Presented by

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Flying Community Friendly –
The Role of High-Lift Aerodynamics

Design concepts & solutions for the future

The high-lift contribution ...

... for reduced fuel burn & emissions:

- **by light systems & structure**
  - Lightweight solutions for classsical systems
  - Enhanced high-lift performance to downsize the required moveables system
- **by multi-purpose devices**
  - Cruise variable camber flaps with differential flap setting
    - to enhance cruise flight performance
    - to provide lift control
- **by novel efficient engines**
  - Novel leading edge moveables to allow close coupled integration of ultra-high-bypass engines
- **by laminar flow wings**
  - Novel Leading edge moveables enabling laminar flow on wing
  - enhanced trailing edge moveables to allow slatless leading edge
  - Cruise variable camber flaps for shock control

The high-lift contribution ...

... *for reduced noise impact:*

- **„by performance“**
  - Enhanced high-lift performance
    - for steep approach
    - for steep climb-out or reduced engine power
- „**by design“**
  - Suppression of source noise on the high-lift system and leanding gear
  - High-lift solutions for configurations with noise shielding

... *for increased airport capacity:*

(i.e. more efficient use of given infrastructure)

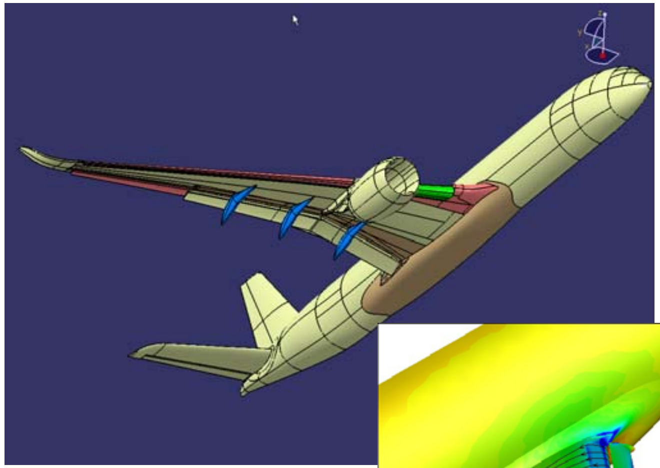
- **by increase of take-off / landing frequencies**
  - climb-out & glide path flexibility
  - wake vortex prediction & control

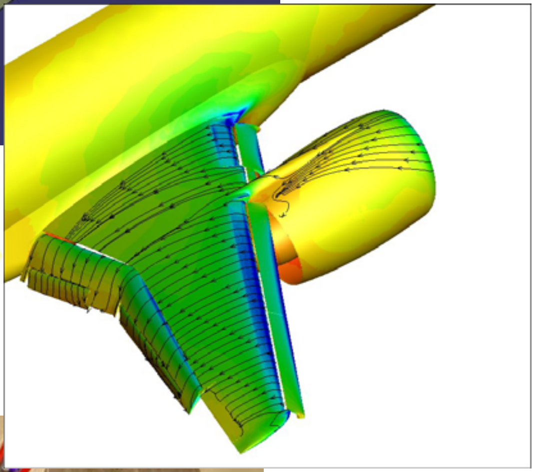
The high-lift contribution ...

... for improved economic performance

(i.e. reduced cost & time to market for novel efficient aircraft):

- Earlier convergence & fidelity of assessment of the configuration by the use of
  - Modern parametric CAD tools allowing close coupled multidiciplinary work
  - High-fidelity 3D CFD
  - High Reynolds-number windtunnel testing
  - Rapid prototyping windtunnel models with minimum lead time
- ... leading to
  - reduction of lead time
  - minimizing uncertainties and resulting unnecessary margins





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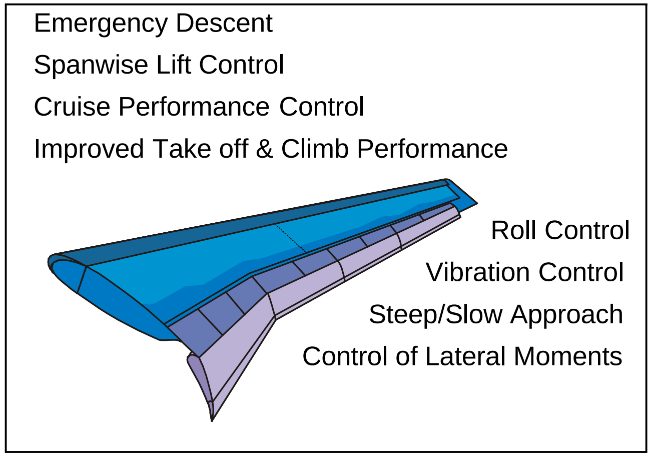
A) Significant evolution of classical configuration

