Unsteady High-Lift Aerodynamics - Unsteady RANS Validation

An Overview on the UHURA Project

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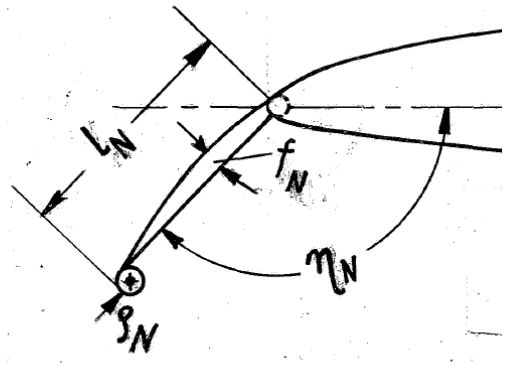
Horizon 2020
European Union funding
for Research & Innovation

What is a Krüger Device?

/nose split flap invented by W. Krüger (1943)

- High-lift leading edge device
- located at the leading edge
- deployed from the pressure side of the wing

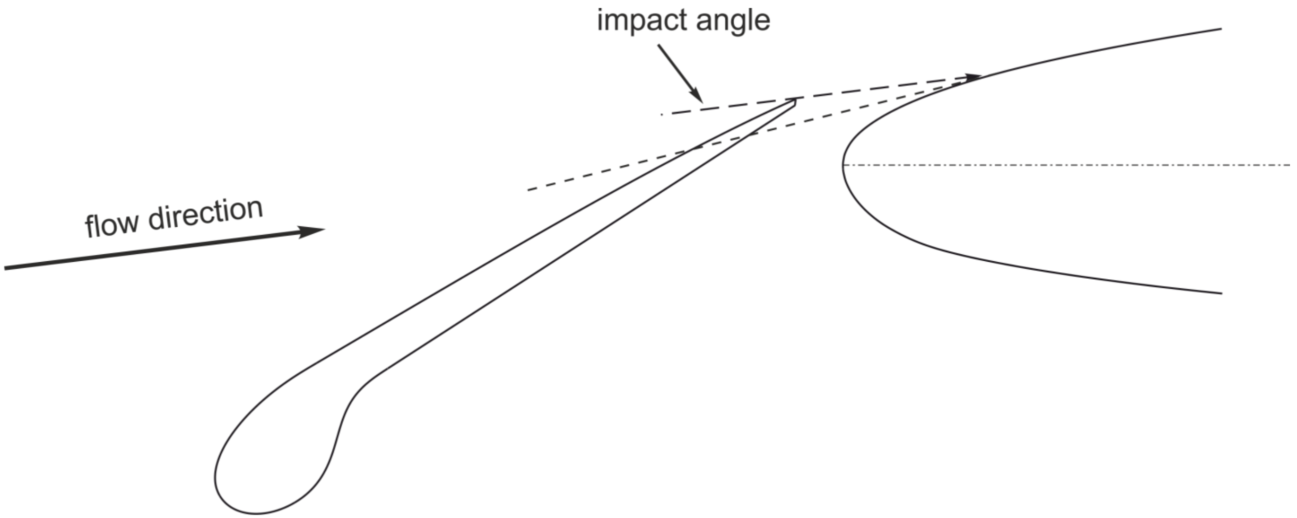


W Krüger, Über eine neue Möglichkeit der Steigerung des Höchstauftriebes von Hochgeschwindigkeitsprofilen, AVA-Bericht 43/W/64, 1943

Why Krueger flaps for laminar wings?

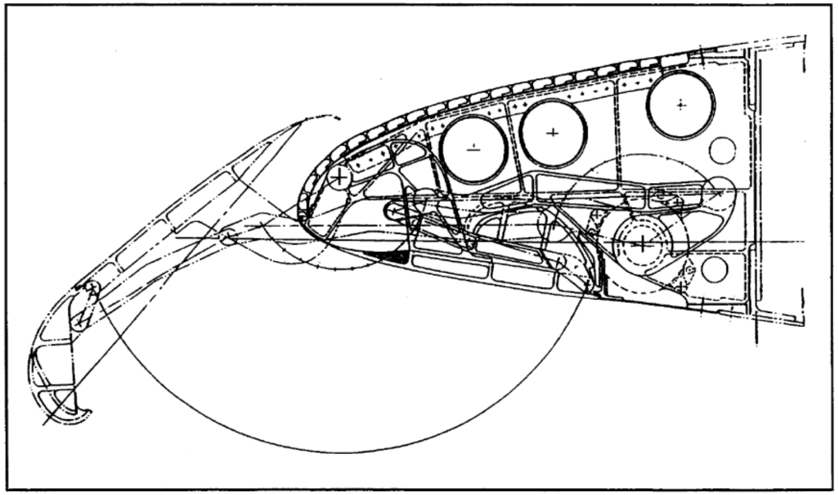
/ Requirements for laminar wing technology

