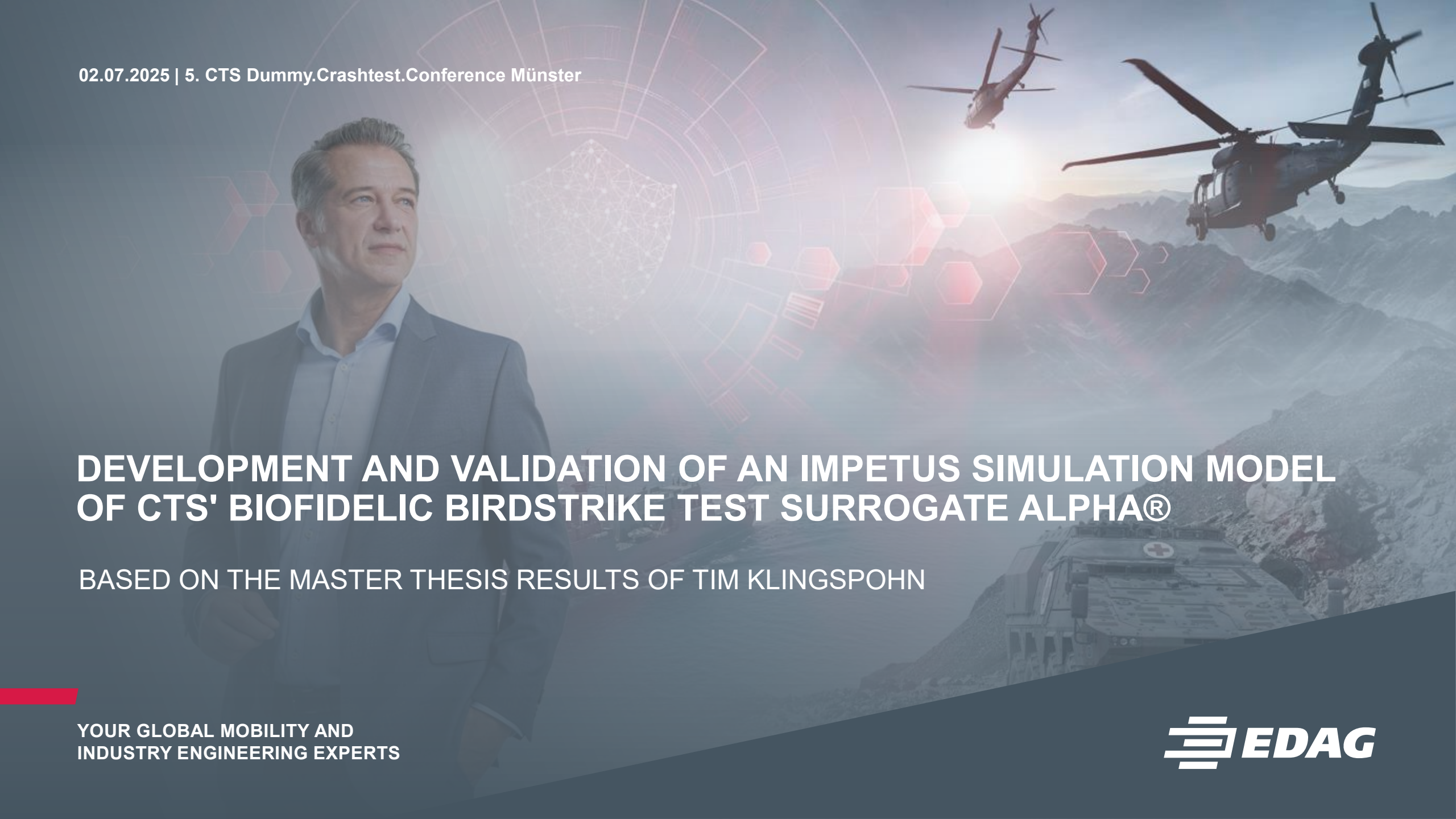


DEVELOPMENT AND VALIDATION OF AN IMPETUS SIMULATION MODEL OF CTS' BIOFIDELIC BIRDSTRIKE TEST SURROGATE ALPHA®

BASED ON THE MASTER THESIS RESULTS OF TIM KLINGSPOHN

YOUR GLOBAL MOBILITY AND
INDUSTRY ENGINEERING EXPERTS

EDAG

OUR
FACTS & FIGURES

1969
FOUNDATION

~ 70
LOCATIONS WORLDWIDE

19
COUNTRIES

~ 8.900
EMPLOYEES

2015
IPO

~ 4 %
TRAINING RATE

844,3
MILLION REVENUE

~ 3,6 %
CAPITAL EXPENDITURE ON REVENUE

EDAG WORLDWIDE

Europe:
- Germany
- United Kingdom
- Italy
- Netherlands
- Poland
- Sweden
- Switzerland
- Spain
- Czech Republic
- Turkey
- Hungary
- Austria

