# The Development and Integration of an Aircraft Carrier "Burble" Model for Piloted Flight Simulation


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Michael Francis Kelly, Dr Mark D White, Prof Ieuan Owen
University of Liverpool

Dr Steven Hodge
BAE Systems

# Overview

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- QEC Industrial CASE Project
- QEC Flight Simulation
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- QEC CFD Validation Program
  - Experimental Approach
  - Areas of Interest
- Next Steps
  - Large Airwake Integration
  - Fixed-Wing Integration

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# Naval Flight Simulation Background

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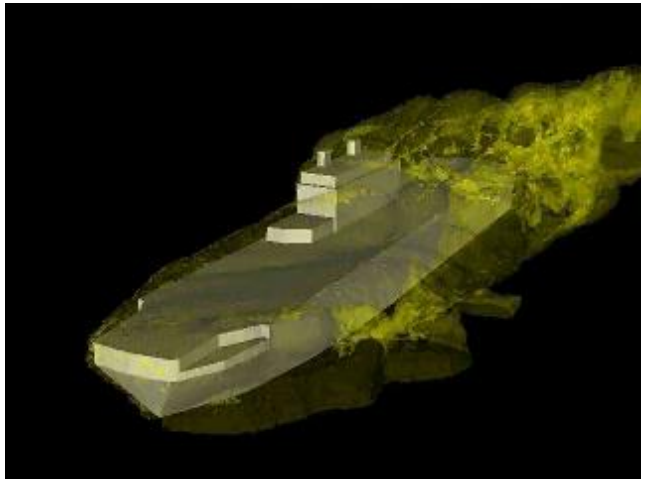
# Aircraft-Ship Operations

Operating fixed-wing and rotary-wing aircraft at sea is an extremely challenging and potentially dangerous activity, placing significant demands upon pilots.

- Deck motion in six degrees of freedom
- Poor visual cueing, particularly at night and during foul weather
- Restricted landing spots
- Unsteady air-wake generated by the ship structure



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# Previous Airwake Issues

**US Navy LHA:**

- Lateral instability found to cause pilot-induced oscillations during sea trials for V-22 Osprey.
- Using CFD studies, un-commanded roll on deck was found to occur due to upwind aircraft.

**UK RFA AOR:**

- FOCFT revealed the forward landing spot to be unsuited for flight operations, due to turbulent airflow immediately aft of the superstructure.

**RAN HMAS Canberra:**

- Catastrophic damage to MRH-90 rotor heads due to complex turbulent flow caused by ship geometry

# QEC Industrial CASE Project

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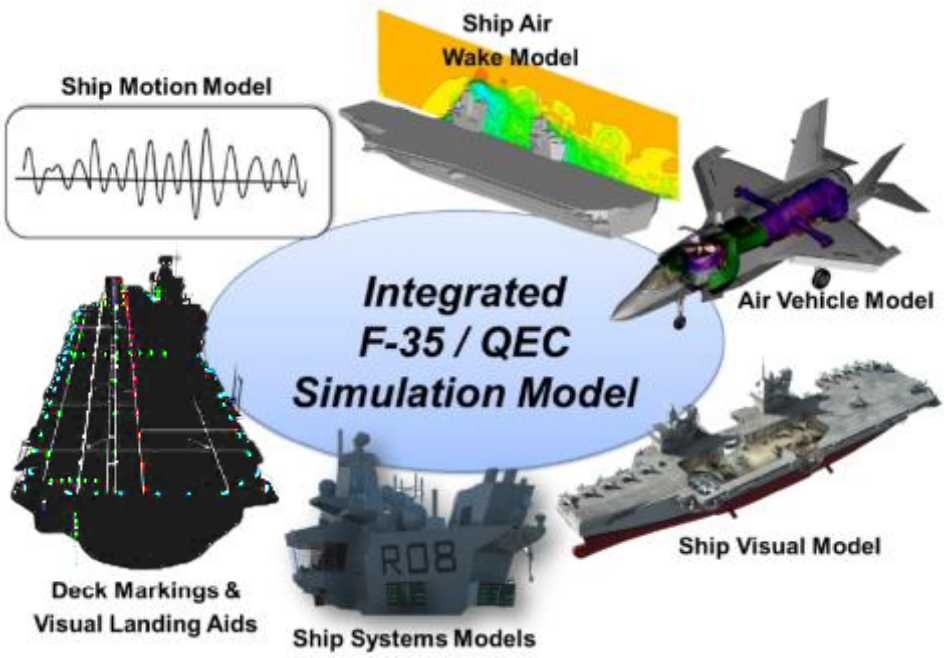
# QEC ICASE Project Aims

- To develop a CFD model of the airwake around the QEC aircraft carriers.
- To validate the airwake model using experimental techniques for ASTOVL.
- To investigate novel methods of integrating large airwake models with real-time piloted simulations, to maximise the fidelity of the integrated simulation.

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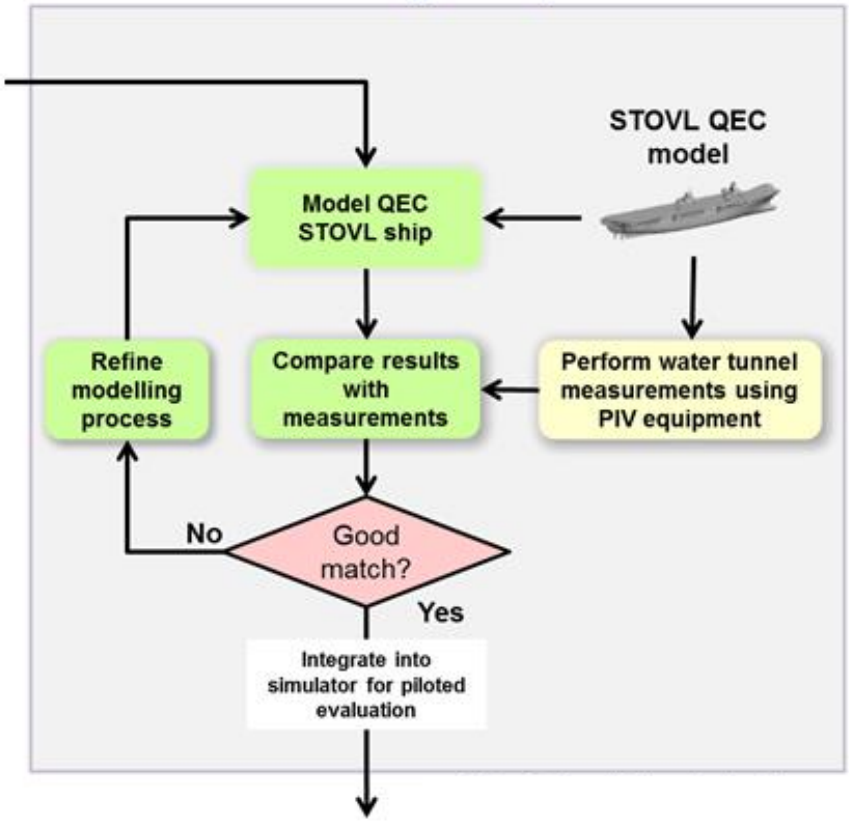
# QEC Simulation Approach

