Brunel
UNIVERSITY
WEST LONDON

Latest from Spin Research at Brunel

Rein Inge Hoff

Spin testing the Super Emeraude

Literature review revealed..

- No reliable risk reduction method exist
  - Incremental, careful flight test approach
- Simplistic methods still being recommended for aircraft design, despite proven to be highly inaccurate
- Several cases of test pilots bailing out of prototypes due to unrecoverable spins

"Small changes might have a big impact"

Spin Research Programme

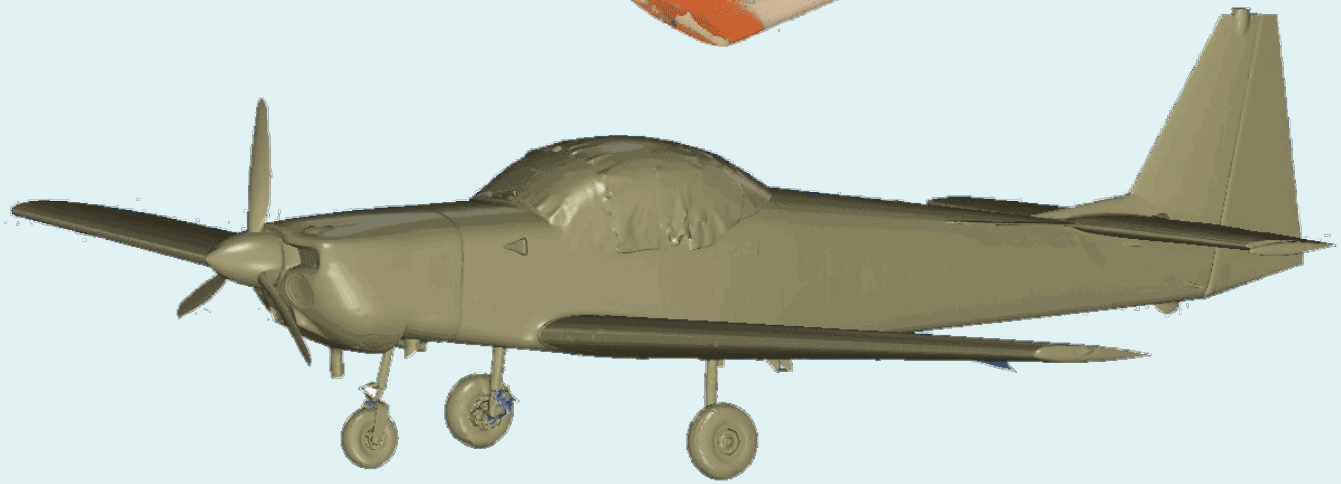
- Camera tracking: capturing the spin motion
  - Laser scan of aeroplane
  - Video imagery from helicopter chase
  - Camera tracking and visualization software

- The aerodynamic flow over wings and empennage
  - Tufts
  - Smoke
  - Several on-board cameras
  - Helicopter chase cameras

