



*CleanSky2*  
*LPA - Platform 1*

Impact Studies with Reduced Size Aircraft  
Stabiliser Demonstrators Including  
Hybrid Laminar Flow Control Technology

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# Motivation

- Reduce drag by hybrid laminar flow control (HLFC)
- Safety requirements against particular risks



Flight testing of HLFC, Source: F. Dambowsky, G. v. Schweppenburg, G. Ernst. [Treibstoffverbrauch durch Absaugung senken: DLR-Forschungsflüge mit revolutionärem Seitenleitwerk](#). 24.04.2018



Bird impacted the leading edge of the left hand wing puncturing the leading edge and causing a large dent. The aircraft continued for a safe landing. Source: SilkAir Airbus A320-200. 13.12.2015 on approach to Brunei International Airport



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# Introduction

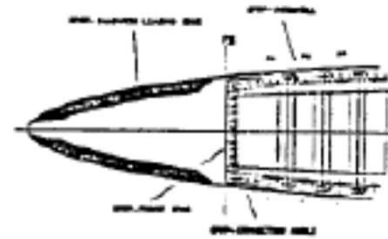
- Impact studies aim to combine design requirements from hybrid laminar flow control (HLFC) with safety requirements
- Include particular risks (bird strike e.g.) / crashworthiness requirements in an early design stage of development
- Application of numerical simulation tools with distinct validation tests, particularly reduced size impact tests
- Route from symmetric (vertical stabilizer) to asymmetric (horizontal stabilizer) leading edges



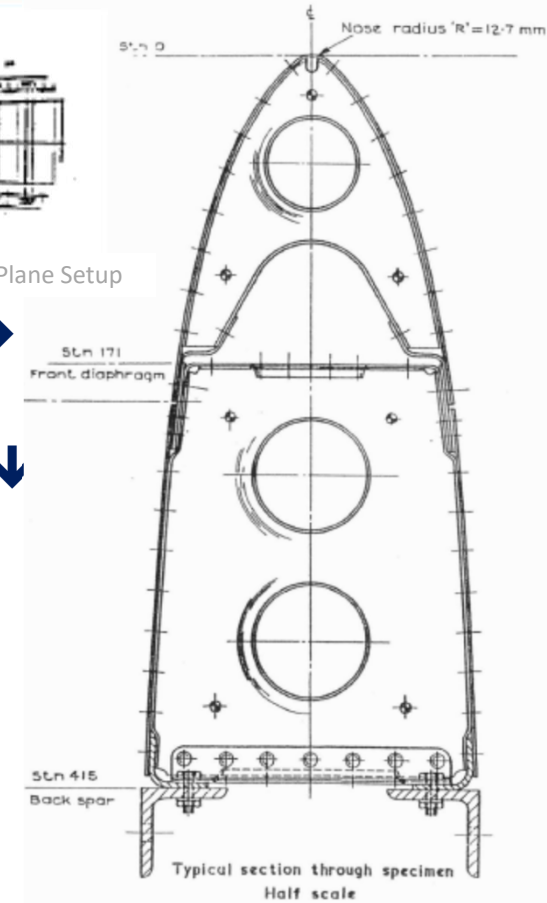
Source: Bird strike testing of leading edge at CEAT / EU CRAHVI

# Leading Edges for Bird Strike Resistance

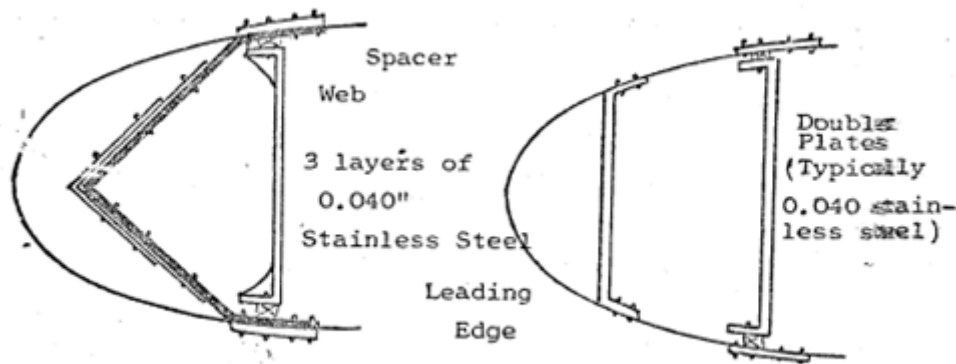
- Classical nose design:  
GFRP Honeycomb Sandwich →
- Early leading edge design suggestions under bird strike consideration by McNaughton in 1972 →
- Earlier splitter design sketches by S. A. McGovern in 1984 ↓



Source: Airbus A320 Vertical Tail Plane Setup



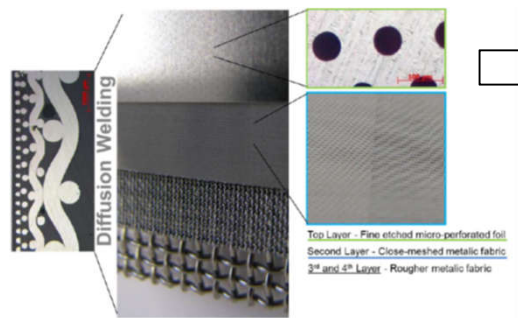
Source: I. I. McNaughtan. The design of leading edge and intake wall structure to resist bird impact. Technical Report 72056. RAE. March 1972.



Source: S. A. McGovern. Bird Strike Design Manual. Gen/B44/30210. British Aerospace Aircraft Group. June 1984.

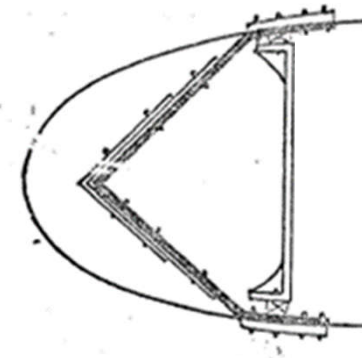
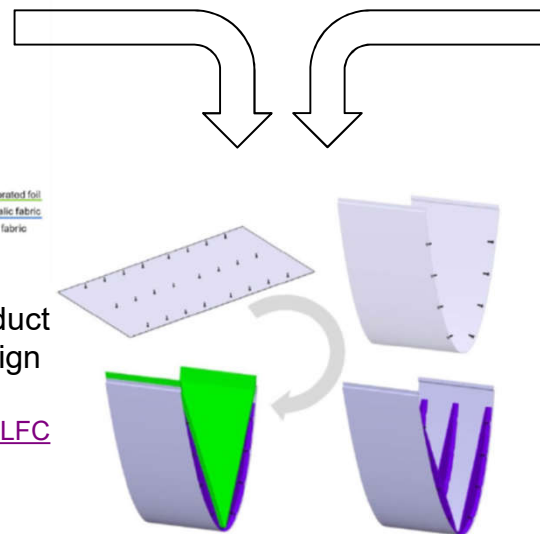
# Combine HLFC with Bird Strike Resistance

- Splitter setup with single duct HLFC for vertical stabiliser
- Micro perforated foil with metallic mesh to allow suction distribution over chord
- Splitter design tries to deflect the bird but not to catch and to protect the front spar shall against impact.



