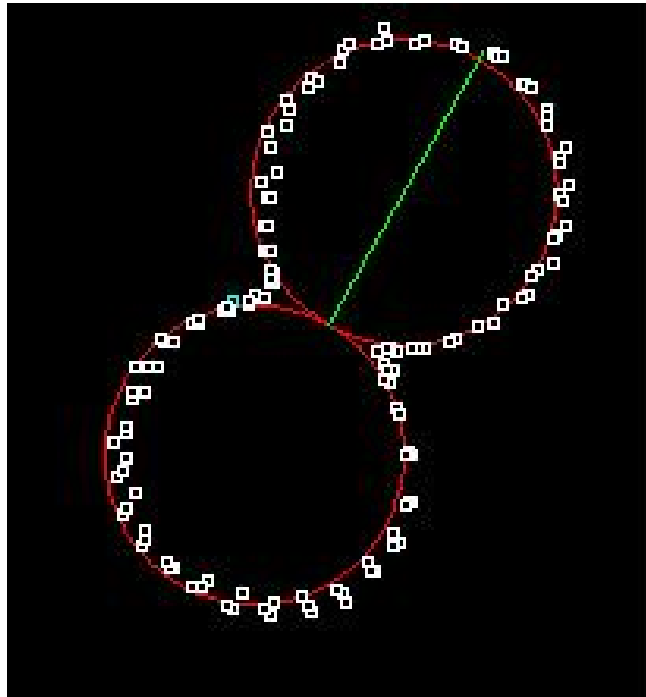


Vertical component



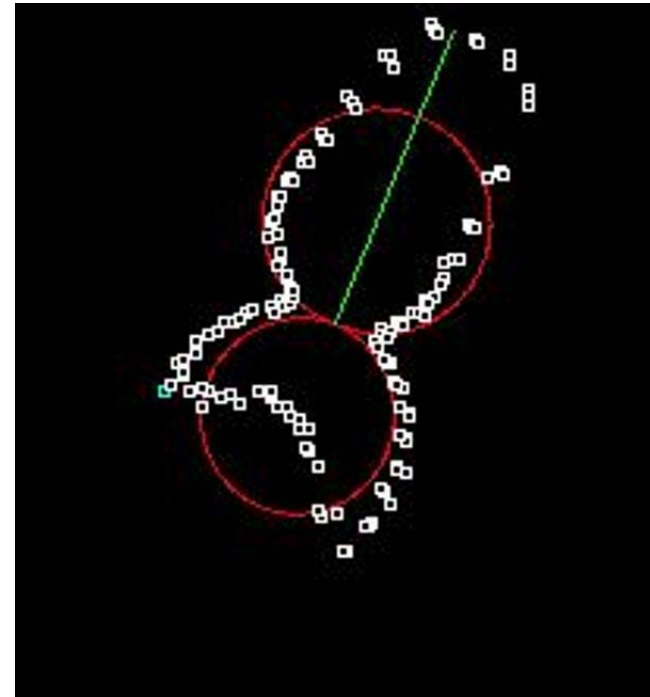
Turbulence

Vortex detection by Aviation ZephIR



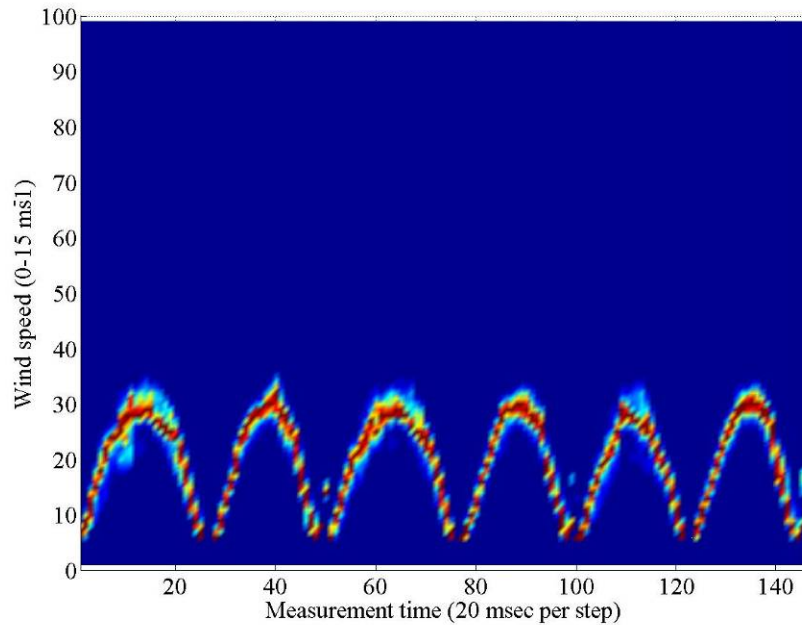
Undisturbed air

North
↗

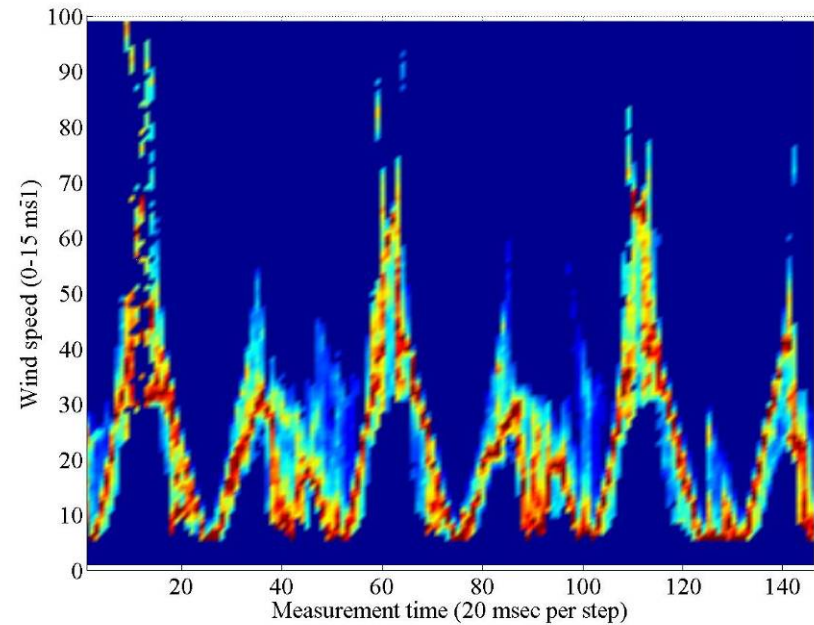


Vortex from Airbus
320

Southern approach to Birmingham (BHX)