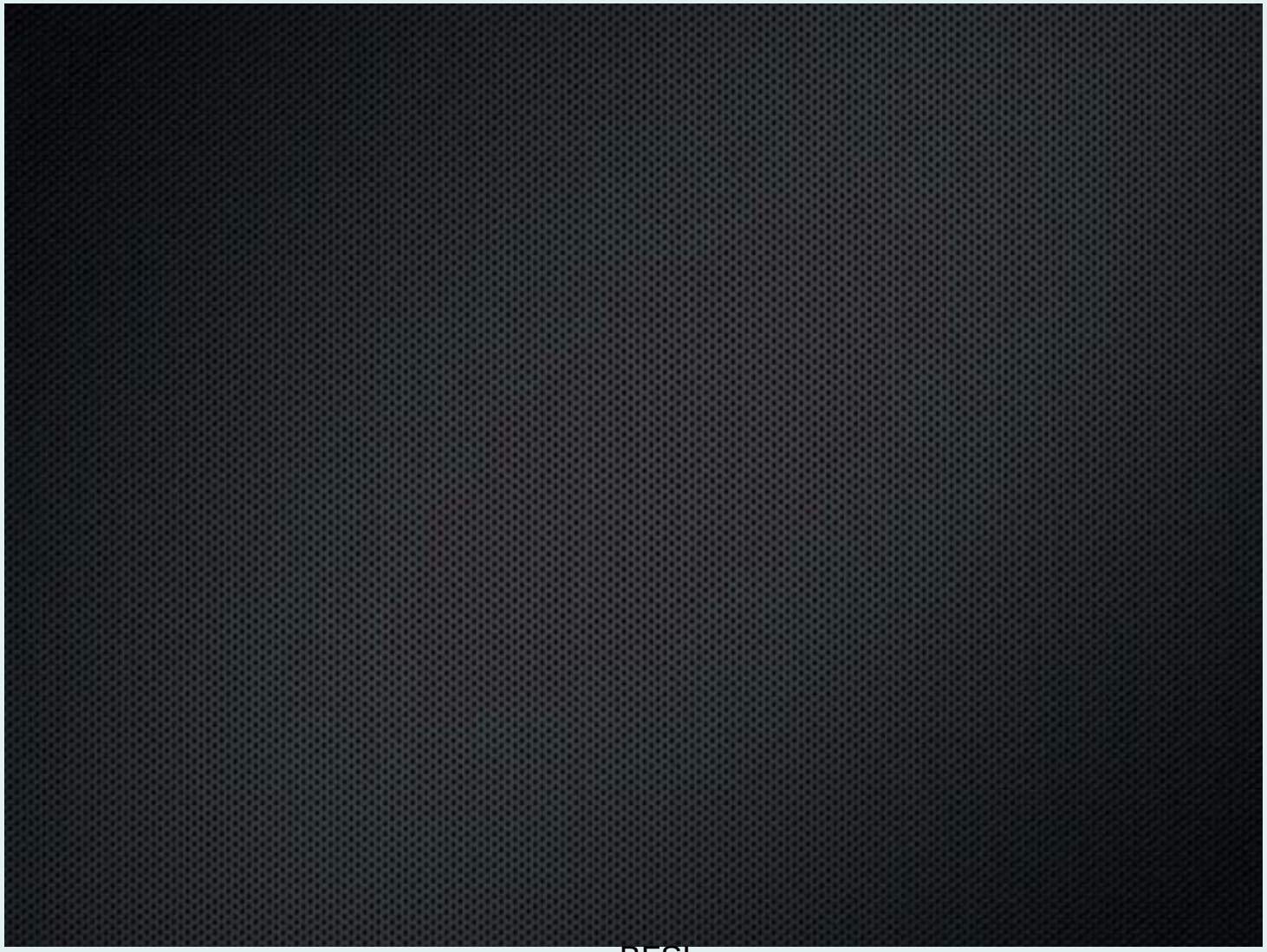
Creating the CAD model

- Slingsby Firefly laser scanned in the hangar

- 9 scan positions, 29.9 million points on aeroplane

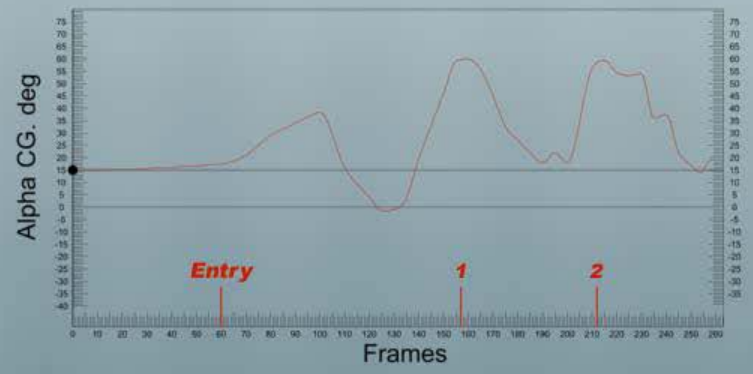


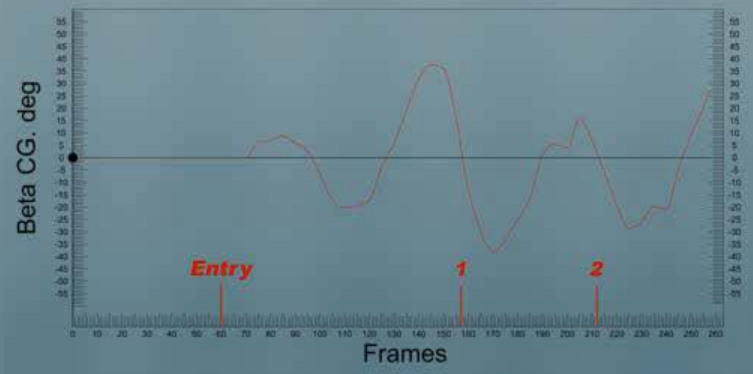