Built-up of tailored skin - single duct surface, Manufacturing and Design Concept

Source: M. Horn et al. [Cost-effective HLFC Design Concept for Transport Aircraft](#). DGLR. 30.09.-02.10.2019.

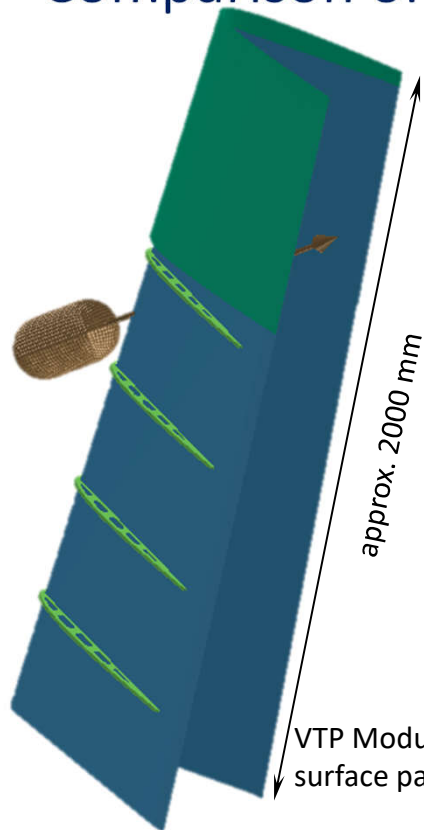


Splitter concept

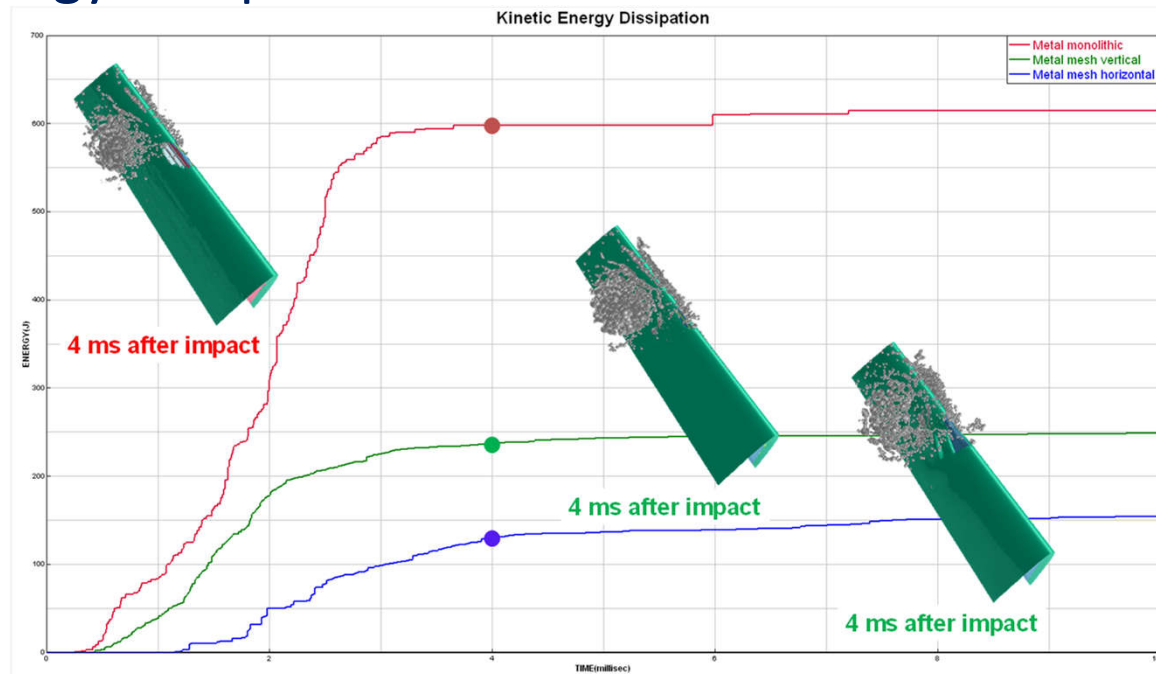
Source: S. A. Ritt, M. Schneider. Structural Design for Hybrid Laminar Flow Control to Toughen up the Laminar Technology. DGLR. 05.-07.09.2017.

# Symmetric Leading Edge with HLFC

- HLFC concept selected by numerical simulation on full segment > horizontal support of outer skin
- Comparison of energy dissipation



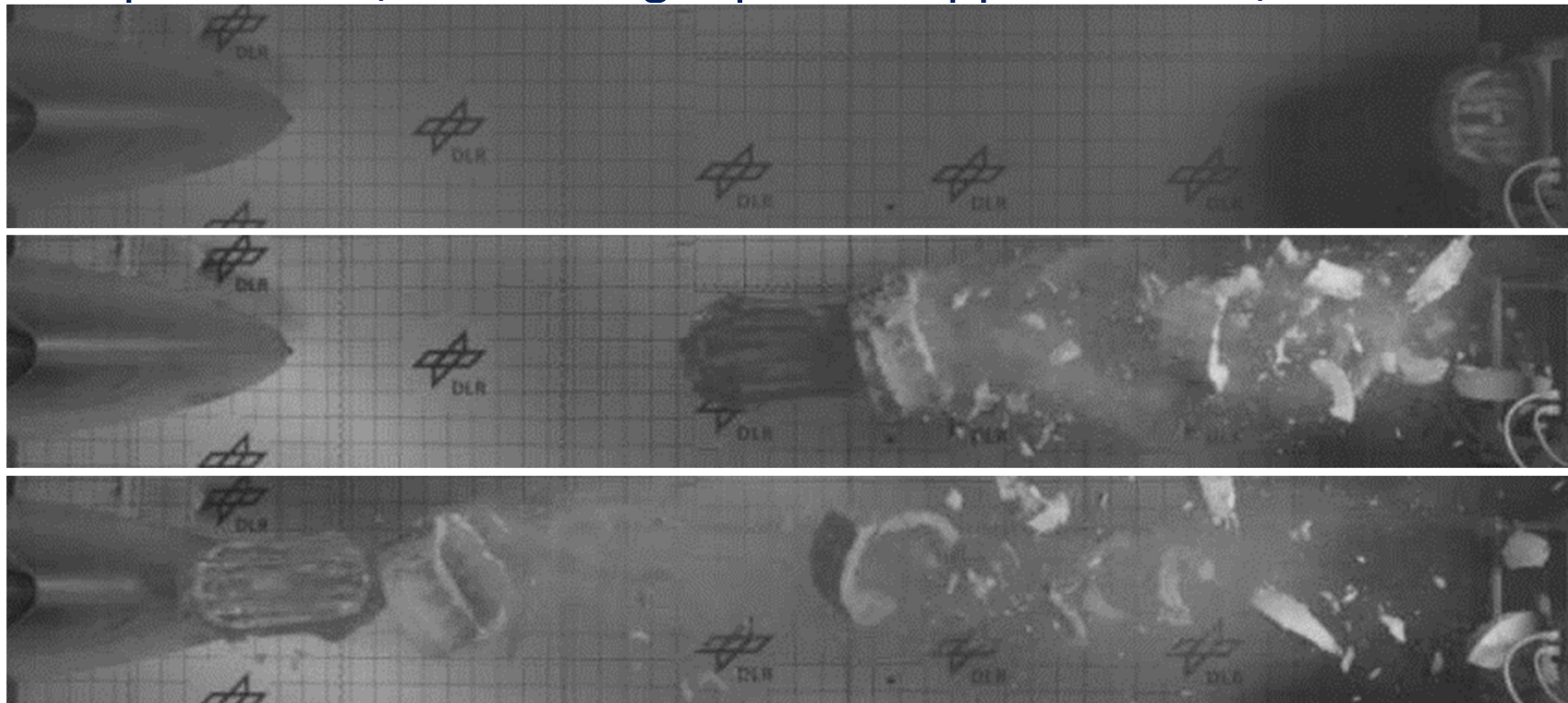
VTP Module 2 analysis model with bird impactor, surface partly not displayed