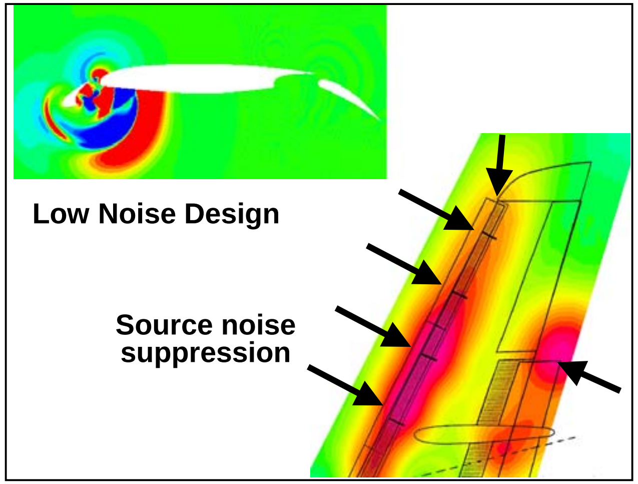
Main elements:

- ***High- / Low Speed Integrated wing design***
- ***New Leading edge concepts***
- ***New Trailing edge concepts***
- ***Passive flow control***
- ***New devices concepts***
- ***Airframe source noise optimised design***
- ***Wake vortex optimised design***

Example: Advanced Trailing Edge Control Surfaces



Example: Source noise prediction & suppression

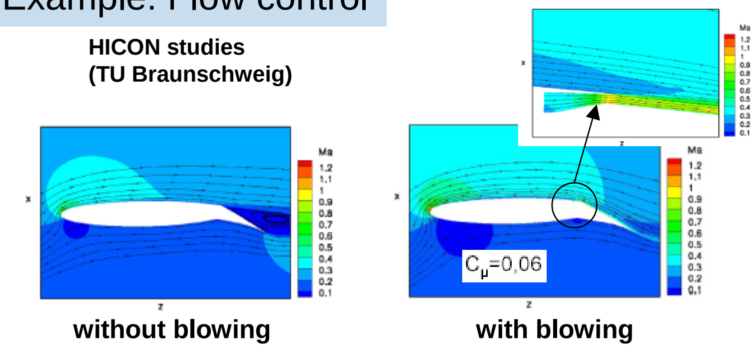


B) 'Smart' configuration with flow control features

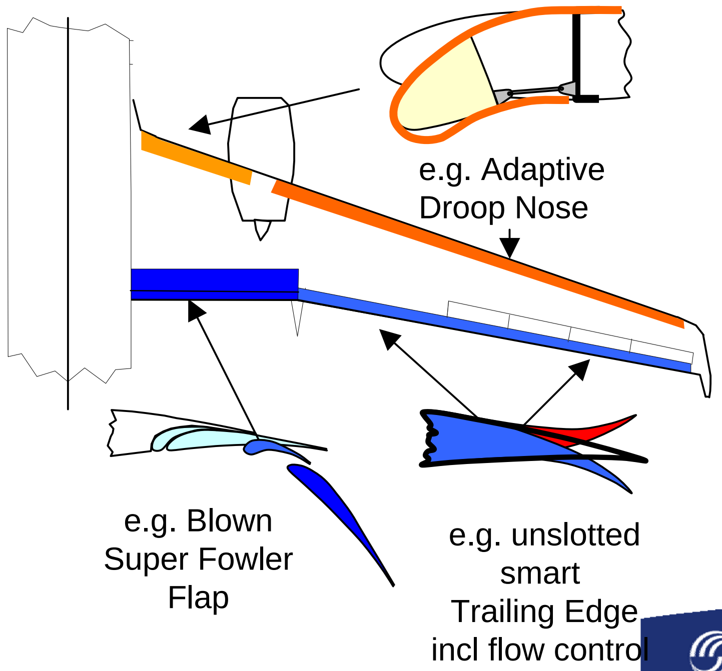
Main elements:

- ***Improved A/C configuration***
- ***Highly advanced high-lift system***
- ***Laminar flow control wing (Active or passive)***
- ***Effective use of active high-lift flow control***
- ***Aeroacoustics optimised airframe layout "by design"***
- ***Integration of UHBR- or open rotor engines***
- ***Optimised (deliberate) interaction between engines and high lift system***
- ***Best compromise between extreme high lift capabilities and system consequences***

Example: Flow control



Example: Smart high-lift devices

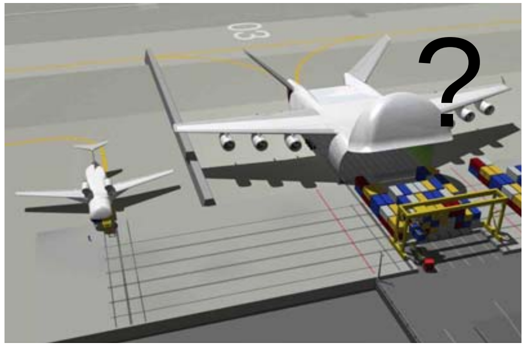


C) Novel configurations

Main elements:

- ***New configuration***
- ***Aeroacoustics optimised airframe layout "by configuration"***
  - Novel engine integration concepts
  - Novel low-noise High-lift concepts
- ***Highly advanced high-lift systems***
  - 'Active flow control on wing & high-lift devices