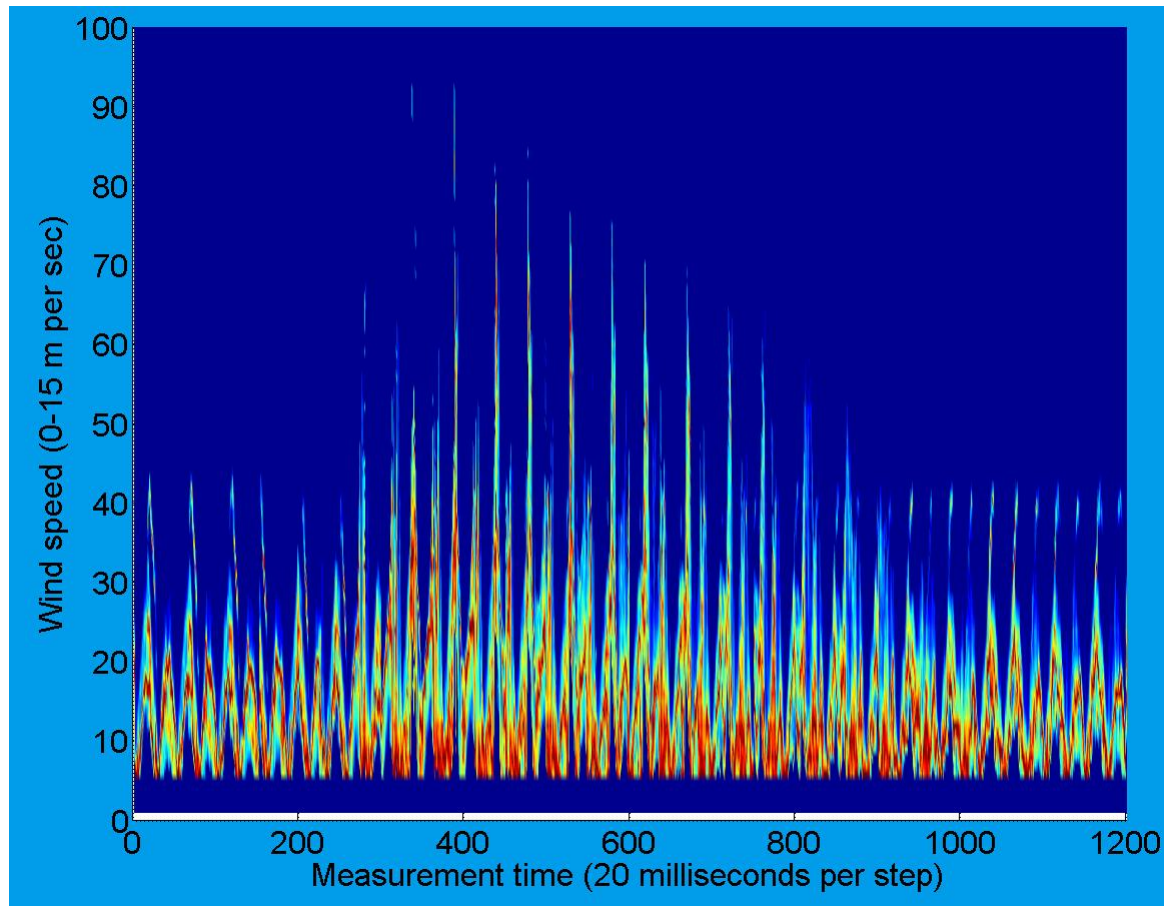
Undisturbed air



Vortices from B777

B777 at Heathrow 27L