Source: S. A. Ritt, M. Schneider. Structural Design for Hybrid Laminar Flow Control to Toughen up the Laminar Technology. DGLR. 05.-07.09.2017.

# Symmetric Leading Edge with HLFC

- First confirmation that the DLR reinforced artificial bird #DLRRAB with 3.6 kg weight maintains its shape at velocities up to 185 m/s over a flight path of approx. 2.5 m / 14 ms.



Source: S. A. Ritt, A. Johnson, H. Voggenreiter. Analysis of Bird-Strike under Blunt and Splitting Impact. ASIDIC. Wichita, USA. 17.-18.10.2017.



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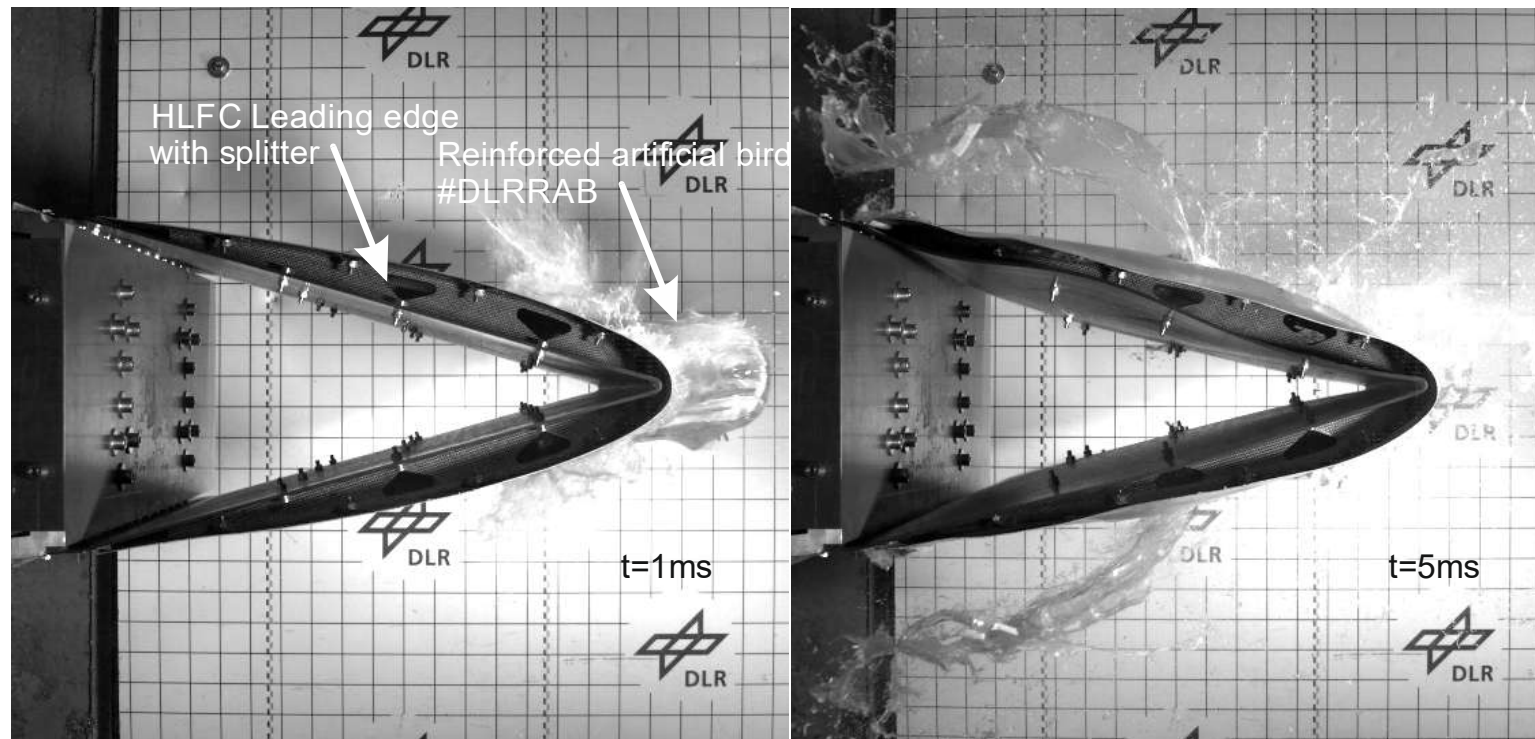
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# Symmetric Leading Edge with HLFC

- Steps for validation: detail level  
Normal impact tests with DLRRAB Mk1 with 3.6 kg at 142 m/s
- Successful splitter tests up to 180 m/s



Source: S. A. Ritt. Der neue DLR-Kunstvogel mit Verstärkung, Experimentelle Methoden zu Crash und Impact, Institutsbericht BT, Teil 1. 2018.



