

A Multi-material, Multi-functional Leading Edge for the Laminar Flow Wing

Olaf Steffen

C. Ückert, Dr.-Ing E. Kappel,

T. Bach, Prof. Dr.-Ing. C. Hühne



Knowledge for Tomorrow

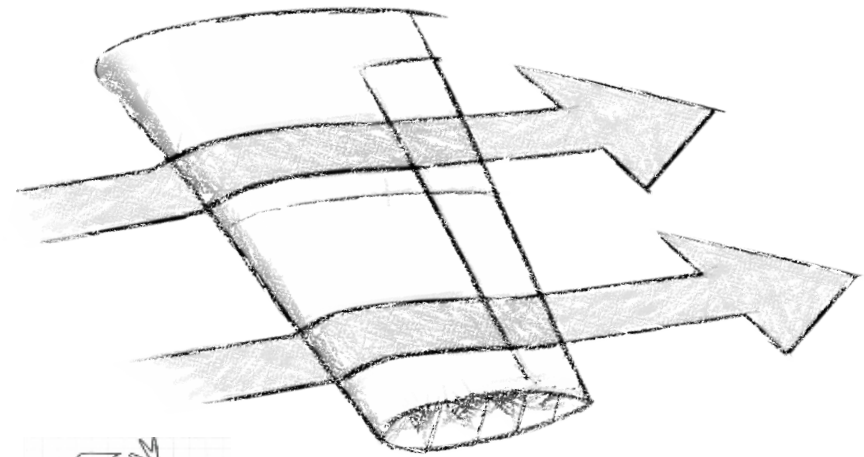


NLF Wing Requirements in a Nutshell

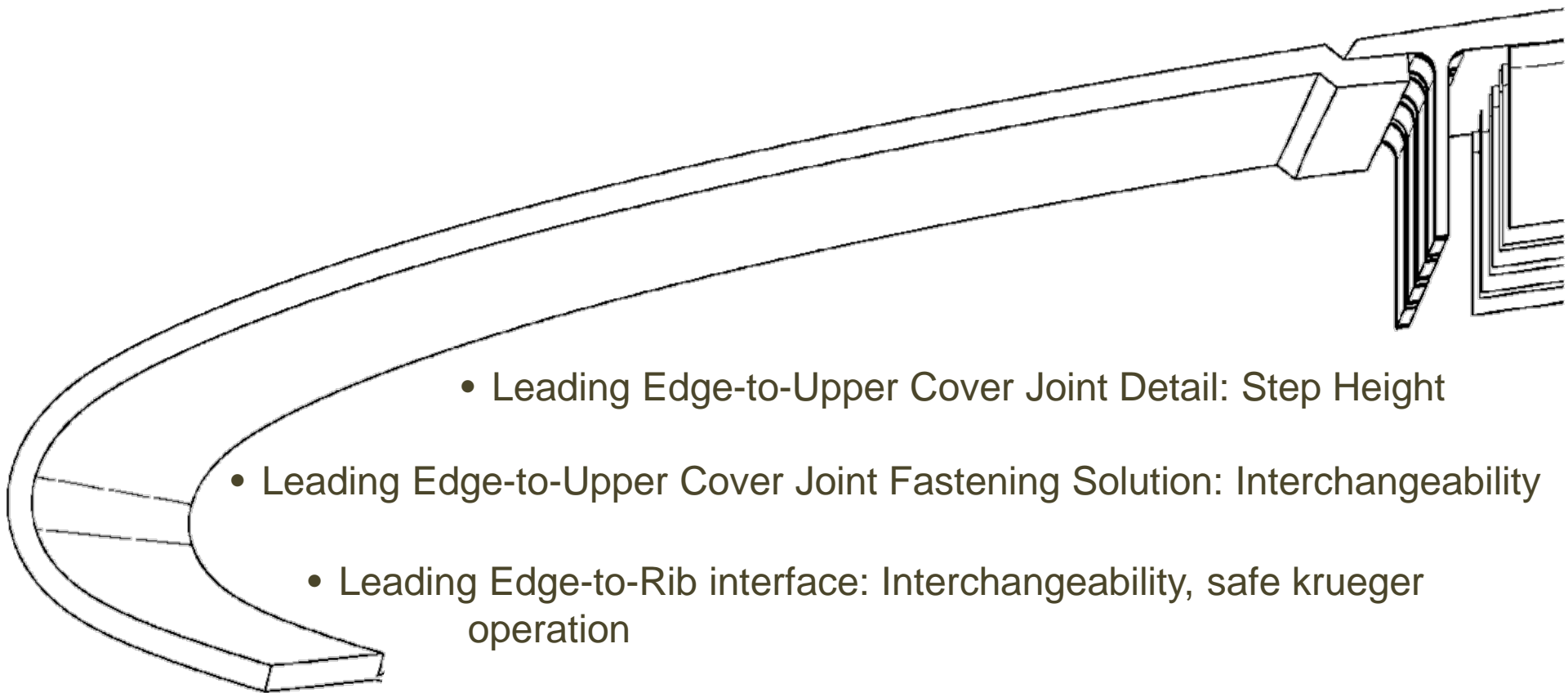
Steps, gaps and surface waviness cause transition

- Fastener heads on the surface
- changes in stiffness...
- and steps and gaps...

...are to be avoided!



Areas of Particular Interest in Leading Edge Detailed Design



- Leading Edge-to-Upper Cover Joint Detail: Step Height
- Leading Edge-to-Upper Cover Joint Fastening Solution: Interchangeability
- Leading Edge-to-Rib interface: Interchangeability, safe krueger operation