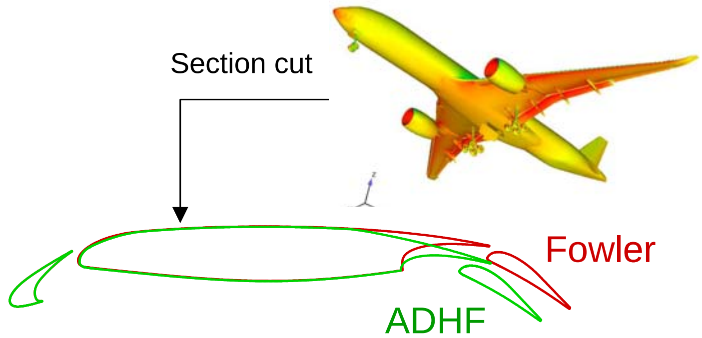
Example: Unconventional configurations



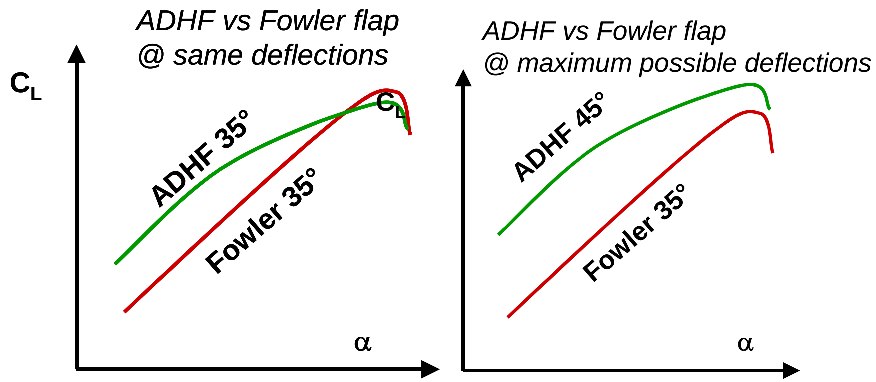
Design solutions – A350XWB
A multi-purpose trailing edge system

The <u>A</u>daptive <u>D</u>ropped <u>H</u>inge <u>F</u>lap

- **Enhanced low speed aero performance**

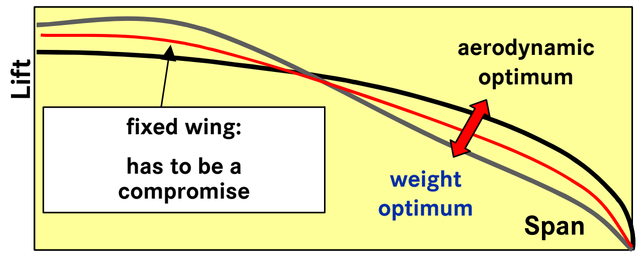


- **Low complexity flap kinematics**



High-lift performance enhancement

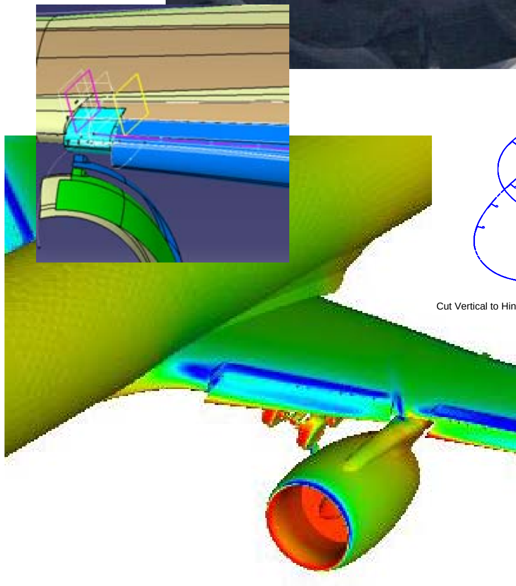
- **Cruise Variable Camber functionality and differential flap setting**

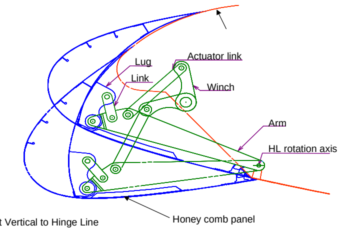


Cruise performance enhancement

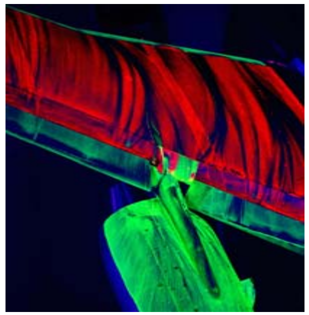
Design solutions – A350XWB
Take off performance & Engine integration