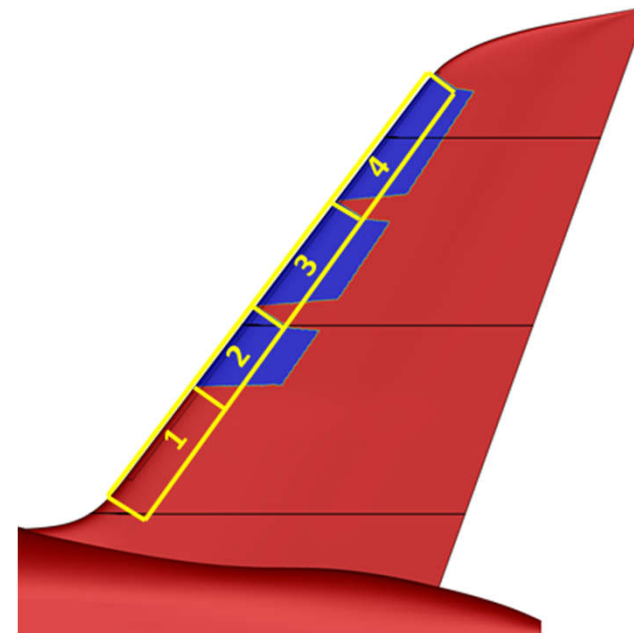
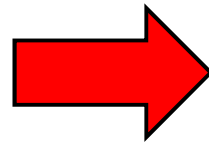
# Impact Studies with Stabiliser Demonstrators

- Symmetric vertical stabiliser (based on A320 VTP)
- Tailored skin - single duct
- Thermoplastic splitter



Source: DLR AFloNext installation. 2018.

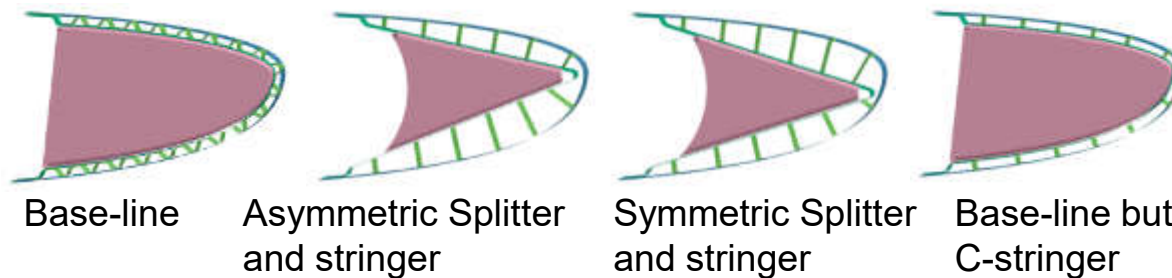
- Asymmetric horizontal stabiliser (based on A350 HTP dimensions)
- Multiple chambers for boundary layer suction



Source: T. Kilian. ECHO Progress Review Meeting. Sevilla, Spain. 07.03.2018

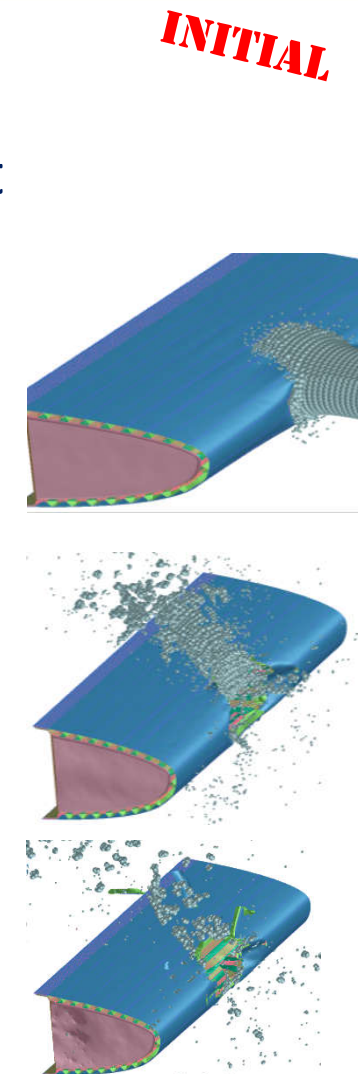
# Reduced Size Asymmetric Leading Edge

- Initial study of multiple chambered HLFC designs
- Numerical simulation of the designs under impact (reduced size, 800 mm segment)
  - Base line design
  - Design alternatives



- Link stochastics with numerical simulation

Source: L. T. Kreimeier, S. A. Ritt. Struktursensitivität von Höhenleitwerksstrukturen mit kammerloser hybrider Laminarerhaltung auf Vogelschlag. DLR-IB-BT-ST-2018-41. 22.02.2018

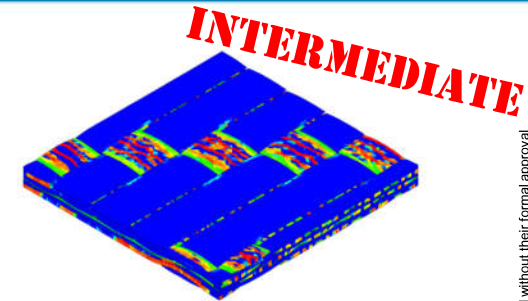
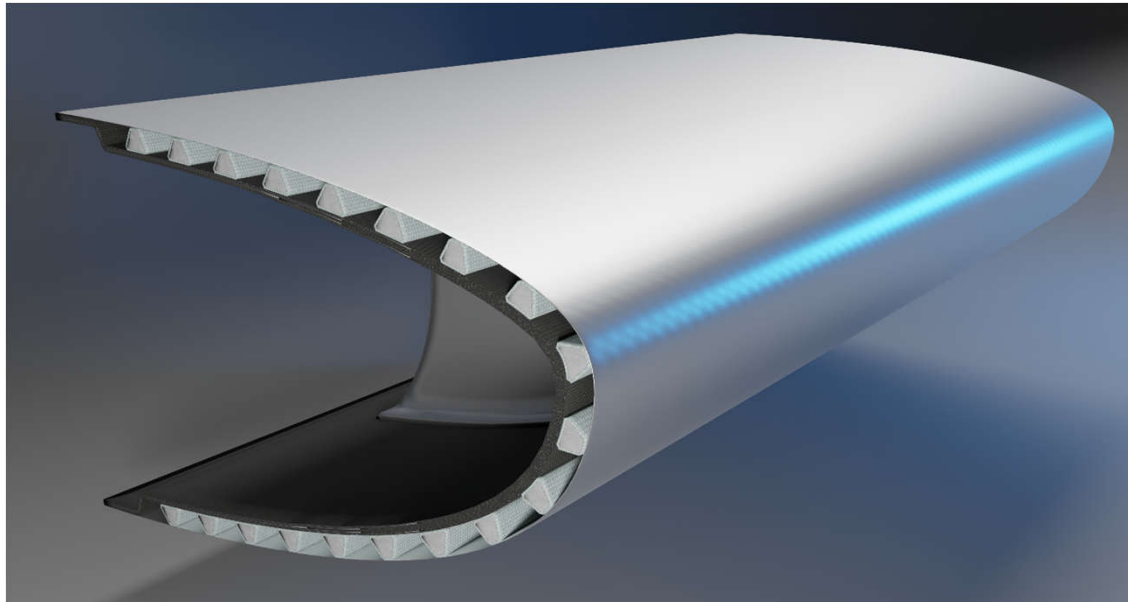


