Industrial Perspective on Friction Drag Reduction in Turbulent flows

Workshop on Turbulent Skin Friction Drag Reduction
Imperial College London

Dr Stephen Rolston

04 December 2017

AIRBUS

Objectives

- *Welcome and thank you for coming !*

- Workshop Objectives

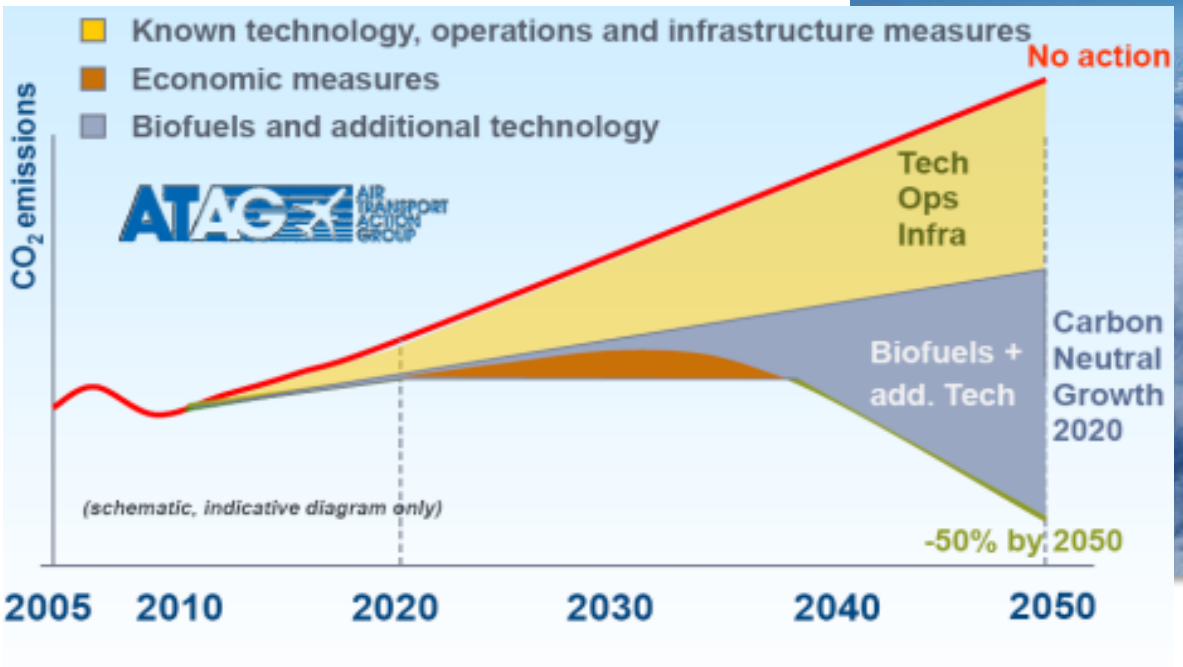
  – To allow Academics to disseminate their work to Airbus and other researchers in the field of turbulent skin friction and viscous drag reduction research.

  – To give Airbus an increased visibility of progress to help inform its future research strategy in low TRL technologies associated to Turbulent Drag Reduction.