Asia:
- China
- India
- Japan
- Malaysia

North & South America:
- Brazil
- Mexico
- USA

IMPETUS

EDAG GERMANY

- Berlin
- Bremen
- Dortmund
- Eisenach
- Friedrichshafen
- Fulda
- Ingolstadt
- Köln
- Leipzig
- Lindau
- München
- Neckarsulm
- Recklinghausen
- Regensburg
- Stuttgart
- Ulm
- Weinheim
- Wiesbaden
- Wolfsburg
- Zwickau

EDAG CAE-SIMULATION PORTFOLIO
RANGE OF SERVICES

EDAG

ADAM'S CARS

SIMULIA ABAQUS

Ansys

FEMFAT

MSC Nastran

IMPETUS

STAR-CCM+

DYNA MORE

esi get it right

META POST PROCESSOR

ALTAIR HyperWorks

ANSA PRE PROCESSOR

MULTIBODY-Simulation
- Driving Dynamics
- Virtual Proving Ground

CFD-Simulation
- Interior / Exterior Flow
- Aero- & Fluiddynamics

CRASH-Simulation
- Structural Integrity
- Crash Strategy Development
- Material Concepts

EXTERIOR-Simulation
- Doors / Hinges
- Hang on Parts

STRENGTH & FATIGUE Simulation
- Stiffness analysis
- Fatigue-Strength evaluation
- Weldseam and Bolt / Screw evaluation

PEDESTRIAN Protection
- Head impact
- Upper / Lower leg impact

NVH-Simulation
- Acoustics, Vibrations
- Static / Dynamic stiffness
- Frequency Response

OCCUPANT Safety
- Restrain Systems
- Airbags and Active Safety

INTERIOR-Simulation
- Seating Systems
- Interior Trim / Dashboard

DEFENCE-Simulation
- Interior / Exterior Ballistics
- Development of Protective Equipment
- Armoured Vehicle Development

Advanced Technologies
- AI-Tools
- HV-Battery Simulation
- EMC Simulation

~ 500
EMPLOYEES

> 30
CAE SOLVER / PROGRAMMS

FORMER COOPERATION
PRIMUS SIMULATION MODEL

https://www.crashtest-service.com/de/biofidel-dummy-/modelluebersicht/primus-breakable/

Structural results

Testing

Optimized design of protection systems!

Simulation

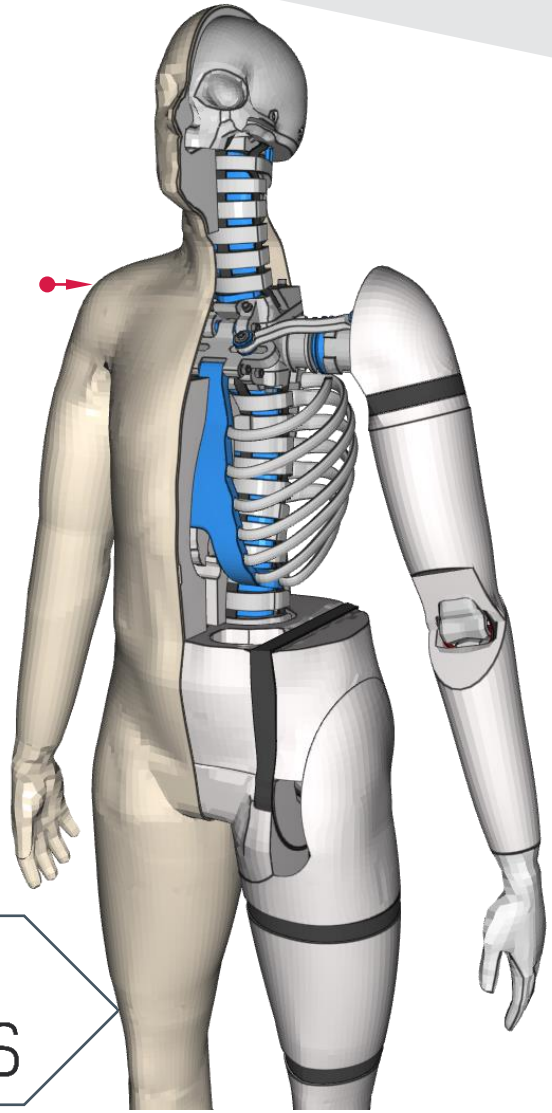
Damage / Injury mechanisms

Cooperation:

CTS crashtest-service

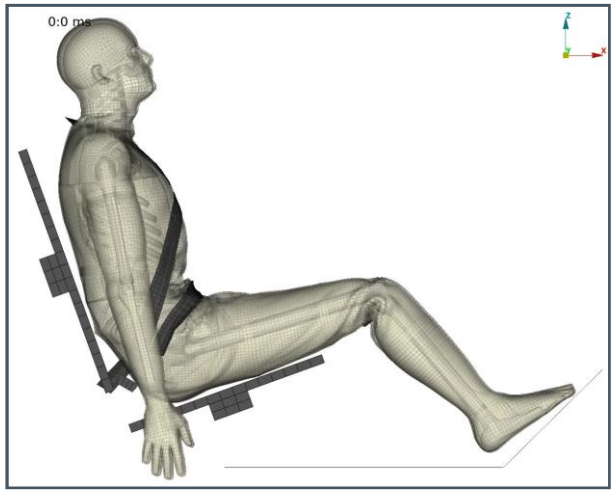
EDAG

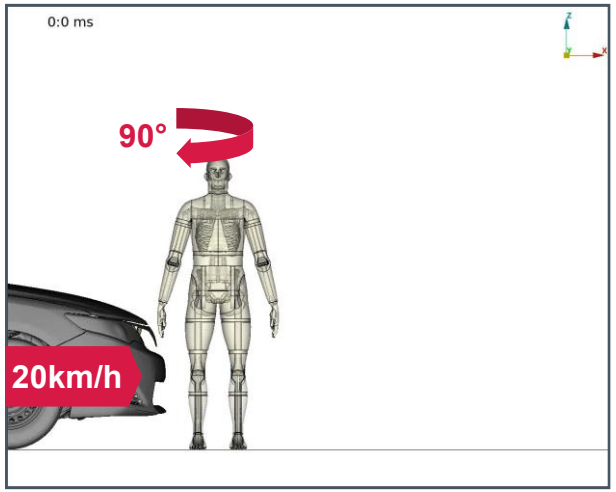
CAD-Geometry preparation:	Meshing & Pre-Processing:	Solving & Post-Processing:
CATIA	ANSA PRE PROCESSOR	IMPETUS

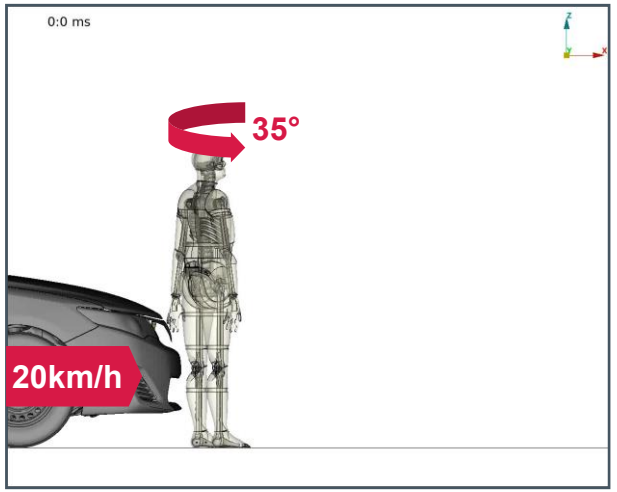


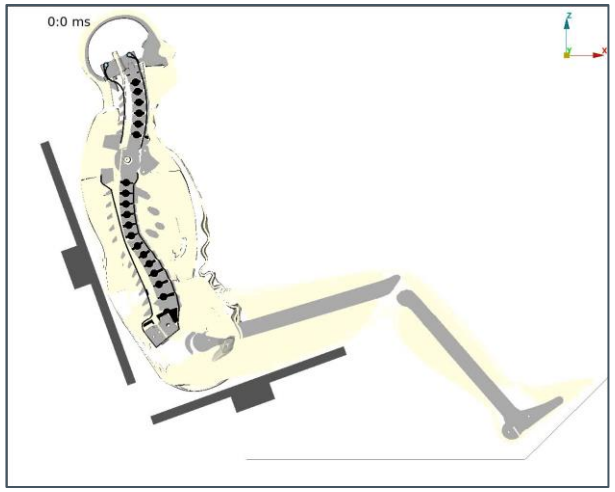
PRESENT COOPERATION
PRIMUS SIMULATION MODEL