- / Avoid disturbance of wing upper side
- / Provide shielding of leading edge against contamination (insects, dust, moisture)



High-Lift System for B757-HLFC
vented folding bull-nose Kreuger device

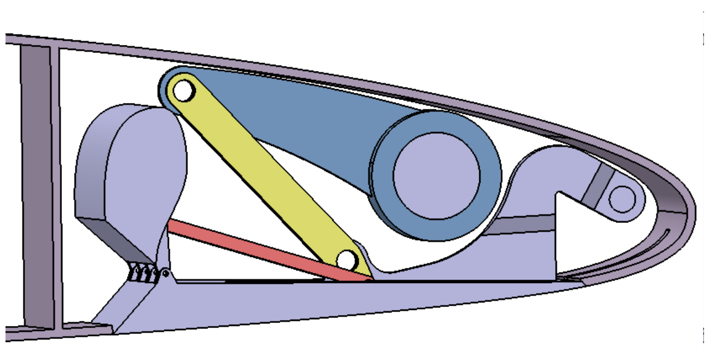
- "Folding, bull-nose (rigid) Krueger - The simple Krueger flap can be improved by adding a folding bull nose to it. Hinged to the aft end in the stowed position, the folding bull nose is a panel that runs the length of the main Krueger panel. It has a D-shaped cross section, and it is connected with a slave linkage that rotates to deploy the bull nose as the main Krueger panel deploys. Because of the rounded bull nose, the folding, bull-nose Krueger is more tolerant to changes in angle of attack. As a result, the flow on the upper surface of the Krueger is attached over a wider angle-of-attack range."
- "Fixed-camber Krueger - There has been no effort to develop the fixed-camber Krueger into a device that has characteristics similar to that of a slat, except for the work done on the 757 hybrid laminar flow experiment. Therefore, this area is one in which research could help the future implementation of hybrid or natural laminar flow concepts."

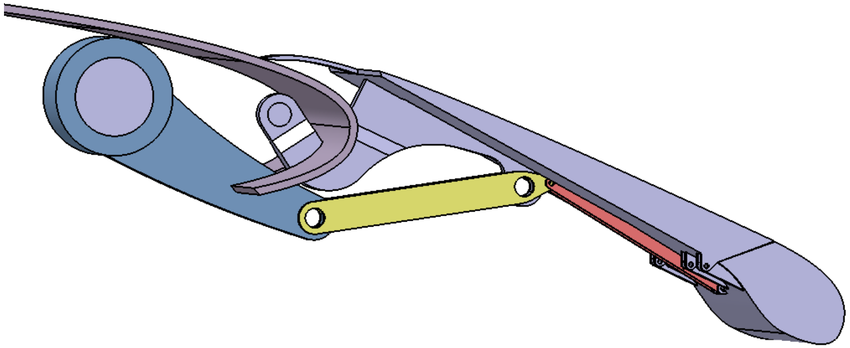


© P.K.C. Rudolph, High-Lift Systems on Commercial Subsonic Airliners, NASA-CR 4746, 1996