AIRBUS

The Need

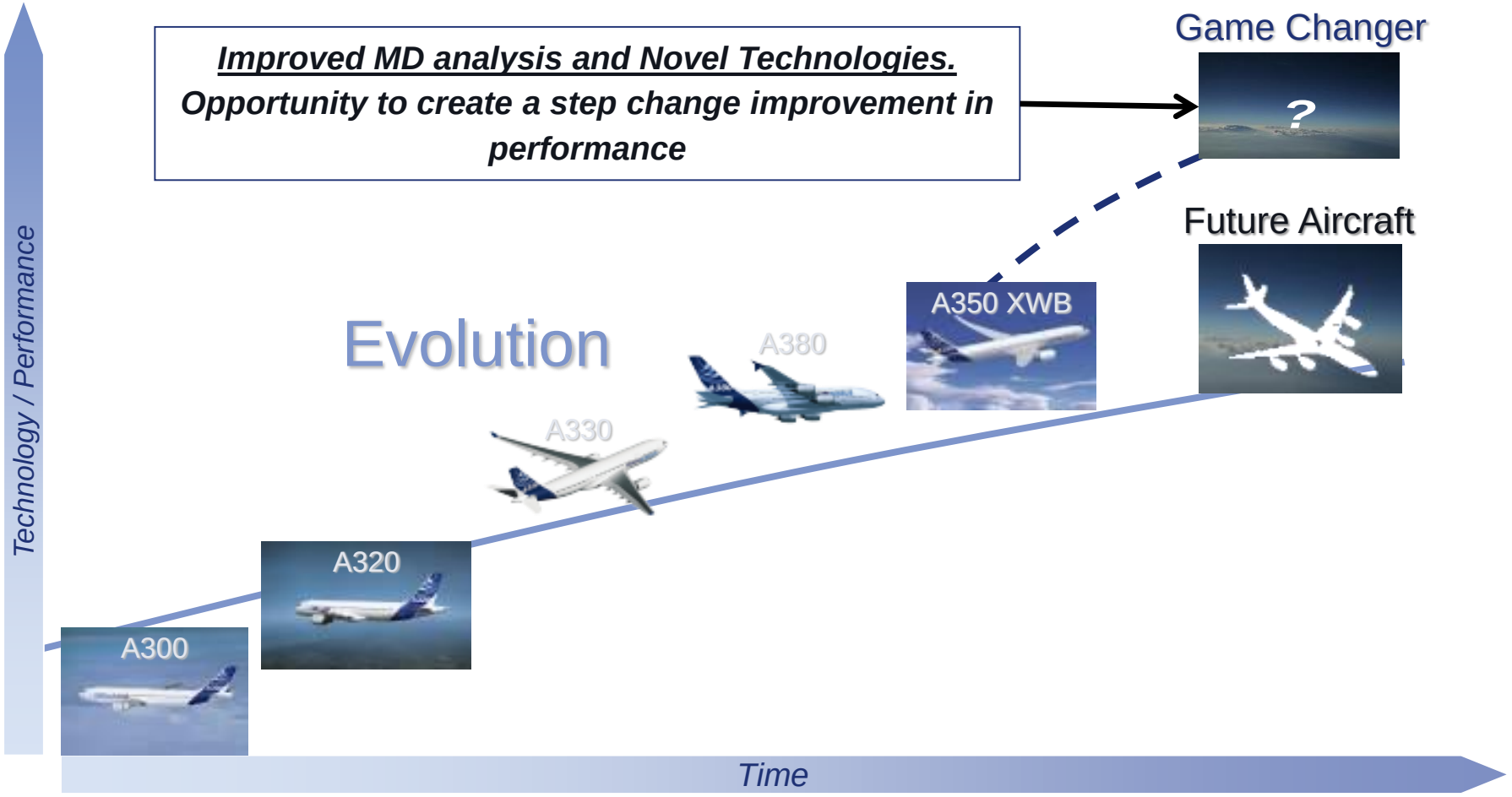
- Flight Path 2050 – Reduce global $C0_2$ emissions due to aviation by 50% by 2050.....



AIRBUS

Performance Evolution of Airbus Aircraft

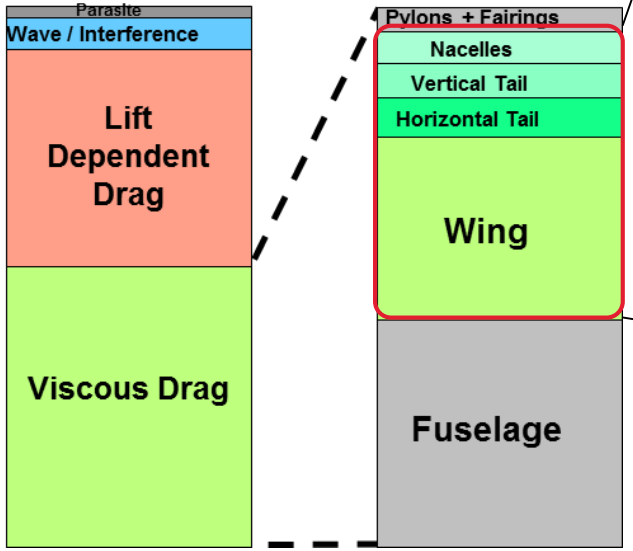
Indication of Saturation Effects



AIRBUS

Where are the technology opportunities for drag reduction?