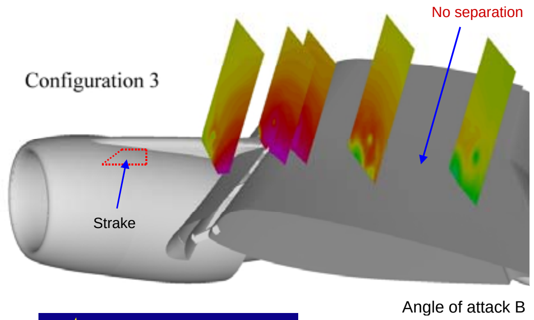
- **Droop Nose Device & Sealed Slats**
  - Significant take-off drag improvement optimised A380 style droop nose device and slats with a sealed take-off position
  - Advanced droop nose concepts and detailed improvements





- **Integration of modern <u>V</u>ery <u>H</u>igh <u>B</u>ypass <u>R</u>atio engines**
  - Closed coupled VHBR engines act as major constraint for the integration of the leading edge moveables
  - Significant shortfall in performance can be triggered from premature flow separation the nacelle/pylon junction area,
    - i.e. careful design optimisation is required
  - Droop Nose device allows a sufficient protection without the need of complex local treatments
  - Strakes / vortex generators provide a further further local improvement of the flow conditions





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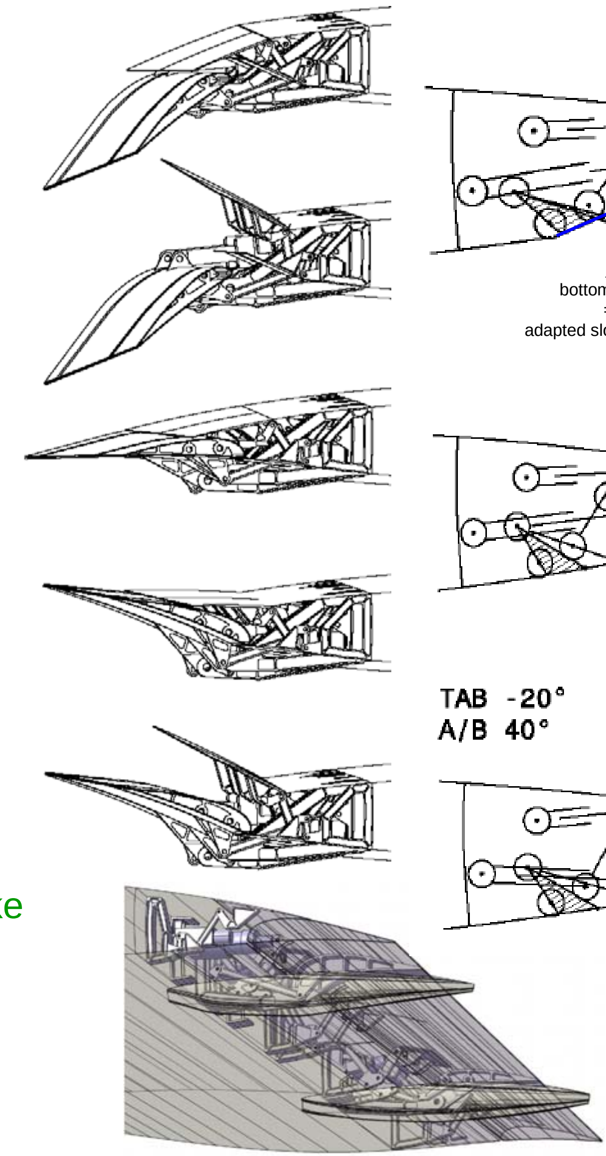
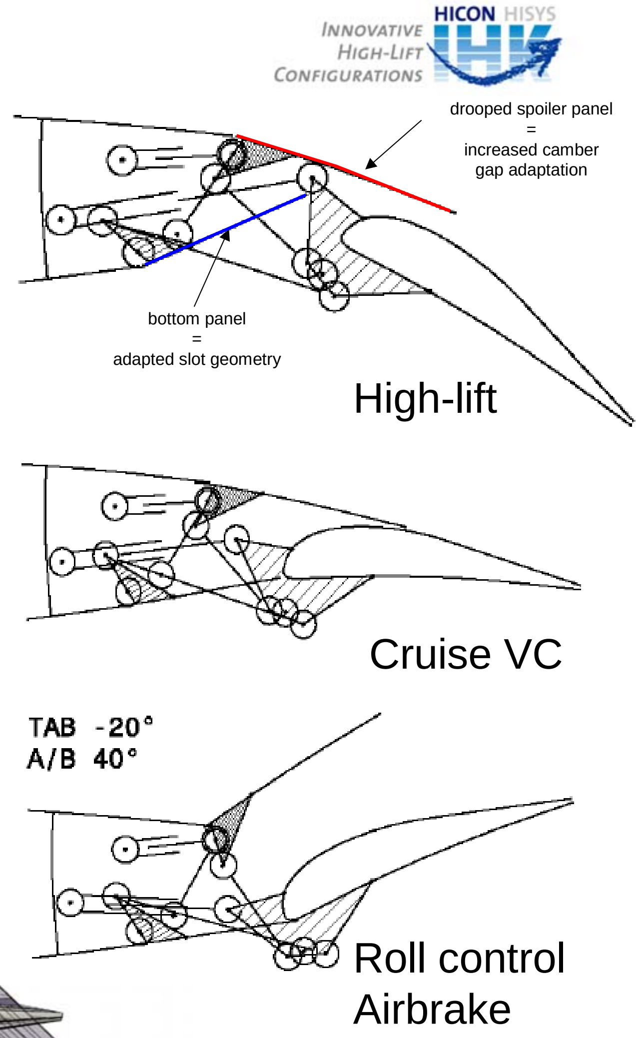
Design solutions – future devices concepts
Fully integrated trailing edge concept