Video imagery from chase aircraft

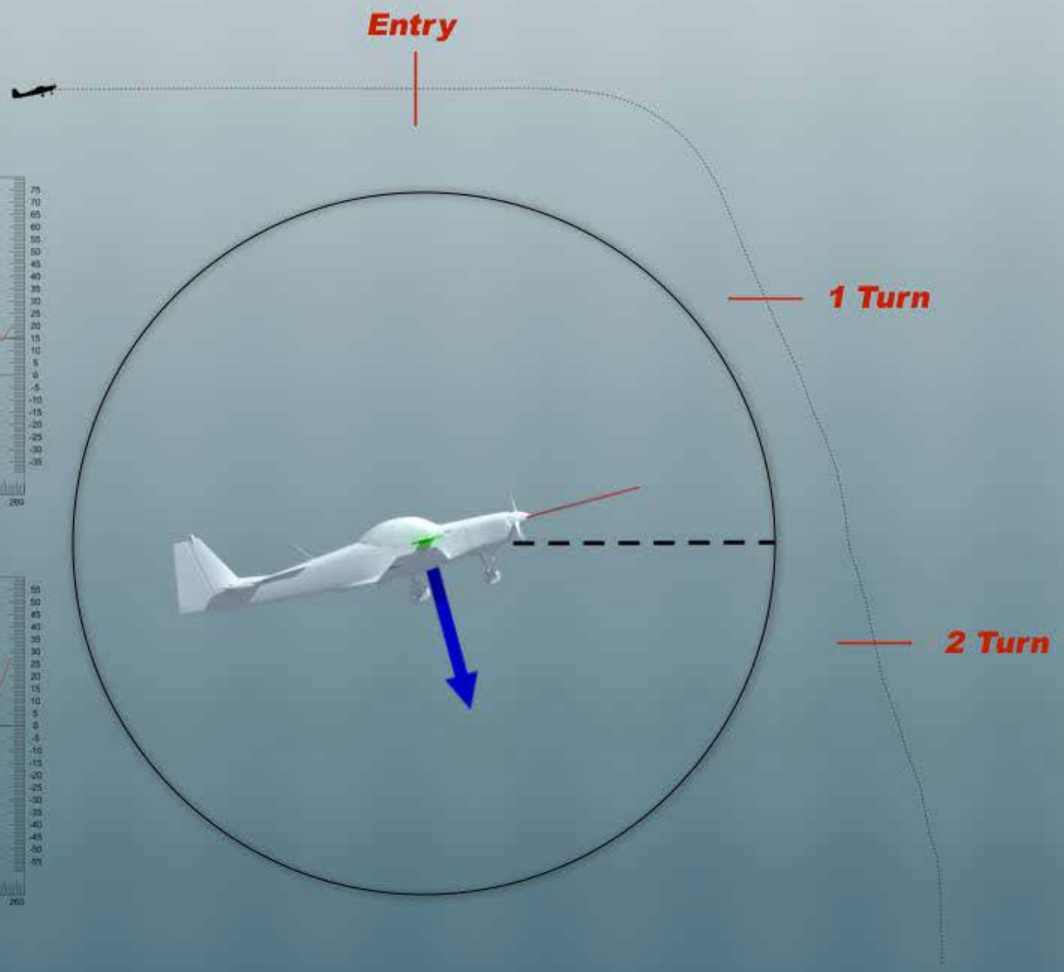


Camera tracking

Left, 2-turn spin





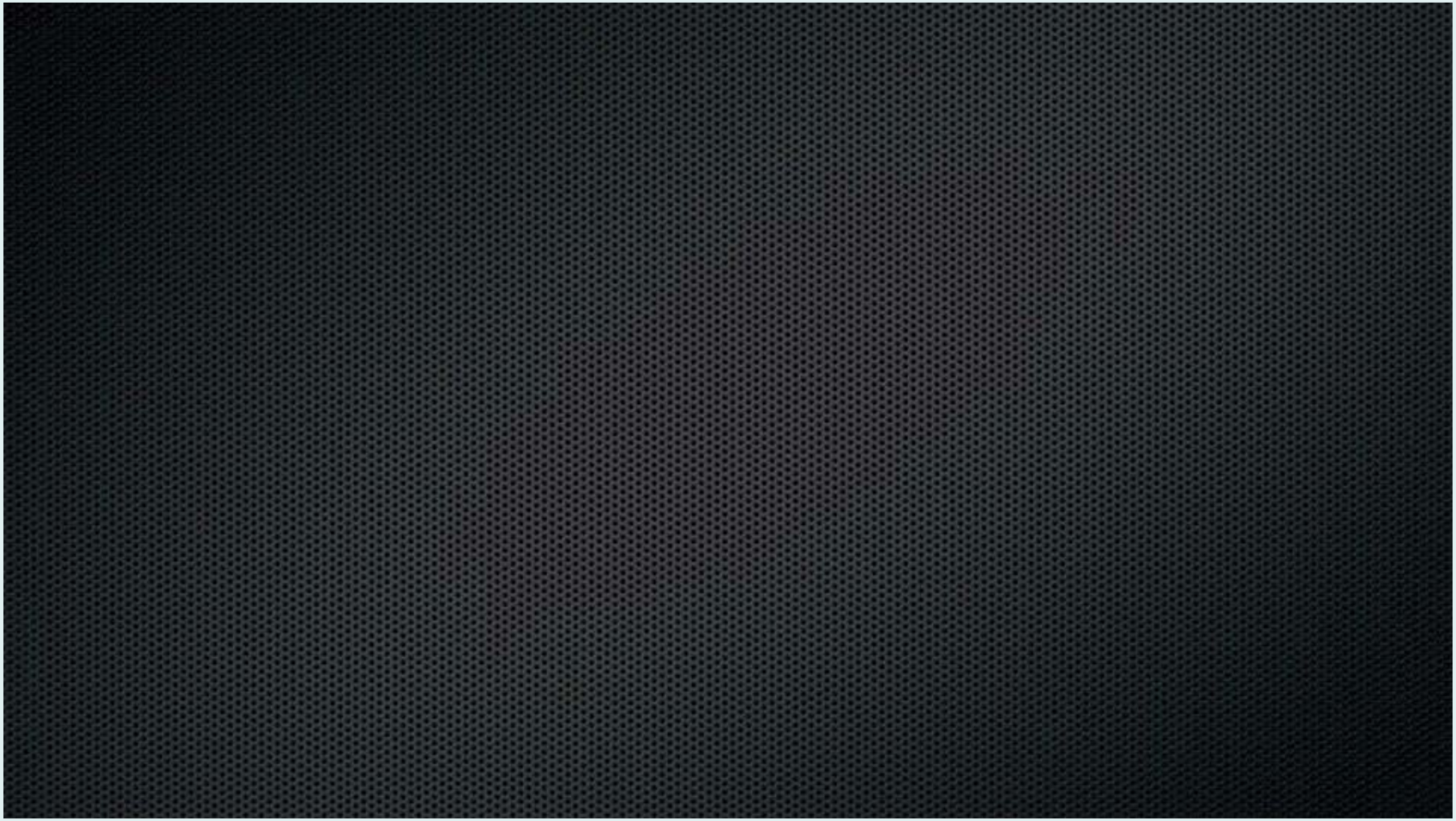


Qualitative assessment of the flow

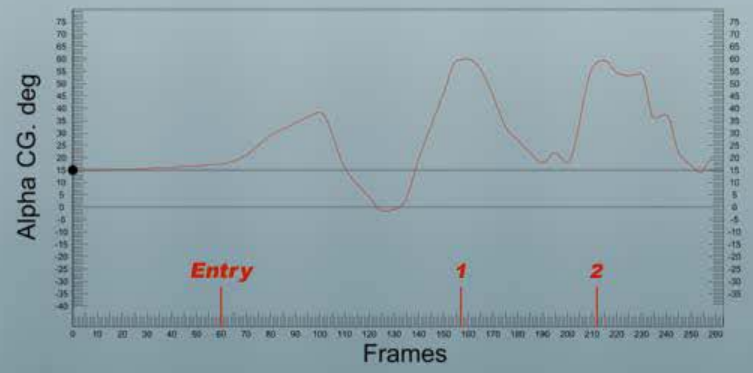