Operational Environment



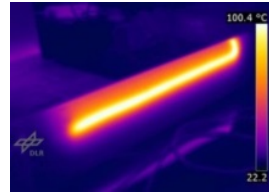
Cruise



Cold weather



Assembly



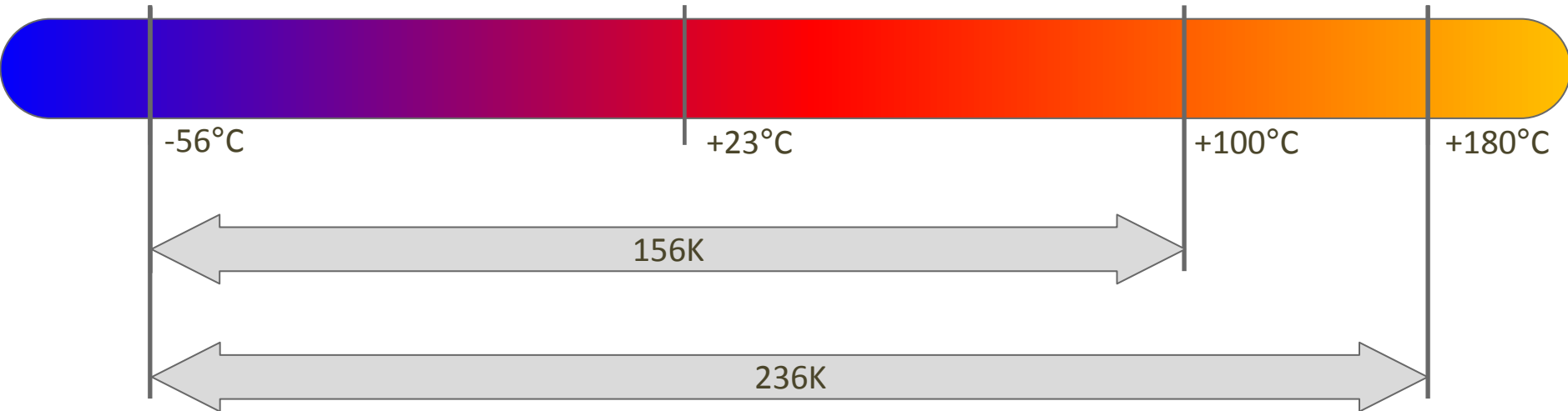
WIPS active



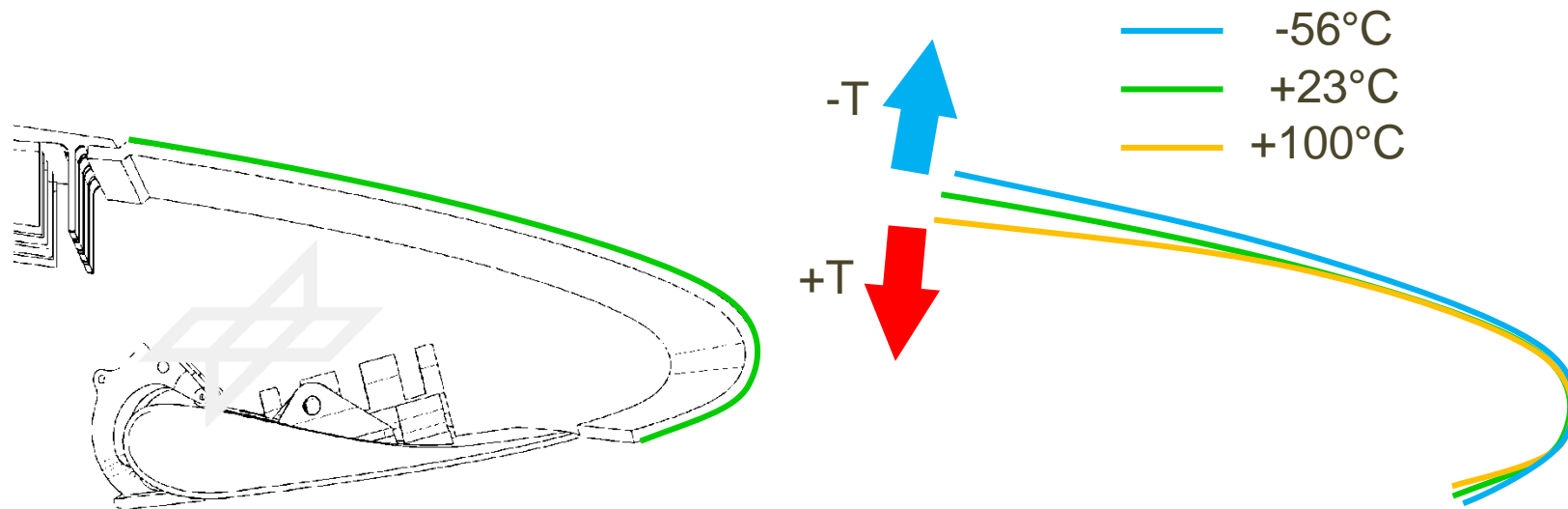
Hot weather



Autoclave



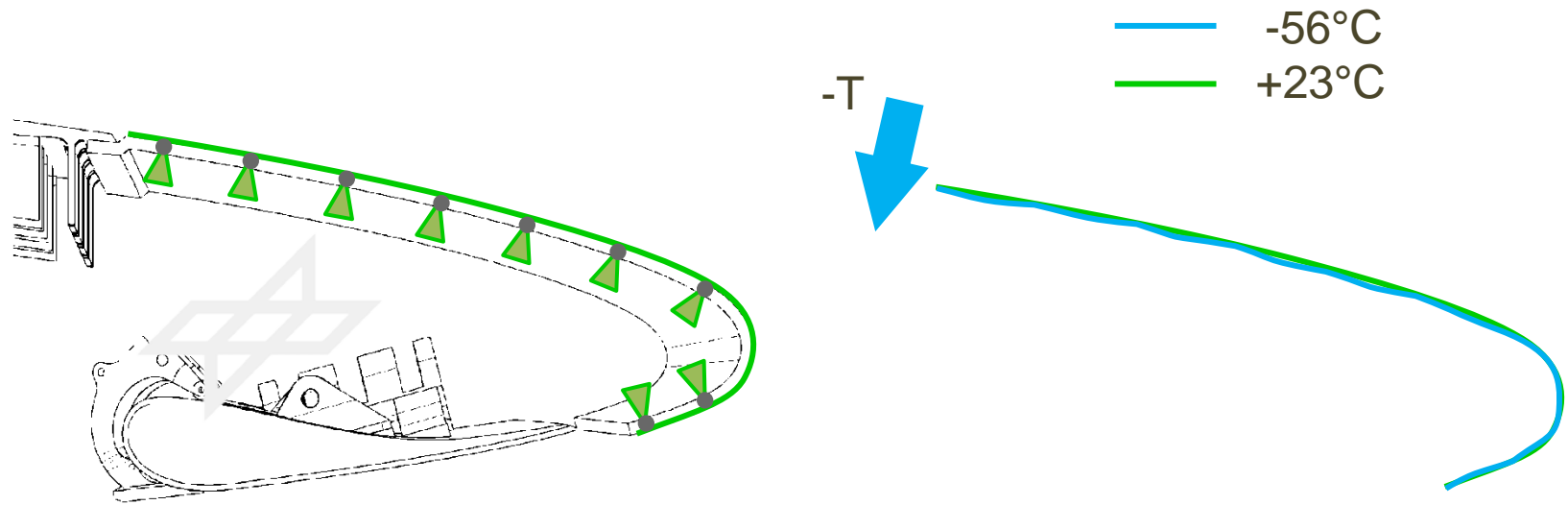
Thermo-elastic Deformation – Unrestrained Leading Edge