Typical drag break down of transonic civil aircraft



Viscous drag is a key element of overall drag

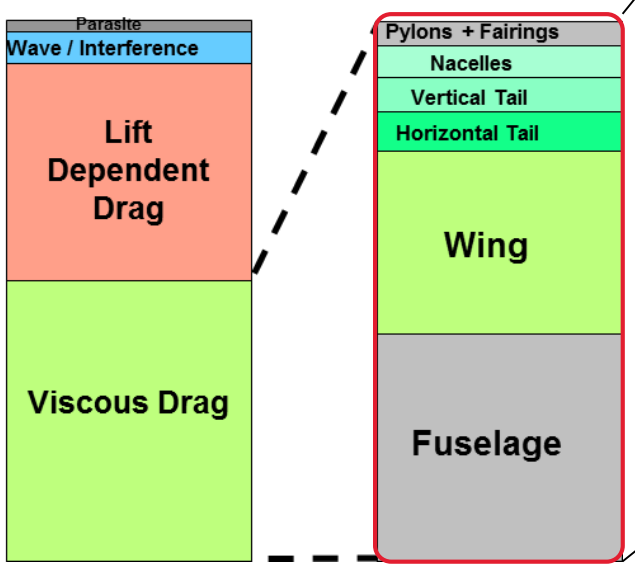
$$\rho_\infty u_\infty^2 \theta_\infty = \int_0^\infty \tau_0 dx + \int_{x=0}^{x=\infty} \delta^* dp$$

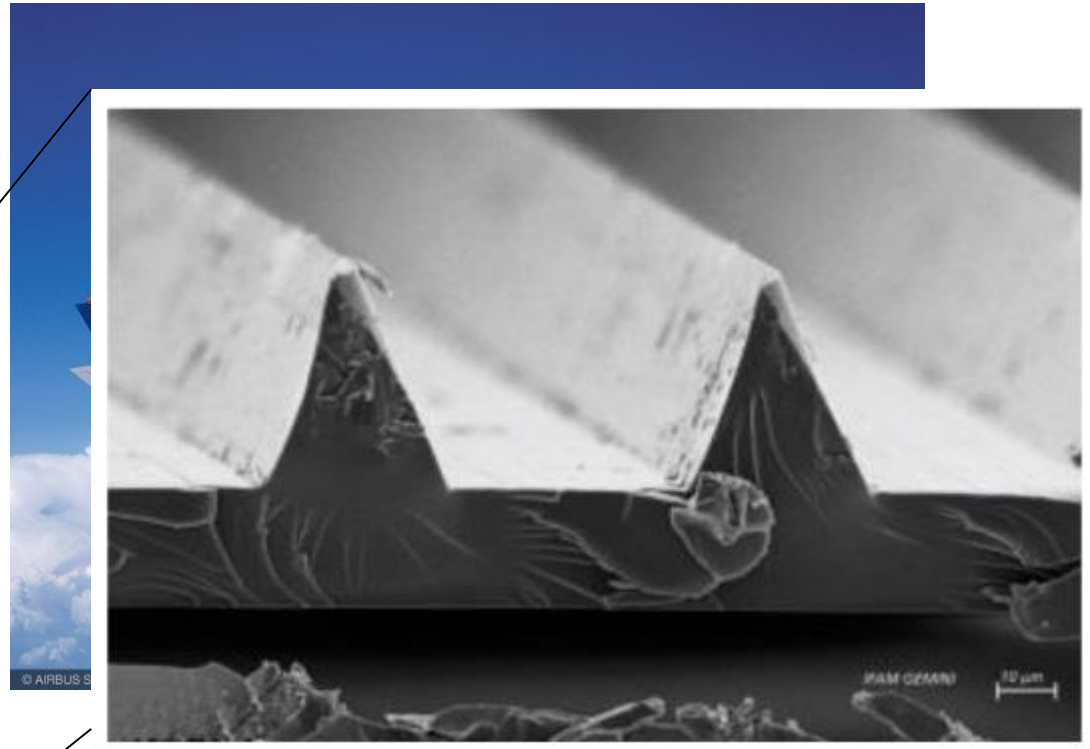
viscous drag = skin friction + form drag

AIRBUS

Where are the technology opportunities for drag reduction?