## Proposed Airwake Modelling and Validation Approach

*Apply tools and techniques to STOVL QEC model and validate against experimental data*

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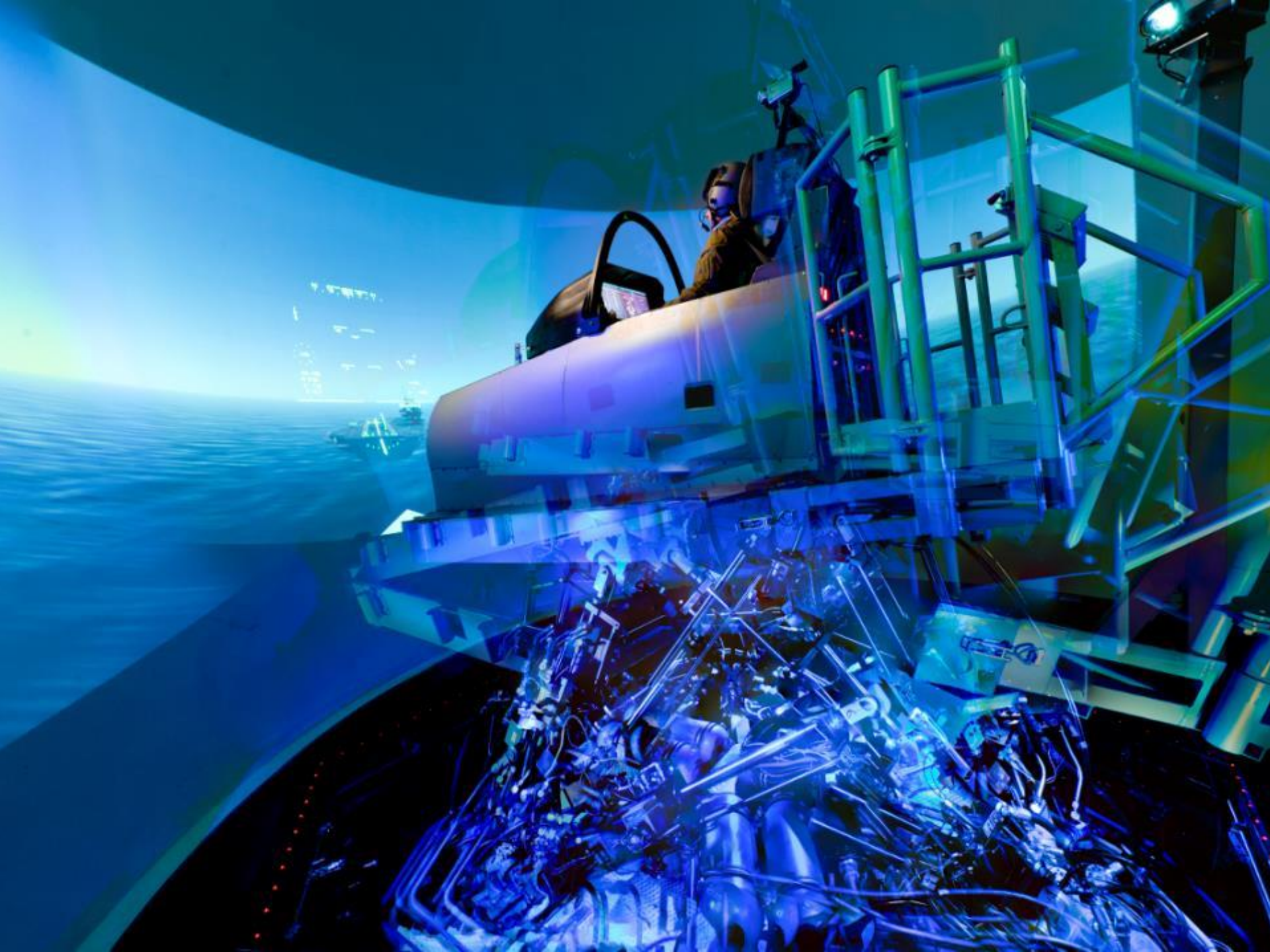

# QEC Airwake Simulation

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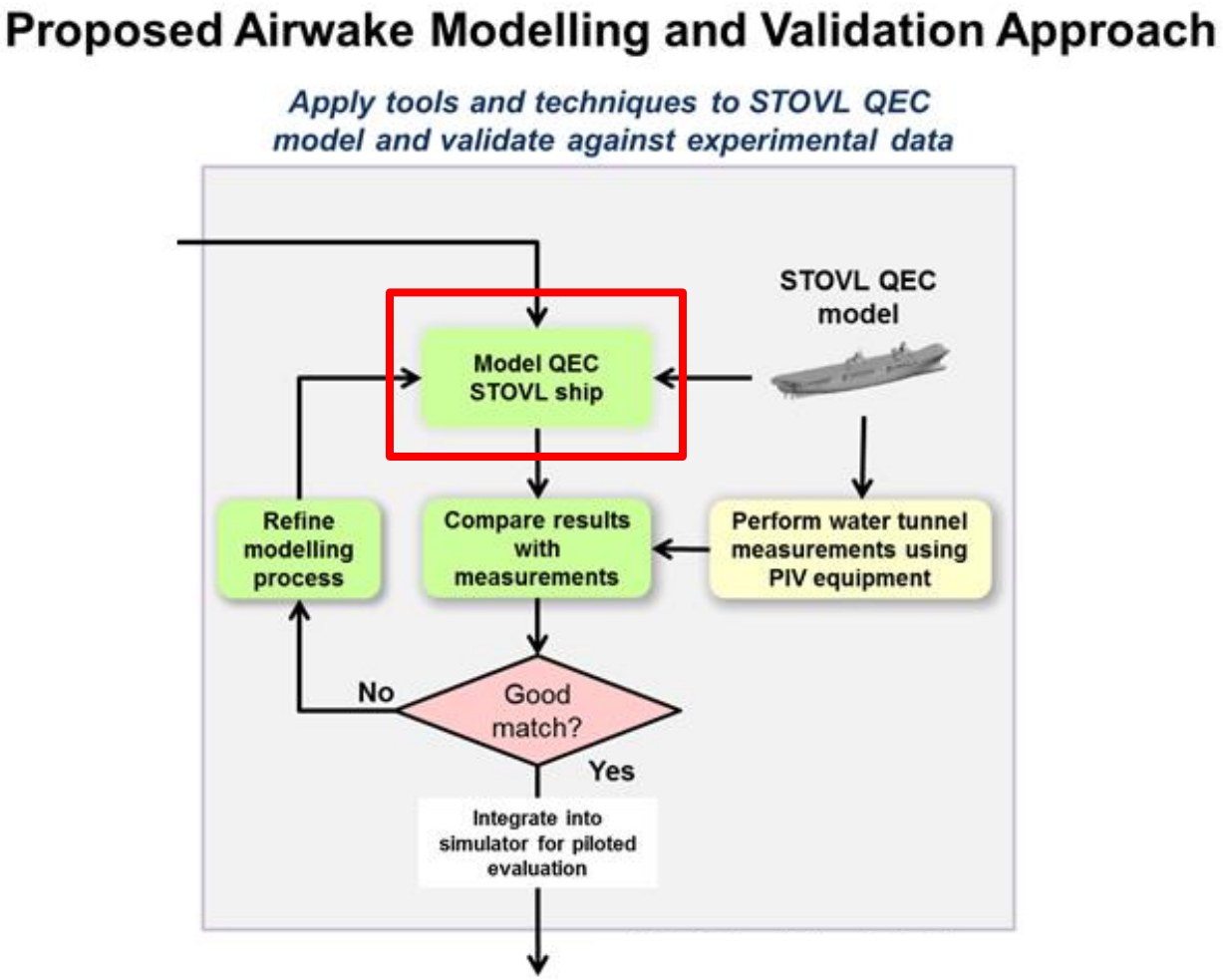
# QEC Simulation Approach