- Nominal shape on ground @ 23°C
- Opening of leading edge in cruise conditions
- Closing of leading edge in hot conditions
- Largest deformations at Upper cover and Krueger joint



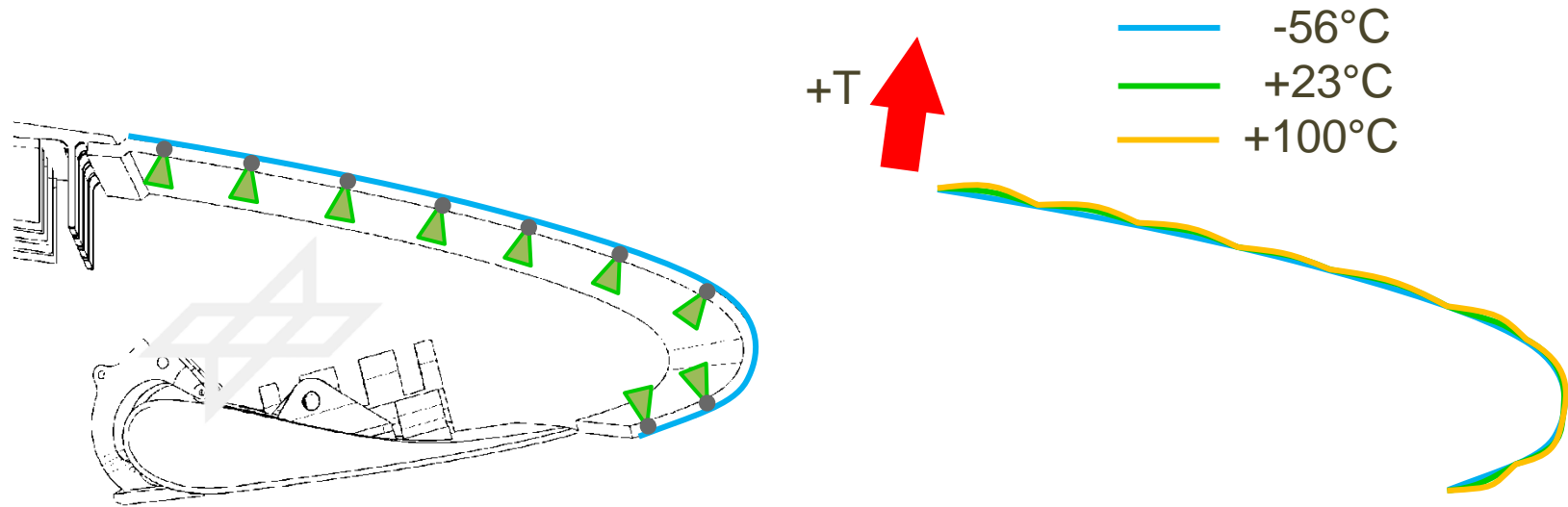
Thermo-elastic Deformation – Conventional Attachment



- Nominal shape on ground @ 23°C
- High constraint forces if deformation is blocked
- Local waviness around fasteners



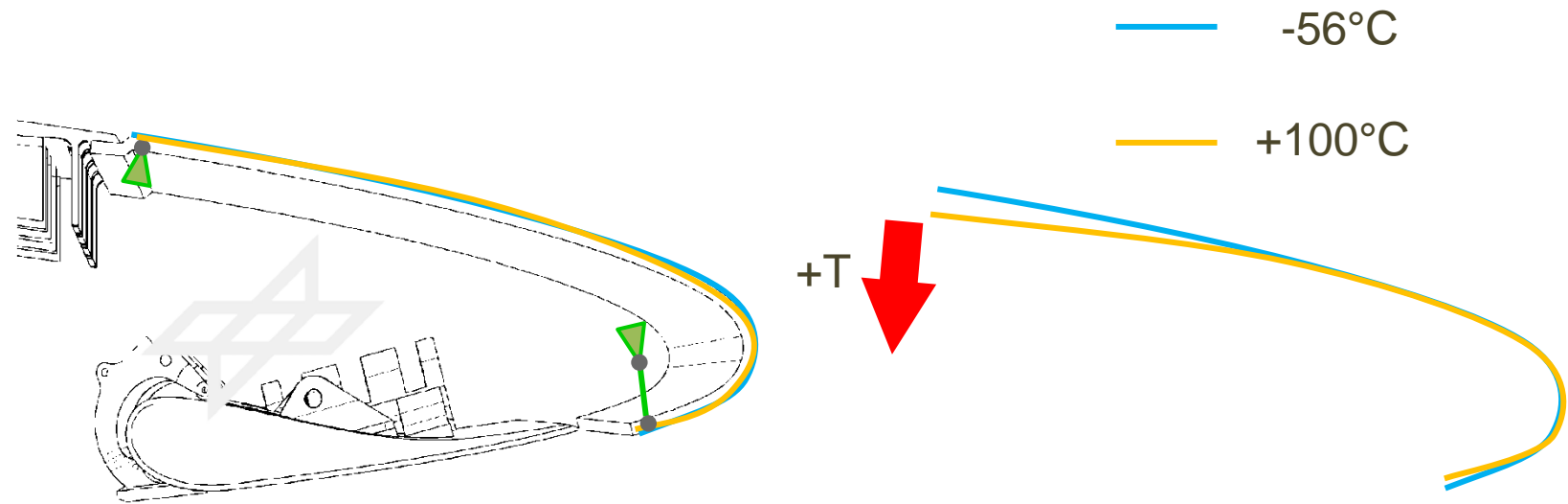
Thermo-elastic Deformation – Compensated Conventional Attachment



- Compensated part with nominal shape in 1G cruise conditions @ -56°C
- Highest constraint forces in hot conditions
- Local waviness only in on ground / hot conditions



