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GREENER AERONAUTICS

Fluid Structure Interactions of Non-planar Wings

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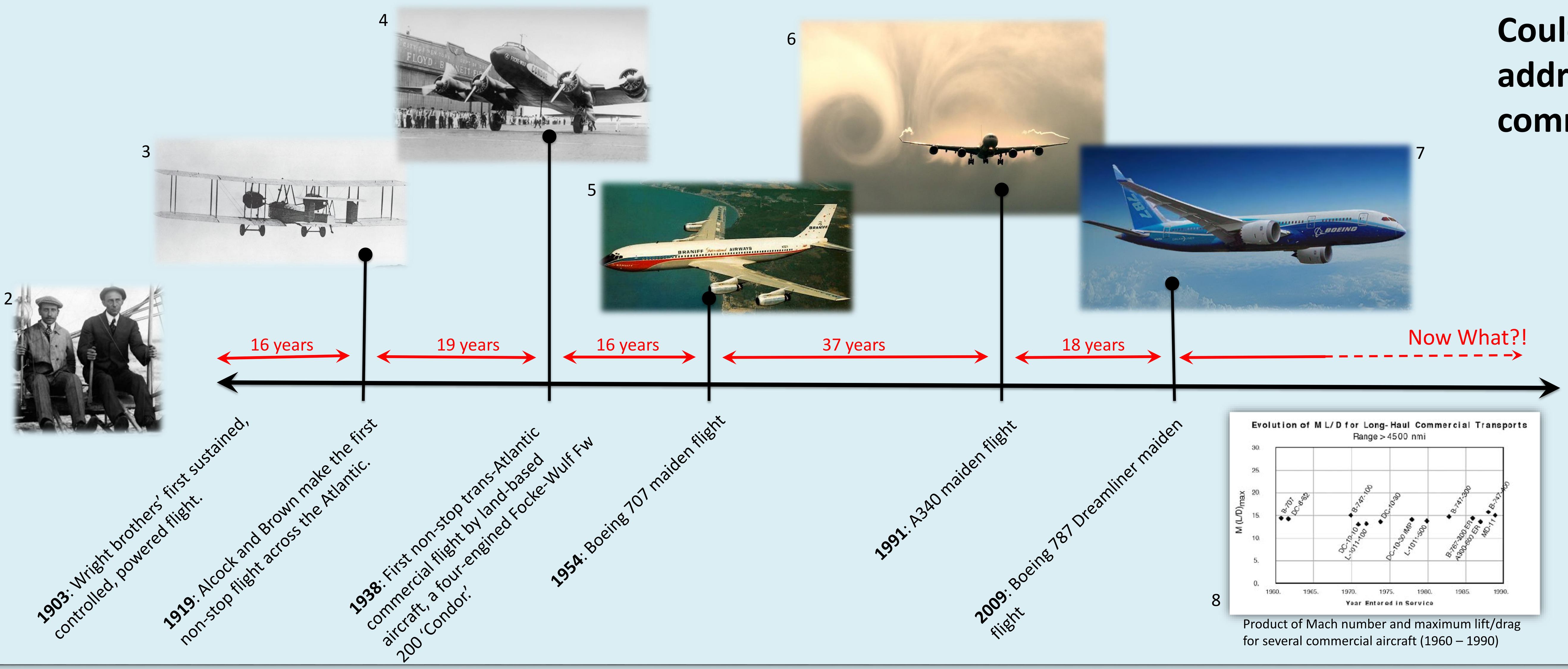
Motivation

The ability to reduce vortex drag at a fixed wingspan, while considering the effects of stability and control, characteristics of wake vortices and structural implications has been the subject of great debate since the dawn of aviation. Interest in large commercial aircraft lies with developments associated with the environmental requirements for dramatically reduced noise, fuel burn and emissions while attempting to maximise the air transportation systems capacity.