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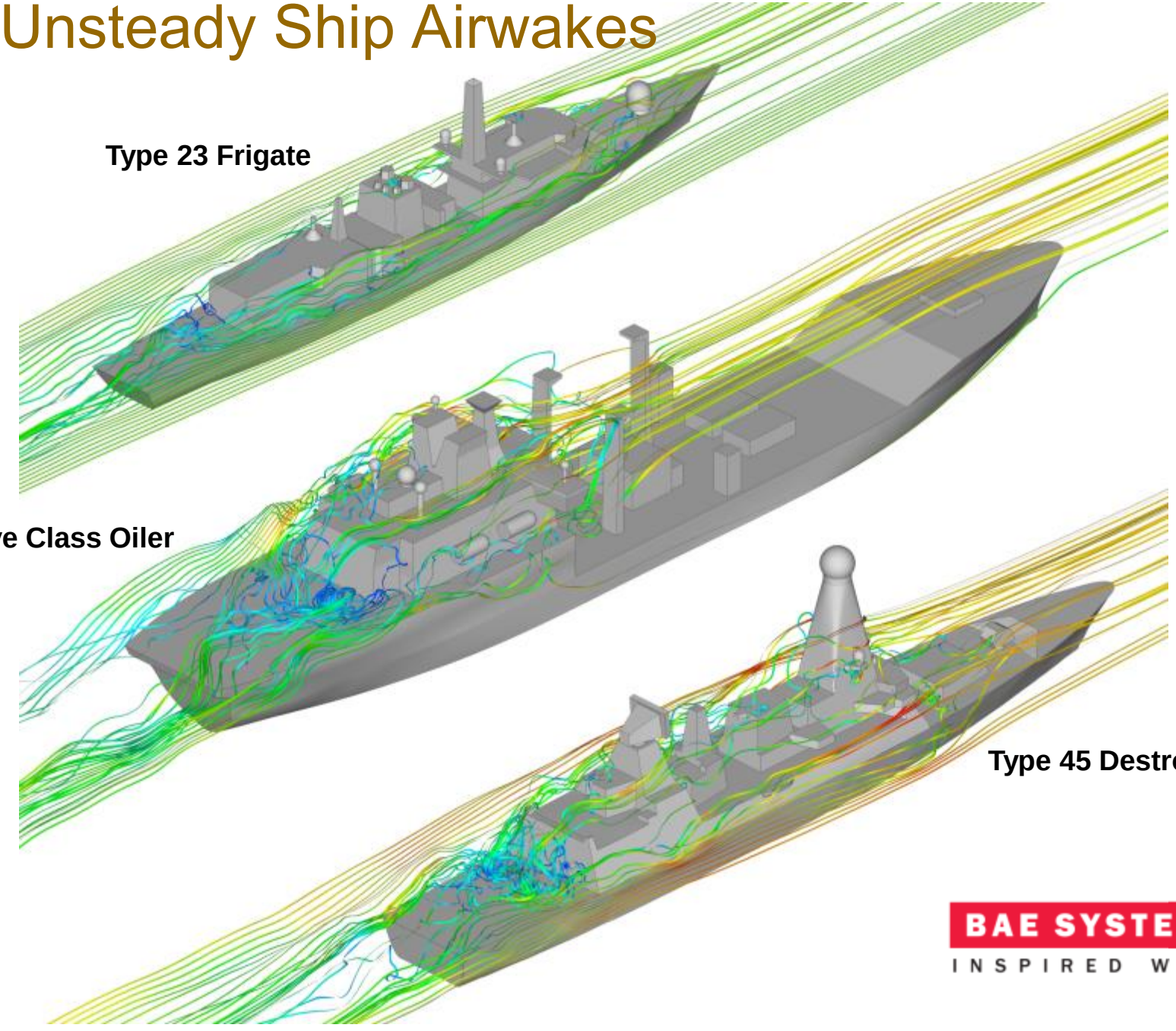
# Unsteady Ship Airwakes

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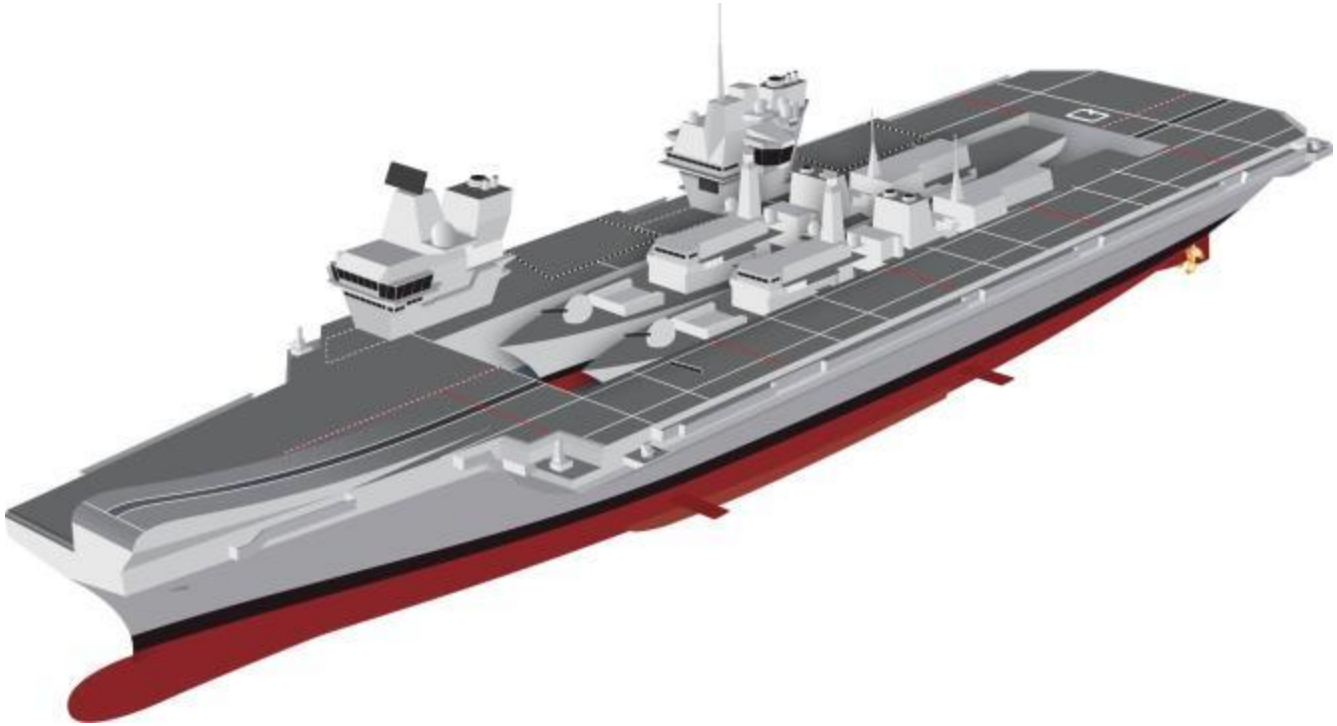
# QEC Hull Geometry

- Length: 280 metres (>2 T23 Frigates)
- Beam: 70 metres (>4 T23 Frigates)
- Airwakes for use with fixed-wing operation, where pilots have reported experiencing ship air-wake over 800 metres aft of CV carriers during landing.