**Wind speed
(0 – 15 m/s)**



LHR25_061200_detections

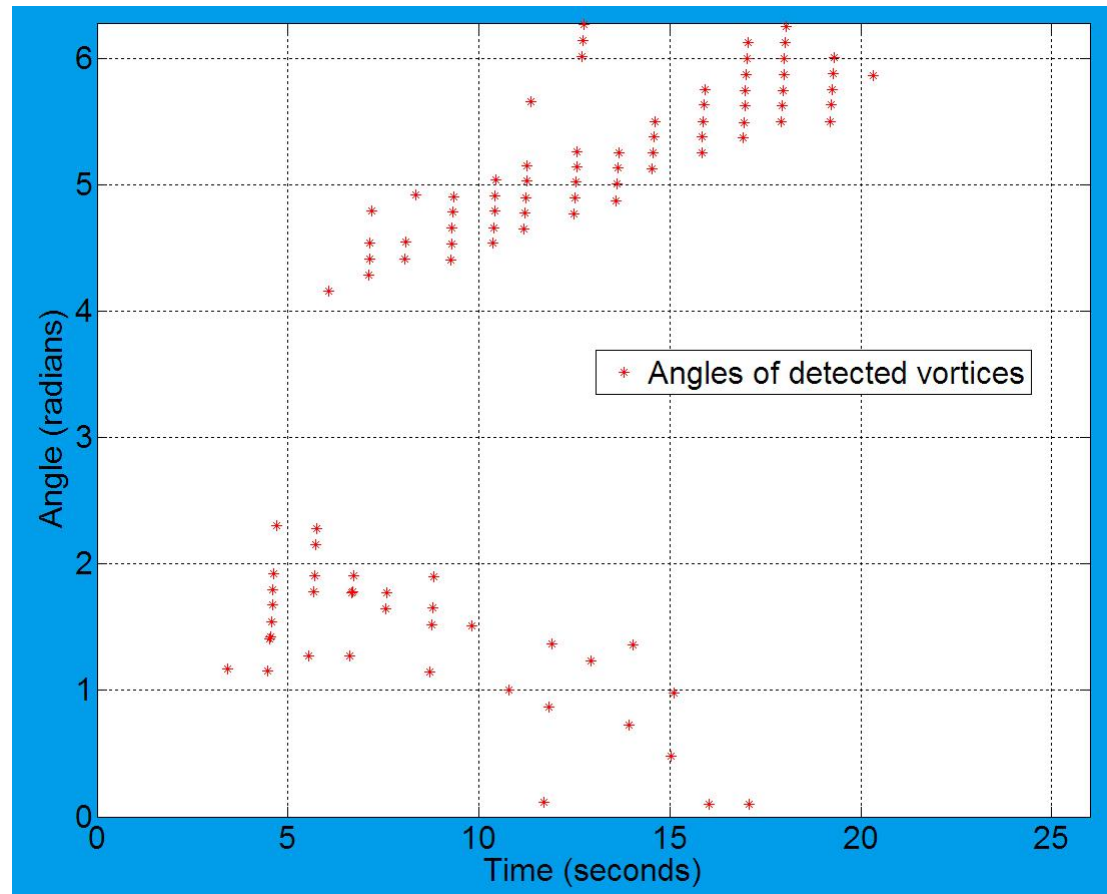
Time (0 – 23 seconds)

