Wissenschaftstag Braunschweig 2015

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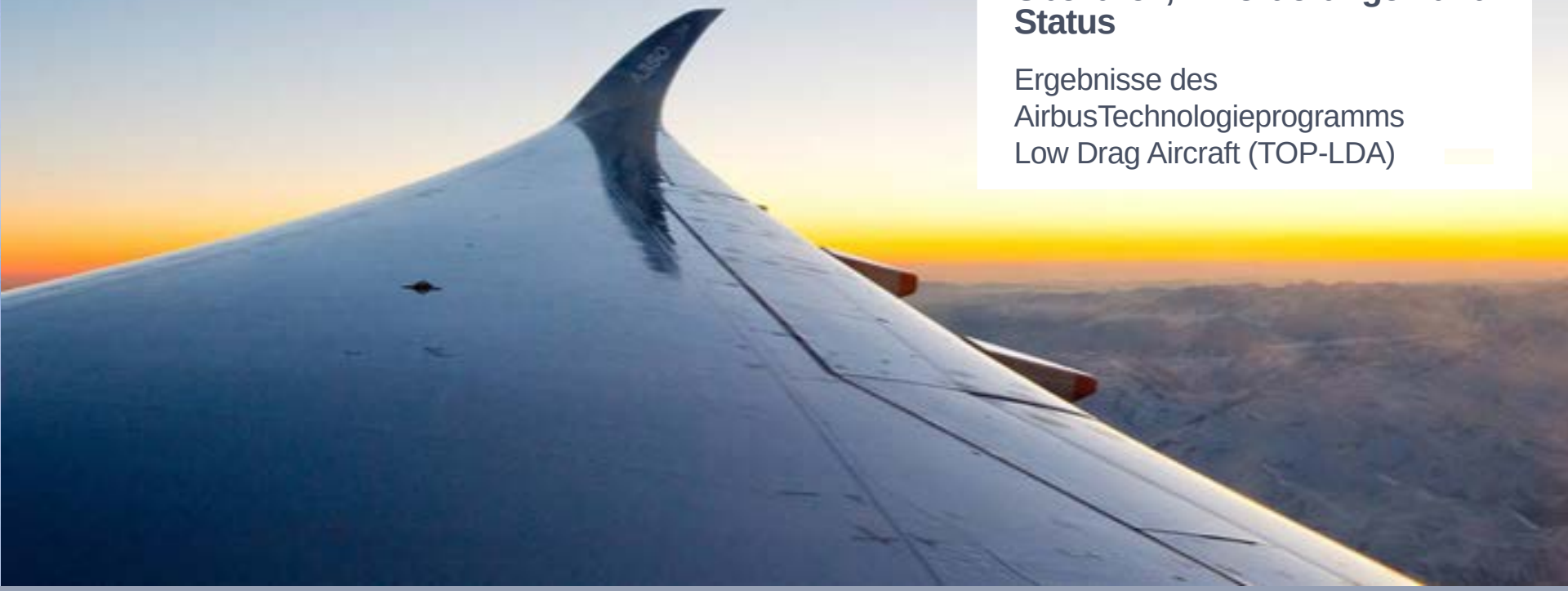
Laminarität für zukünftige Verkehrsflugzeuge

Überblick, Anforderungen und Status

Ergebnisse des AirbusTechnologieprogramms Low Drag Aircraft (TOP-LDA)



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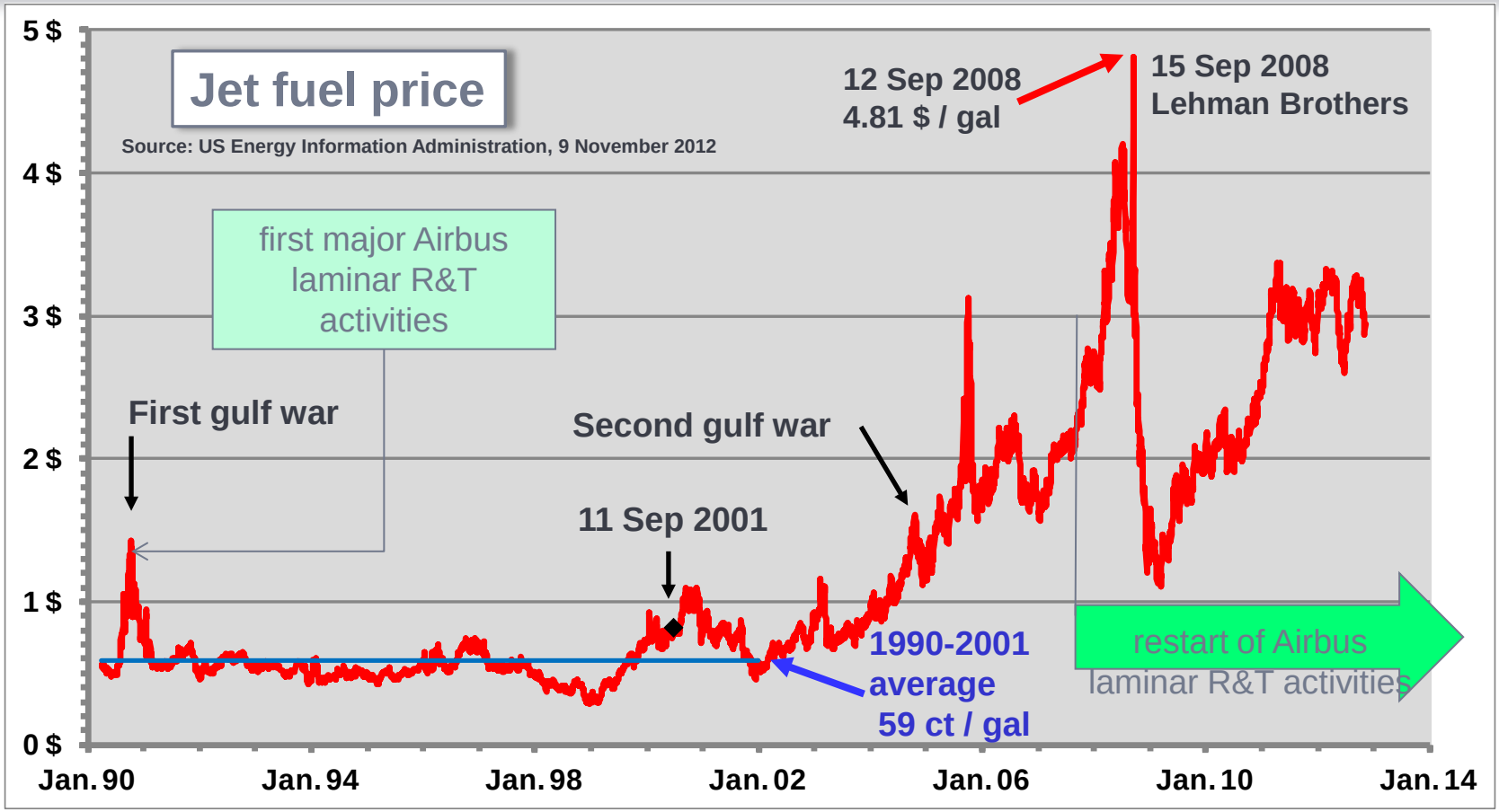
Jet Fuel Price as Driver for Performance Improvement