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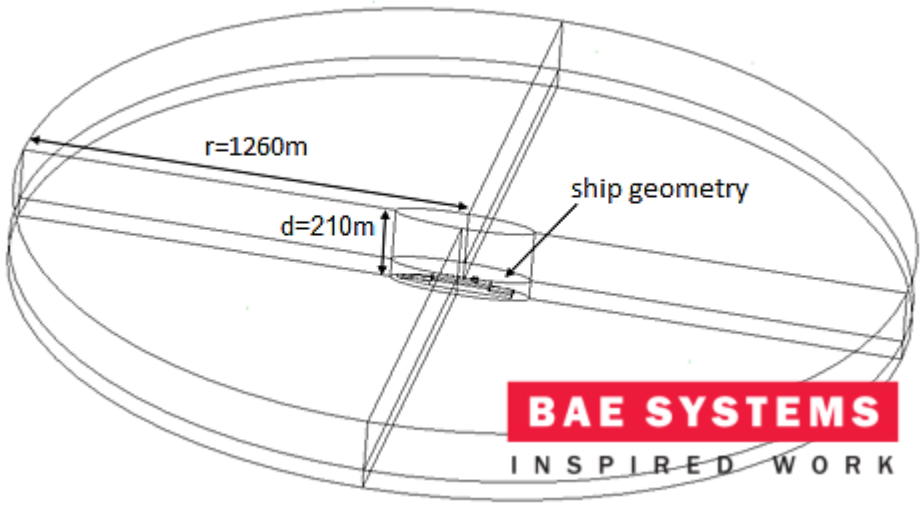
# QEC Airwake Simulation

The approach previously validated for rotary-wing piloted flight simulation at the University of Liverpool has been adapted for use with fixed-wing airwake simulation.

- CFD computed using Delayed Detached Eddy Simulation (DDES) method with the SST k-ω turbulence model
- Scale resolved, time-accurate air-wakes produced in the free shear-layer turbulent regions of ship air-wake
- At-sea atmospheric boundary layer incorporated
- Current grids in the region of ~120 million cells (~16GB per time-step)
- Parallel processing using HPC
  - ULGBC5
  - CHADWICK

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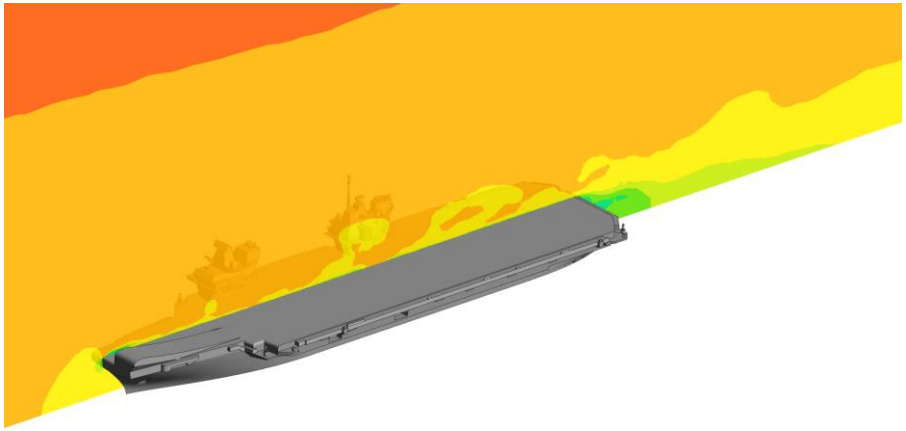
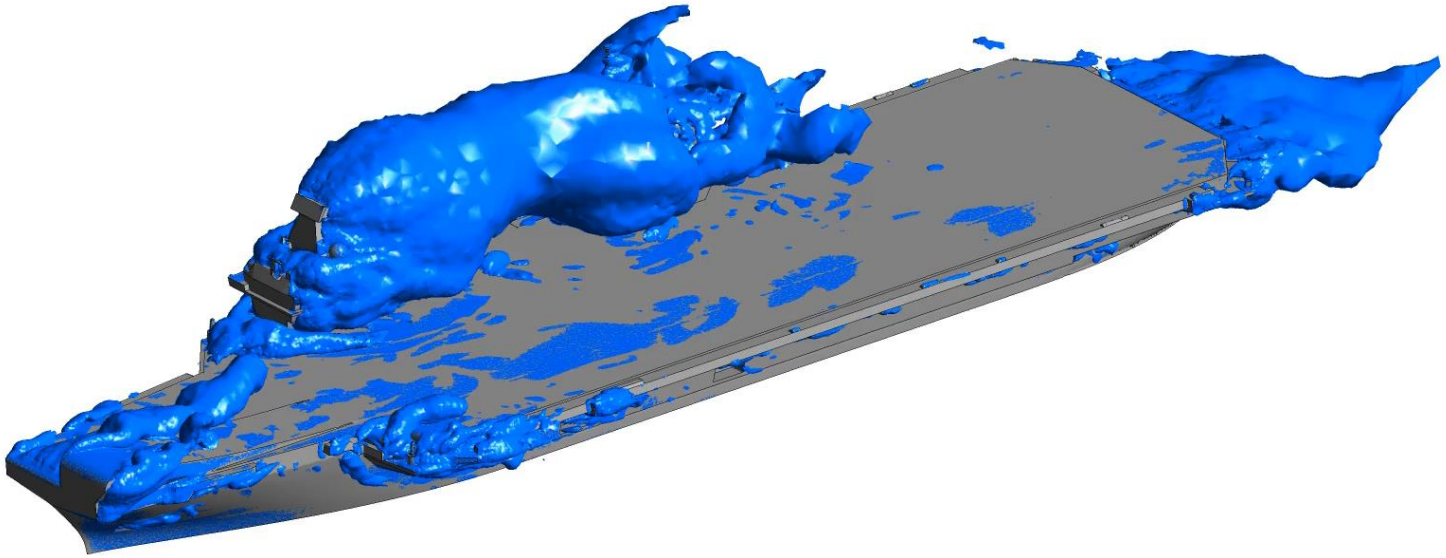
# QEC Airwake Simulation



- 25Kts, Ahead (H000)
- CFD mesh ~120 million cells
- Used to path-find BAE Systems flight simulator integration
- Full airwake too large for use in simulators – requires interpolation



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# QEC CFD Validation Program