The **European Commission** and the **Advisory Council for Aeronautics Research** (ACARE) have joint strategic goals in place to address these issues while considering economic and social benefits. Some specific goals highlighted in their **Flightpath 2050**[1] plan include a **75% reduction of Co_2 emissions** per passenger kilometre whilst also **reducing observed noise emissions of flying aircraft by 65%** regardless of traffic growth. It is recognised that the world is entering a new age in which challenges in globalisation, fluctuating financial systems, climate change, realisation of our finite recourses, and the demand for an evermore efficient/sustainable infrastructure is driving modern innovations.



Product of Mach number and maximum lift/drag for several commercial aircraft (1960 – 1990)

Could a novel C-Wing configuration address the issues of modern large commercial aircraft?

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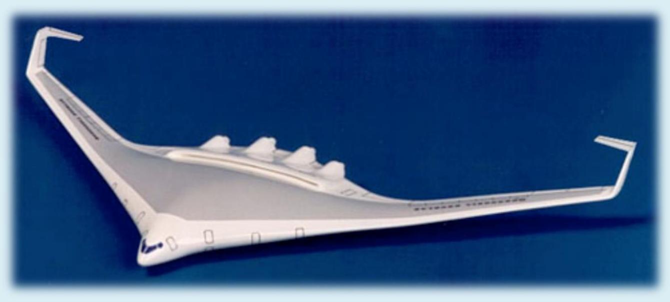

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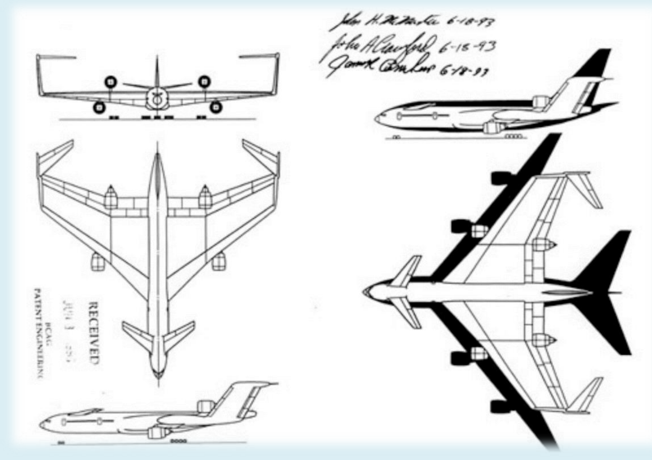

The Boeing 787 Dreamliner, despite the significant technological breakthroughs, looks very similar to it's 707 ancestor (credited with ushering in the jet age). The 'tube-wing' configuration has been wrung for every last drop of performance to the point where this configuration is arguably reaching an apparent stagnation. Technological breakthroughs principally surround avionic capabilities (many originating from WWII & US satellite development), engine performance, stability and control augmentation, and materials, while the aerodynamics of these aircraft have seen little, if any, revolutionary development. This is apparent if we consider how the product of Mach number and lift-to-drag ratio has changed over the last 40 years. Taking note of the significance in the heritage of technology, along with the tremendous cost and risk associated with new technologies, this helps to explain the 'unchanged' commercial configuration. However, it is also apparent that to create an aircraft that may even begin to address the issues of modern large commercial aircraft, a configurational aerodynamic change must happen. **Future designs must stretch beyond the development of tip-fences, shark-lets, single piece skins and paints and begin to optimise the entire aero-structural aircraft system**.

A Novel C-Wing Configuration - The Possibilities?

- Reduce wing span
- Reduce tip vortex strength
- Reduced vortex drag (improved Lift/Drag ratio)
- Efficient trim with shorter, tailless fuselage
- Improved lateral handling
  - Lower effective dihedral
  - Reduced adverse yaw
- Potential aero-elastic control
  - active flutter control
  - Prevent aileron reversal
- Control at high angles of attack
- Gust Control & load Alleviation
- Improved aero/structural performance though span loading

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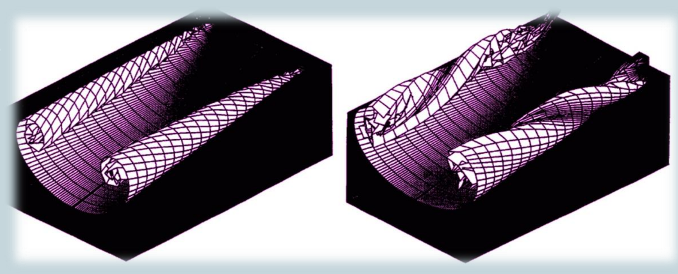

Vortex sheet rollup investigation of a conventional wing (left) and C-Wing (right). Note accelerated breakdown of the wake system for the C-Wing.