Drag reduction (by laminar flow) and efficient engines are key elements for reduction of fuel consumption

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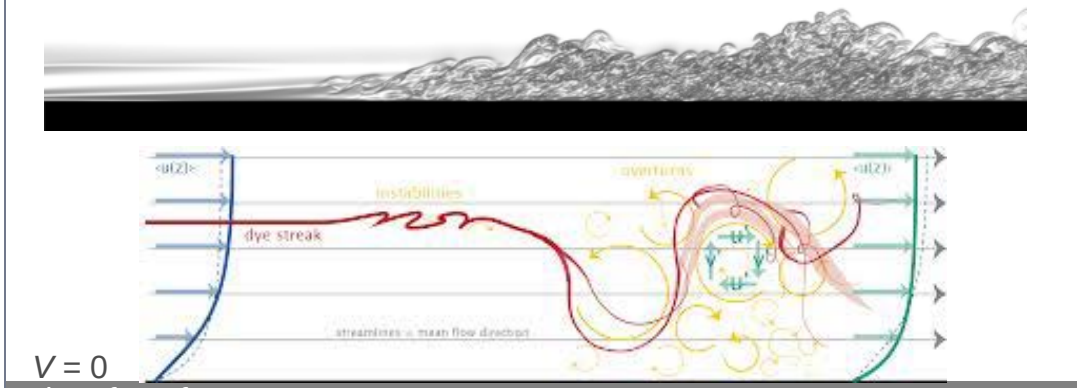
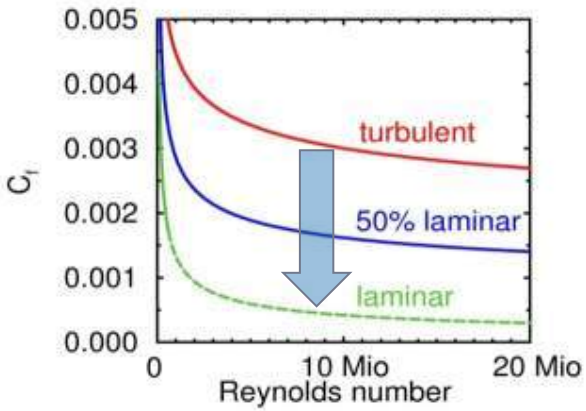
What is laminar flow?

Schematic Representation of Boundary Layer



Skin friction coefficient



- Laminar flow can reduce friction drag significantly
- Friction drag contributes to total a/c drag with ≈ 50%
- Biggest contributor to friction drag is wing and fuselage
- Laminarisation of fuselage is very challenging
- A laminar wing upper side has a bigger effect than lower side (≈ 65%)

For a typical wing application a reduction of total drag in the order of up to 8% is possible by laminar flow on upper side

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What are major influence factors for laminar flow?

Natural laminar flow (NLF):
→laminar boundary layer by wing airfoil shape only

Hybrid laminar flow (HLF):
→active control (suction, cooling) of boundary layer & airfoil shaping

Laminar flow influenced mainly by:

- Wing pressure gradient (= airfoil shape)
- Reynolds number (= size, speed, altitude)
- Leading edge sweep (= Ma number)

} **Aero**

- Smoothness of wing surface (waviness, steps, gaps, roughness)
- Three dimensional disturbances (fasteners, insects, scratches, ...)

} **Structure**

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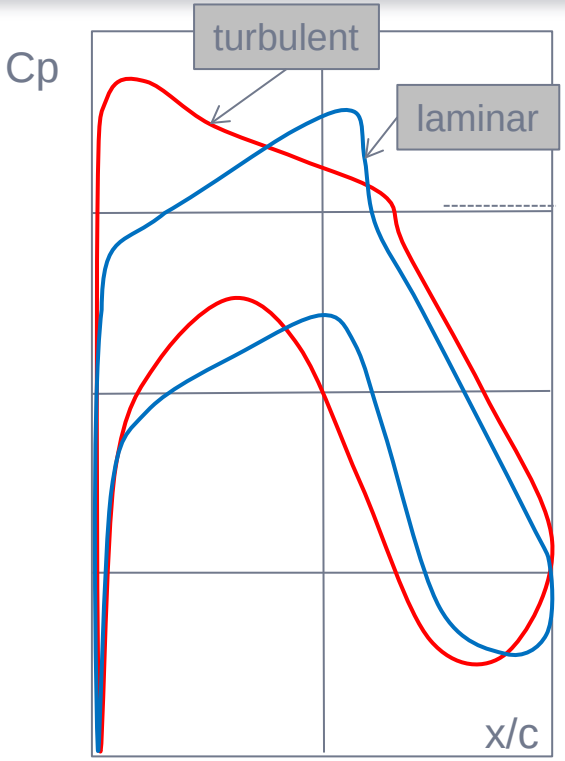
Characteristics of laminar Airfoils



thick & round leading edge

- max thickness far aft
- increased rear spar height

- narrow & sharp leading edge
- front spar moved back

- accelerated flow needed to get large extent of laminar flow
- this has a negative effect on shock strength (especially at high Ma)
- wing box of laminar wing similar to turbulent but more volume aft
- leading edge: sharp, less space → front spar more aft

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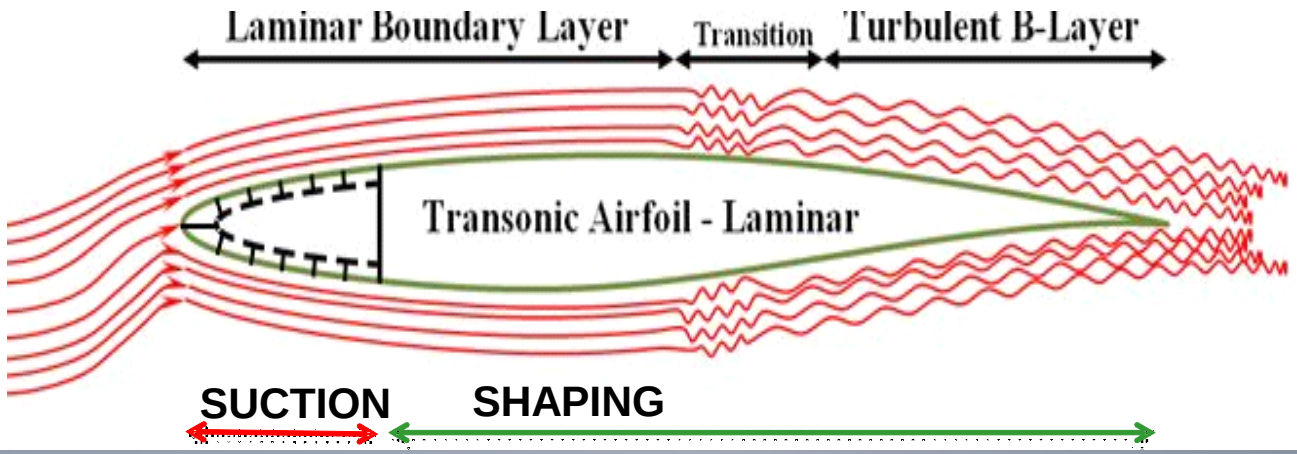
How Hybrid Laminar Flow works