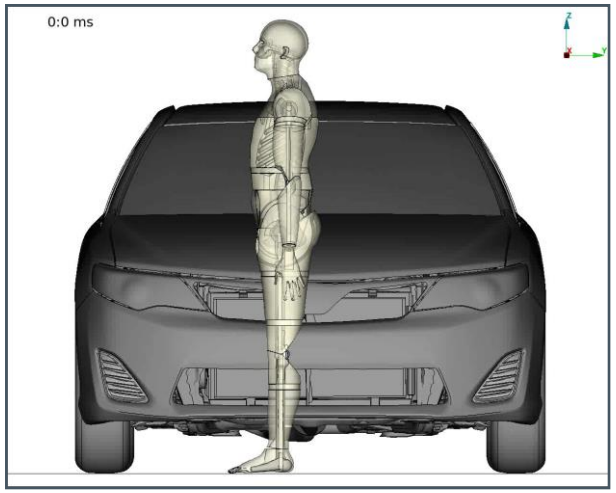
IMPETUS → Simulation Model Conversion → DYNA MORE An Ansys Company



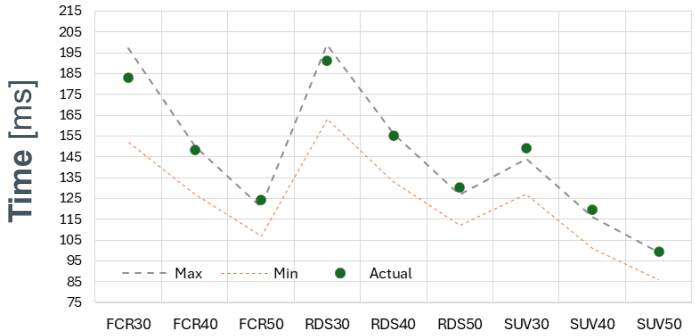








EURO NCAP QUALITY CHECK (Head impact time)



AGENDA

1. BIRD STRIKE SURROGATES

a. Introduction

b. Surrogates for Bird Strike Testing

2. ALPHA® CHICKEN SURROGATE

a. Chicken Birdstrike Surrogate Model

b. Validation Strategy and Underlying Experiments

c. Validation Pyramid (SAE G-28)