Aerodynamic design for a NLF wing
high-lift concepts for laminar wings

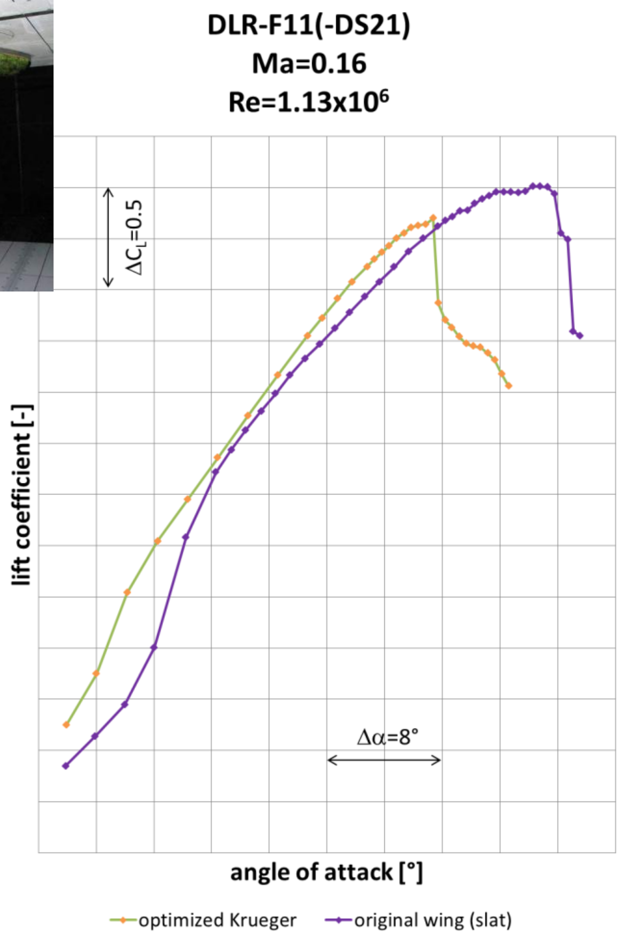
- **analysis of different high-lift system concepts for compatibility with NLF wing requirements**
  - high aerodynamic performance
  - guaranteed shielding against insect contamination
- **select and design the compatible high-lift system including constraints from mechanical integration**





The DeSiReH project has received funding from the European Community's Seventh Framework Programme FP7 under grant agreement n° -233607

Aerodynamic design for a NLF wing *performance assessment*



Key achievements

/ designed Krueger device laminar wing closely comparable to turbulent wing with slat

/ assessment of project achievements on Overall Aircraft Level (OAL) verified 4-7% fuel benefit of the high-lift enabled laminar wing aircraft

/ assessment of project contributions to ACARE Vision 2020 targets shows significant contributions

/ derivation of design strategy recommendations for industrial use of design optimization procedures

/ formulations of testing guidelines for applying optical measurements at high Reynolds number testing

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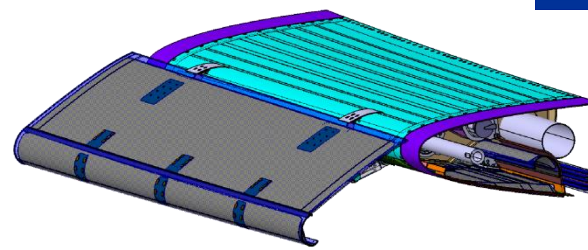
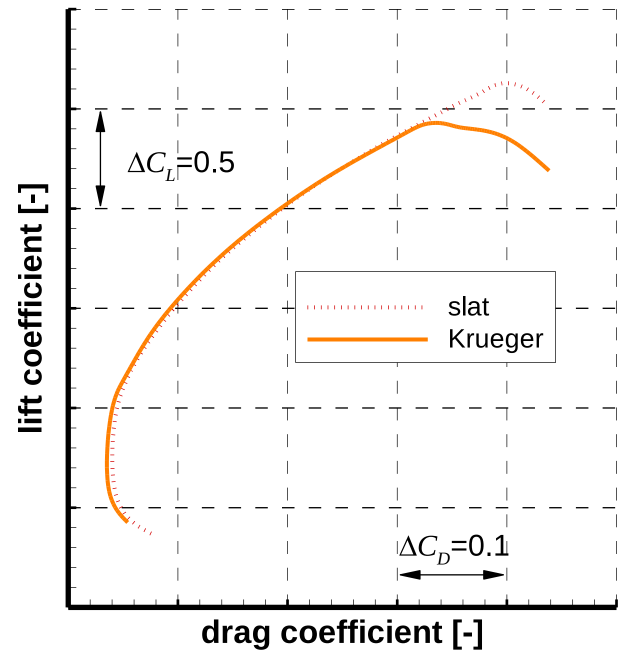
Aerodynamic design for an HLFC wing

wing integration



- **140° Krueger deflection**
  enabled by goose neck type kinematics
- **125° bullnose retraction angle**
  significantly benefits the space allocation in stowed position.
- **reduced actuation loads**
  due to late bullnose deployment
- **sealing foreseen for closing plate and Krüger**
  to enable cavity as suction camber
- **most forward position of opening/closing plate**
  behind stagnation line
- **in vertical position the Krüger panel is below the LE.**