*Several adaptive trailing edge concepts developed in past R&T **…** however, heavy & complex solutions due to additional element at the fowler flap*

The HICON approach: Full multi-purpose use of the high lift element





→ The "Slotted Camber Tab" (SCT)

- Provide low complexity / weight flap kinematics
- Avoid disadvantages of Dropped Hinge Flaps:
- Multi-purpose HL system use in cruise
- HL system used for roll control & airbrake

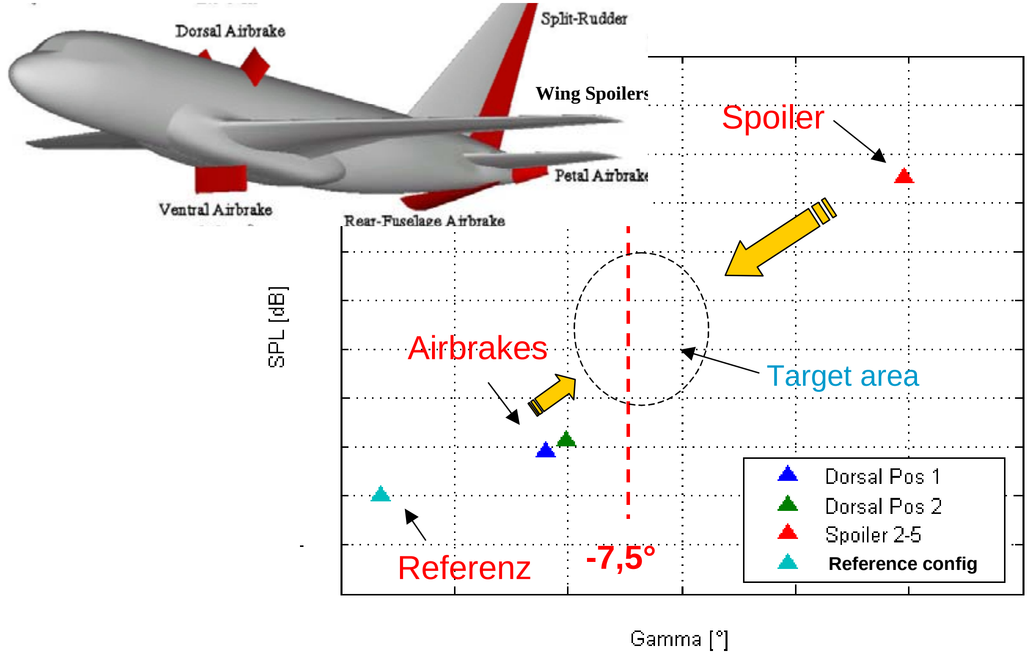
Design solutions – future devices concepts
Steep approach

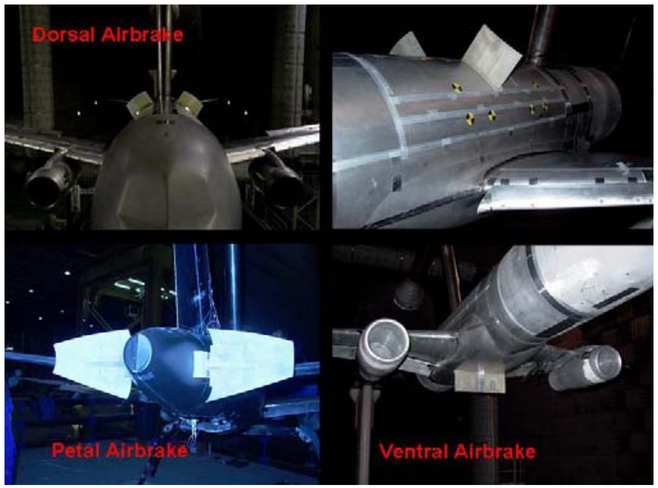
- **Steep approach flight is seen as a major opportunity to alleviate community noise impact**

- Devices which create drag without loss of lift are most efficient
  - Add-on devices are effective but create unwanted weight effect & integration challenge
    - ... which may even outbalance the overall benefit

- The aim is to design additional functionality into the baseline high-lift & controls concept
  - ... to provide steep approach performance as „fall-off"
  - ... while enabling low source noise of the devices

- Novel spoiler concepts and low complex add-on devices are being developed in this context