- In-flight photographing of wool tufts using multiple cameras
- Areas of particular interest: airflow over wings and tail

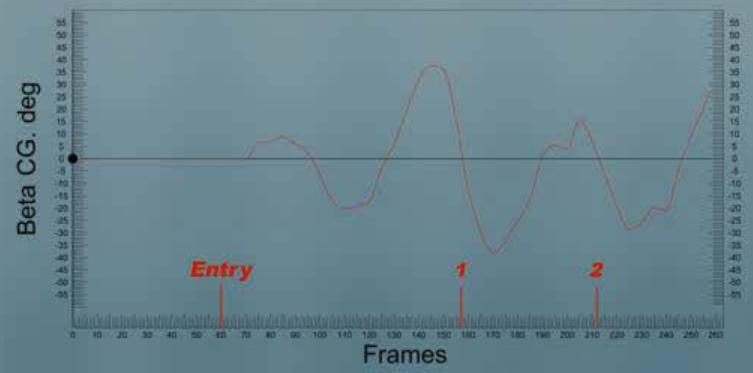

LN-TFF

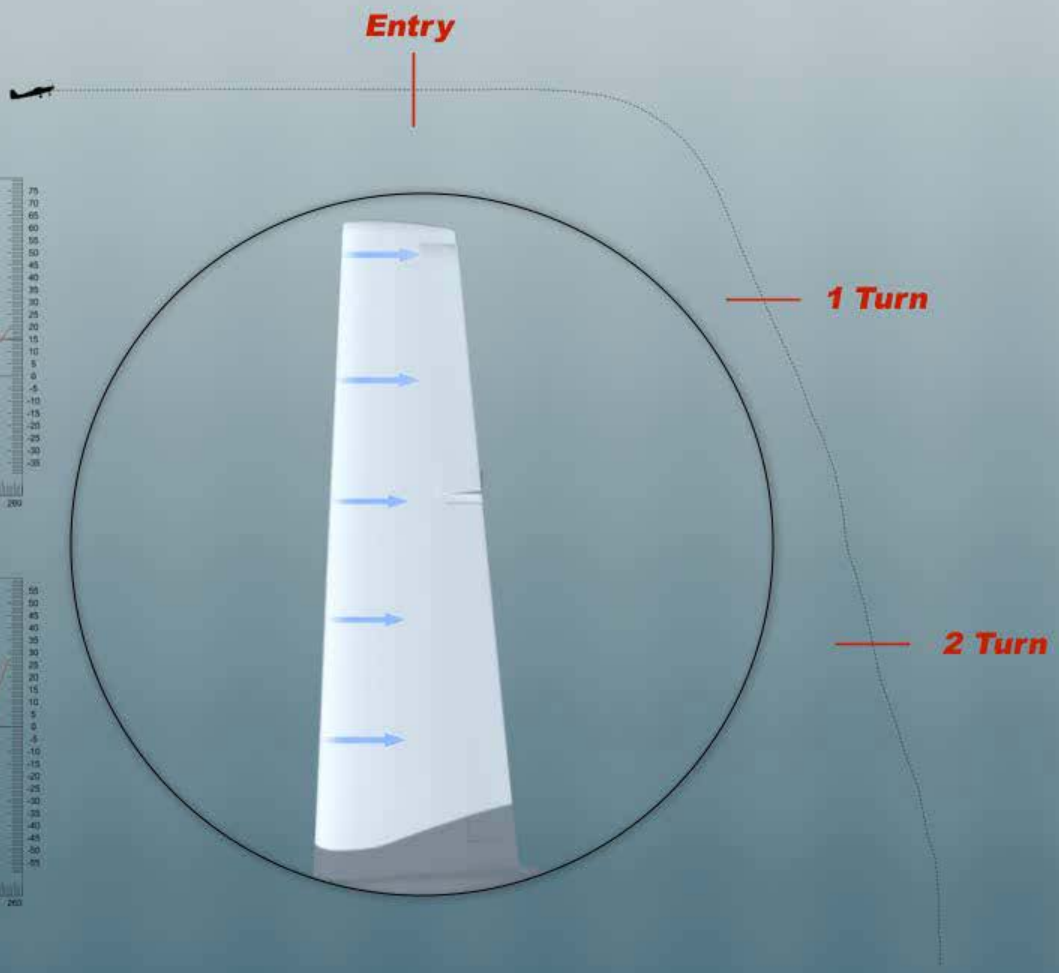
Vortex Visualization – tufts 1/10 speed Slingsby Firefly