3. AVIATION FORECAST

a. Impact on Aviation Structures

4. ALPHA® GOOSE SURROGATE

a. Goose Birdstrike Surrogate Model

b. Chicken to Goose Differences in Impact on Aviation Structures

BIRDSTRIKE SIMULATION MODEL
BIRDSTRIKE INTRODUCTION

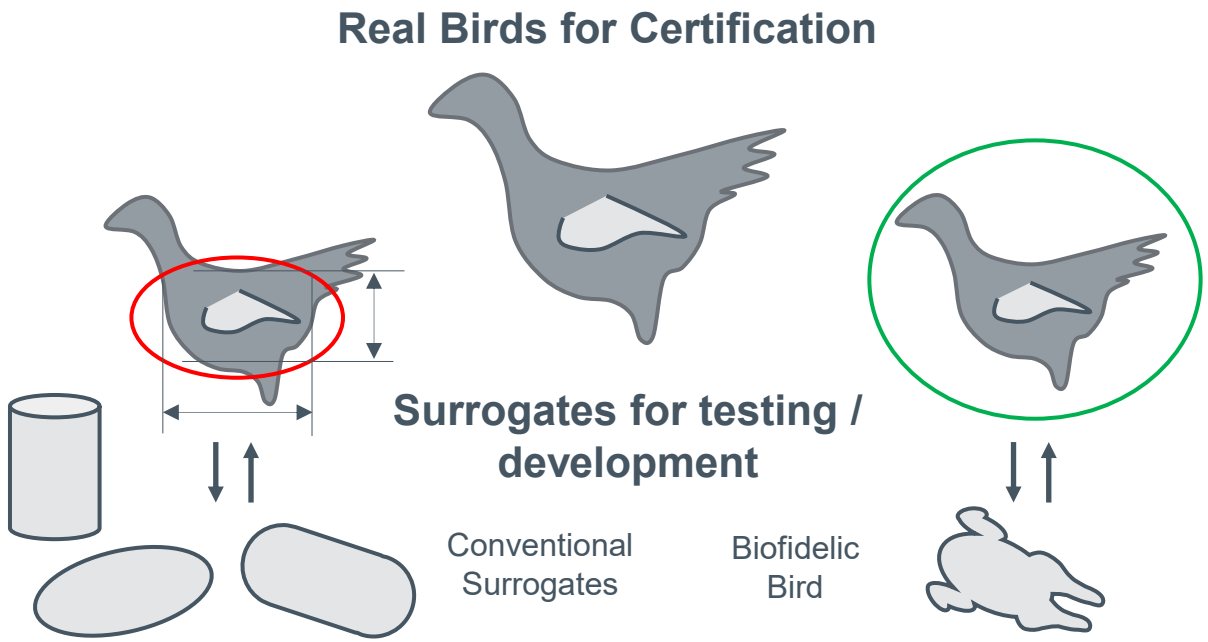

https://www.expats.cz/czech-news/article/nato-video-captures-czech-pilot-birdstrike


https://de.m.wikipedia.org/wiki/Datei:Jet_engine_damaged_by_bird_strike.jpg


Bird strike in aviation : statistics, analysis and management

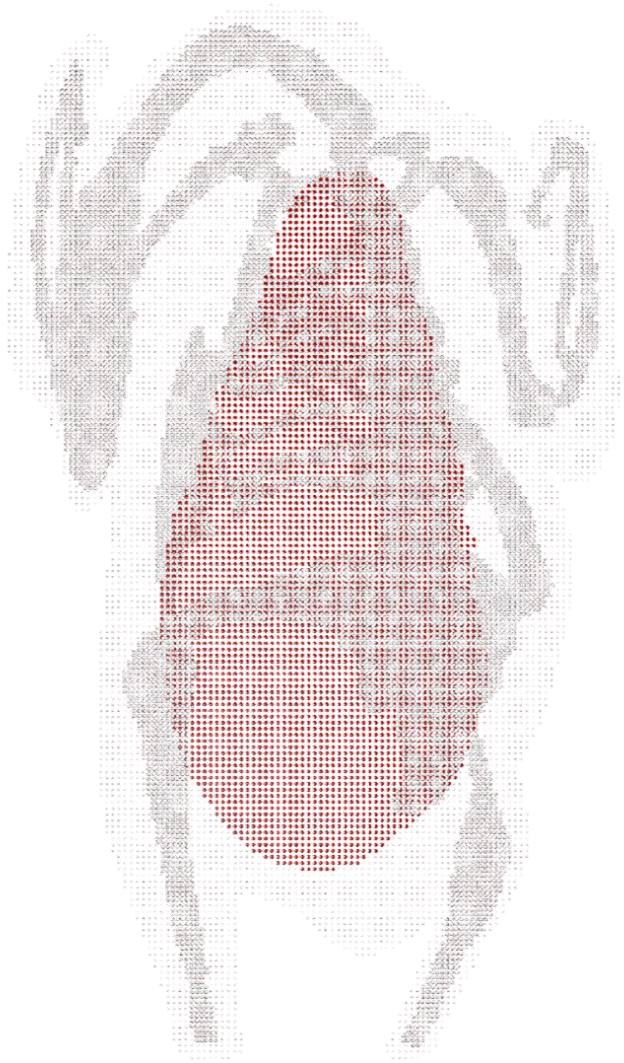
BIRDSTRIKE SIMULATION MODEL
BIRDSTRIKE TESTING

BIRDSTRIKE SIMULATION MODEL
ALPHA® BIRDSTRIKE-SURROGATE (CHICKEN)