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# Reduced Size Asymmetric Leading Edge

Intermediate studies with preliminary data

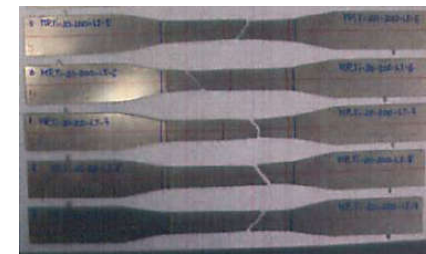
- CFRP inner skin
- Braided foam profiles
- Perforated titanium outer skin



Source: M. Vinot, M. Holzapfel, N. Toso. Materialmodellierung und virtuelles Testen, in: Der digitale Protoyp. Springer. 2019.



Source: IMA contribution. LuFo V-1. 2013.

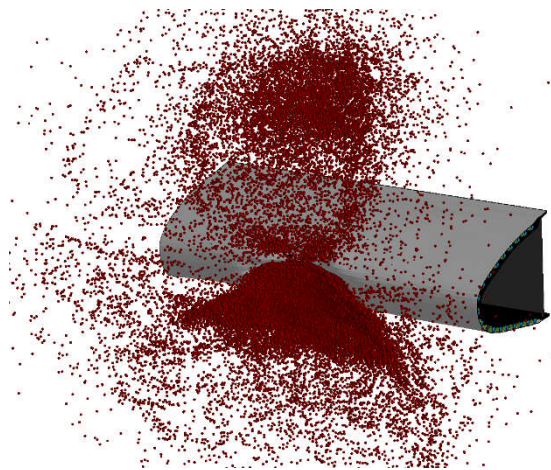


Source: Aernnova, Clean Sky 2 „ECHO“. 2018.

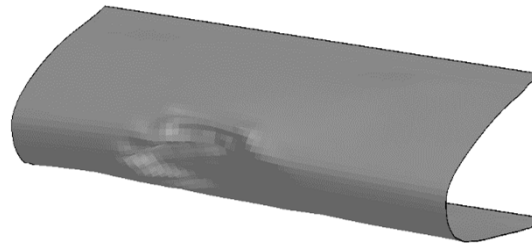
# Reduced Size Asymmetric Leading Edge

- Contribution of deformation in impact simulation

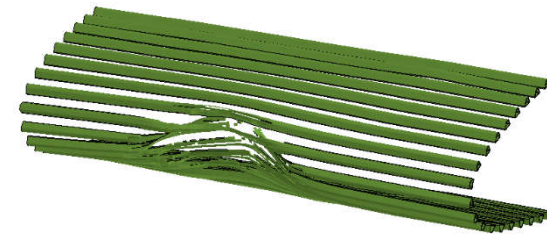
**INTERMEDIATE**



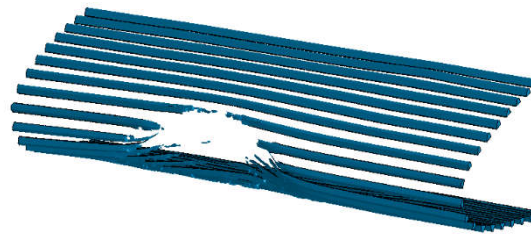
Titanium outer skin



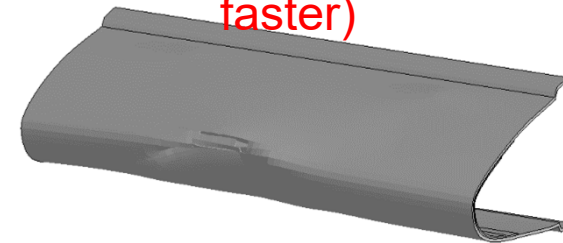
Stringer - braid



Omega stringer - foam



CFRP inner skin  
(1 layer thick shell > faster)



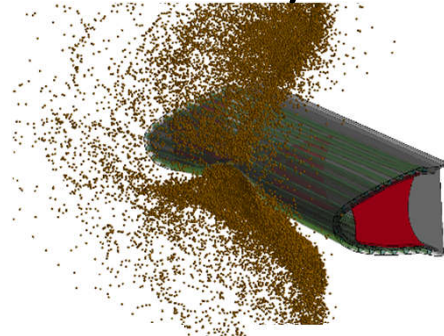
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# Reduced Size Asymmetric Leading Edge

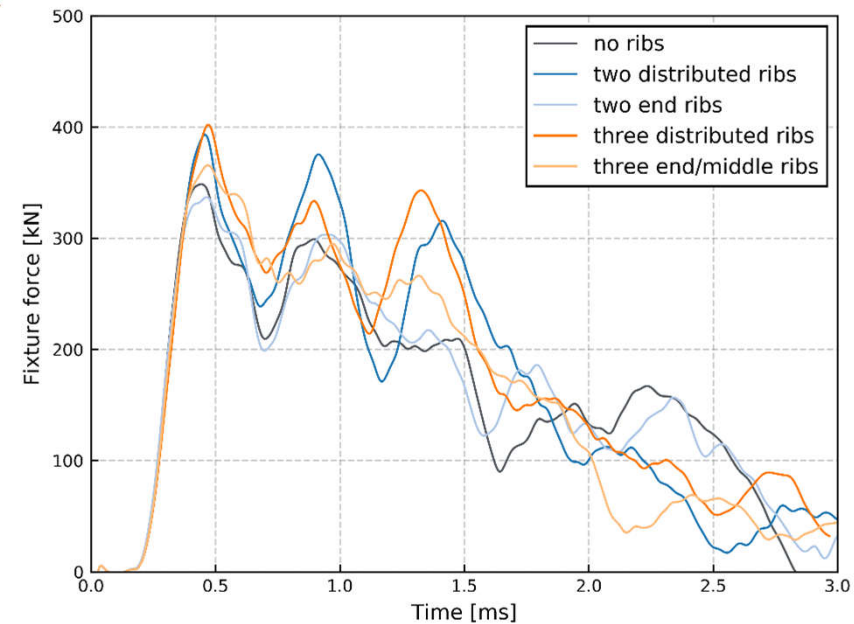
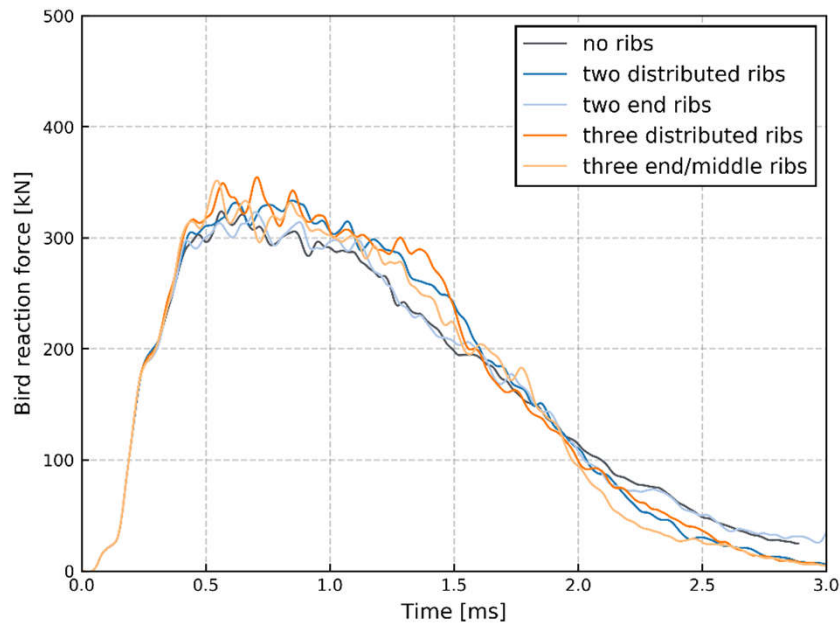
- Influence on impulse transfer by rib configurations