Left, 2-turn spin (slow speed)

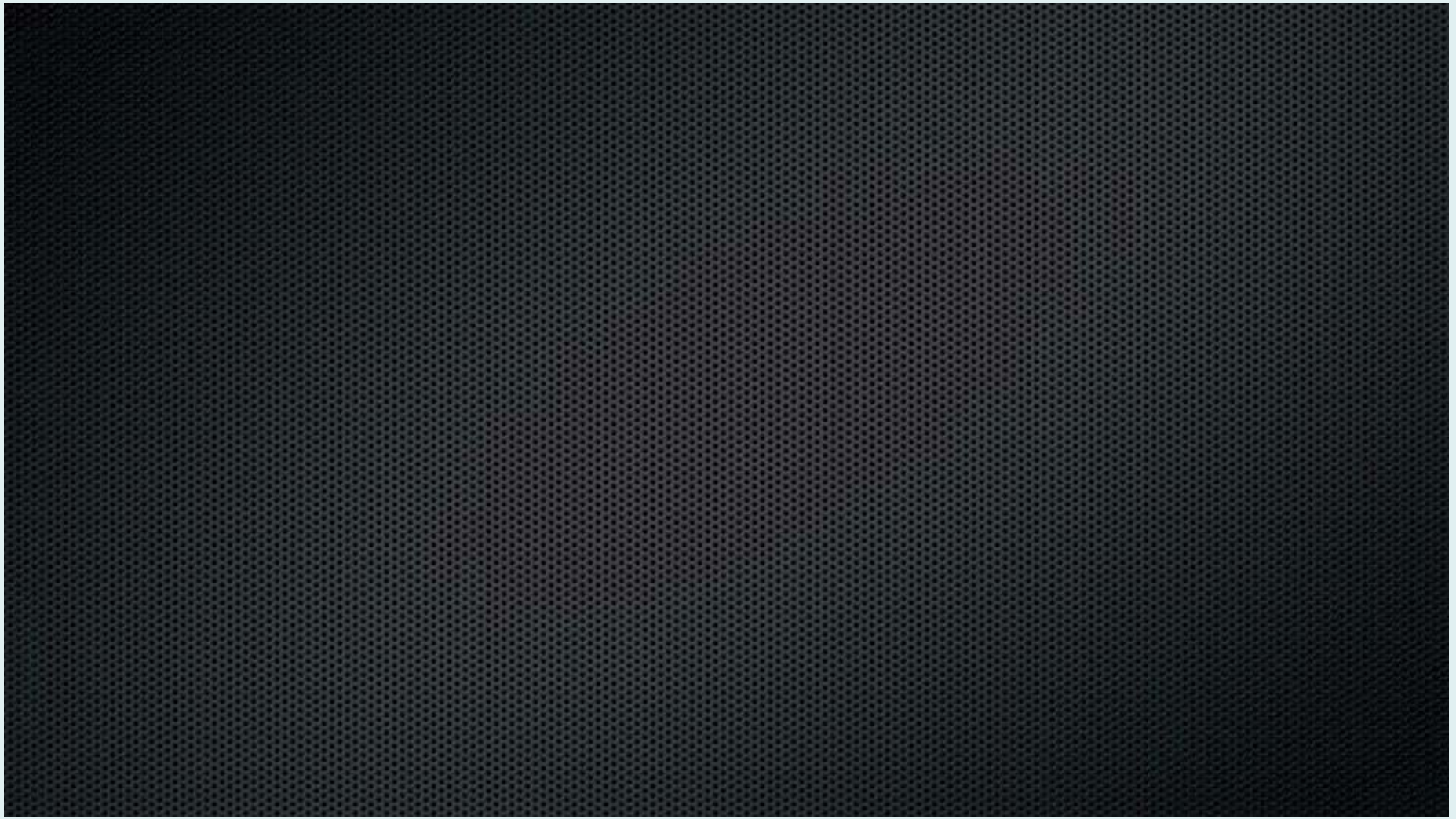


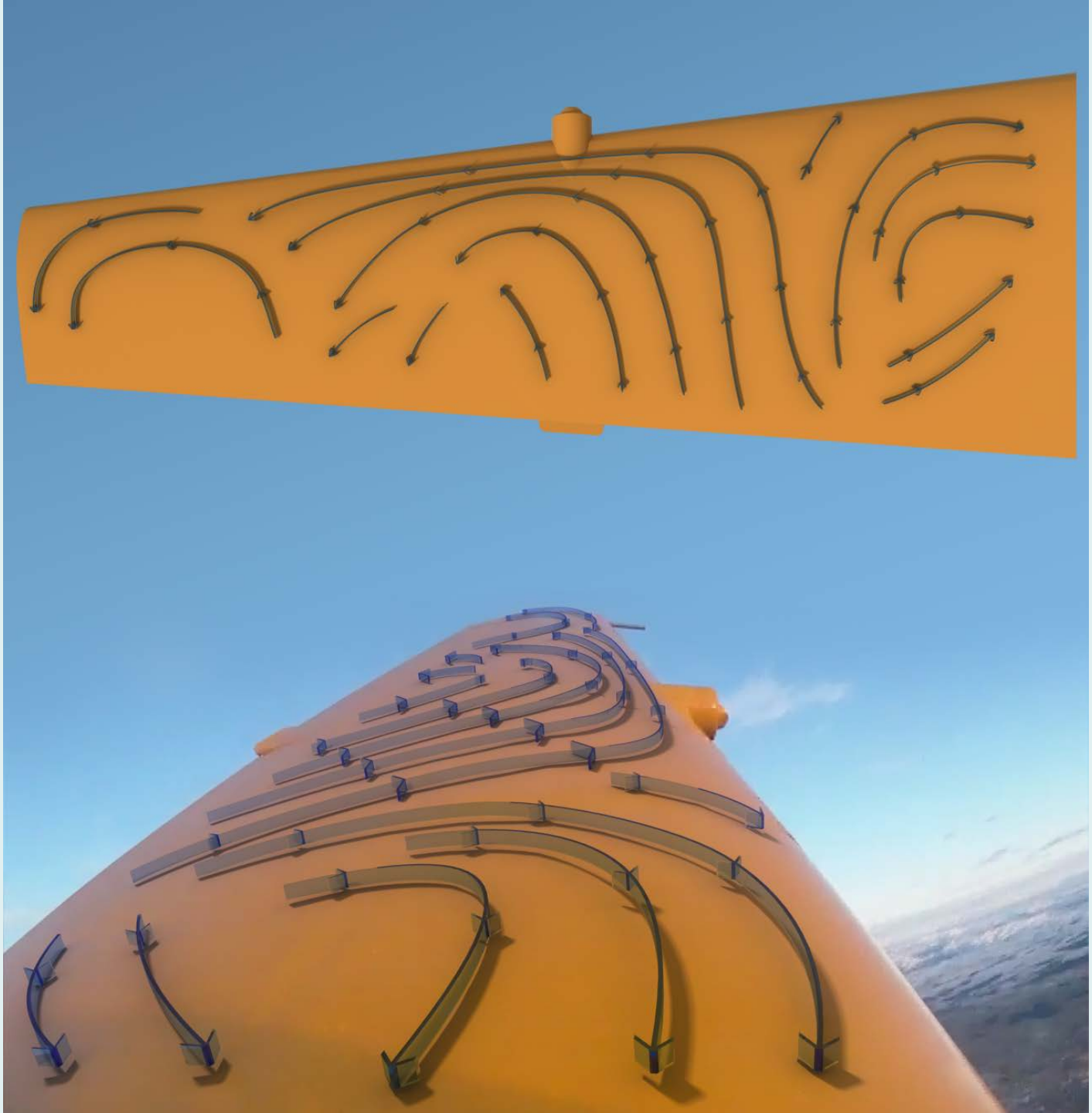




Saab Safir

Vortex Visualization – tufts 1/10 speed
Saab Safir





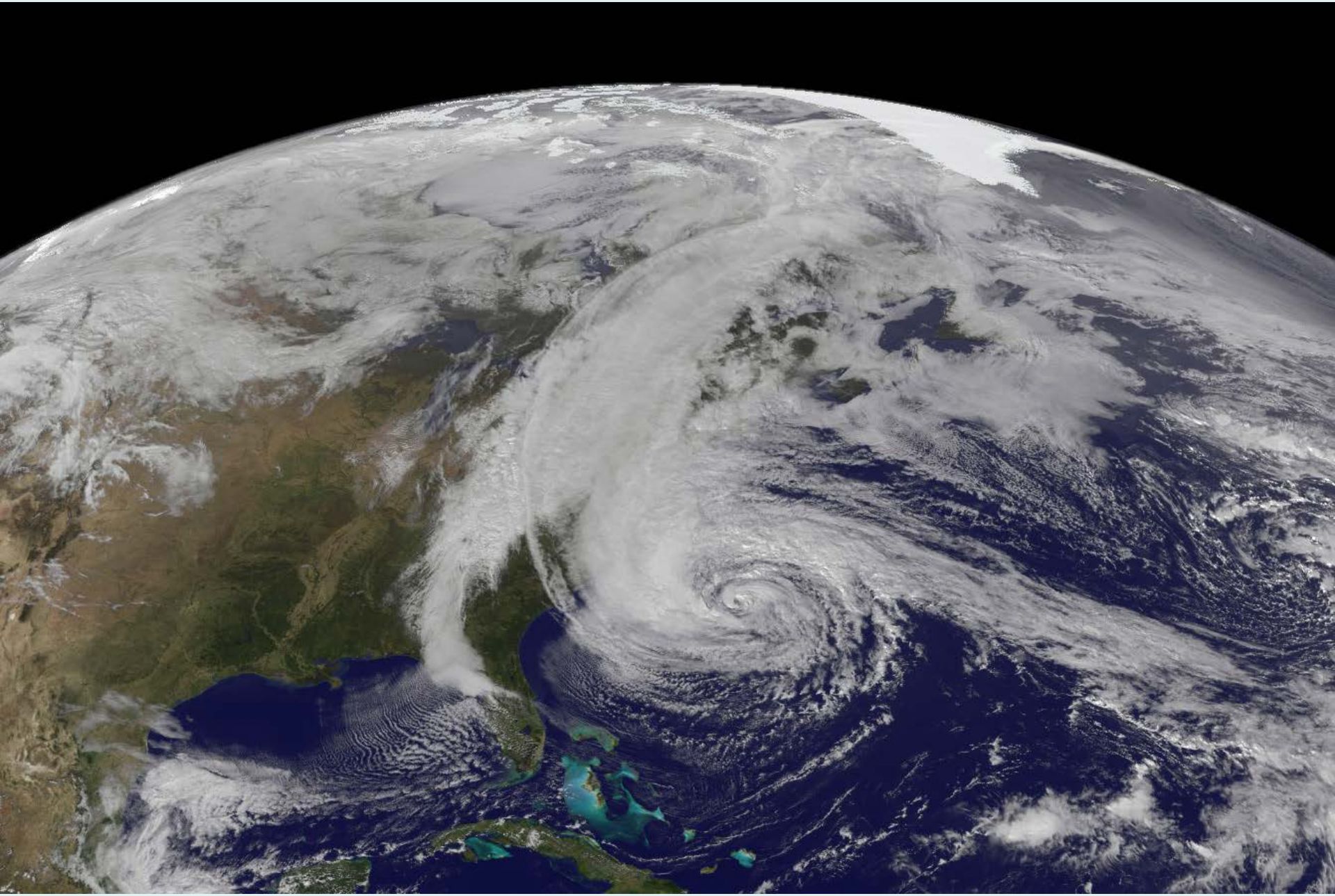


Image: GOES-13, NASA

The breakthrough in understanding?