Hybrid Laminar Flow Control (HLFC)
required at high sweep of leading edge (LE) and high Reynolds number
Can be reached by:

- Optimized aerodynamic shape of the airfoil **and**
- Small suction at the leading edge for stabilization of boundary layer
- Tight control of the manufactured shapes to remove perturbations at the skin, and

A320 VTP Flight Test with suction 1998



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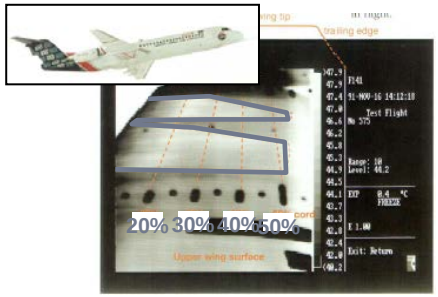
What is different in comparison to the past?

ATTAS NLF Glove 1987

F100 NLF Glove 1992



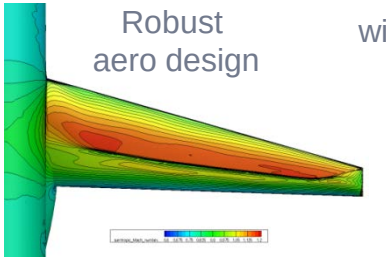
A340 HLFC Glove

A320 HLFC Fin

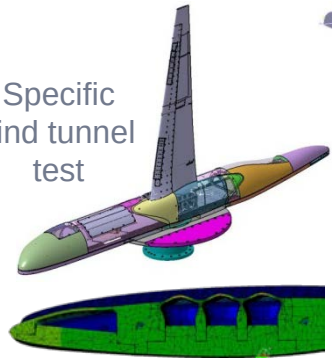
Past: Aerodynamic basic research with glove technology and hand finishing of surface

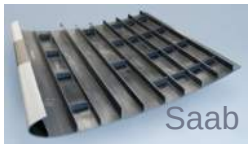
Today: Realistic structure concept fulfilling aerodynamic requirements <u>and</u> manufacturing at acceptable cost; demonstration of concepts on ground and in FT

Robust aero design



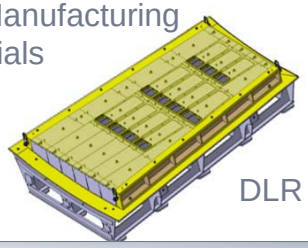
Specific wind tunnel test





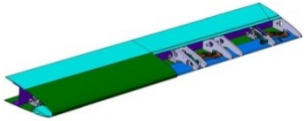
Saab

Manufacturing trials

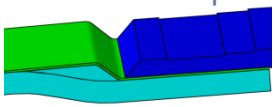


DLR

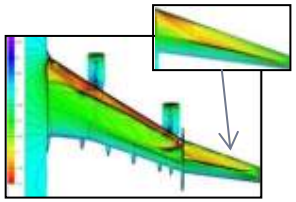
Large NLF wing LE ground demonstrator



Joint concepts



NLF wing



BLADE Flight Test

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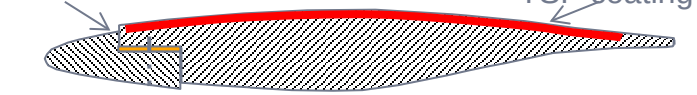
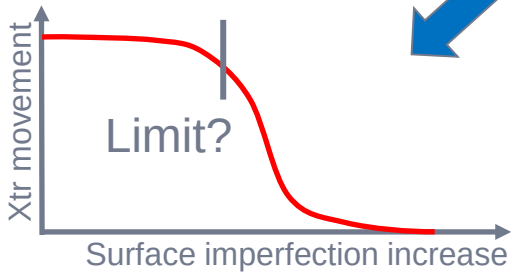
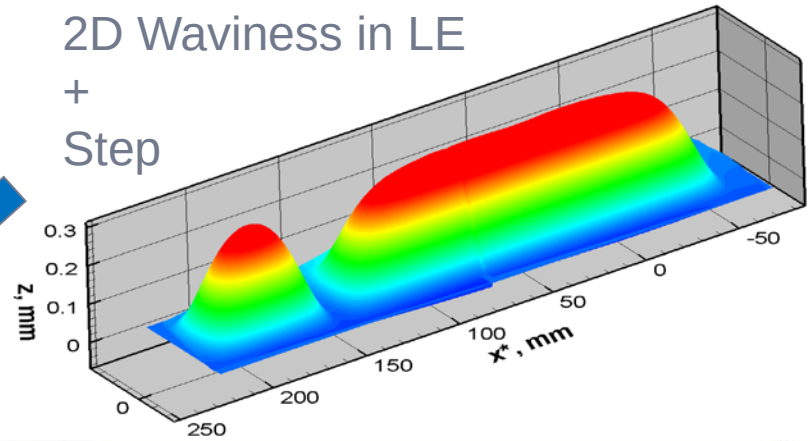
Surface Requirements: Experimental approach