B777 at Heathrow 27L

2π

Angle in
conical
scan
(0 - 2π rad)

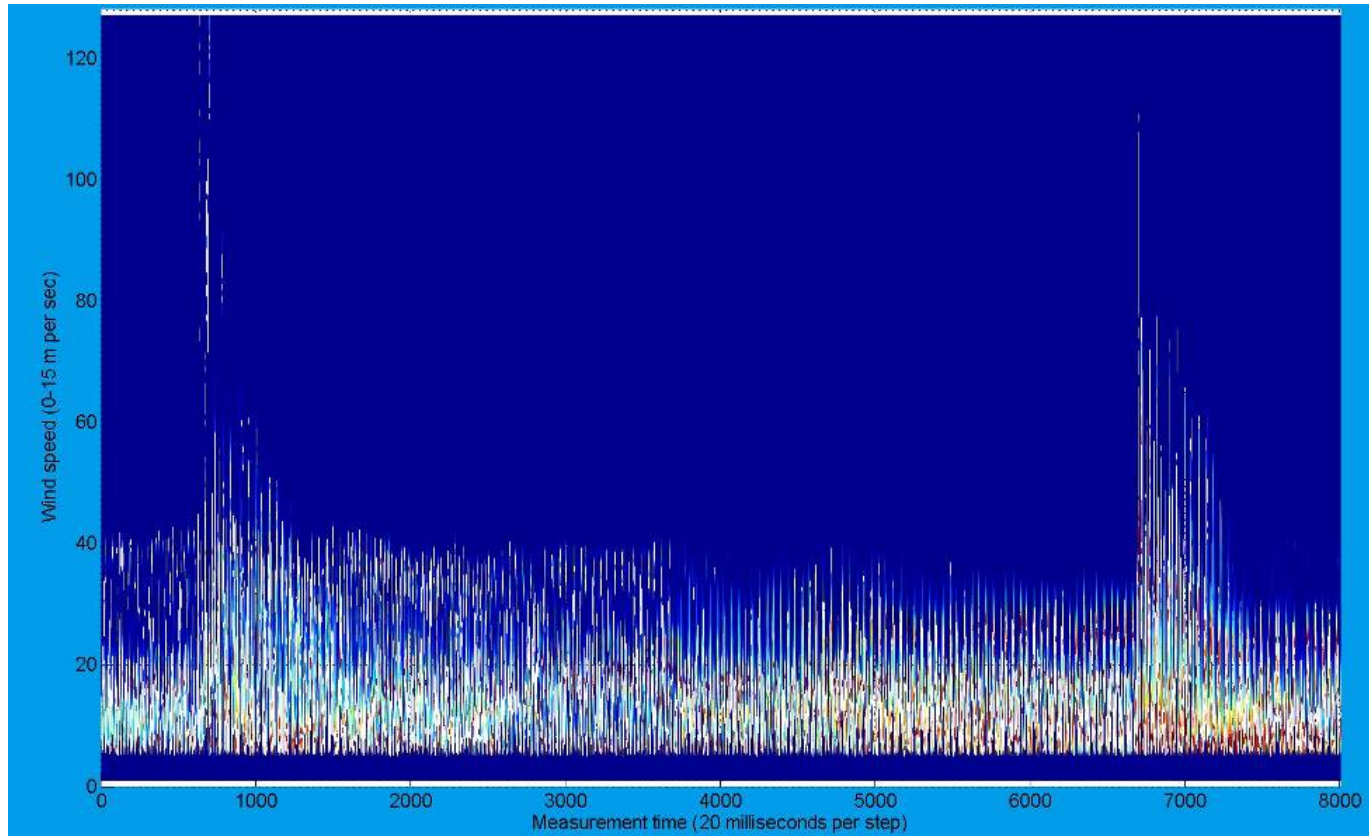
0



LHR25_061202_detections

Time (0 – 23 seconds)

A380 followed by B747 at LHR



Aviation ZephIR: Benefits

- **Minimum measurement range ~ 10 m (pulsed lidars have a “dead zone” of tens of metres)**
- **Range resolution maximised at lower altitudes (critical regions for some aviation applications)**
- **50 measurements per one-second conical scan (7° interval):**
 - **Redundancy – we can afford to lose some measurements**
 - **Verification of uniform flow assumptions**
 - **Vortex tracking through scan cone**
- **Wind profiling assists prediction of vortex motion outside field of view**

Recent Improvements