Thermo-elastic Deformation – Compensated with Novel Attachment Concept

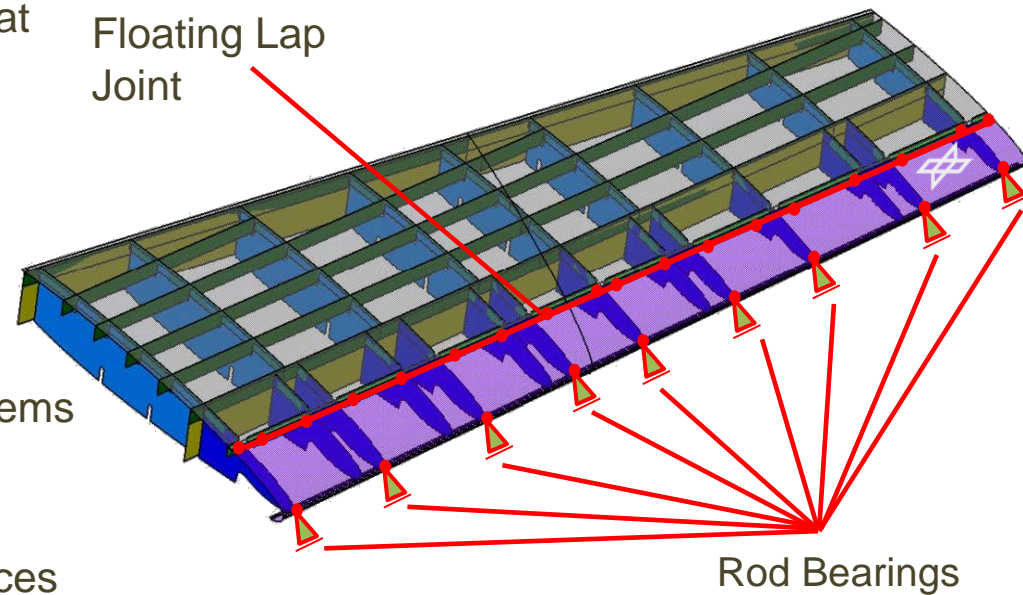


- Nominal shape in 1G cruise conditions @ -56°C
- Statically determined, fixed near joints
- Closing of leading edge on ground and hot conditions is not blocked
- Curvature change causes global rotation
- No local waviness due to constraint forces
- Larger deformation range due to aero-loads



Principal Leading Edge Attachment Solution

- Leading Edge is designed to achieve nominal shape in 1G cruise conditions at -56°C → compensated tool necessary
- Thermo-elastic deformation has no influence on step-height of upper cover joint
- Avoidance of assembly tolerance problems and constraint forces
- No local waviness due to constraint forces
- Variation of manufacturing induced deformations can be compensated in the assembly process



Floating Lap Joint Details – Step Height Control and Avoidance of Surface Disturbances

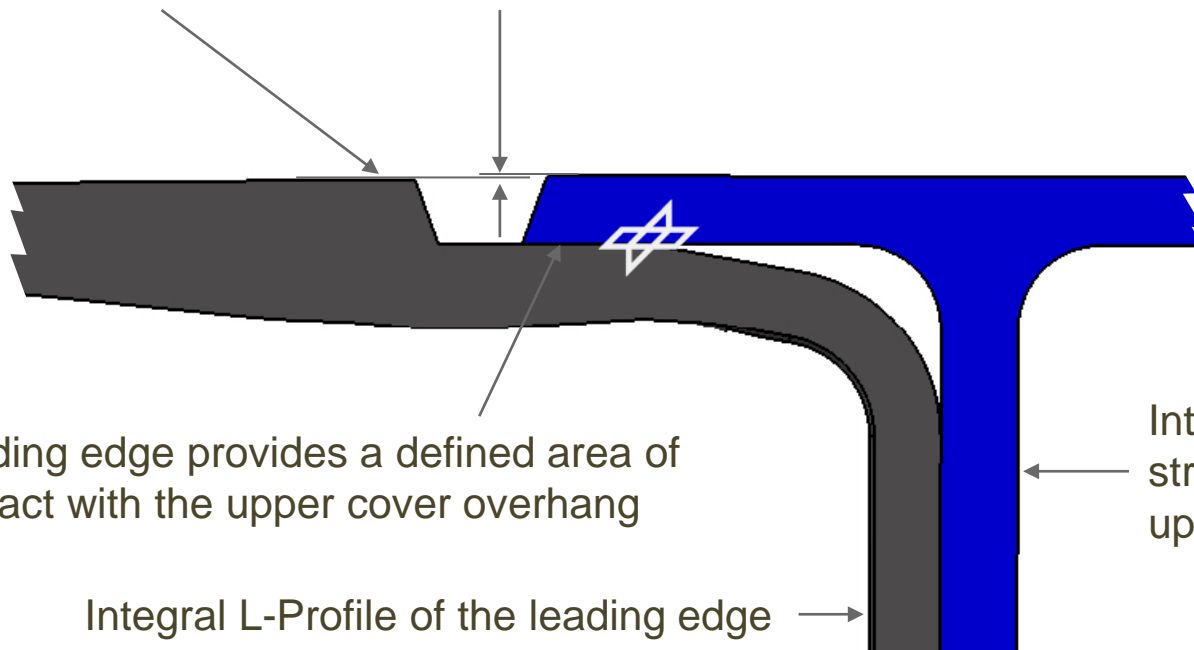
Filler geometry as per definition from Airbus Group Innovations