Typical drag break down of transonic civil aircraft





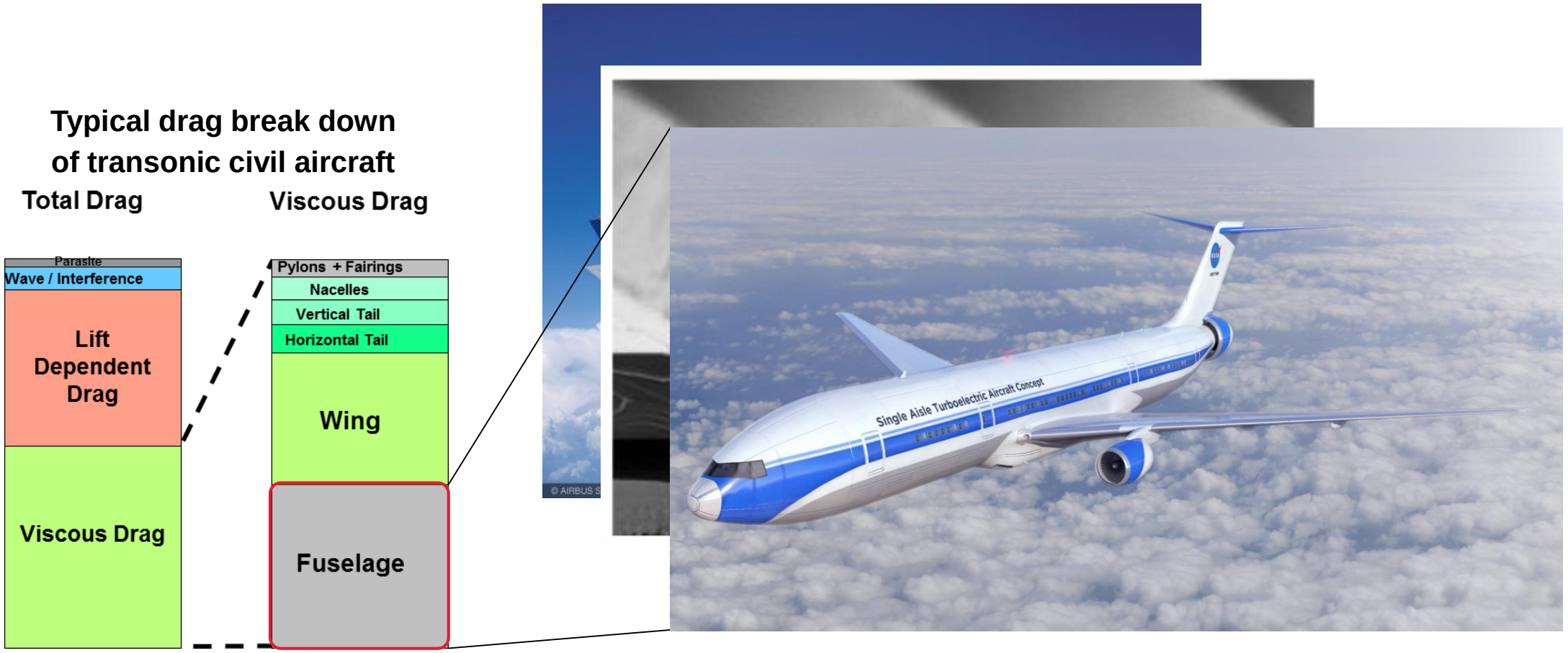
Viscous drag is a key element of overall drag

$$\rho_\infty u_\infty^2 \theta_\infty = \int_0^\infty \tau_0 dx + \int_{x=0}^{x=\infty} \delta^* dp$$

viscous drag = skin friction + form drag

AIRBUS

Where are the technology opportunities for drag reduction?



Viscous drag is a key element of overall drag

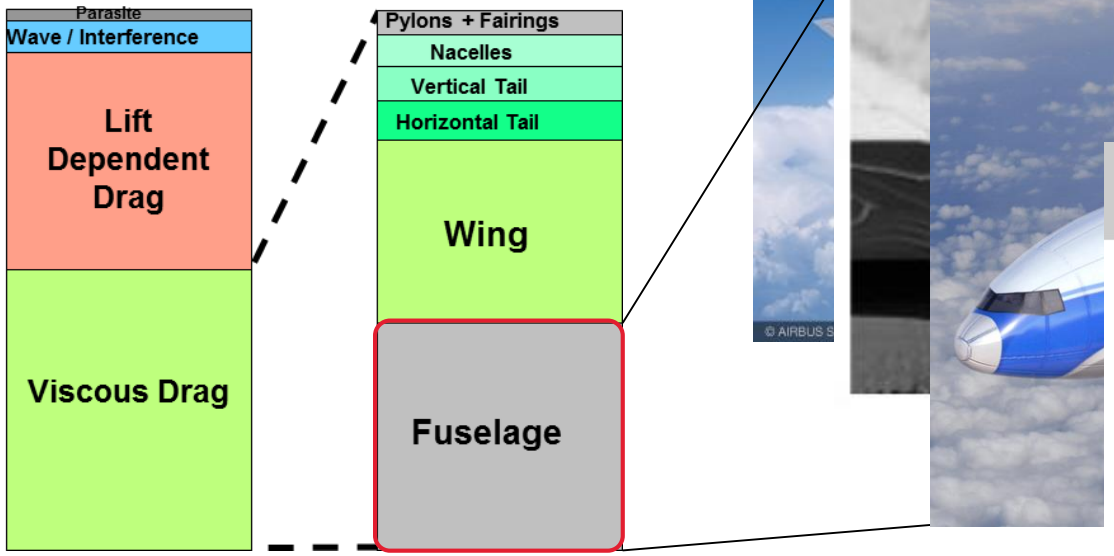
$$\rho_\infty u_\infty^2 \theta_\infty = \int_0^\infty \tau_0 dx + \int_{x=0}^{x=\infty} \delta^* dp$$