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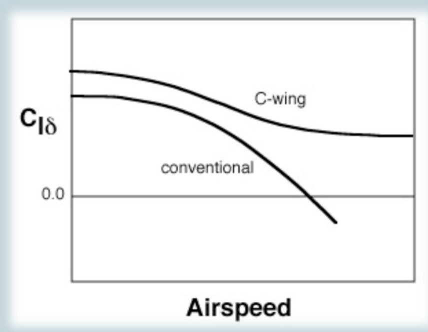

Ailerons on wing and elevons on tip extension could eliminate aileron reversal.

Our Capabilities

- Aero-structural optimisation through development of genetic algorithms to achieve multi objective design of a C-wing configuration that is also capable of aero-elastic consideration and gust alleviation development.
- Experimental Campaign
  - 7ftx5ft Hanley Page Wind Tunnel
  - Particle Image Velocimetry (PIV)
  - V3V™ Volumetric 3-Component Velocimetry
  - Flutter Analysis
  - Gust Control
  - Active Flow Control Investigation
    - Plasma Actuators
    - Boundary Layer Control (suction)
  - Passive Flow Control Investigation
    - Vortex generators

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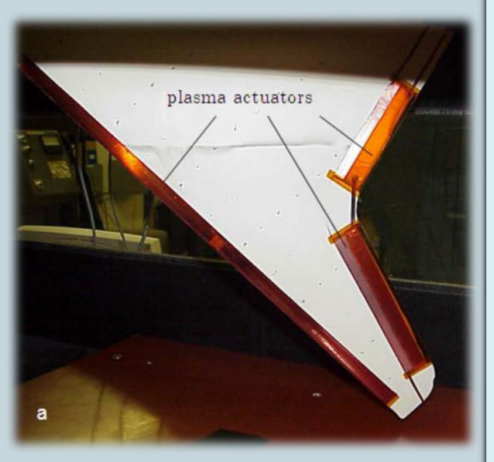
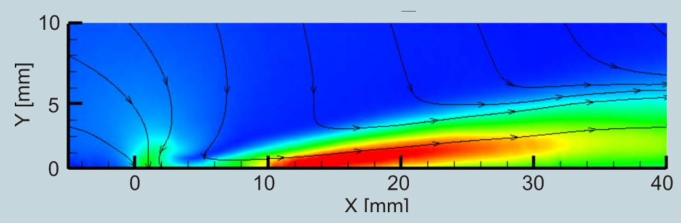
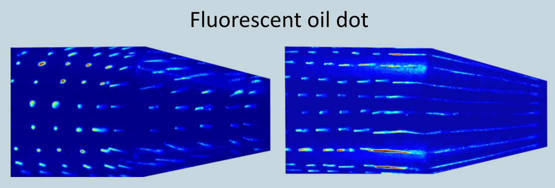


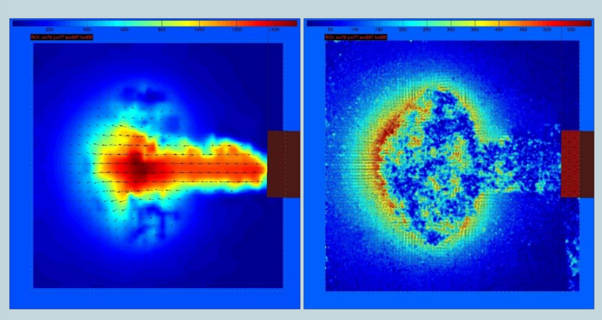
Wing model with plasma actuators mounted on the leading and trailing edges



PIV of flow induced over plasma actuator

Fluorescent oil dot





PIV investigation of shock-tube vortices an induced velocity. Contours show velocity magnitude