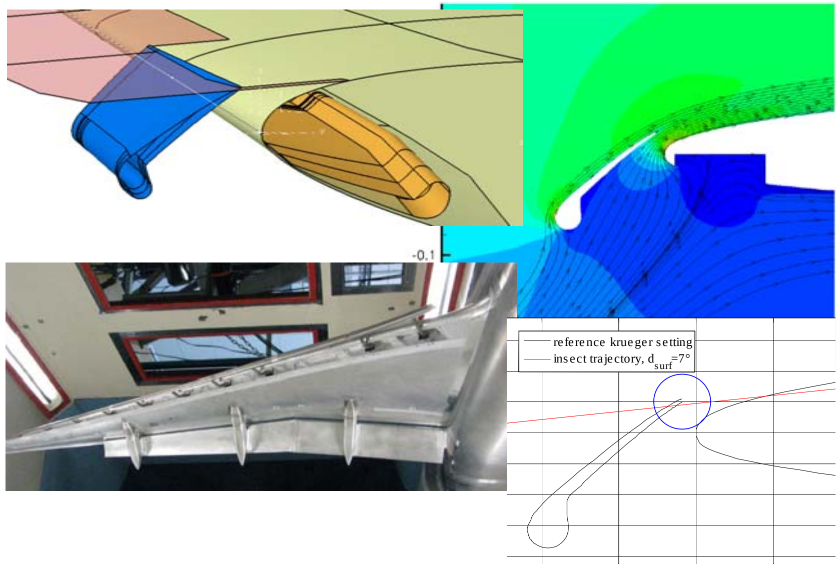


A318 at London City Airport

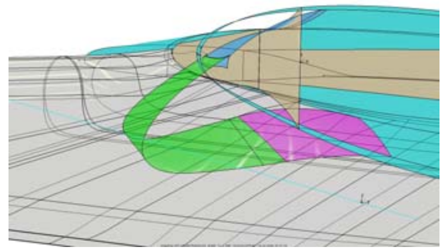
→ Spoiler used for steep approach configuration

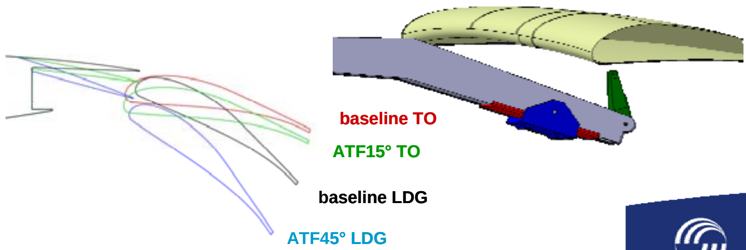
Design solutions – future devices concepts High-Lift solutions enabling a laminar wing

- **„Laminar wing tailored“ Leading edge devices**
  - to provide sufficient maximum lift performance despite sharp laminar wing nose
    → avoidance of significant oversizing of the cruise wing to meet high-lift performance
  - **Advanced Krüger-Slat**
    - enabling laminar flow on wing upper surface
    - Functional integration of high-lift and shielding function



- **Variable Camber Trailing edge devices**
  - to provide control of cruise pressure distribution shock location → maximise operating range with laminar flow
  - **Adaptive Dropped Hinge Flap** (A350)
  - **Advanced Tracked Flap**
    - Combining advantages of a tracked fowler flap with variable camber function





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Design solutions – Active Low Speed Flow Control

- **Active flow control for low speed applications**
  - To enhance the performance of passive high-lift systems
  - To „repair“ critical areas on the wing
  - To fully replace classical high-lift systems
  - ... with the aim of flow control solutions being more effective or lighter than passive mechanical high-lift solutions

- *In recent R&T (e.g. JTI SFWA, AVERT and Lufo4/Aeronext) the convergence of suitable solutions is pursued with the aim to lead to selected multidisciplinary optimised and aircraft qualified applications*