viscous drag = skin friction + form drag

AIRBUS

Where are the technology opportunities for drag reduction?

Typical drag break down of transonic civil aircraft



Viscous drag is a key element of overall drag

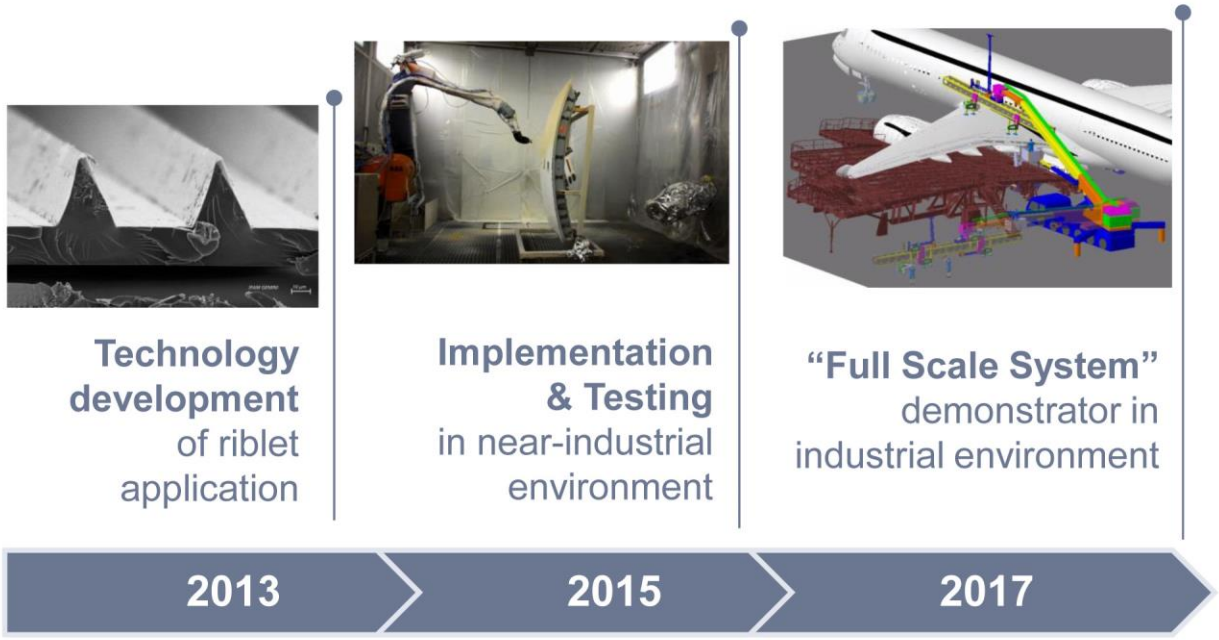
$$\rho_\infty u_\infty^2 \theta_\infty = \int_0^\infty \tau_0 dx + \int_{x=0}^{x=\infty} \delta^* dp$$