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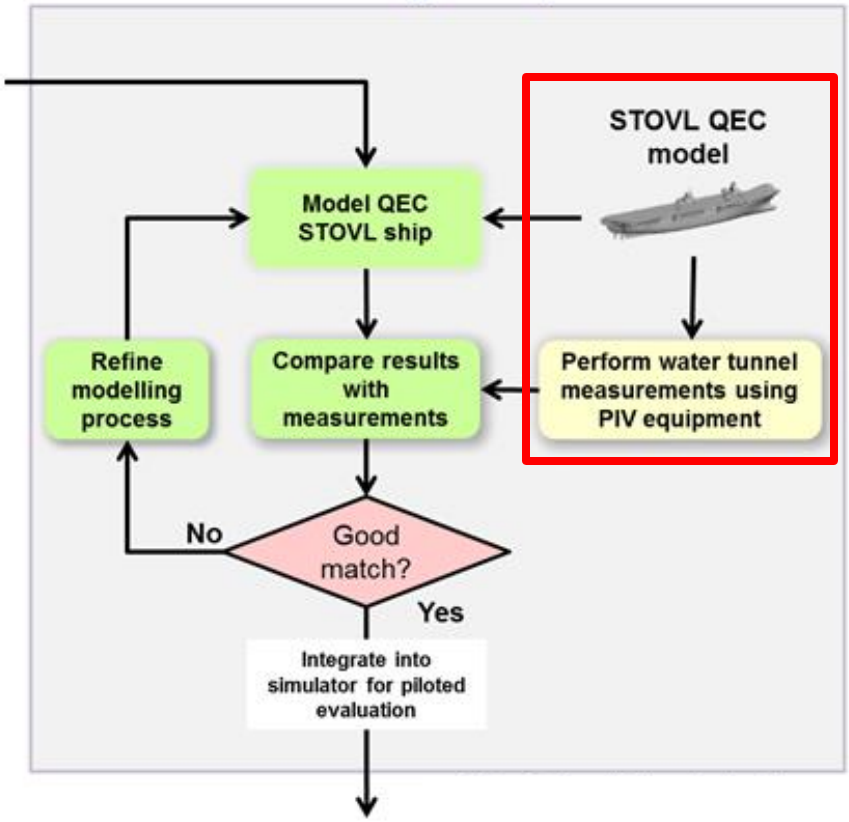
# QEC Simulation Approach

## Proposed Airwake Modelling and Validation Approach

*Apply tools and techniques to STOVL QEC model and validate against experimental data*

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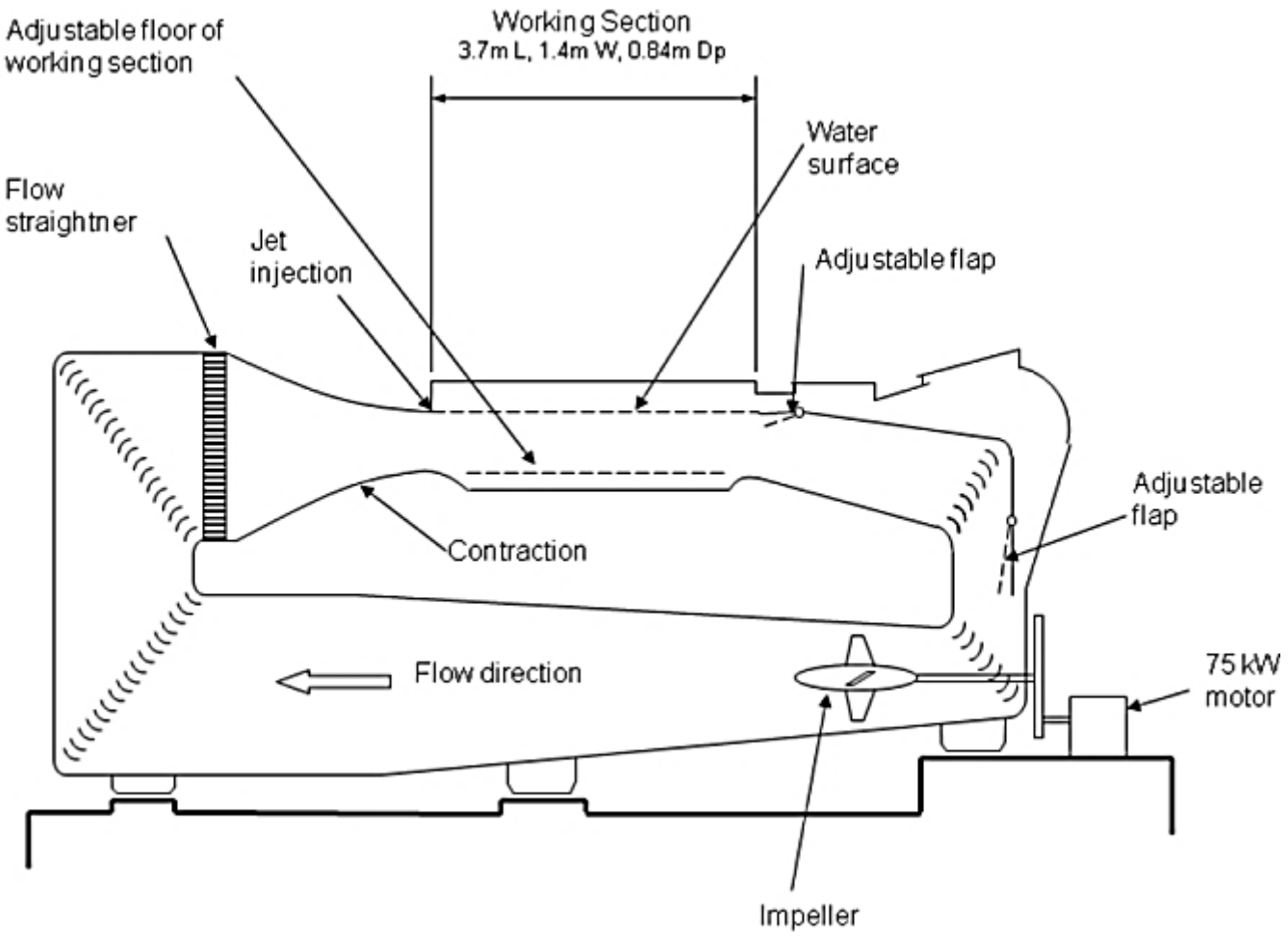
# UoL Recirculating Water Channel