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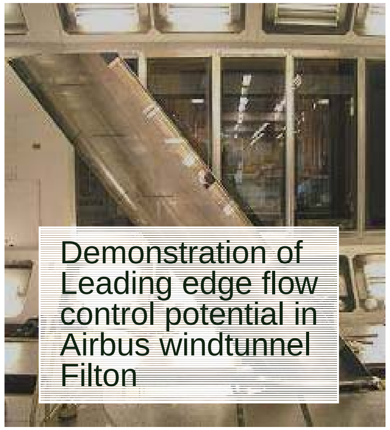
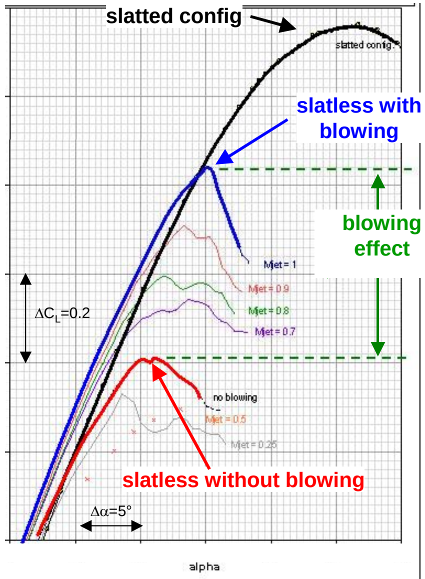
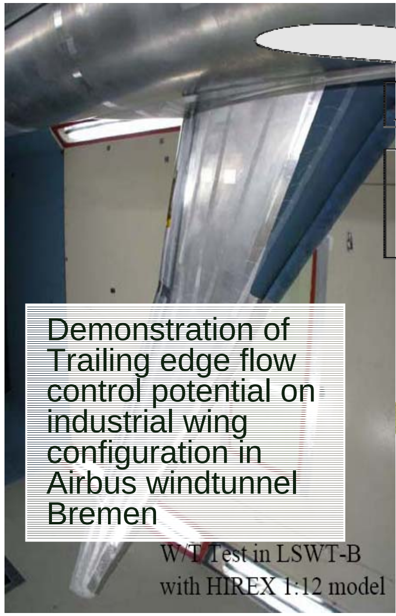
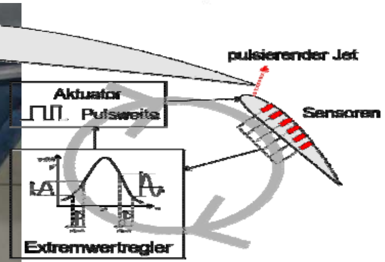


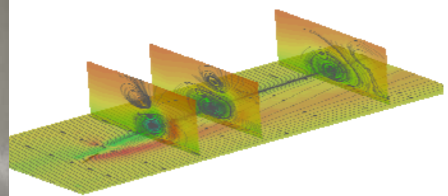
Demonstration of Leading edge flow control potential in Airbus windtunnel Filton





Demonstration of Trailing edge flow control potential on industrial wing configuration in Airbus windtunnel Bremen





Development of CFD prediction capability

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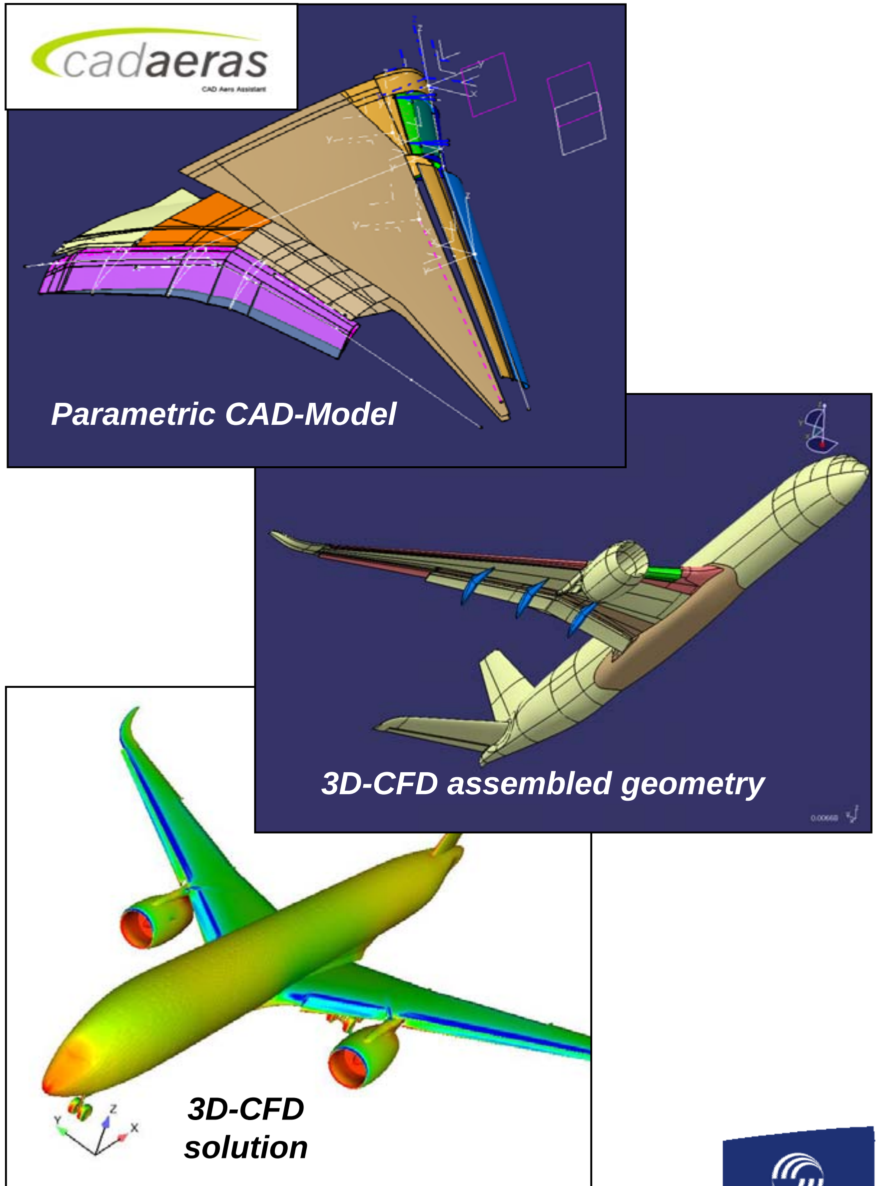
Advanced tools – Design tools & CFD