0.2mm positive step

Leading edge provides a defined area of contact with the upper cover overhang

Integral leading edge stringer of the wing upper cover

Integral L-Profile of the leading edge

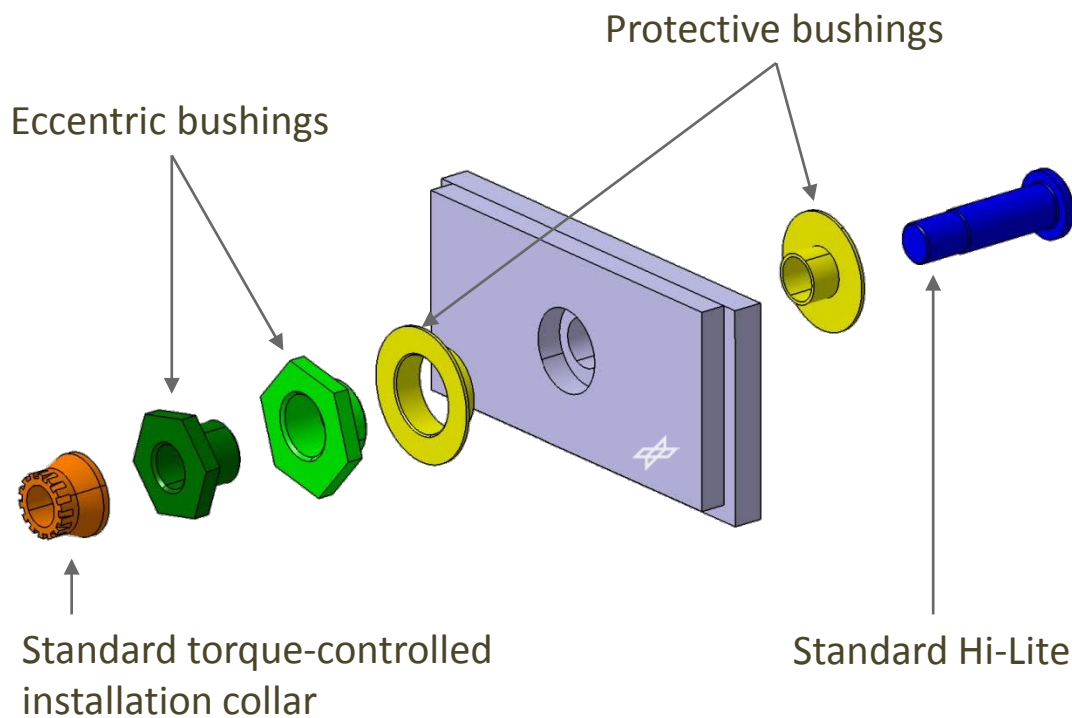


Leading Edge

Wing Upper Cover



Detailed Design of Floating Lap Joint Interchangeable Fastening Solution



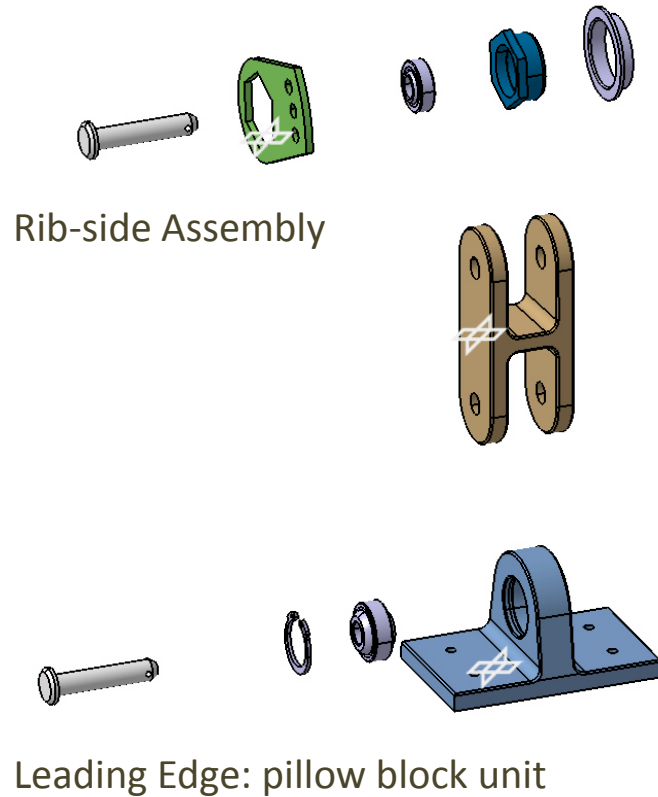
Eccentric bushings



Eccentric bushings installed with Hi-Lite



Leading Edge-to-Rib Interface – Rod Bearings

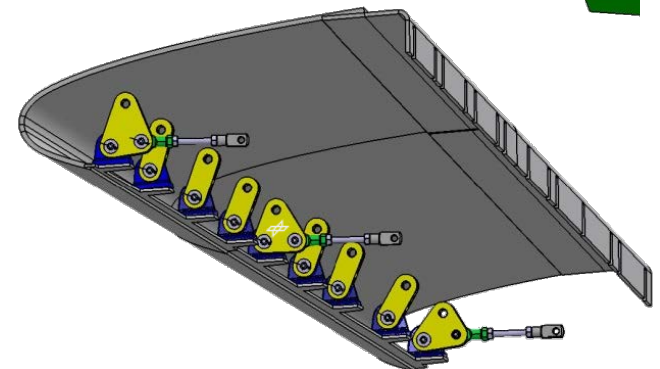
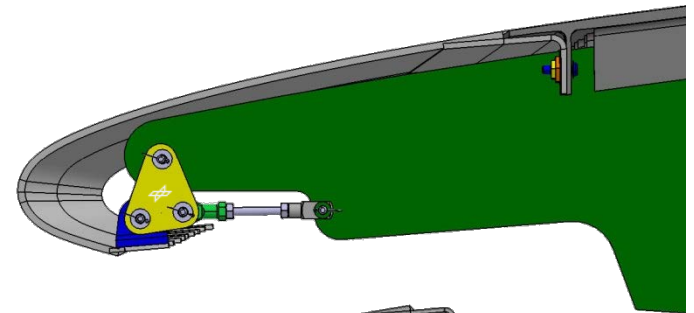
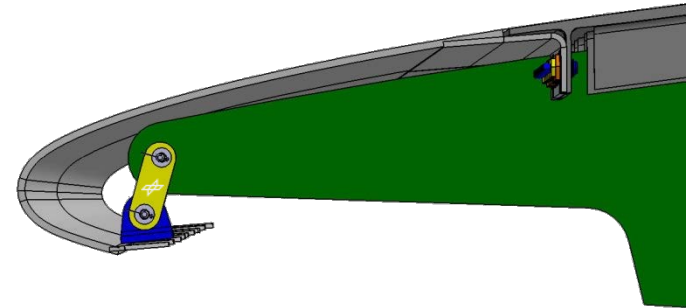