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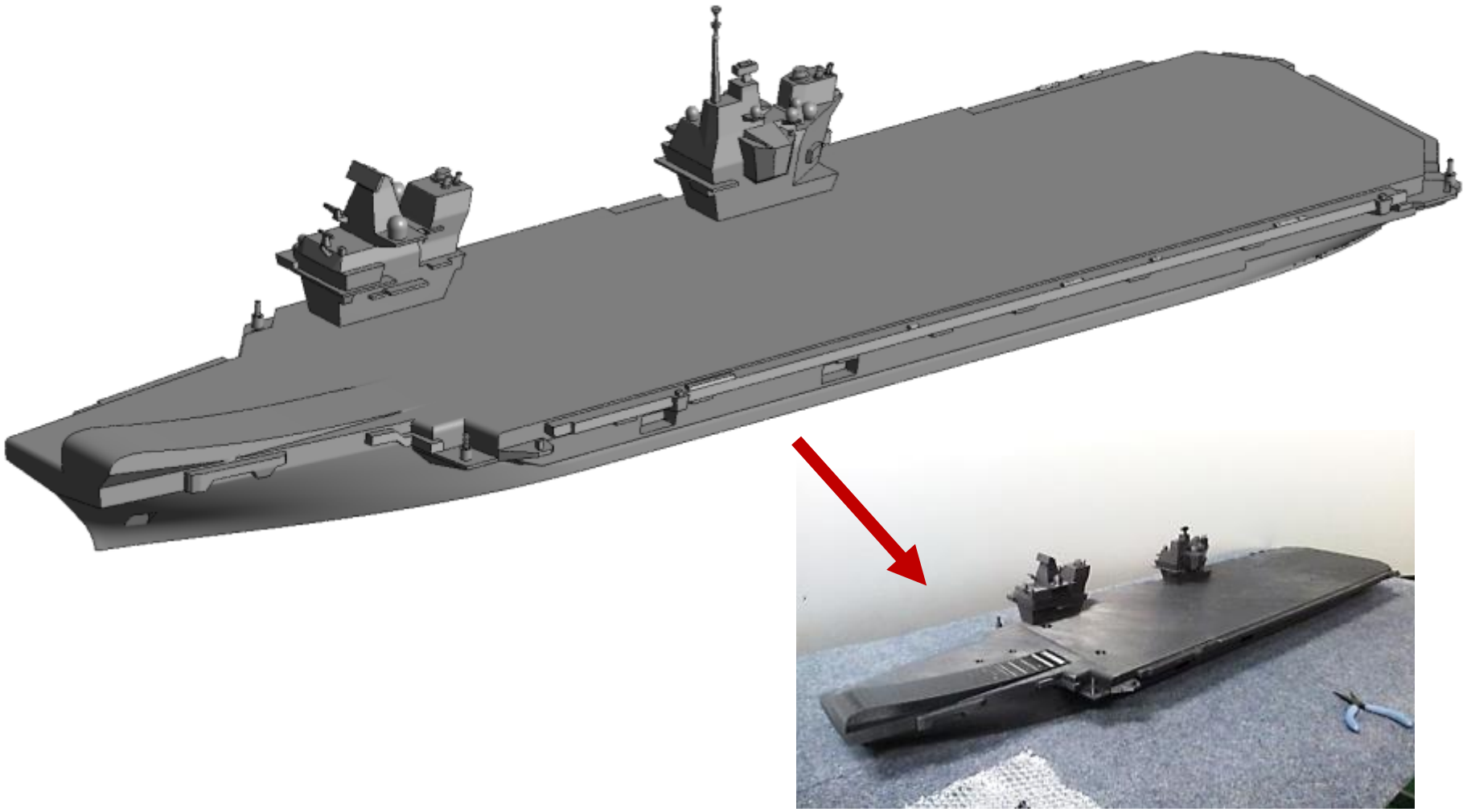
# QEC Experimental Model



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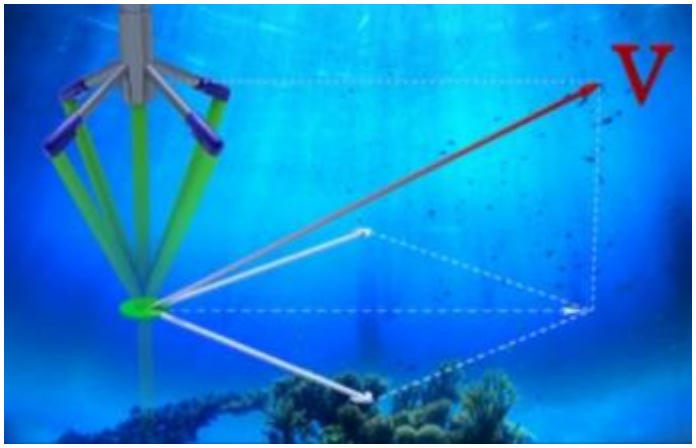
# Acoustic Doppler Velocimetry (ADV)

- High-resolution velocimetry, able to measure 3D flow velocity at high frequency (200Hz).
- Measurements are to be taken of the flow around a 1:202 QEC model, in the UoL water channel.
- ADV will provide mean flow data, in addition to unsteady velocity in the direction of the sensor.
- Well suited to measurement of unsteadiness along aircraft approach path, and over landing spots.

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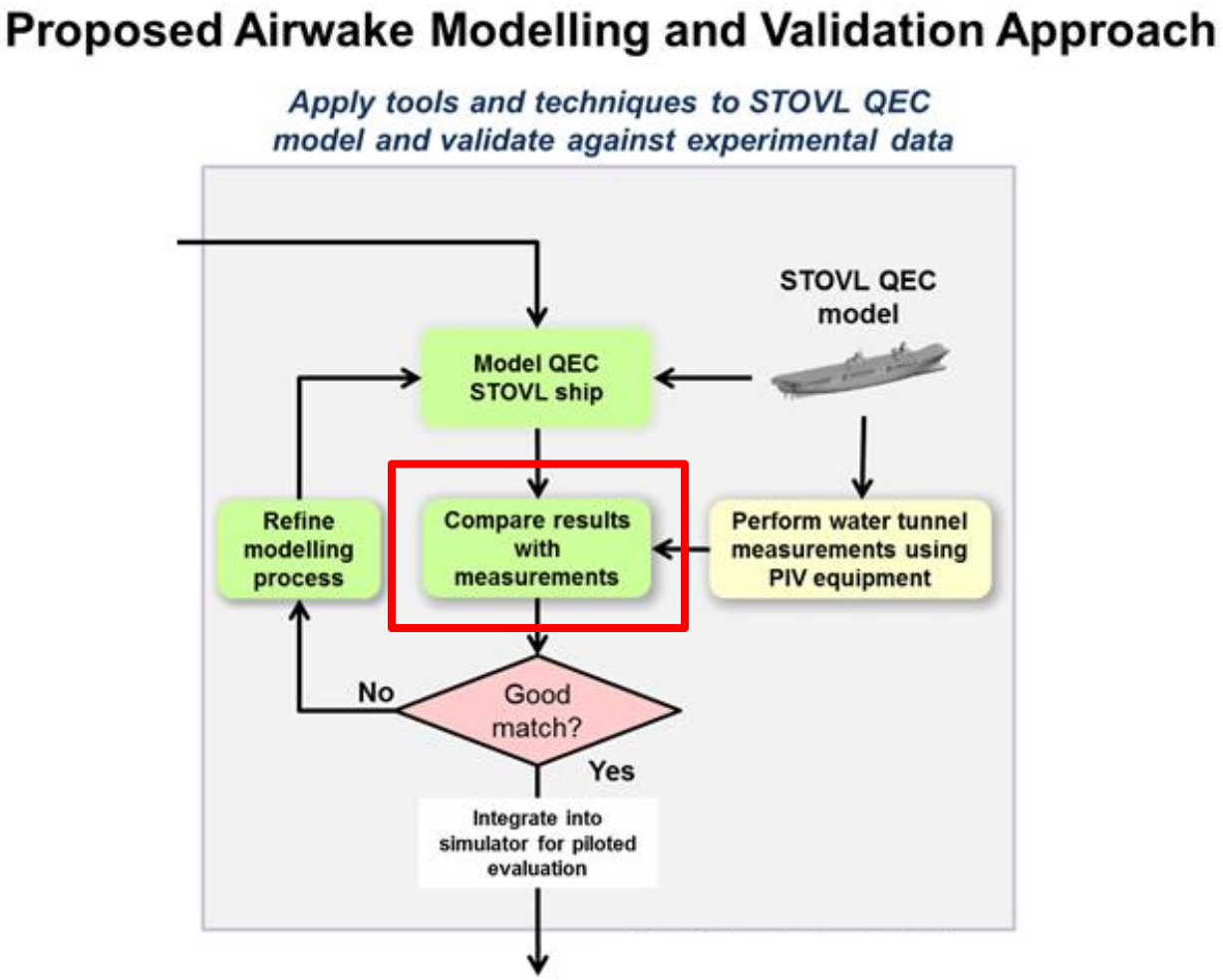
# QEC Simulation Approach