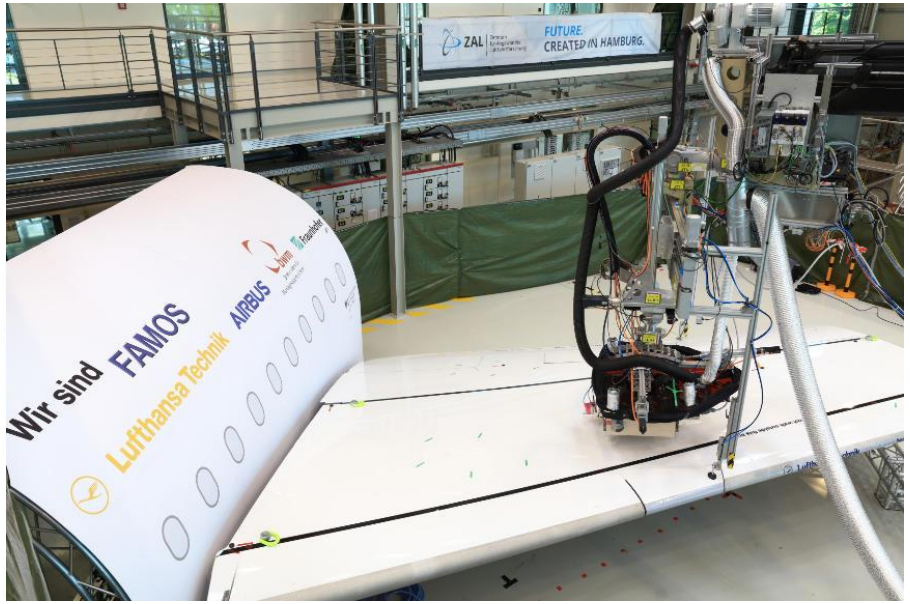
viscous drag = skin friction + form drag

AIRBUS

Riblets

Significant breakthrough on the industrialisation of riblets at AIRBUS.





Expected Benefits

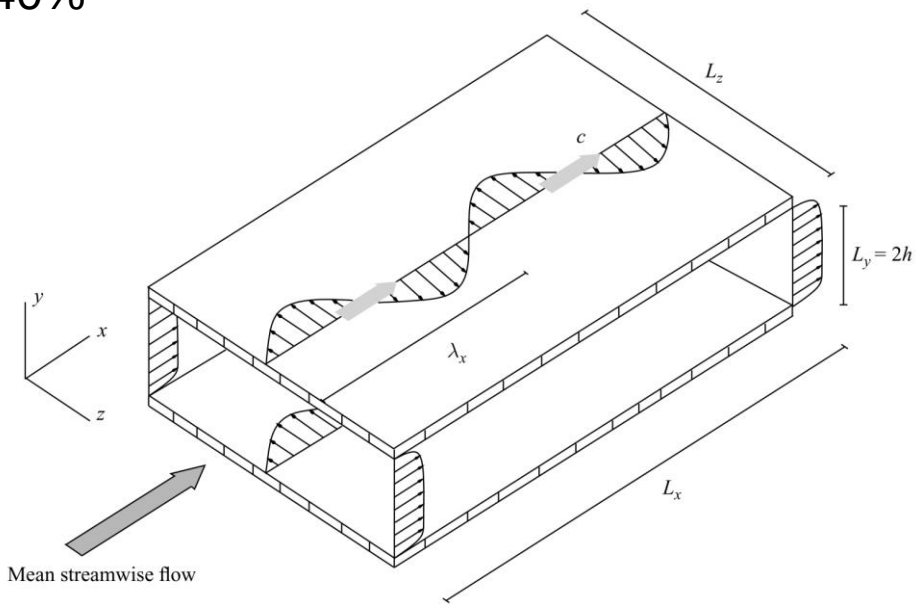
-1.5% fuel burn
dependent on aircraft type, mission, area applied and riblet efficiency

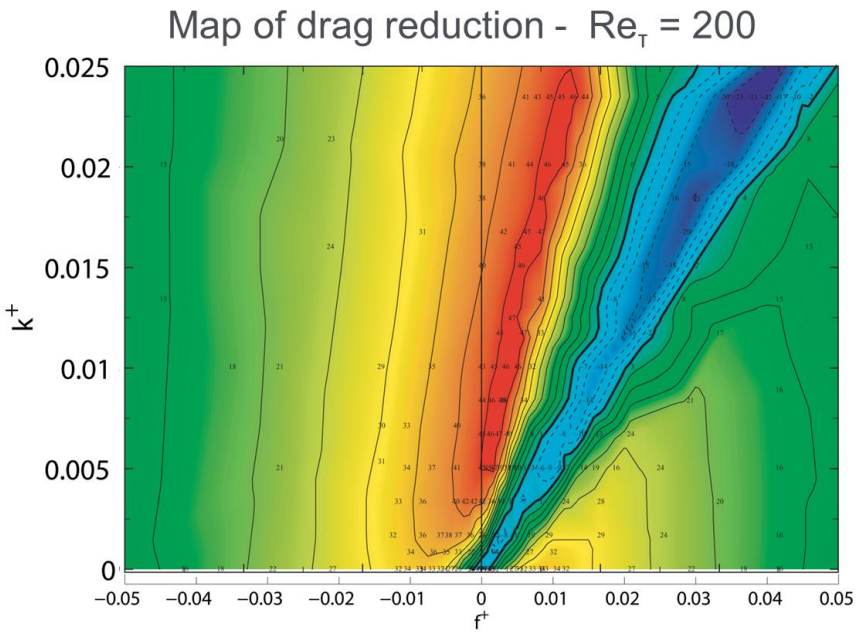
https://airwaysmag.com/industry/airbus-new-technologies-reinvent-aircraft-manufacturing/