Installed rod bearing

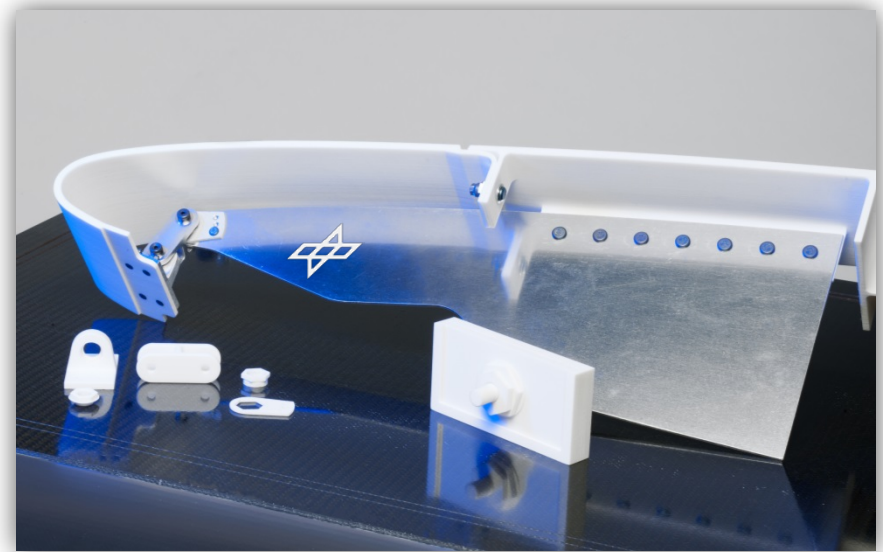
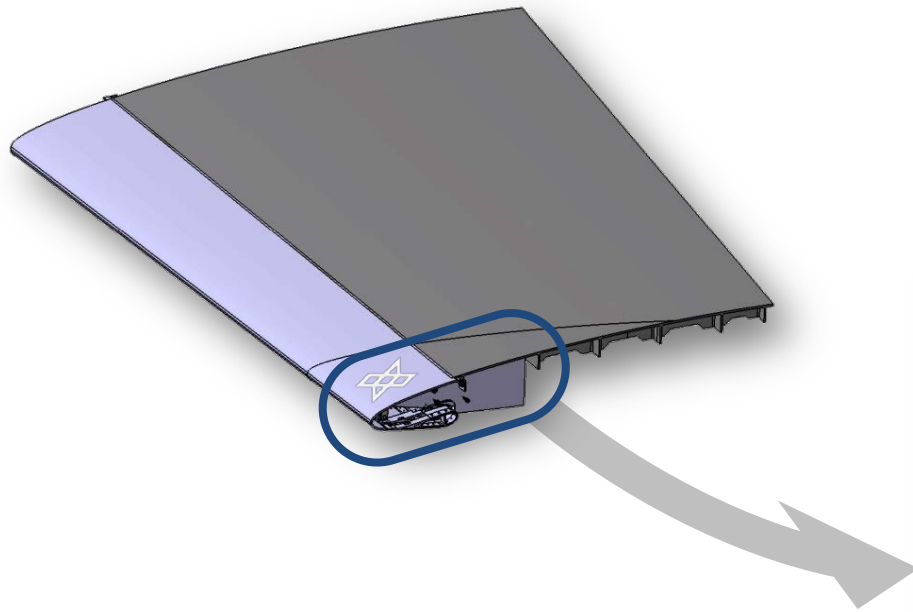


Inclusion of the Concepts in the Wing Model

- Two different types of rod bearing were included in the CAD wing model
 - Type A, basic
 - Type B, sporting an additional rod to transfer loads in flight direction
- The rod bearings and fasteners in the leading edge-to-upper cover joint were also investigated in the wing FE model
- Compliance with laminar flow requirements was shown for combined thermal and aero loads
- The number of fasteners in the leading edge-to-upper cover joint could be reduced to 48 on a 4.3m leading edge segment