AFLoNext
Deutsches Zentrum für Luft- und Raumfahrt German Aerospace Center
DLR
asco
INVENT

The AFLoNext project has received funding from the European Community's Seventh Framework Programme FP7 under grant agreement n° 604013

Motivation

Identified issues

- deployment path critical in case of actuation failure/jamming
- deployment sequentially or in groups recommended

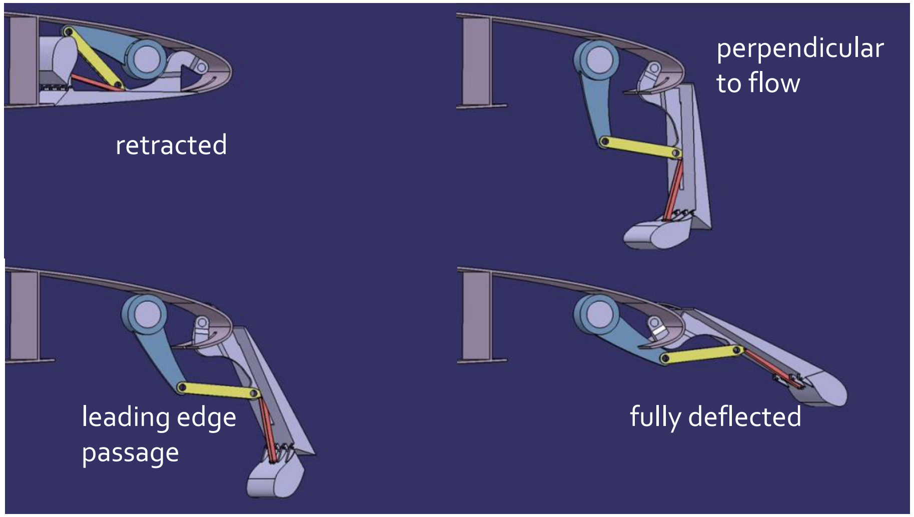
Challenges

- limited overall deployment time increases required deployment speed
- unsteady effects during deployments likely
- need for validated simulation methodology