**INTERMEDIATE**

**Front side forces**



**Rear side forces**

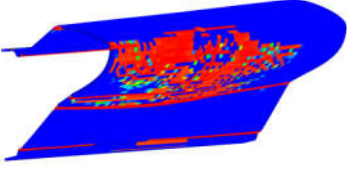
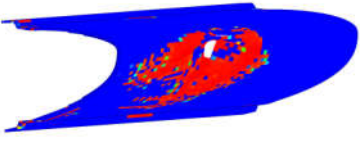
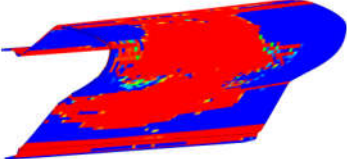
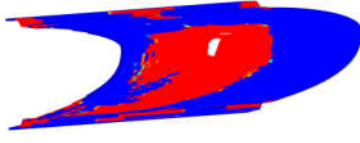


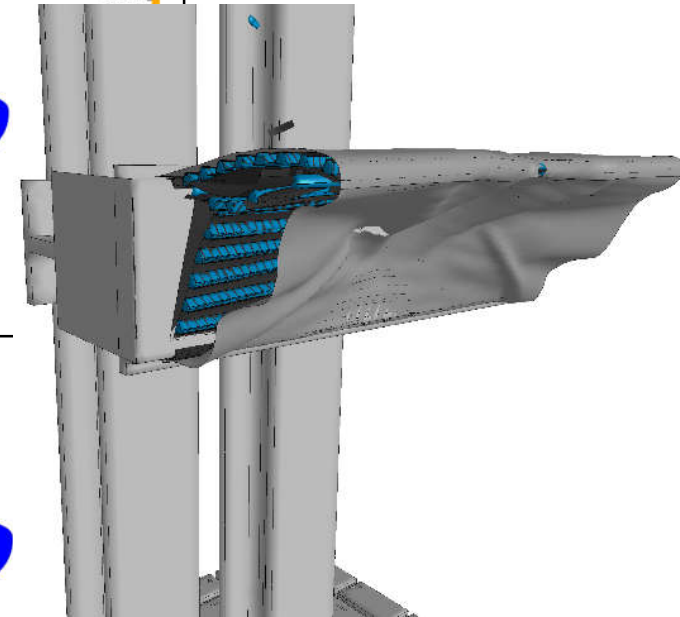
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# Reduced Size Asymmetric Leading Edge

**INTERMEDIATE**

- Rib effect in composite skin

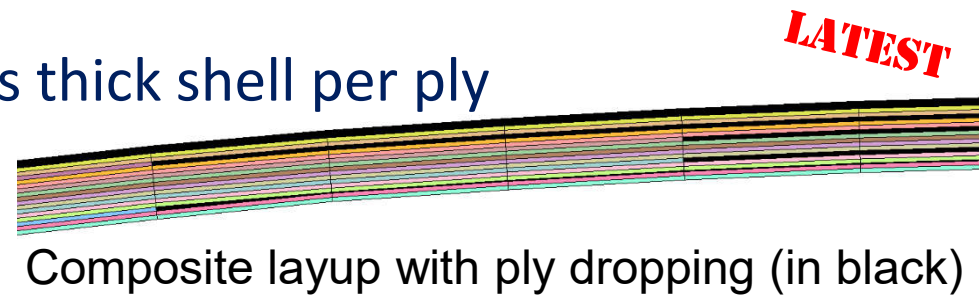
	No Ribs	Three Ribs
Fibre failure	 <p>History Variable#5</p> <p>9.990e-01 9.590e-01 9.191e-01 8.791e-01 8.392e-01 7.992e-01 7.592e-01 7.193e-01 6.793e-01 6.394e-01 5.994e-01 5.594e-01 5.195e-01 4.795e-01 4.396e-01 3.996e-01 3.597e-01 3.197e-01 2.797e-01 2.398e-01 1.998e-01 1.598e-01 1.199e-01 7.992e-02 3.996e-02 0.000e+00</p>	 <p>History Variable#5</p> <p>9.990e-01 9.590e-01 9.191e-01 8.791e-01 8.392e-01 7.992e-01 7.592e-01 7.193e-01 6.793e-01 6.394e-01 5.994e-01 5.594e-01 5.195e-01 4.795e-01 4.396e-01 3.996e-01 3.597e-01 3.197e-01 2.797e-01 2.398e-01 1.998e-01 1.598e-01 1.199e-01 7.992e-02 3.996e-02 0.000e+00</p>
Matrix failure	 <p>History Variable#8</p> <p>9.990e-01 9.590e-01 9.191e-01 8.791e-01 8.392e-01 7.992e-01 7.592e-01 7.193e-01 6.793e-01 6.394e-01 5.994e-01 5.594e-01 5.195e-01 4.795e-01 4.396e-01 3.996e-01 3.597e-01 3.197e-01 2.797e-01 2.398e-01 1.998e-01 1.598e-01 1.199e-01 7.992e-02 3.996e-02 0.000e+00</p>	 <p>History Variable#8</p> <p>9.990e-01 9.590e-01 9.191e-01 8.791e-01 8.392e-01 7.992e-01 7.592e-01 7.193e-01 6.793e-01 6.394e-01 5.994e-01 5.594e-01 5.195e-01 4.795e-01 4.396e-01 3.996e-01 3.597e-01 3.197e-01 2.797e-01 2.398e-01 1.998e-01 1.598e-01 1.199e-01 7.992e-02 3.996e-02 0.000e+00</p>