Rapid Prototyping Demonstration of Attachment Design

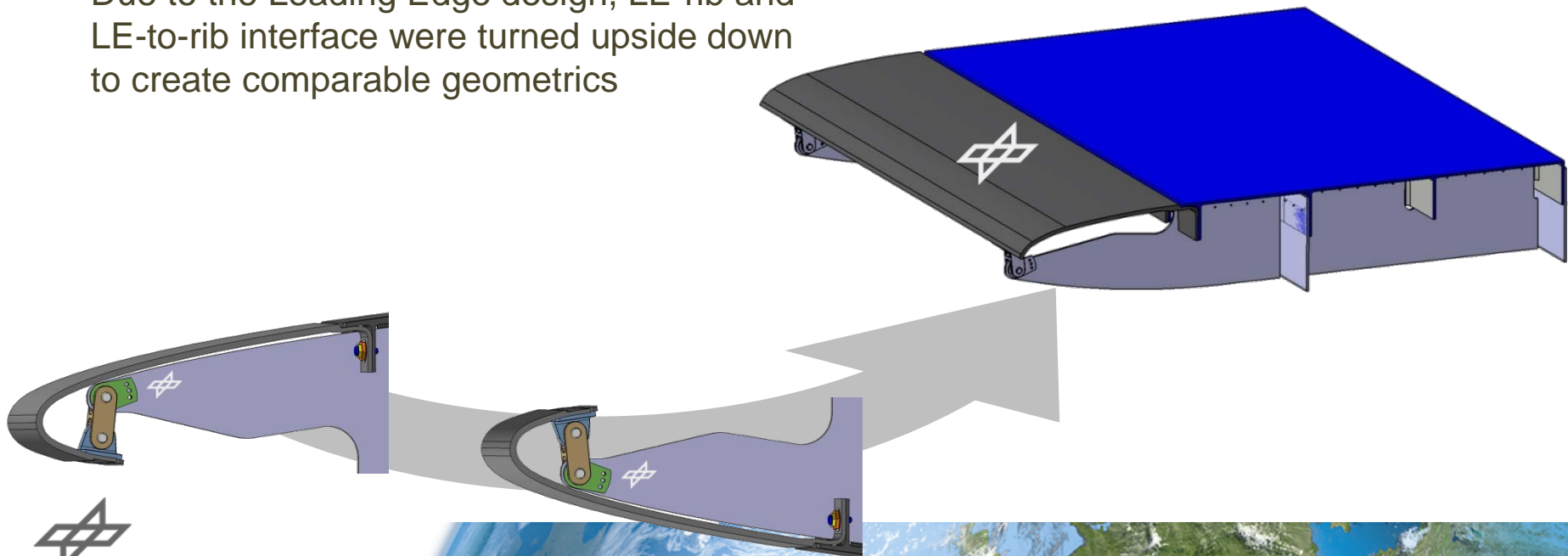


Rapid prototyping model of the original leading edge geometry



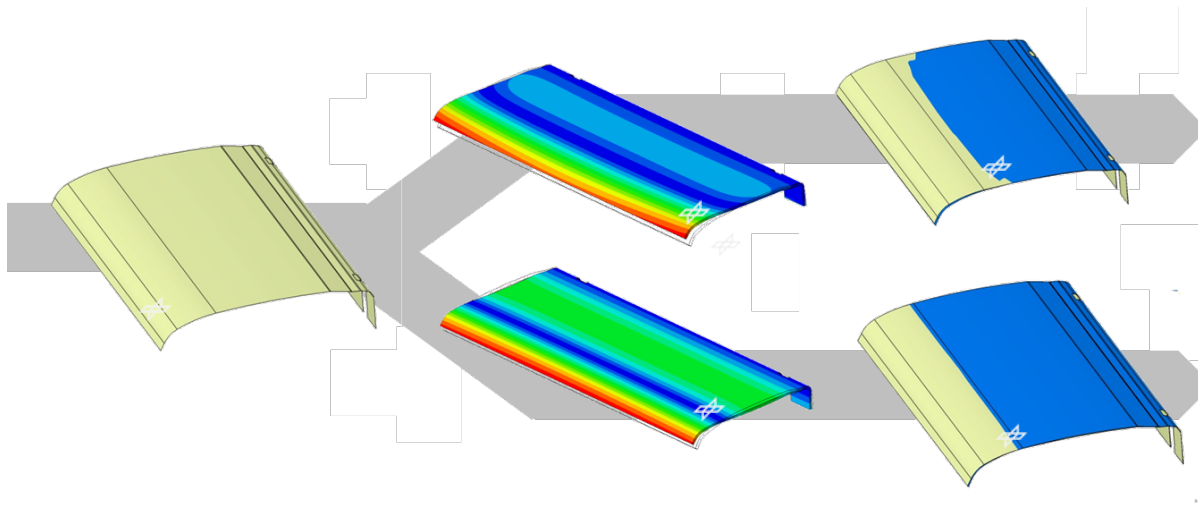
Demonstrator Box Design

- The design of the demobox uses the same parts fitting into the investigated area of the original wing and validated using the rapid prototyping demonstrator
- To reduce cost and time effort for the demonstration, only the upper side of the leading edge was designed
- Due to the Leading Edge design, LE-rib and LE-to-rib interface were turned upside down to create comparable geometrics



Part compensation– two possibilities

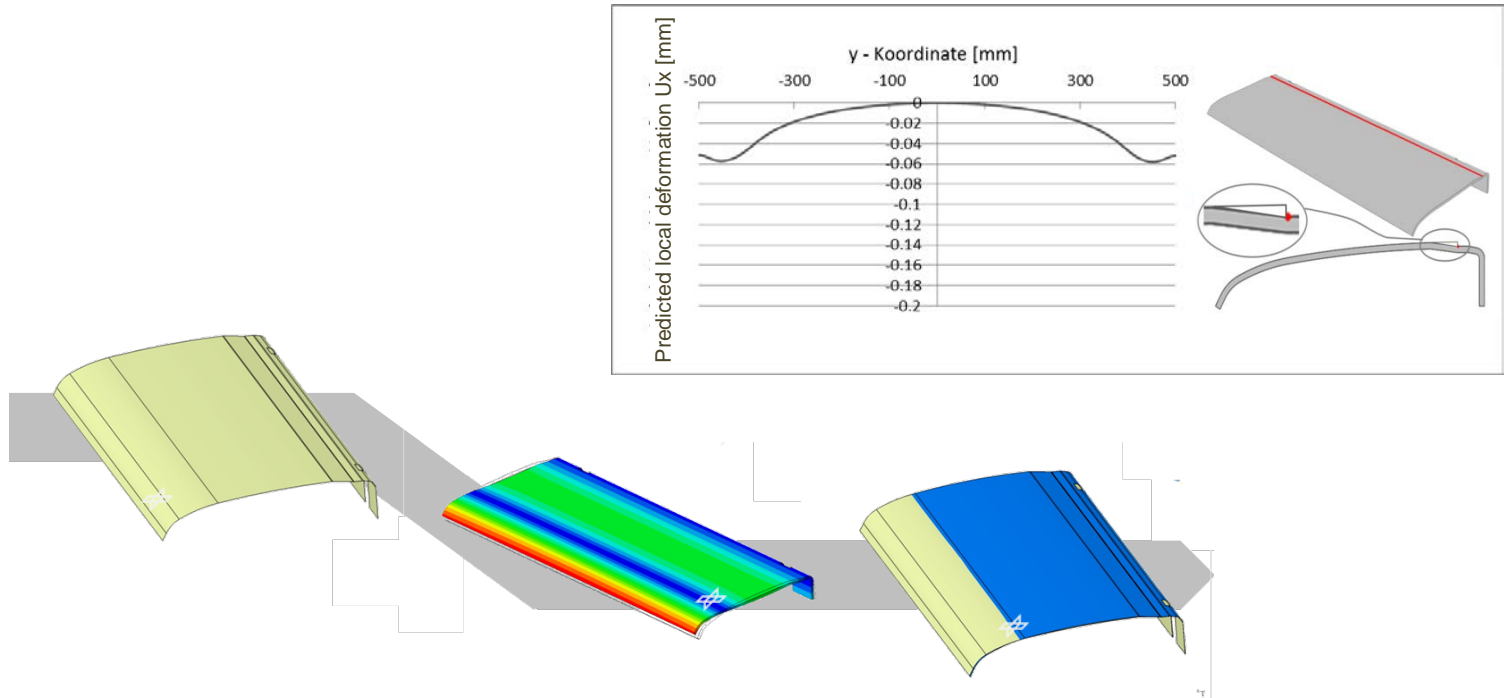
1. Full compensation of thermal deformations and spring-in, leading to full 3-dimensional curved tool surface



2. Compensation of deformations in mid-section (spring-in only), leaving spanwise deformations unattended, but simplifies tool surface



Part compensation– two possibilities



2. Compensation of deformations in mid-section (spring-in only), leaving spanwise deformations unattended, but simplifies tool surface



Mult-material Leading Edge Demonstrator

- Two leading edge demonstrators produced in a one sided mould using prepreg are used in the interchange trials
- The leading edges are installed to a demonstrator box providing the necessary leading edge stringer and overhang



Multi-material leading edge demonstrator



Leading edge installed to the demobox

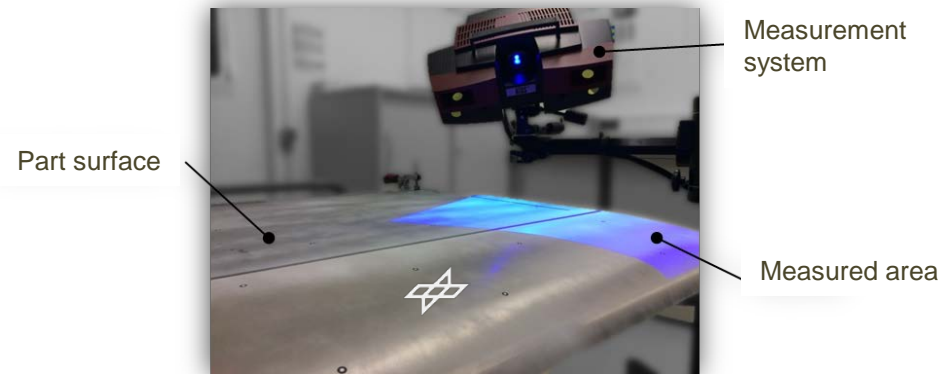
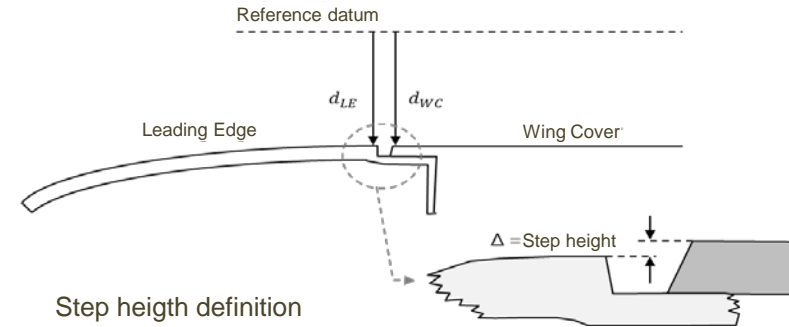