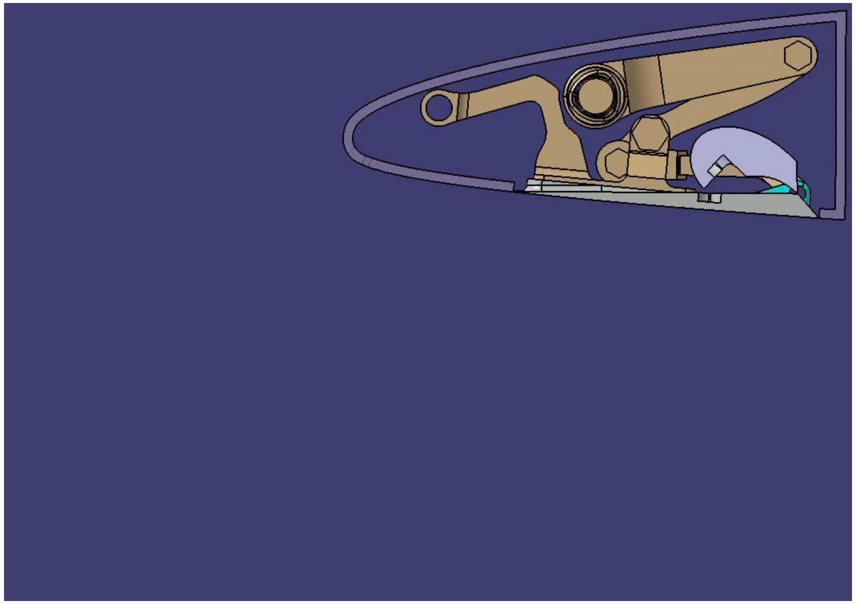
Source: airliners.net © Teemu Tuuri

Source: youtube.com © user/Jet3TV

Aerodynamic challenges

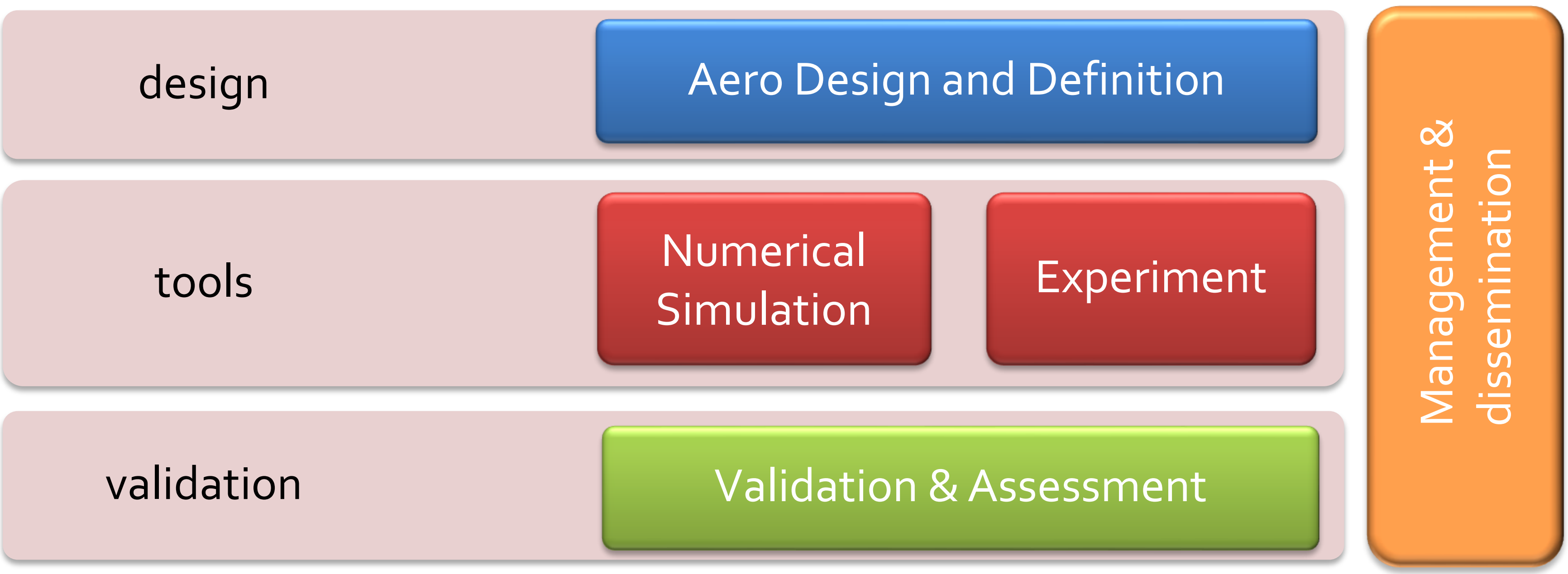


Specific critical conditions

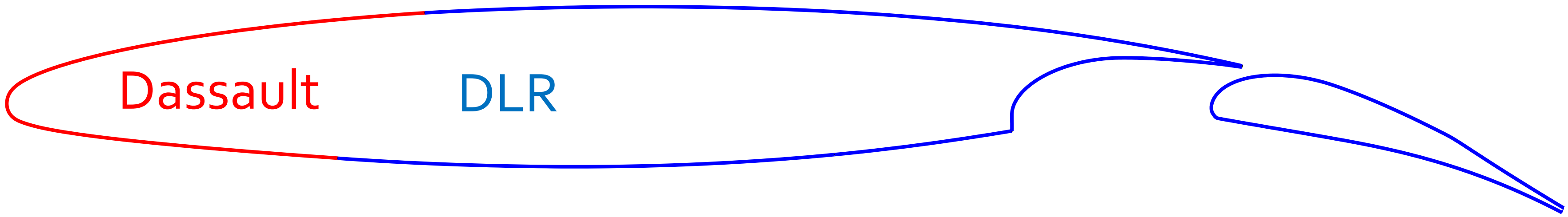


Targeted deployment time: 1s

Approach


design
Aero Design and Definition
tools
Numerical Simulation
Experiment
validation
Validation & Assessment
Management & dissemination

Background
DLR-F15-LLE airfoil shape



- laminar wing version of the DLR-F15 airfoil, leading edge designed by Dassault
- developped in CS2 Smart Fix Wing Aircraft