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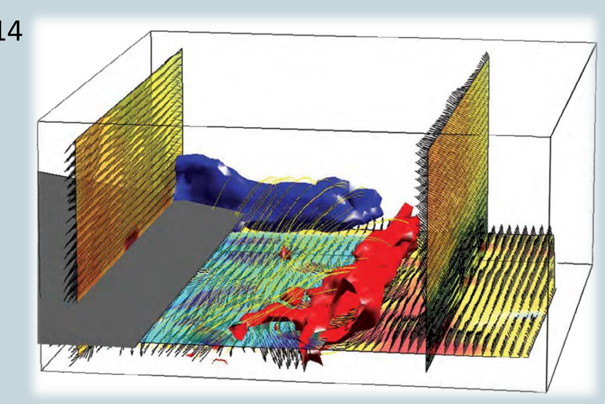
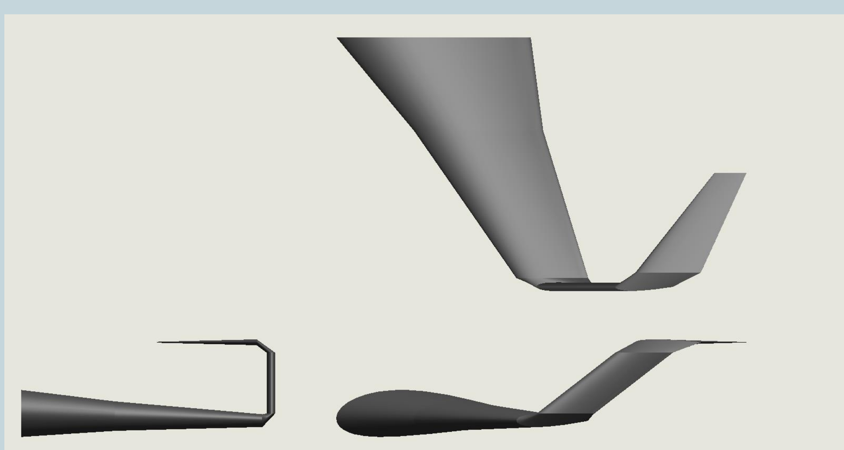


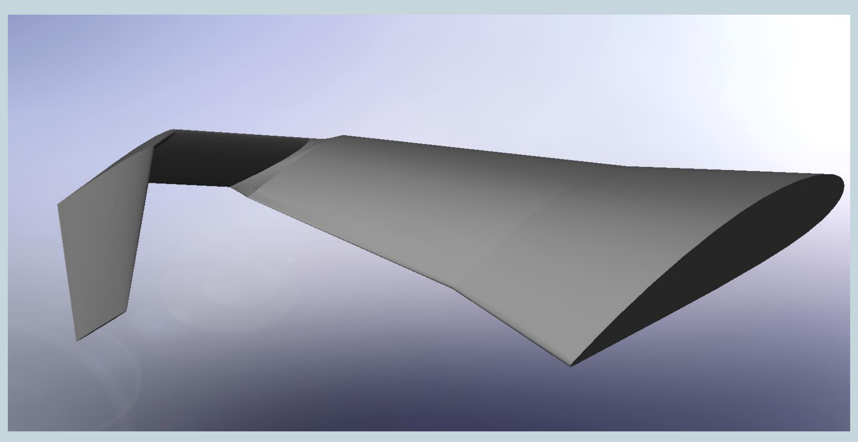
Starting vortex (red) and tip vortex (blue) generated From an impulsively initiated aerofoil (grey).

The Goal

- A robust and adaptable, experimentally validated, geometric planform modifying genetic algorithm designed to optimise the aero-structural properties of a C-wing. This will be tailored to exploit the non-planar geometry to aid in gust control and load alleviation.
- Extensive experimental campaign involving the addition of passive and active flow control.
- CFD Investigation using Star CCM+ to investigate fluid structure interactions computationally.

➢ **To develop a novel C-wing configuration that can address the issues associated with large commercial aircraft!**





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[3] Image Credit: Cynthia Long.
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