- **Parametric shape design tools**
  - → *significant multidisciplinary turn around time improvement and shape quality control*
- **Integrated CFD toolchain**
  - → *turn around time and optimisation depth improvement by „on-line shapes assessment"*
- **3D CFD**
  - → *design maturity improvement due to analysis of complex flow features and limiting effects*
- **Computational aeroacoustics**
  - → *awareness of source noise optimisation potentail*



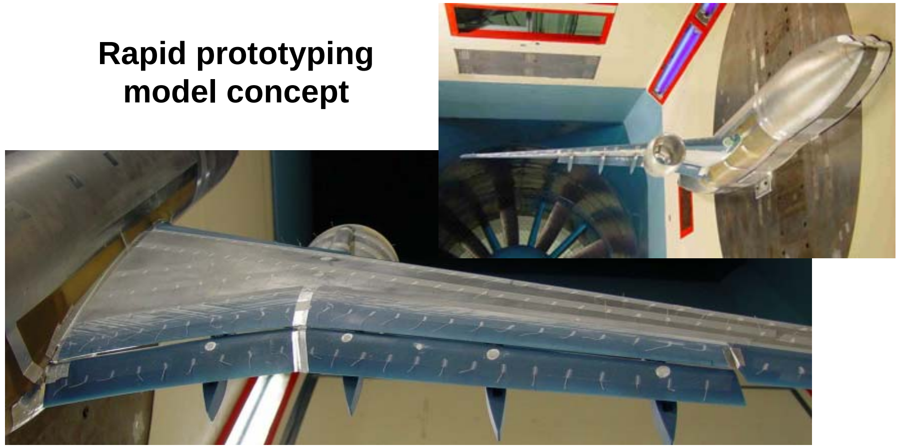
Advanced tools – Windtunnel testing

- **Extensive low Reynolds number testing (Airbus Windtunnels Bremen & Filton)**
  - *→ design concept variaztion & convergence*

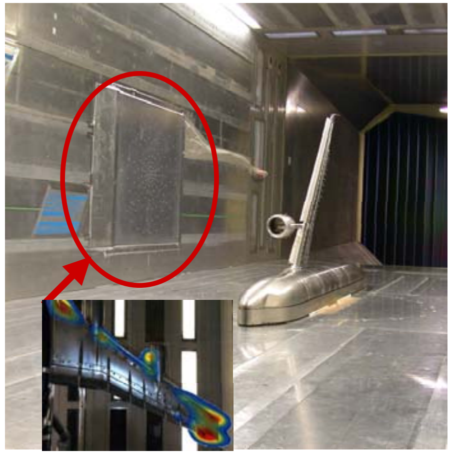
- **Medium Reynolds numbers testing (Onera F1, DNW)**
  - *→ detailed design convergence and comprehensive data generation*

- **High Reynolds number testing in cryogenic conditions (ETW)**
  - *→ reduction of uncertainties and avoidance of unnecessary margins*

Rapid prototyping model concept



High Reynolds number testing in ETW



Low Reynolds number testing including acoustic array

Where do we want (& need) to be ? – Expected key outputs from High-Lift R&T

Short Term

- Multidisciplinary feasibility and potential of **advanced leading & trailing edge concepts** proven
- Improved capability on high/-low speed **integrated design**
- Basic understanding of airframe noise drivers and first concepts for **noise reduction** available for application
- **CAA-codes and experimental acoustics** available in design process
- **Flight-Reynolds-testing** further established as design verification tool

Mid Term

- Novel **smart solutions** for advanced leading & trailing edge concepts available
- **Design to noise capability** and new solutions for noise reduction available
- **Integrated high-/low-speed design** process fully established
- **3D-CFD and flight-Reynolds-verification** established as major design verification tools

Long Term

- Fully integrated **multidisciplinary 3D design process** for high-lift wing already in early concept phase established
- **Integrated 3D-CFD&CAA** tools established as major design & verification tools
- **Smart High-lift solutions** for extreme noise and traffic requirements available
- High-lift solutions for **novel configurations** beyond 2020 established

The role of high-lift aerodynamics - Conclusion

- High-Lift Aerodynamics is a key contributor to enable future aircraft to show significant improvements in
  - **Environmental impact (emissions)**

    → with light & efficient multifunctional high-lift systems
  - **Community noise**

    → with optimised flight performance as well as source noise optimised configurations
  - **Economic performance**

    → with weight & complexity improved solutions in shorter design cycles

- Airbus aerodynamics is conducting a targeted approach in high-lift R&T to address these future challenges for its product portfolio

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