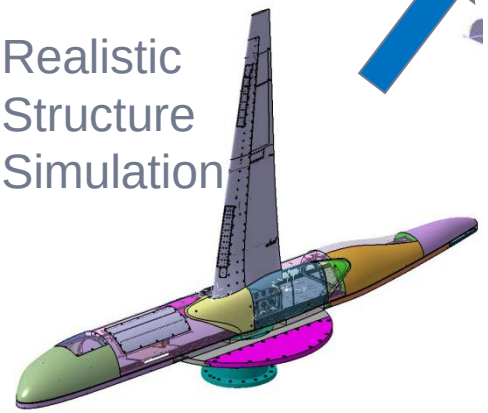
2D Step testing



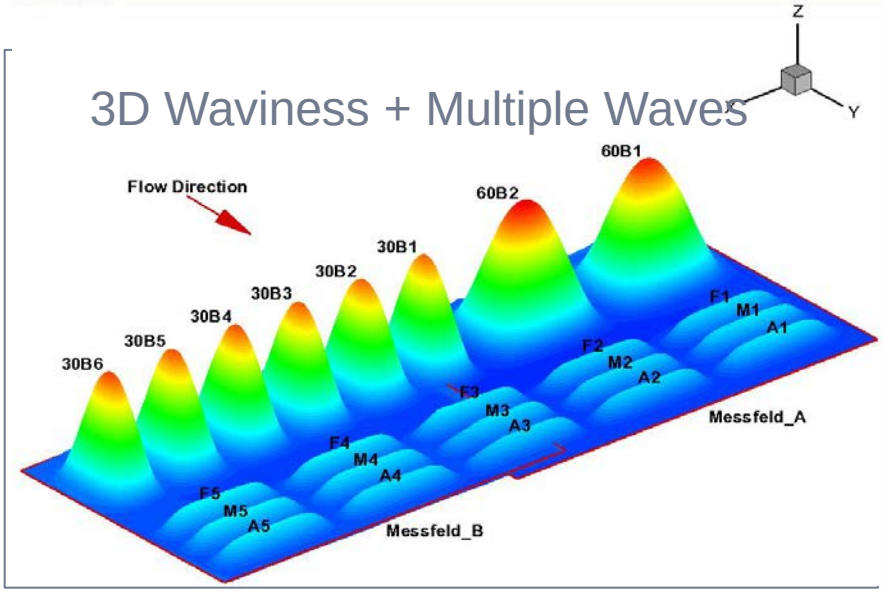
2D Waviness in LE
+
Step



Realistic
Structure
Simulation



3D Waviness + Multiple Waves



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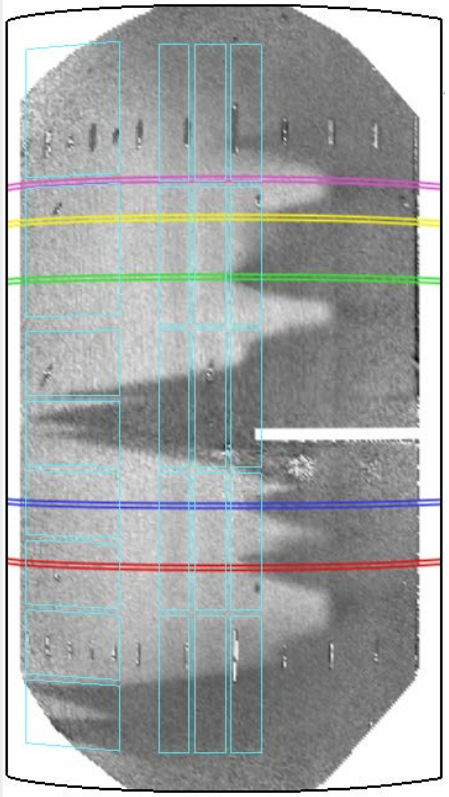
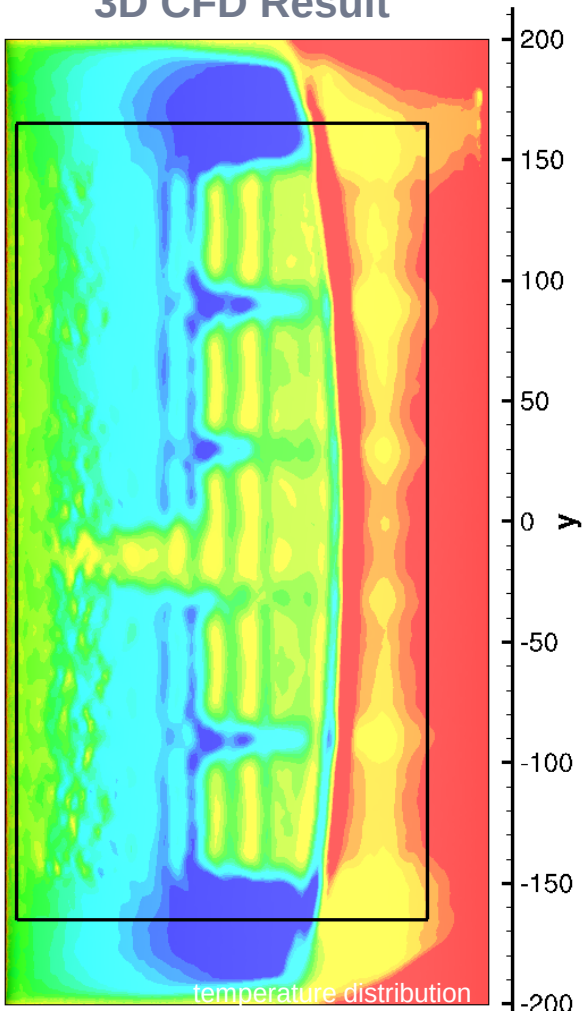
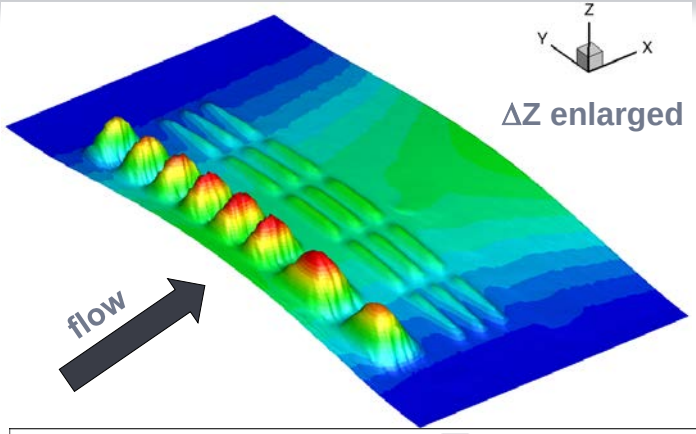
CFD Validation for Surface Requirements

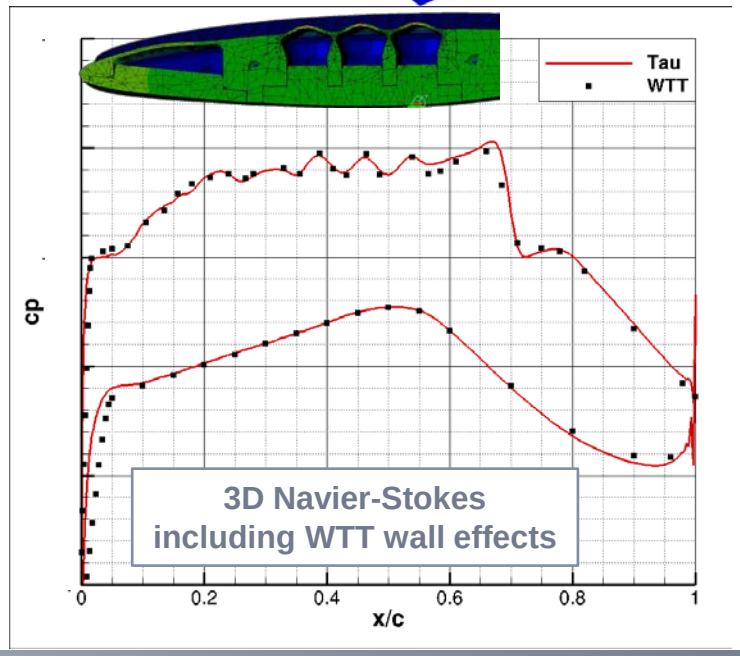
Experiment in KRG
Ma=.75 Cl=design
Re=13Mio