- The aeroplane in a spin must be considered as a rotating frame of reference
- The centrifugal, Coriolis and Euler accelerations do affect particles moving in a rotating system
- Hypothesis:
  - The turbulent layer on the upper surface, on the outside wing of a spinning aeroplane, is accelerated due to additional, spin induced accelerations

Additional acceleration terms

- Coriolis acceleration varies with rotation rate and flow velocity:

$$-2\Omega \times v_u$$

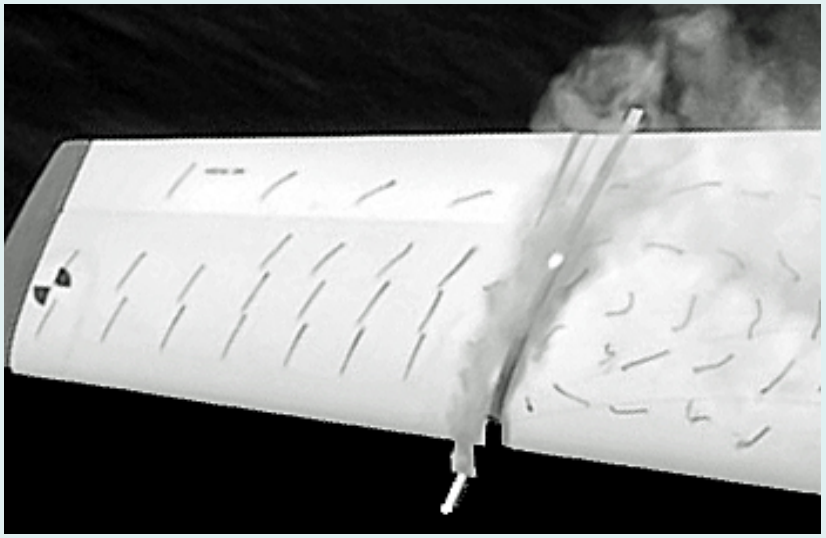
- Centrifugal acceleration varies with rotation rate squared and radius:

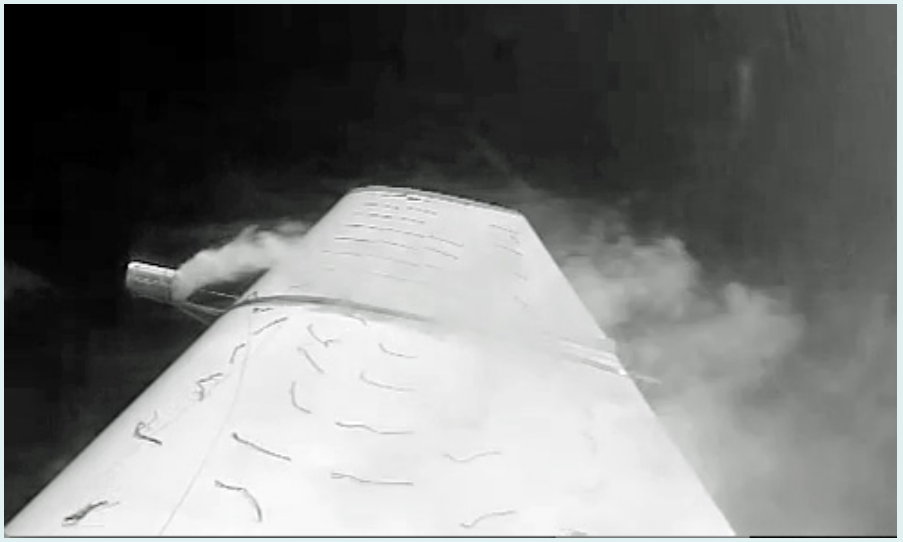
$$-\Omega \times (\Omega \times r)$$

- Euler acceleration varies with time derivative of rotation rate and radius:

$$-\dot{\Omega} \times r$$

Vortex Visualization using smoke



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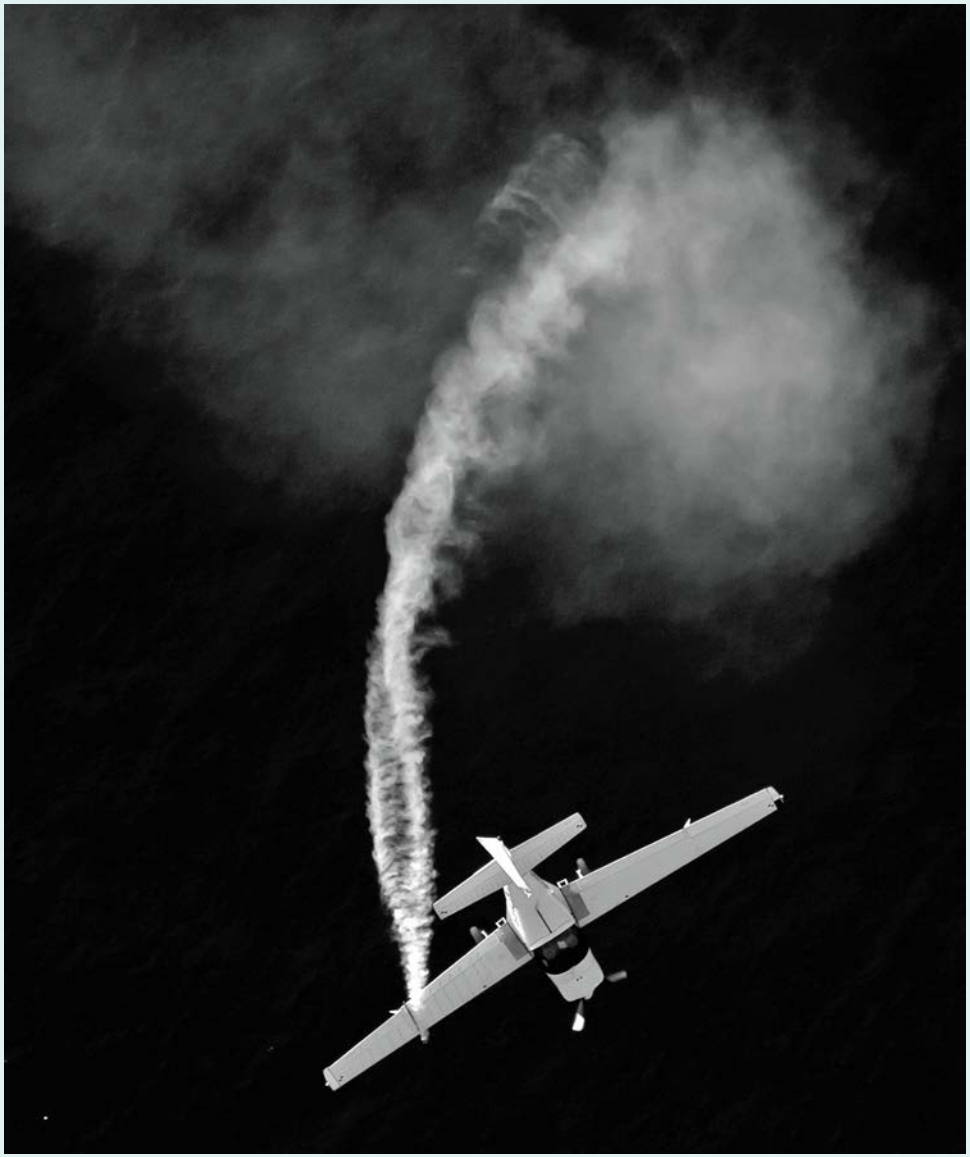
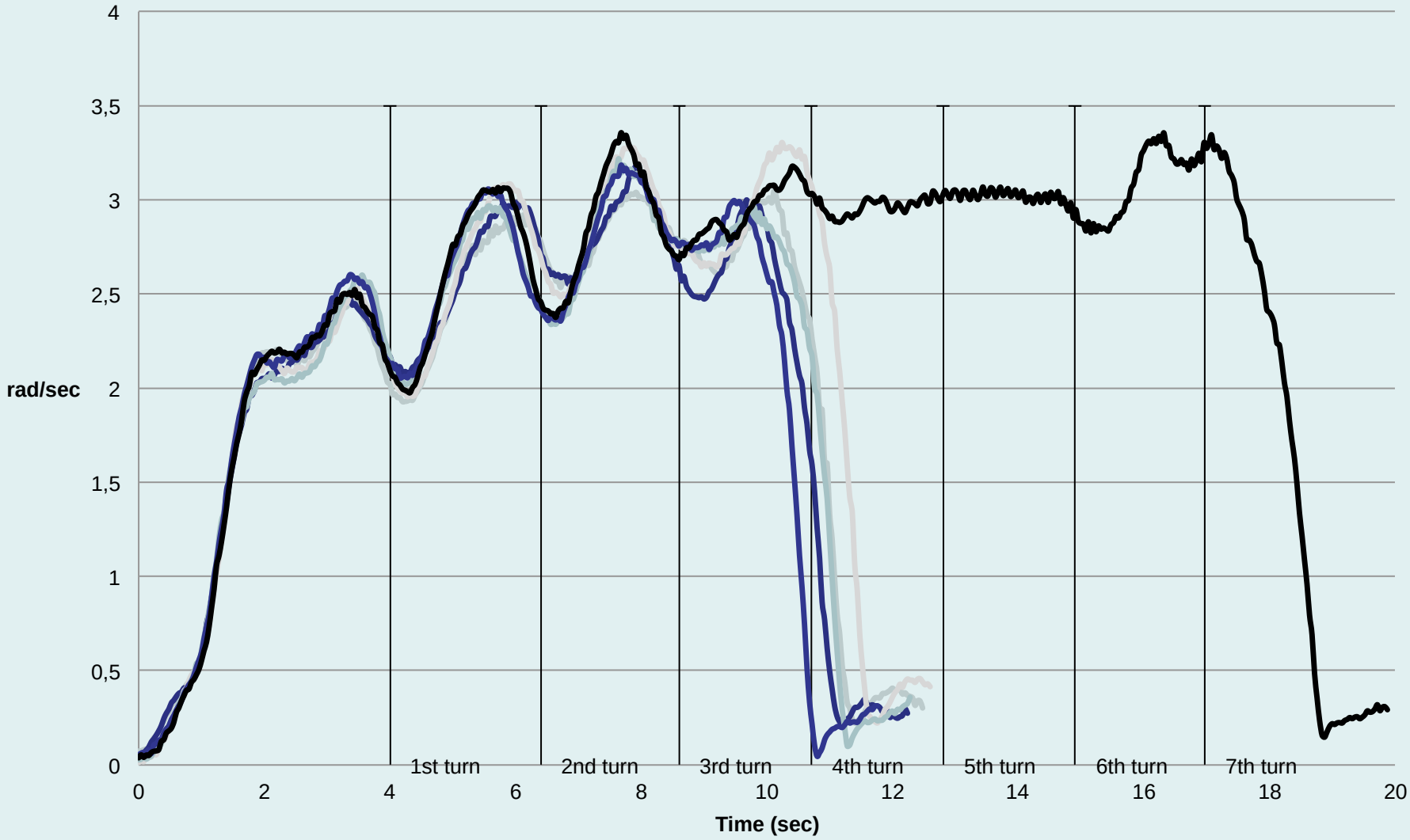