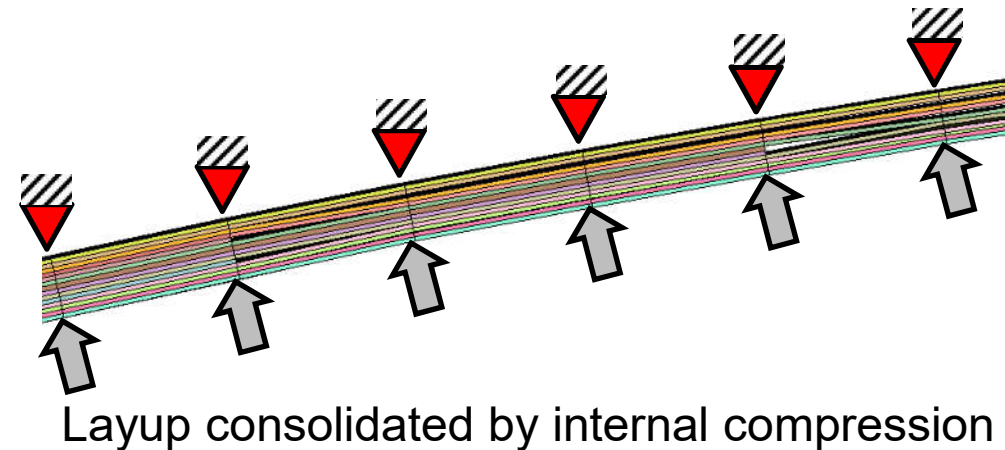
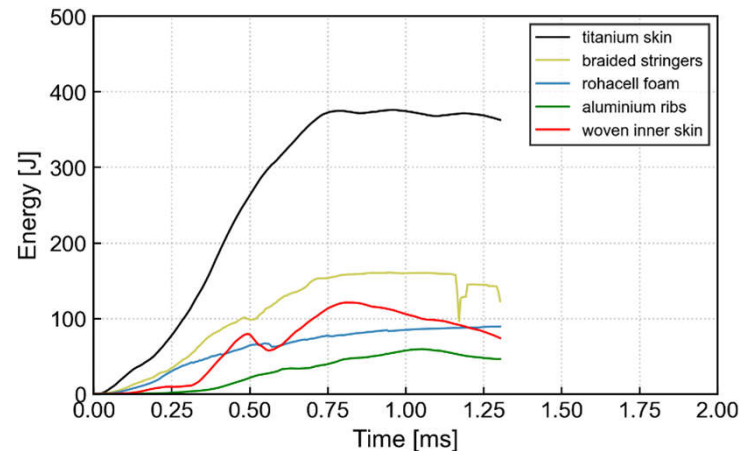
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# Reduced Size Asymmetric Leading Edge