3D CFD Result







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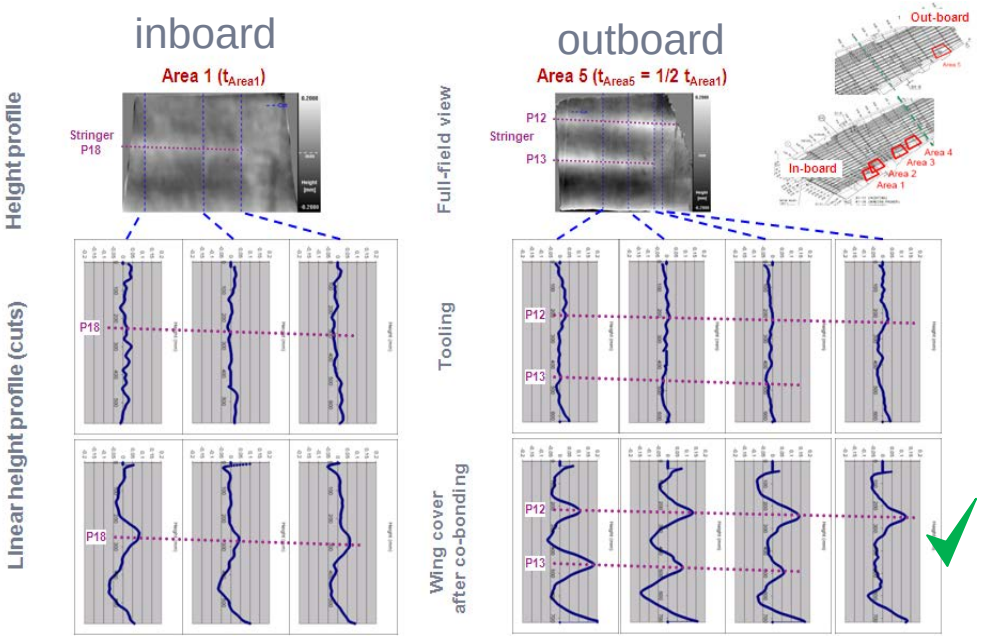
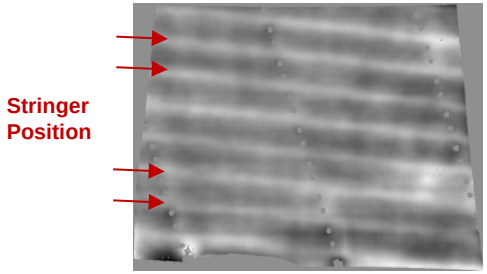
Surface quality measurements

Wing box example



Flap box example

flaps measurements before & after assembly



MBF
(Composite Structure)

Manufacturing Waviness is strongly dependent on build concept (stringer spring in, etc.)

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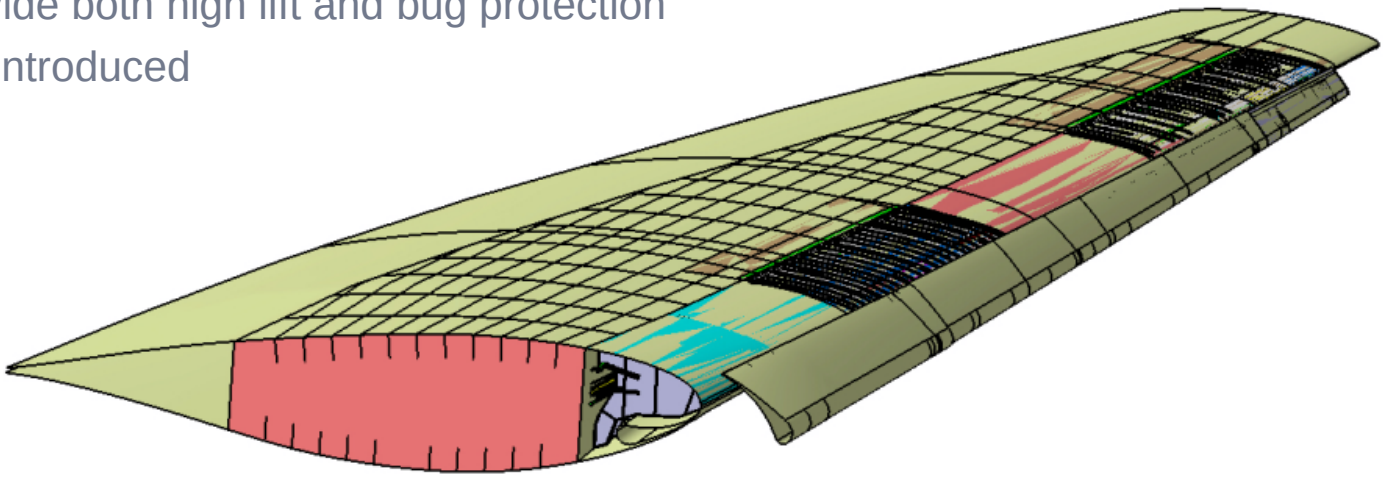
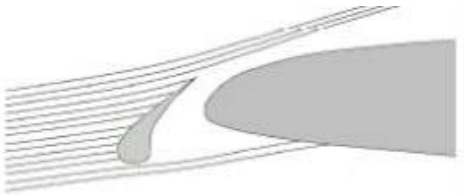
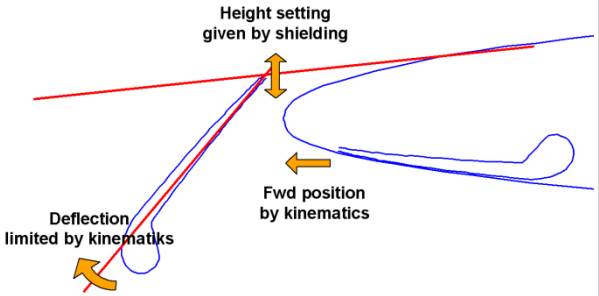
NLF Wing Structure Overview

- Box
  - Minimal change to turbulent box configuration
  - Lower Skin, Rear Spar and lower flange of Front Spar construction unchanged
  - Upper Skin certification challenges for “no fastener” joints and integral front spar cap
- Leading Edge
  - Change to LE design **key** to meeting NLF requirements
  - Joint to box critical, challenging build requirements and life management
  - Slats replaced by Krüger-Flaps
    - which provide both high lift and bug protection
  - Electric WIPS introduced