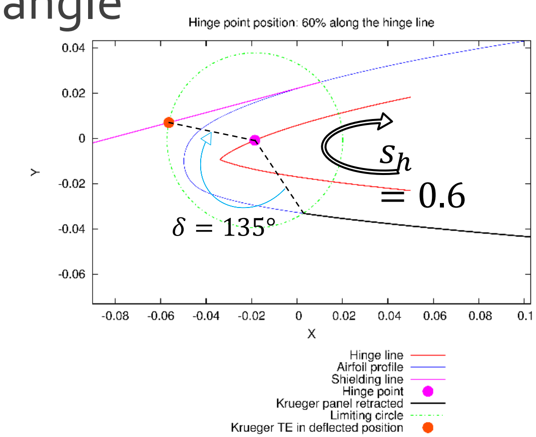
concurrent design optimization

/ **Kinematics based coupling of size and position**

- 1 curvilinear parameter: hinge point along offset from upper surface
- limiting circle: centered in the hinge point and passing trailing edge position (guaranteed contamination shielding)
- upstream cavity: intersection limiting circle/airfoil contour

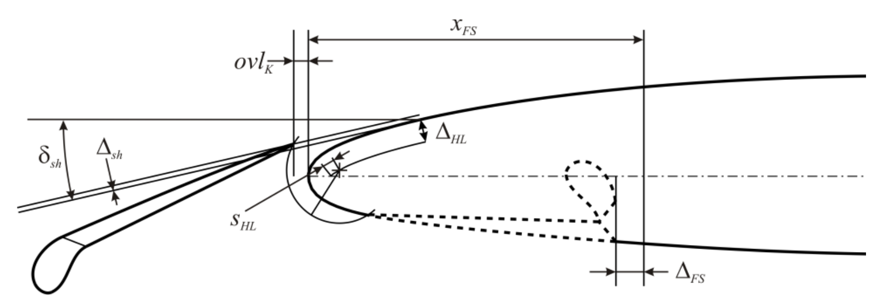
/ **CIRA parameterization**

