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 classical 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 landing 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 multidisciplinary 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
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

- Emergency Descent
- Spanwise Lift Control
- Cruise Performance Control
- Improved Take off & Climb Performance

Example: Source noise prediction & suppression

- Roll Control
- Vibration Control
- Steep/Slow Approach
- Control of Lateral Moments

- Low Noise Design
- Source noise 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

- HICON studies
  (TU Braunschweig)

  - without blowing
  - with blowing

Example: Smart high-lift devices

- e.g. Adaptive Droop Nose
- e.g. Blown Super Fowler Flap
- e.g. unslotted smart Trailing Edge incl. flow control
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”
Design solutions – A350XWB
A multi-purpose trailing edge system

The Adaptive Dropped Hinge Flap

- Enhanced low speed aero performance

- Low complexity flap kinematics

- Cruise Variable Camber functionality and differential flap setting

The A
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lap

Enhanced low speed aero performance

Low complexity flap kinematics

Cruise Variable Camber functionality and differential flap setting

Section cut

ADHF vs Fowler flap @ same deflections

ADHF vs Fowler flap @ maximum possible deflections

Cruise performance enhancement

ADHF

Fowler

α

Lift

fixed wing: has to be a compromise

weight optimum

aerodynamic optimum

Span

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 Very High Bypass Ratio 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 local improvement of the flow conditions
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
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
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
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 potential
Advanced tools – Windtunnel testing

• Extensive low Reynolds number testing (Airbus Windtunnels Bremen & Filton)
  → design concept variation & 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
## 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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