Krüger High-lift and Shielding Concept and Testing

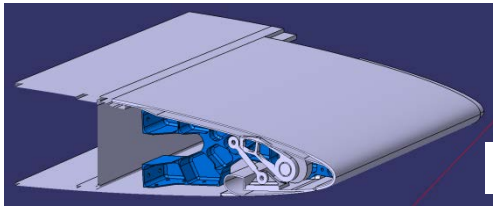




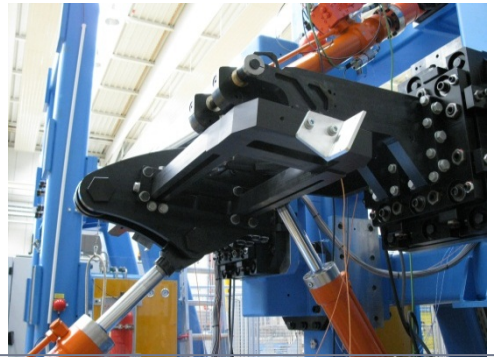
Krueger shielding

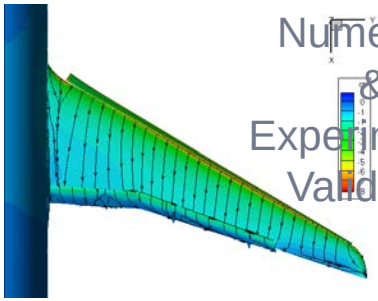
Definition of acceptable values for Krueger setting
Constraints for structure and kinematics concept

Coating Studies

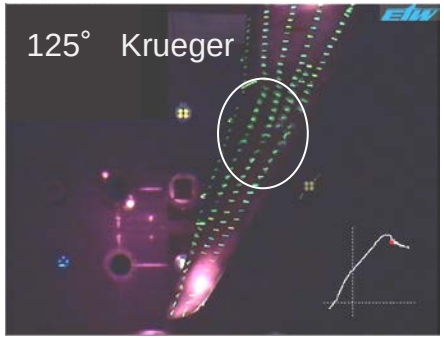


Kinematics Validation





Numerical
&
Experimental
Validation



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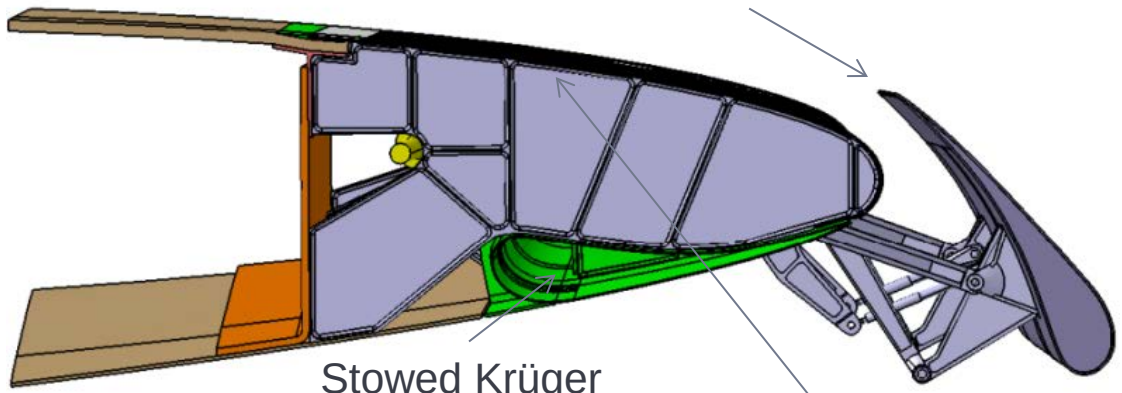
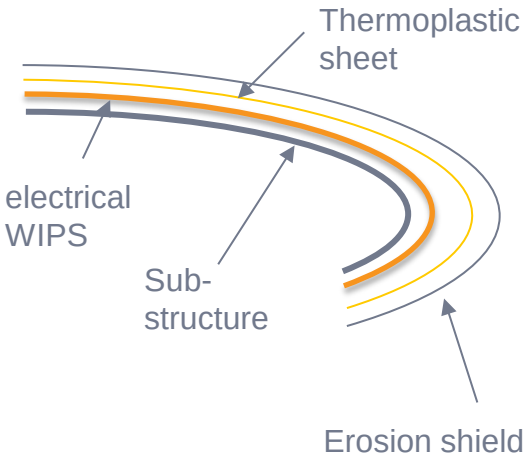
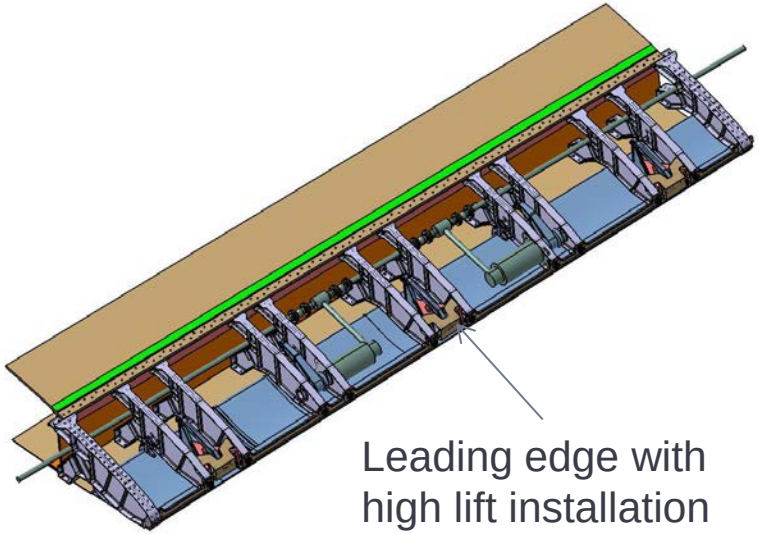
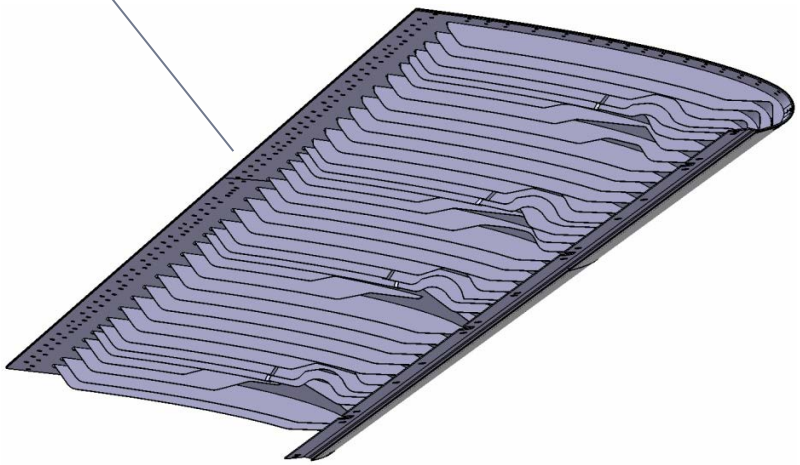
NLF Leading Edge Skin sub assembly