AIRBUS

New insights into Skin Friction Drag Reduction

Direct Numerical Simulation (DNS) of the production of turbulence has identified that spanwise wall motion can introduce significant reductions in skin friction drag – up to 40%

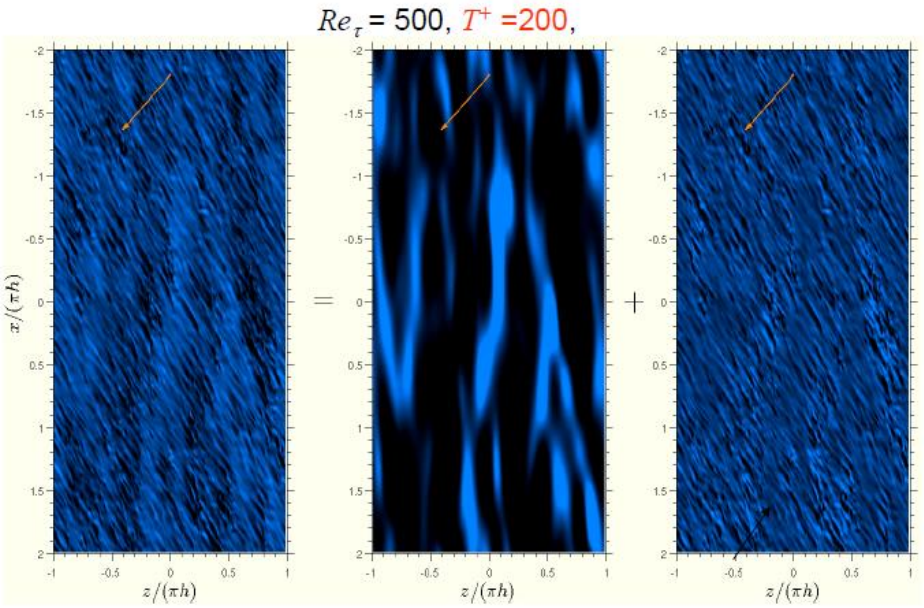




Quadrio (2009) "Streamwise-travelling waves of spanwise wall velocity for turbulent drag reduction"

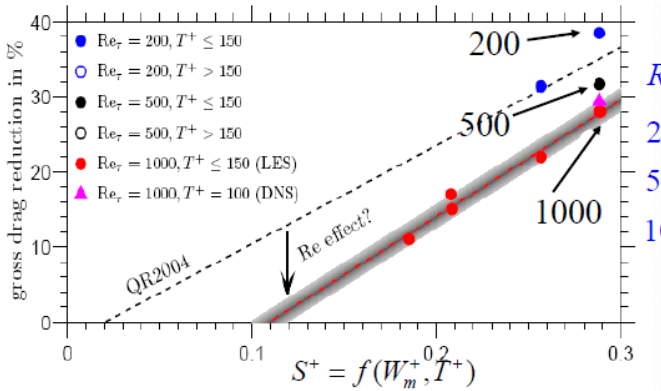
AIRBUS

Scaling with Reynolds number and the role of the ‘Outer Layer’



- Near-wall structure dominated by streaks
- Modulation by outer large-scale motions
- Actuation suppresses near-wall streaks and turbulence

- Transverse motion generates unsteady Stokes layer
- Confined to $y^+ \approx 20$ to be effective
- Ensured by $T^+ \approx 100$
- Drag reduction, channel flow, $Re_\tau = 200...1000$



$\propto Re^{-0.2}$

Re_τ =	$\Delta C_{f,\max} \approx$
200	36%
500	30%
1000	27%

$T^+ = 100$

Touber & Leschziner, JFM 2012

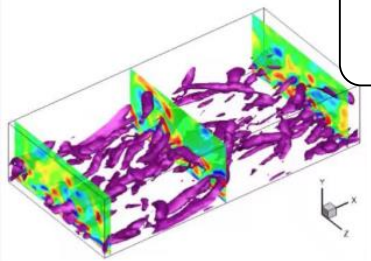
M Leschnizer, S Chernyshenko D LockerbyInvestigation of alternative drag-reduction strategies in turbulent boundary layers by using wall forcing EPSRC EP/G061556/1.