- Krueger panel size fixed
- shielding requirement for 9° impact angle

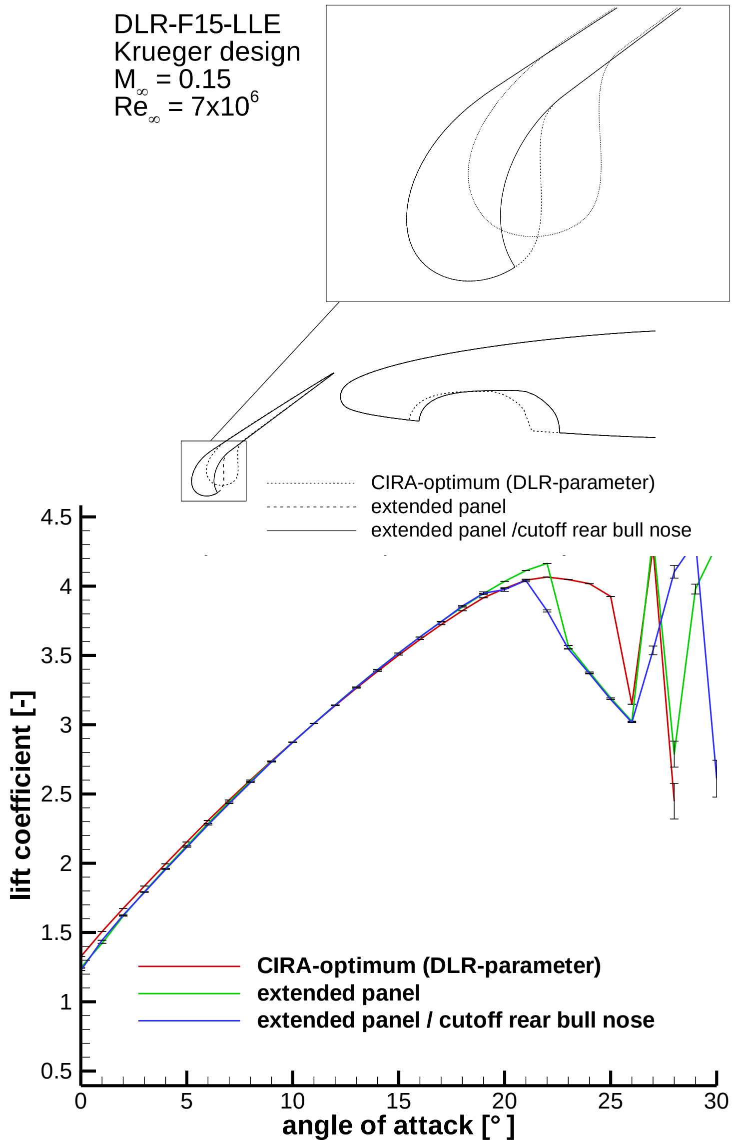


/ **DLR parameterization**

- front spar limit at 25%c
- shielding requirement for 7° impact angle



kinematics compliant design

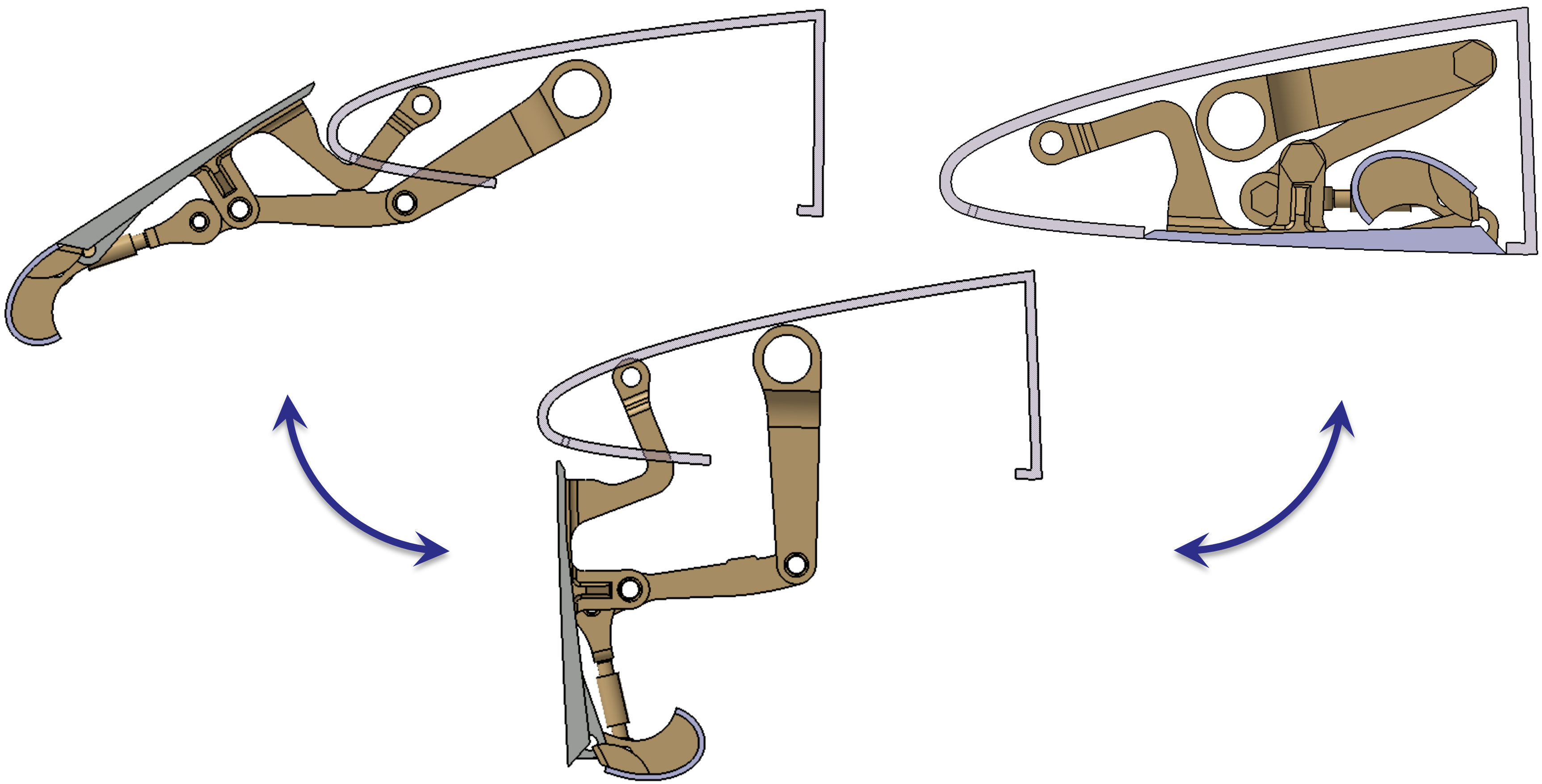


- respect requirements after first kinematics design loop
- extend rear cavity end for passing of kinematics levers
- cut rear bull nose shape allowing more compact folding