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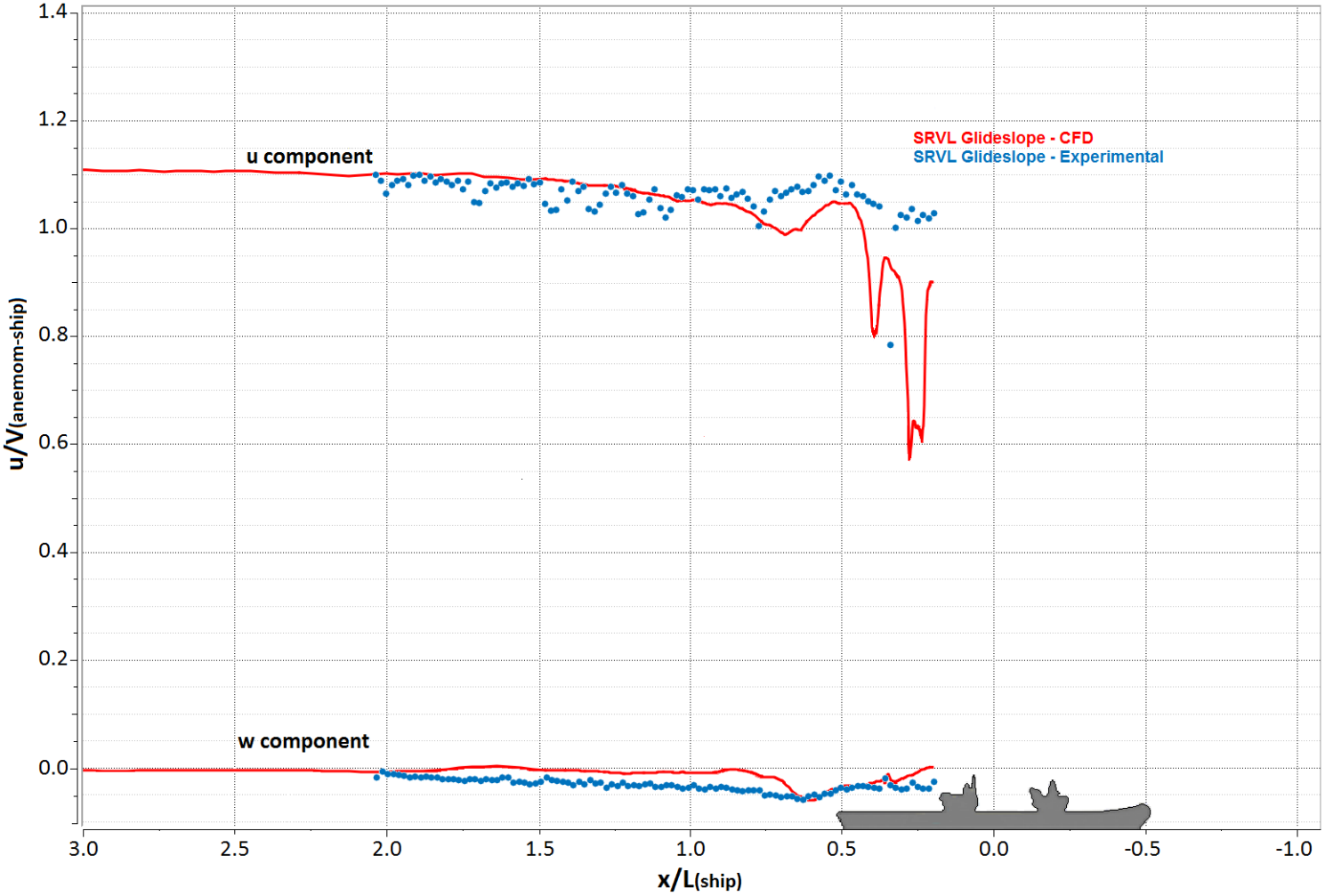
# Initial ADV Results

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# Next Steps

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# HELIFLIGHT-R Flight Simulator

- Re-configurable 6DoF motion base simulator
- Large library of flight mechanics models
- 220x70° field of view
- Ship model, lights, and ship motions
- Can be integrated with time-accurate unsteady air-wakes

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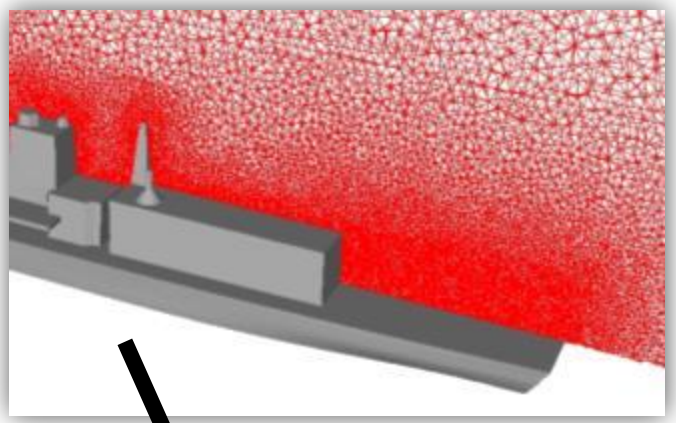
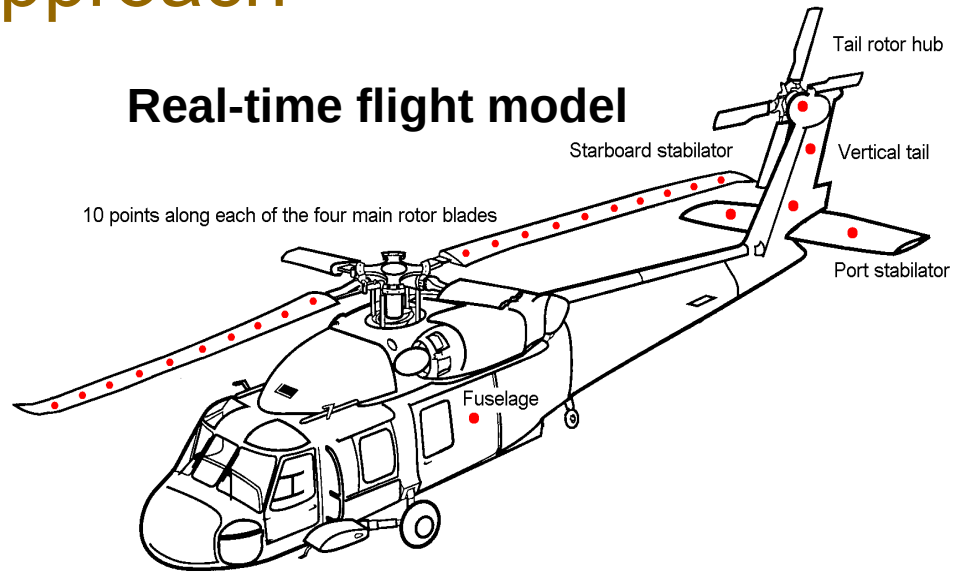
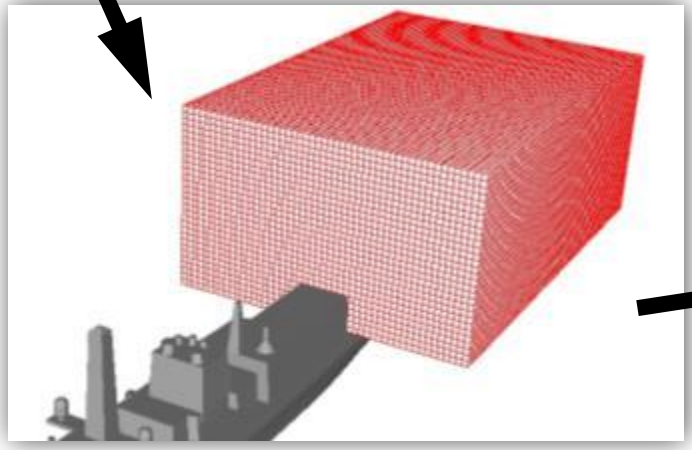
# Airwake Integration Approach