Range increased from 150 m to 200 m:

- **Detailed checks vs mast anemometers**

Low-noise laser + improved processing:

- **Smaller insensitive region near zero Doppler**

Direction-sensing:

- **New hardware: +/- sign of Doppler explicitly measured for each angle = WindScanner project at Risø for 3D wind profiling**
- **New software: wind direction obtained from scan-to-scan correlation**

Aviation ZephIR summary

A calibrated and validated remote anemometer

- No masts – Easy to deploy – Eyesafe
- Low maintenance – Optically and mechanically simple
- Range 10 m to 200 m

Fills a gap in the critical areas for airport sensors

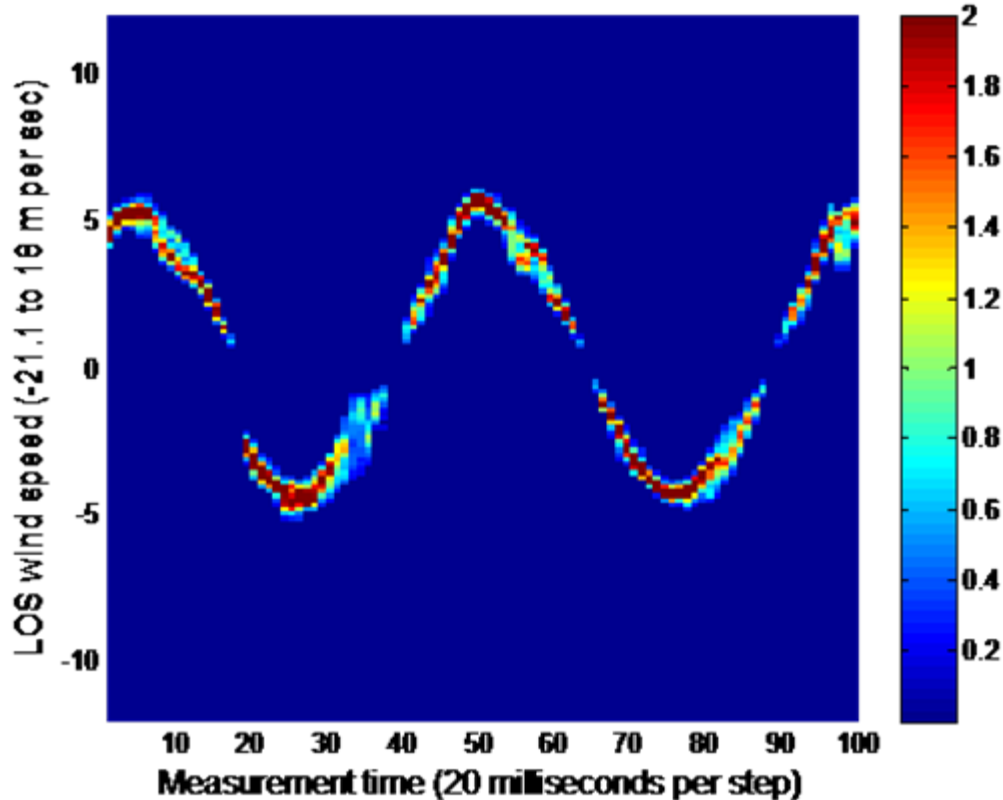
Measures wind vector in real time on the glide slope