AIRBUS

New Enablers for Drag Reduction

These technology streams will continue their rapid development in future years independently of aerospace sector…

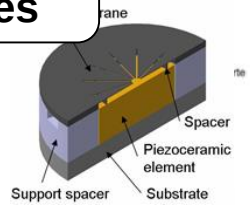
Increased computing power

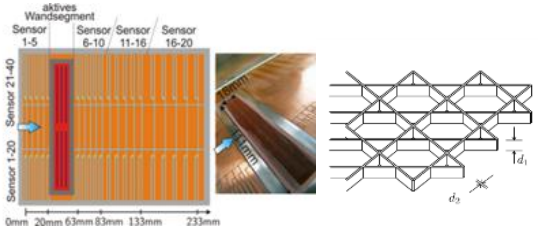


… can give us greater insight into the drag generating mechanisms in Turbulent boundary layers.

Experimental Techniques

Micro fabrication





… can give us the means to manipulate small scale Turbulent structures

What new opportunities for drag reduction can these technologies deliver?

Can we identify future 'system' that could deliver a net saving in a 10-20 year timescale?

AIRBUS

Some things that cannot be (completely) forgotten

- For any technology that goes on the aircraft we must consider
  - ***Performance Readiness***
    - ***Does the technology deliver the necessary improvements in performance?***
  - ***Engineering Readiness***
    - ***Do we have the capabilities to deploy the technology on a real aircraft?***
  - ***Operational Readiness***
    - ***How will the technology fit into normal operation?***
  - ***Manufacturing Readiness***
    - ***Can the aircraft be built at a sufficient rate and quality?***
  - ***Value and Risk***
    - ***What are the risks associated with the technology and are they quantified?***

- **If we are considering a technology far in the future some apparent 'show stoppers' can be overcome**
  - **But if some are impossible to overcome we must admit it!**

AIRBUS

Some Questions to consider over the next few days …

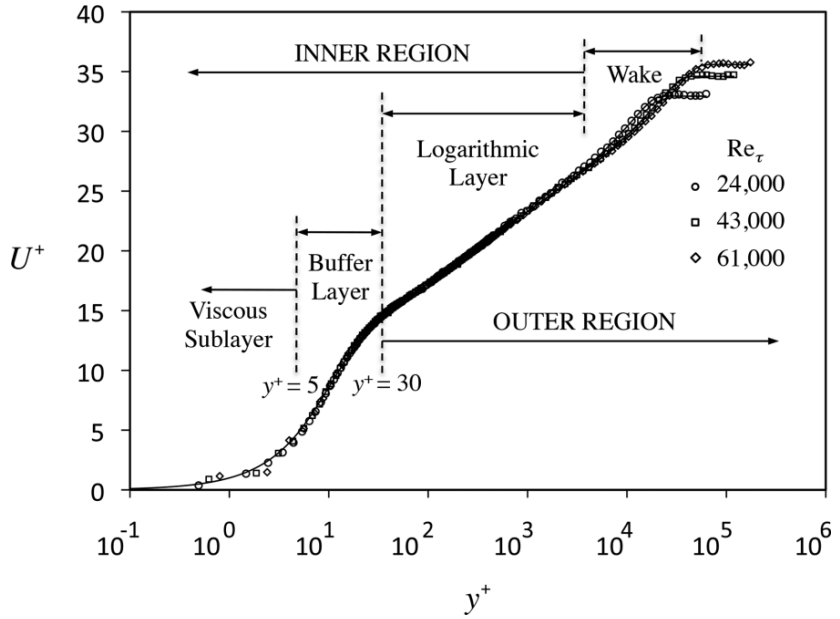
- Do we have any evidence today of a control concept that would be significantly better than riblets at aircraft scale Re.
  - *Significantly simpler to implement for a similar improvement* **or**
  - *Give a more effective net benefit*

- The outer layer's influence on drag increases with Re and cannot be ignored
  - Do we need to control the outer layer directly (or indirectly via the near wall)?
  - Is there a particular scale of turbulence that we need to control or must many scales be controlled?

- Have we any evidence today that control of outer layers can reduce drag?

- Do we foresee a SFDR concept that can give a net 'power' saving?

- Where could we be in (say) 10 years time in terms of:
  - Re that can be achieved ('routinely') by DNS?
  - Experimental capabilities to support ground based demonstration?
  - System / Surface Fabrication to realise the control ?



AIRBUS

Thank you

AIRBUS