3d Optical Measurement

- Measurement System: ATOS Triple Scan of gom mbH
- Identification of step height between leading edge and upper cover
- Evaluation via fitted plane and reference datum



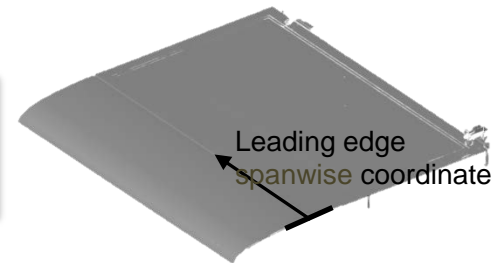
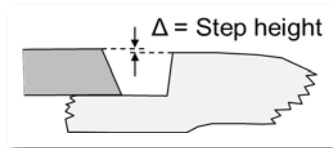
Area of interest between leading edge and upper cover



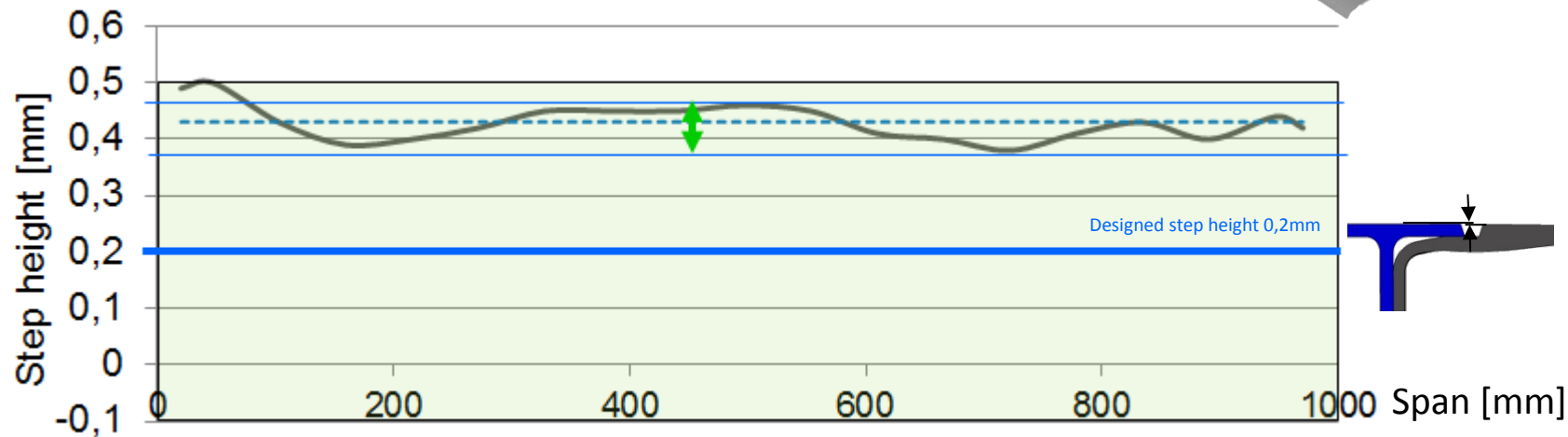
Optical measurement of deombox



Results

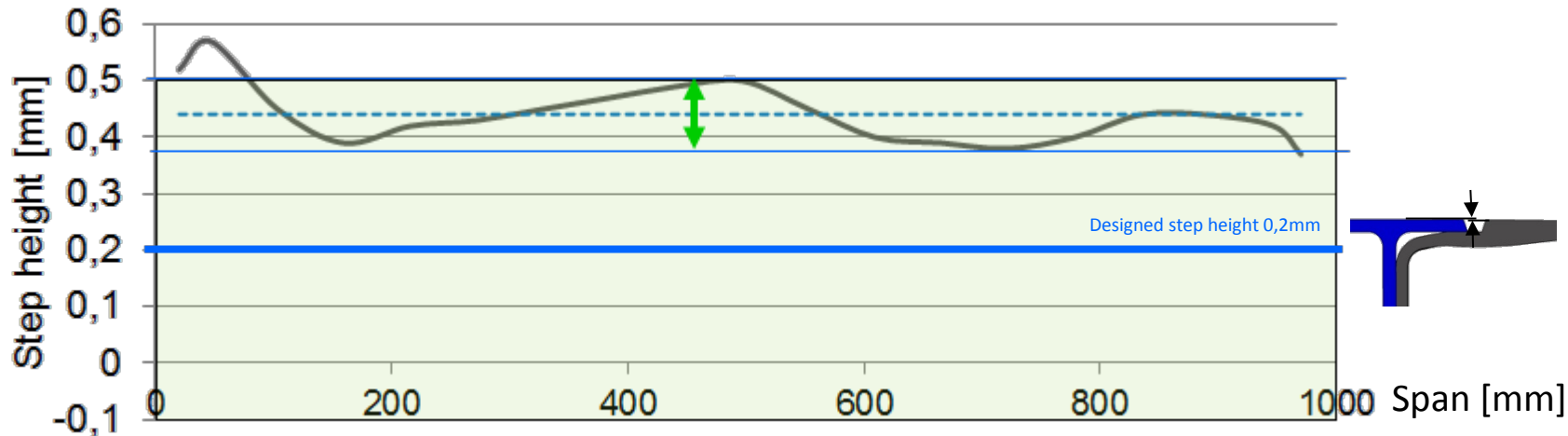


LE 1



Step height within required boundaries, very small variation

LE 2



Acknowledgements

- DLR Institute of Composite Structures and Adaptive Systems, Braunschweig & Stade



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Contact Information

Olaf Steffen, M.Sc.

DLR
Institute of Composite Structures
and Adaptive Systems

Ottenbecker Damm 12
21684 Stade
Germany

Phone: +49 531 295 3715
Email: olaf.steffen@dlr.de



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