Detects and tracks vortices

Acknowledgements



Conical scan with direction-sensing ZephIR

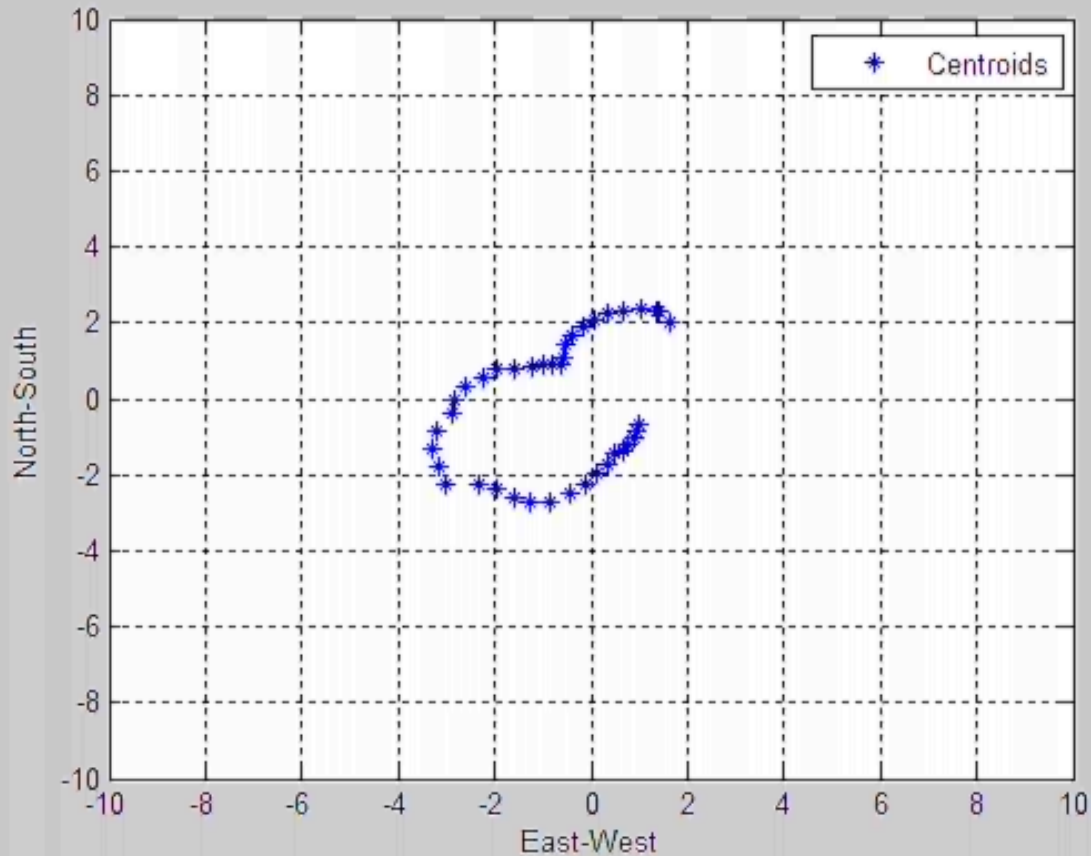


Both +ve and -ve frequency bins are available

Least-squares fitting routine uses signed quantities rather than magnitudes

B777 at Heathrow 27L

North



Aviation ZephIR: Pilot's view of BHX approach