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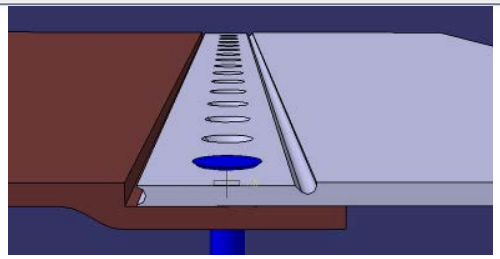
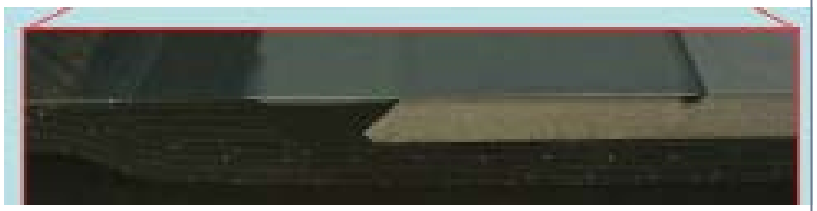
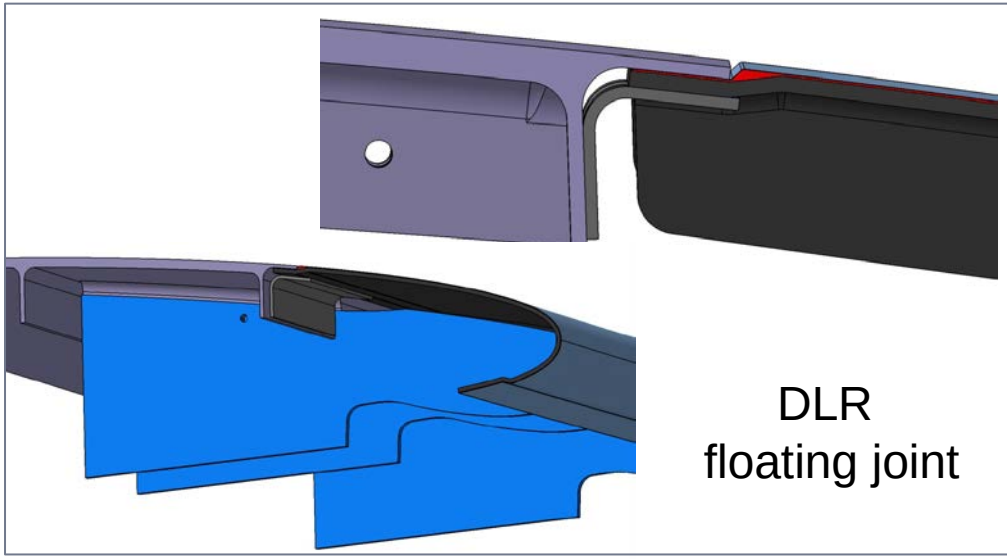
Examples of Joint and Fastener Head Options



AGI
filler cover





DLR
floating joint

The joint area and the filler application is a very critical zone for a laminar wing structure concept

Several partners are working on that topic and flight demonstration in BLADE is planned as well

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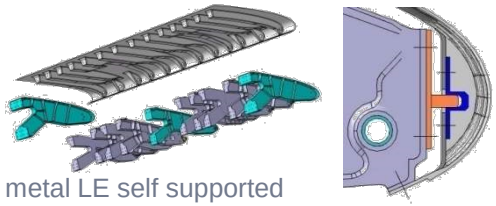
Ground Based Demonstrators in context of TOP-LDA

Airbus metal LE concept



metal LE self supported

GKN CFRP LE concept

machined joint

DLR CFRP LE concept

floating joint

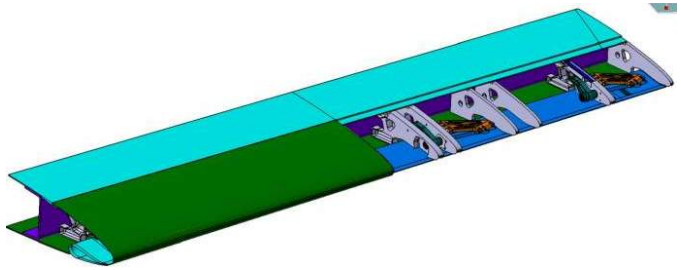
BLADE demonstrators

Saab

GKN

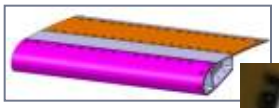
& machined metal LE

Ground Based Demonstrator in SFWA



4.5m span NLF leading Edge

Krueger Test rigs



Check several approaches and select the best mix out of the different demonstrators

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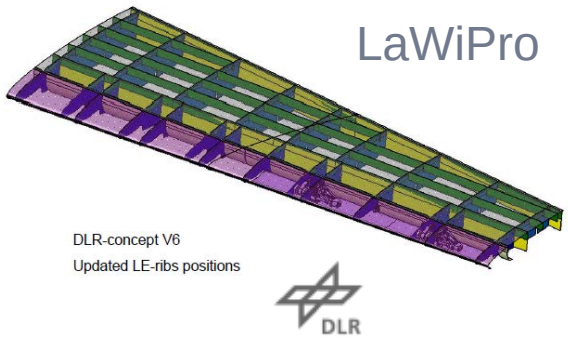
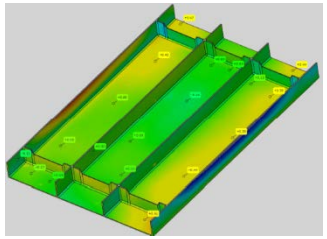
Upper Cover DLR NLF Manufacturing Demo

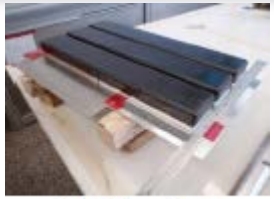




Surface quality analysis

Cutter

Preforming Cores



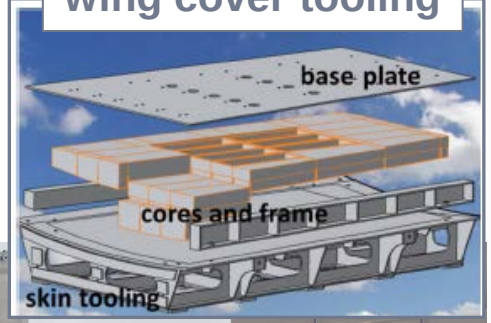
Positioning

Applying radius filler

Test panel

Autoclave

wing cover tooling



Stade 13.6.2013

Major Objectives:

Development of new CFRP wing cover structure concept and manufacturing demonstration for laminar wing application

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GKN Ground based NLF LE Demonstrator

Ground based NLF leading edge demonstrator including Krueger and WIPS integration

4.5m length

Major Objectives:

Demonstration of full LE integration of all NLF leading edge components and manufacturing and assembly quality of large leading edge parts