- Simulation of composite as thick shell per ply for detailed studies



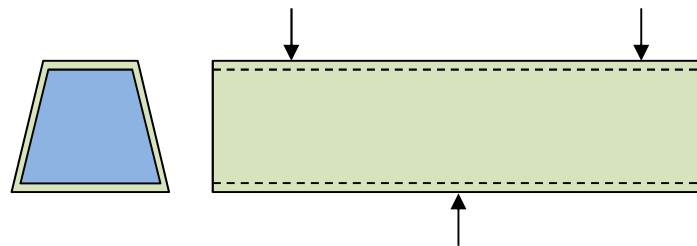
- Internal energy distribution



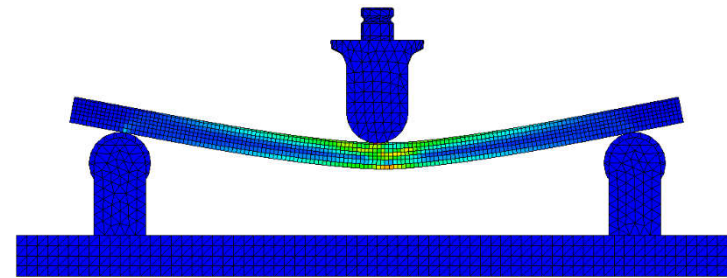
# Reduced Size Asymmetric Leading Edge

- Calibration coupon / element tests and simulation

**LATEST**

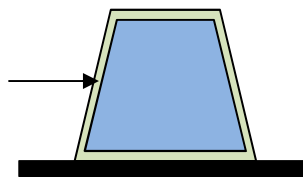


3-point bending setup

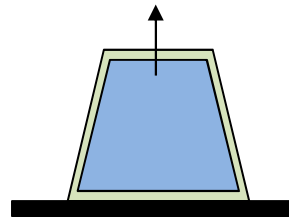


3-point bending simulation

Shear-off test



Pull-off test



Coupon / element specimens in preparation

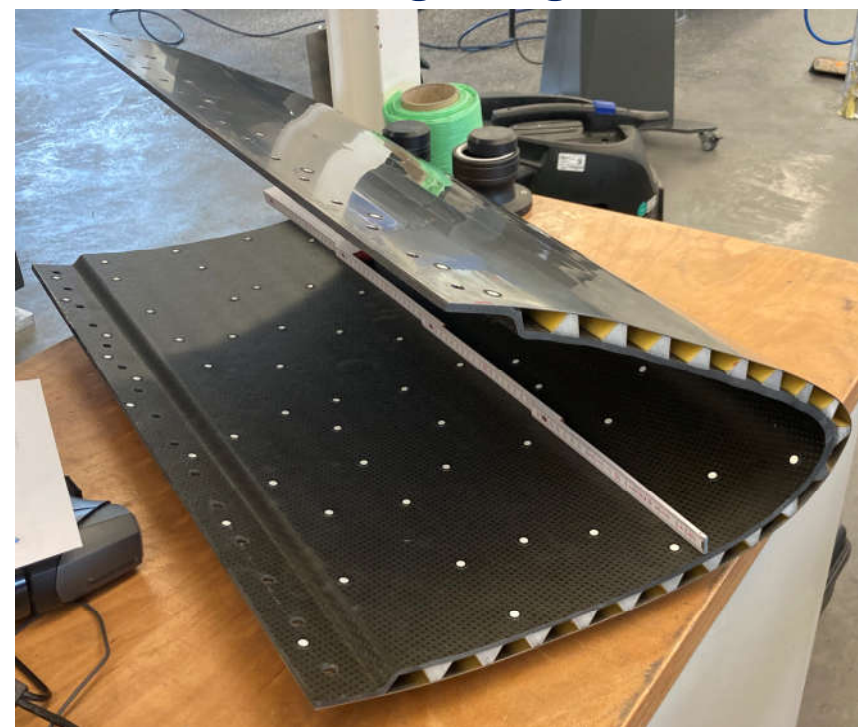
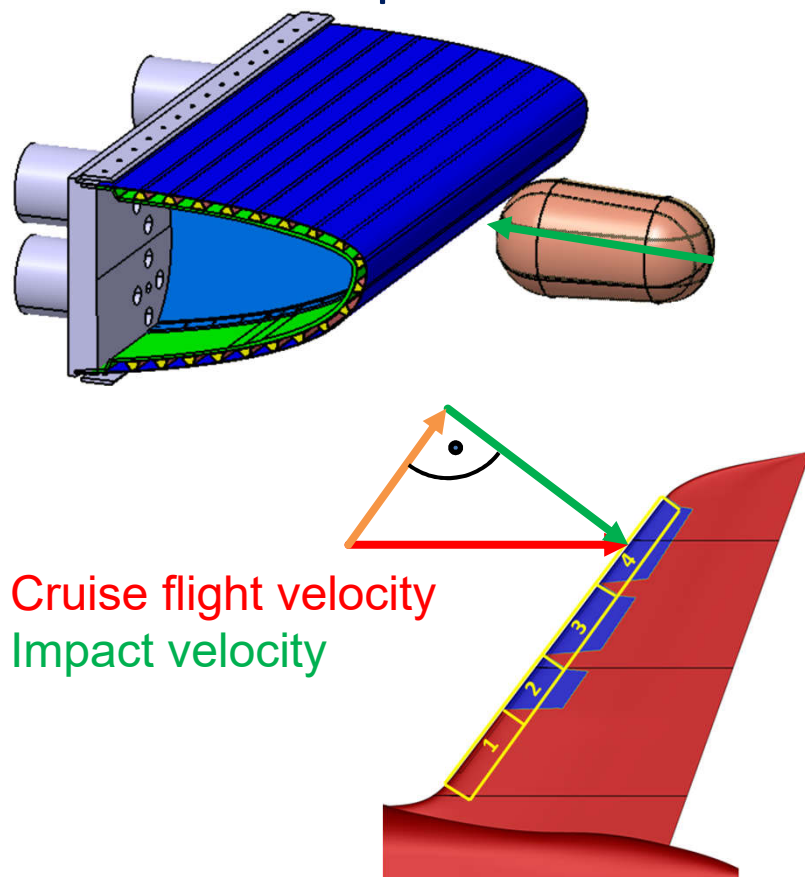




# Extended Size Asymmetric Leading Edge

**LATEST**

- Test setup for impact demonstrator
- Normal impact with DLR artificial bird of 3.6 kg weight

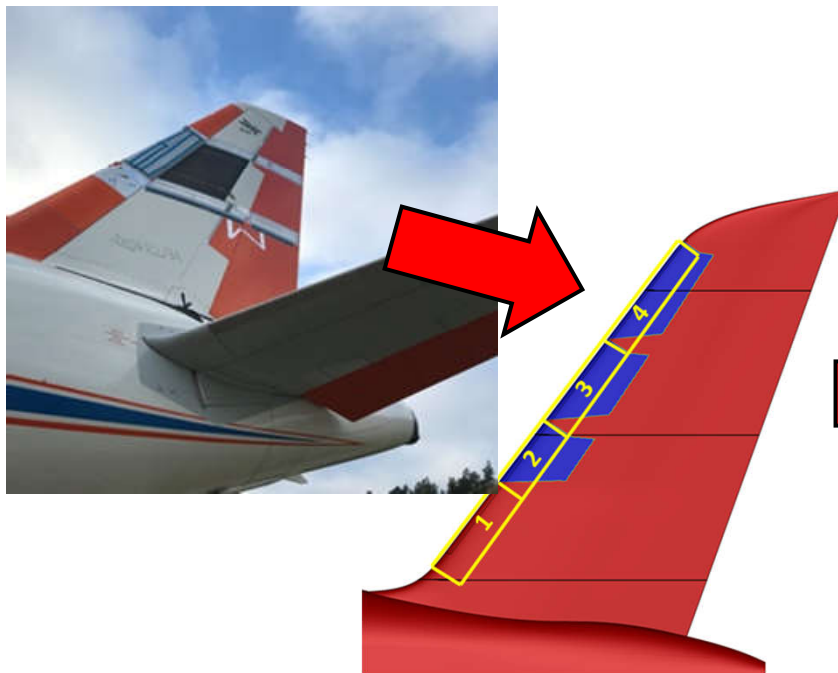


Asymmetric leading edge demonstrator in preparation for testing

# Outlook

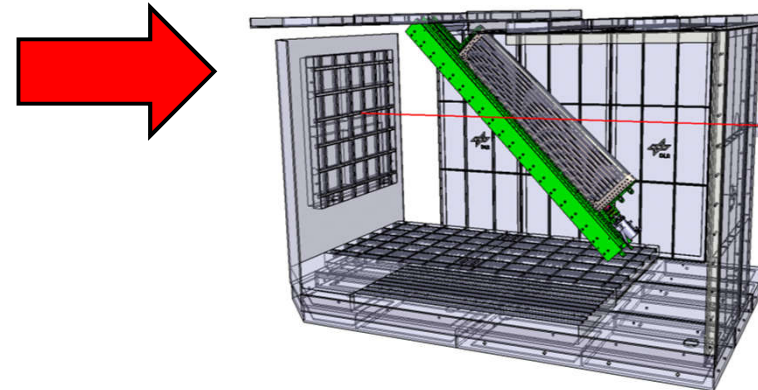
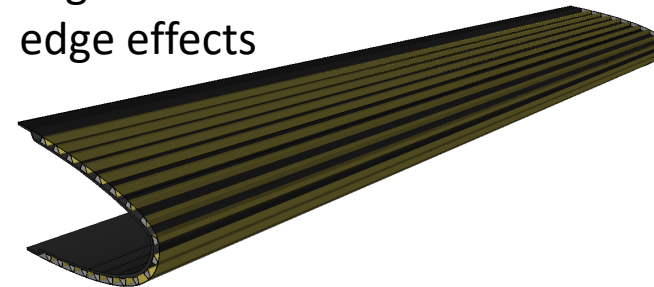
## Reduced size demonstrators

- Symmetric vertical stabiliser
- Asymmetric horizontal stabiliser



## Full Size Demonstrator

- Segment 4 demonstrator to study edge effects
- 3D designed asymmetric horizontal stabiliser leading edge



# Thank you for your attention!

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Source: ABC News Photo Illustration, 27.03.2009

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- The presented work has received funding from the Clean Sky 2 Joint Undertaking (JU) under grant agreement No 945583 (ECHO, HLFC-WIN). The JU receives support from the European Union's Horizon 2020 research and innovation programme and the Clean Sky 2 JU members other than the Union.
- The presented work has received institutional funding of DLR under the aeronautical research programme.

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