Kinematics design

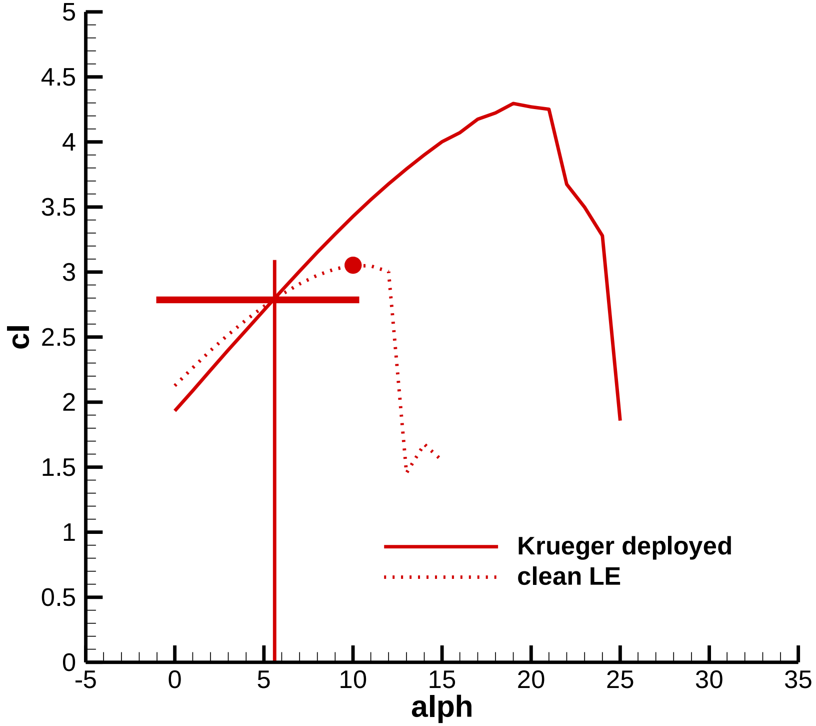
Gooseneck type kinematics

- compact design
- minimum number of moving parts
- fully stressed



Krueger flap operation

- full dynamic deflection at maximum angle of attack is neither feasible nor required
- loads requirements:
  - full angle-of-attack range (up to stall) in steady mode only
  - dynamic mode only at reasonably low angles of attack
- for operating loads: choose angle of attack safe for Krueger retraction
  - C_L-condition: $C_L = 2.9$
  - α-condition: $\alpha = 6°$



CFD studies
coverage

Meshing

- Chimera method
- local reconnection
- local refinement

Solver

- uRANS / Chimera
- immersed Boundaries
- hybrid RNAS-LES
- Lattice-Boltzmann

Detailed presentations following in this session

Wind tunnel experiments

ONERA-L1, closed test section, DLR-F15, 2D wall-to-wall: medium Reynolds number (approx. 2-3x10^6), detailed flow field with PIV, influence of deflection rate.

DNW-NWB, closed test section, DLR-F15S, 2,5D cantilever wing: influence of sweep, wake measurements (5-hole probe rake), possibly SPR

DNW-LLF, open test section, DLR-F15LS, 2D und 2.5D: realistic actuation & kinematics, effect of Reynolds number (ca. 6x10^6), effect of span loading, detailed flow field with PIV, force integration, Krueger flap deformation

wind tunnel models

/ DLR-F15 and DLR-F15LS wind tunnel models

DLR-F15-LLE in ONERA L1

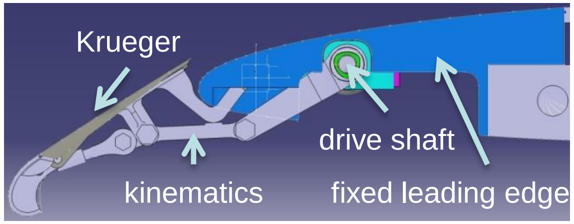
DLR-ONERA CRP LEAFCO

DLR-F15*S* in DNW-NWB

LuFo V project MOVE.ON

DLR-F15L*S* in DNW-LLF

EC project OPENAIR



600 mm chord

2.4 m span (0°)

2 m span (30°)

1200 mm chord

7 m span

Status and next steps

/ Numerical simulation

- / see following presentations

/ Wind tunnel tests

- / model manufacturing of first model nearly completed
- / first tests in ONERA L1 in October 2020
- / large scale test in DNW-LLF expected end of 2020 to early 2021

Thank you

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