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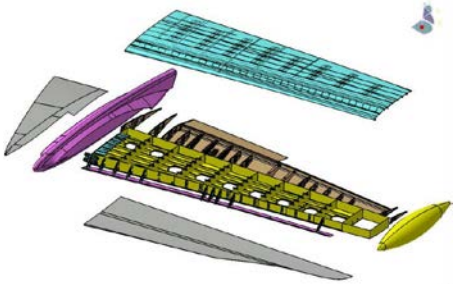
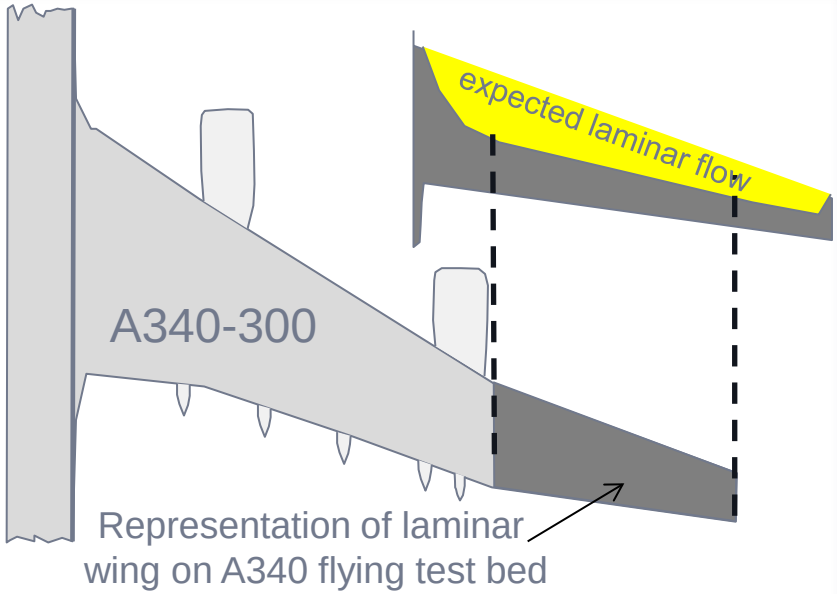
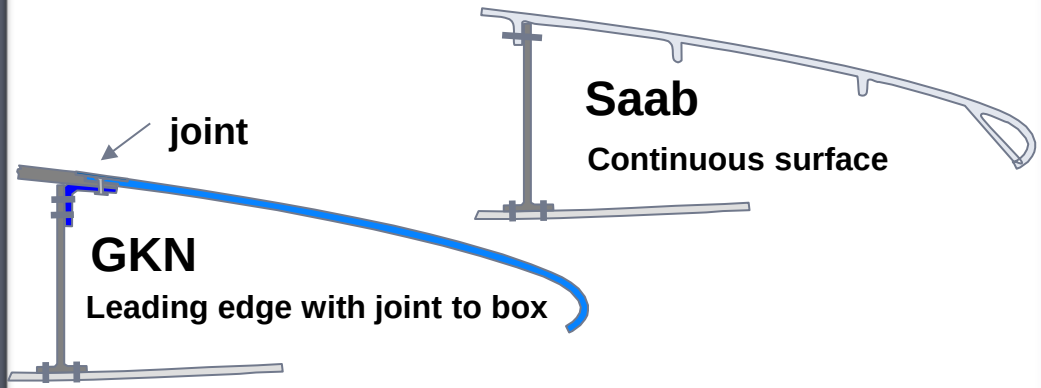
BLADE A340 MSN1 Flight Demonstration





Major Objectives:

- Design and manufacturing of NLF outer wing
- Flight testing of NLF wing with **two different structure concepts**
- Demonstration and validation of aero design and CFD tools
- Validation that selected structure concepts are feasible and deliver expected surface quality
- Testing of artificial disturbances and operation simulation
- Testing of Kruegershielding



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Summary and Outlook

- Surface quality is a major challenge for laminar flow application and detailed knowledge about surface requirements is needed to find best compromise between structure solution and aero performance
- Specific wind tunnel test have been designed to get such precise requirements
- CFD capabilities further improved and validated to predict such effects
- Small, medium size and full wing demonstrators and validation experiments including large scale flight test with A340MSN1 will be used to get confidence in what is possible
- There are several activities with different partners running to find the best structure and manufacturing concept for the leading edge and upper cover of a laminar wing
- Operability of such laminar wings and surface quality degradation effects will be an additional important topic in the future

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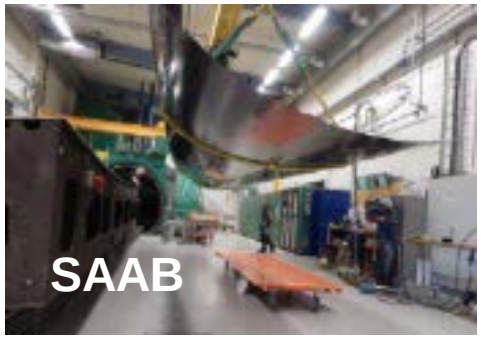
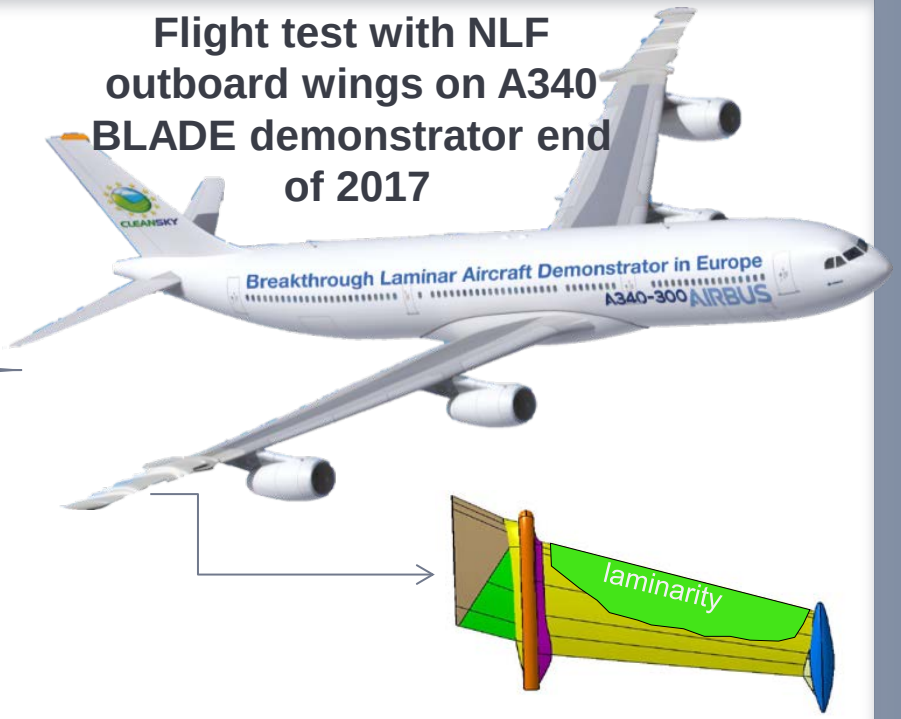
What will come next?



Manufacturing of BLADE large FT demonstrator

Final assembly

Flight test with NLF outboard wings on A340 BLADE demonstrator end of 2017



Flight test with simplified HLFC on the VTP of the A320 DLR ATRA aircraft in 2017

Wing LE HLFC Ground Demonstrator

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