**Unstructured CFD data**

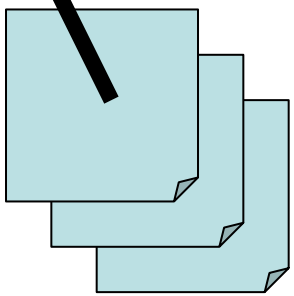


**Real-time flight model**



**Structured airwake data**



**Look-up tables**

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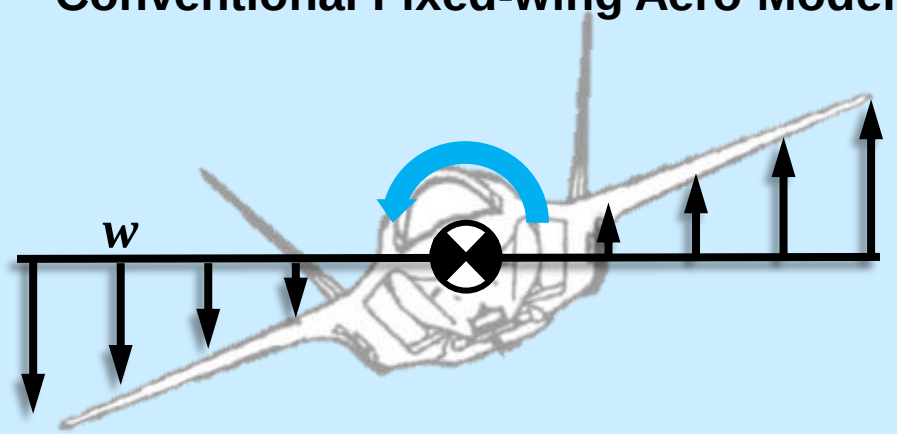
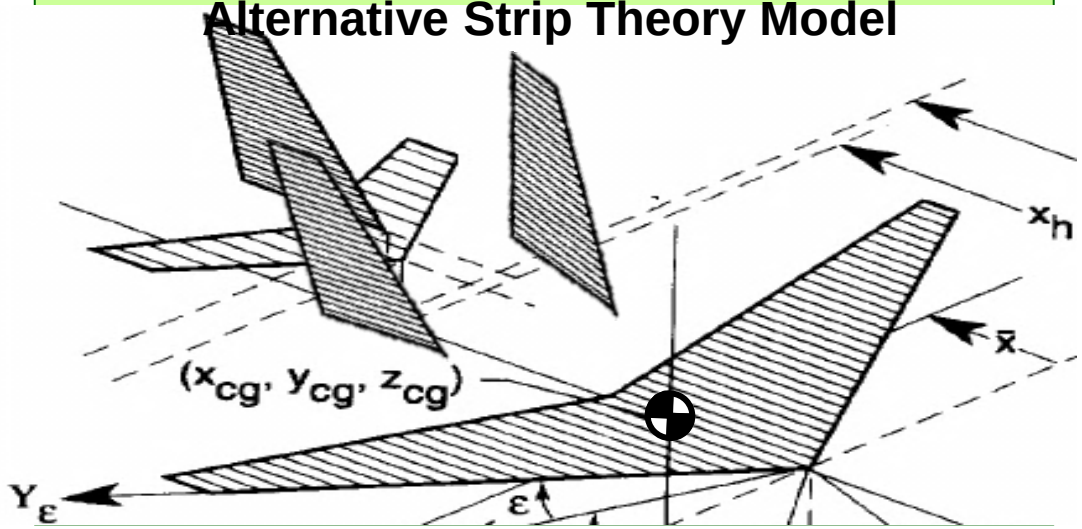
# Fixed-Wing Airwake Integration

**Conventional Fixed-wing Aero Model**




- Airwake velocities only applied at CoG, therefore limited rotational disturbances due to flow gradients

**Alternative Strip Theory Model**




- Airwake velocities applied at several points across wing and tail surfaces (like helicopter BEM), therefore better captures rotational disturbances due to flow gradients

# Conclusions

- The University of Liverpool is working in collaboration with BAE Systems Warton to achieve advances in piloted flight simulation.
- Development and integration of high-fidelity CFD airwakes around the Queen Elizabeth Class aircraft carriers, for use with fixed-wing and rotary-wing piloted flight simulation.
- Experimental validation of these CFD airwakes to ensure solution accuracy prior to at-sea AFAP and FOCFT for F35-B Lightning II.
- Implementation of an improved method for fixed-wing airwake integration for use with UoL and BAE Systems flight simulators, allowing a more accurate simulation of rotational disturbances (roll, pitch, yaw) upon ASTOVL aircraft.

# Conclusions

- The University of Liverpool is working in collaboration with BAE Systems Warton to achieve advances in piloted flight simulation.
- First time flight simulation has been used to inform fixed-wing FOCFT in the UK.
- Increased airwake simulation fidelity, offering an order-of-magnitude higher resolution than previously available.
- Improved integration with fixed-wing flight dynamics models.
- Development of a novel experimental validation methodology.
- Current research effort making a significant contribution to delivery of a key UK defence capability.

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**Thank you.**

**RAeS Advances in Simulation – Session 3**
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**Michael Francis Kelly**
PhD Student
Flight Science & Technology
University of Liverpool

tel: +44 (0)151 794 8511
e : M.F.Kelly@liv.ac.uk
in : linkedin.com/in/mfkelly1