Omega - Saab Safir, Right Hand Spins

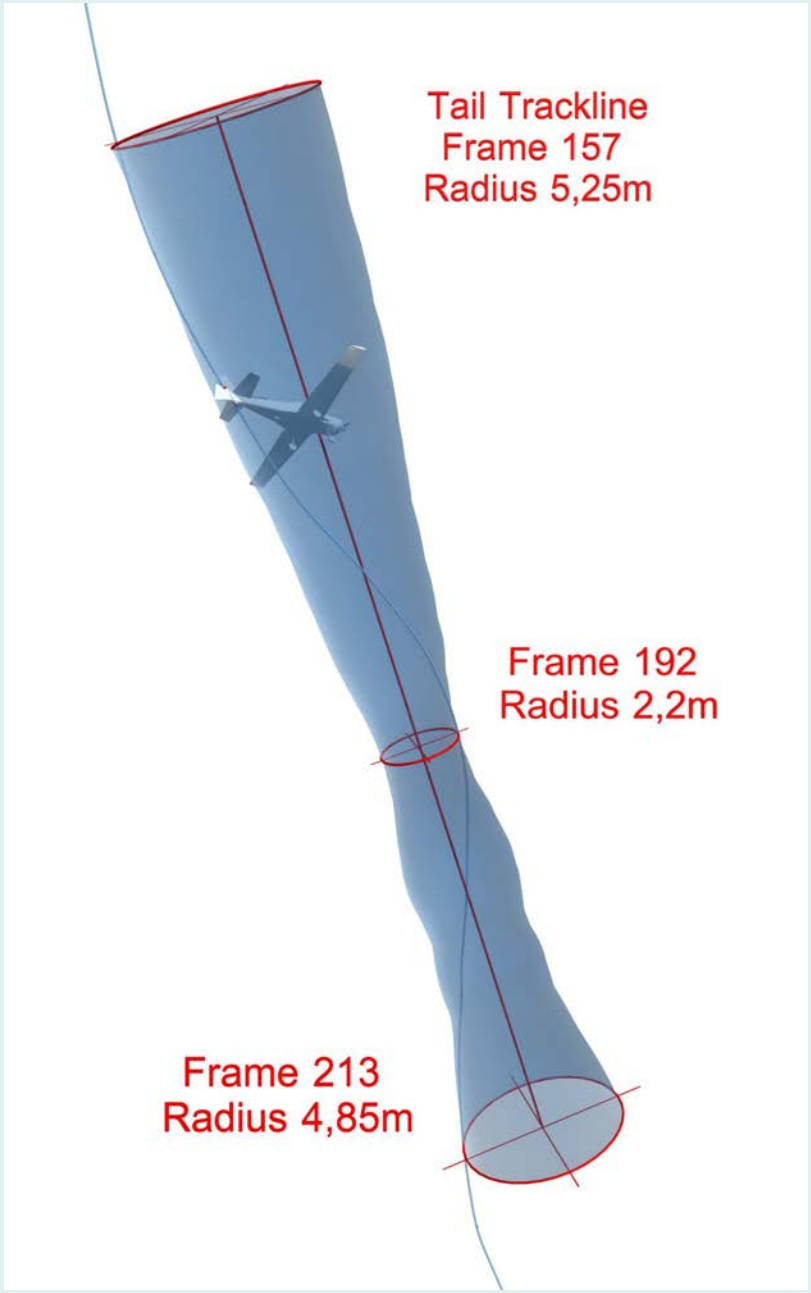


Flow over the horizontal tail

Flow over the horizontal tail cont.

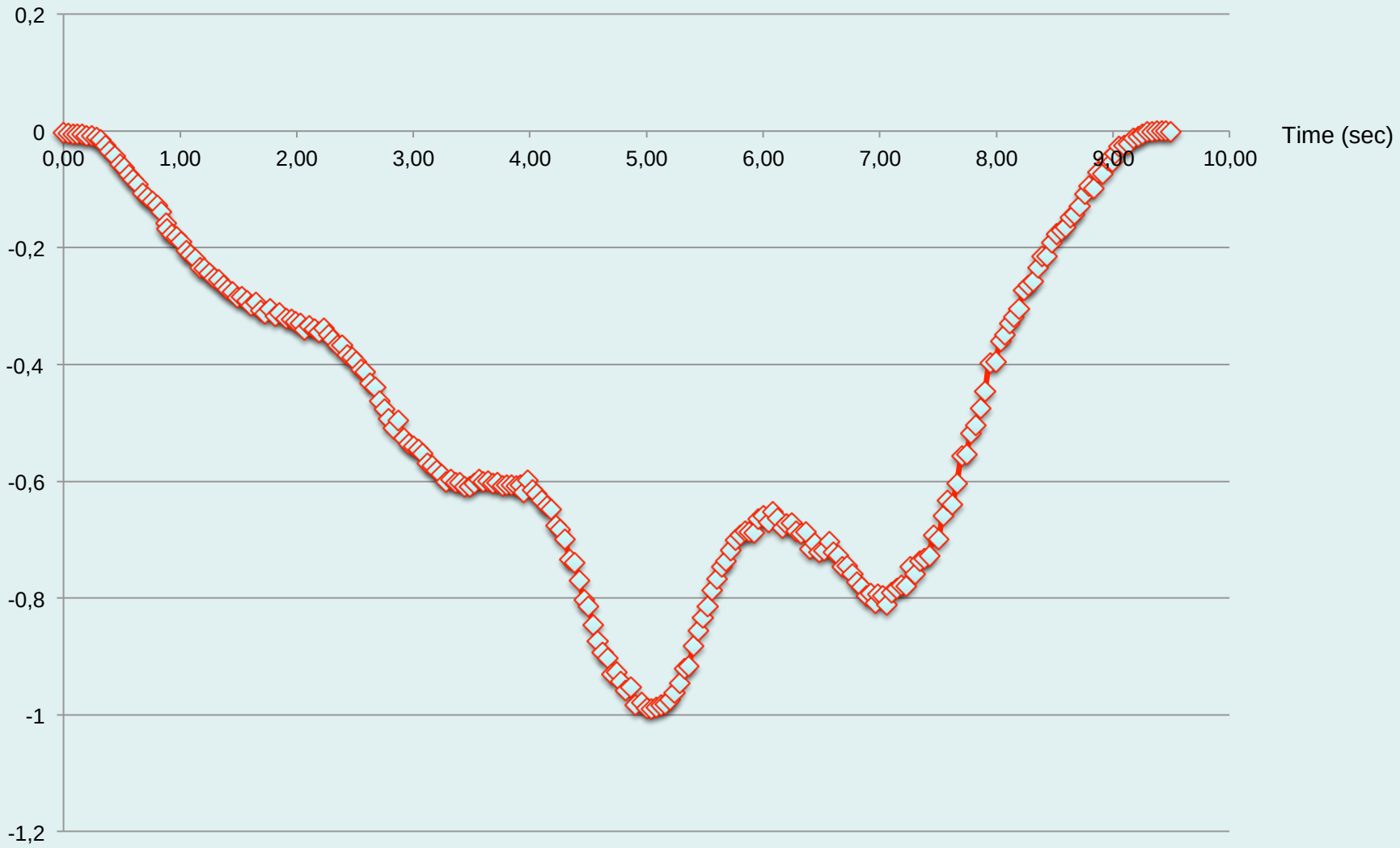
Spanwise flow on outside stabilizer

- RH spin Safir
- LH spin Slingsby


Tail Trackline
Frame 157
Radius 5,25m
Frame 192
Radius 2,2m
Frame 213
Radius 4,85m


CG Trackline
Radius 1,45m

Slingsby 2 turn spin - Estimated pitching moment (Cm)



Summary

- Flow visualization, using tufts and smoke, indicate the presence of 3 dimensional, complex flow fields
- Hypothesis: The turbulent layer on the upper surface, on the outside wing of a spinning aeroplane, is accelerated due to additional, spin induced accelerations
- These effects might be key to understanding the spin dynamics (e.g. turbulent flow impact on tail during spin, reversal of elevator effect and nose down pitching moment)

Future research

We got observations and a hypothesis – we now need more data to validate the hypothesis

- More Instrumentation of research aeroplane
  - Flight data recorder
  - Air data probe
  - Differential pressure sensors
- Mathematical modelling

Questions?

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