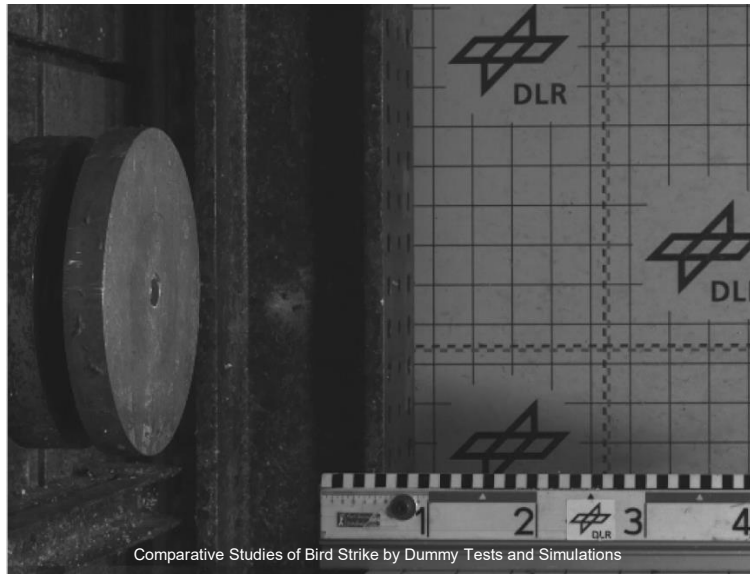


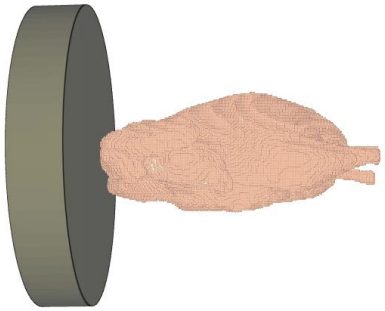
Alpha® Birdstrike-Surrogate (Chicken)

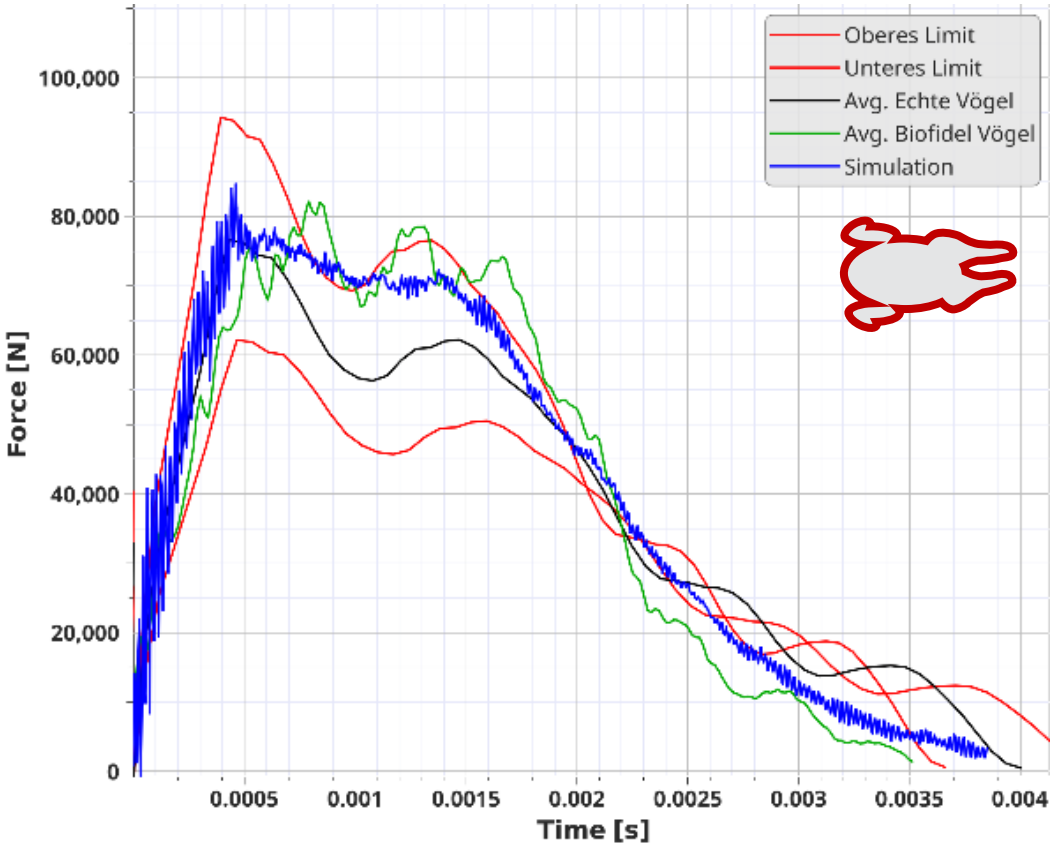
- 1,8kg
- Based on CT-Scan of a prepared Chicken
- Inner soft organs
- Skeleton structure (slightly simplified)
- Outer muscular tissue



BIRDSTRIKE SIMULATION MODEL
ALPHA® BIRDSTRIKE-SURROGATE (CHICKEN)

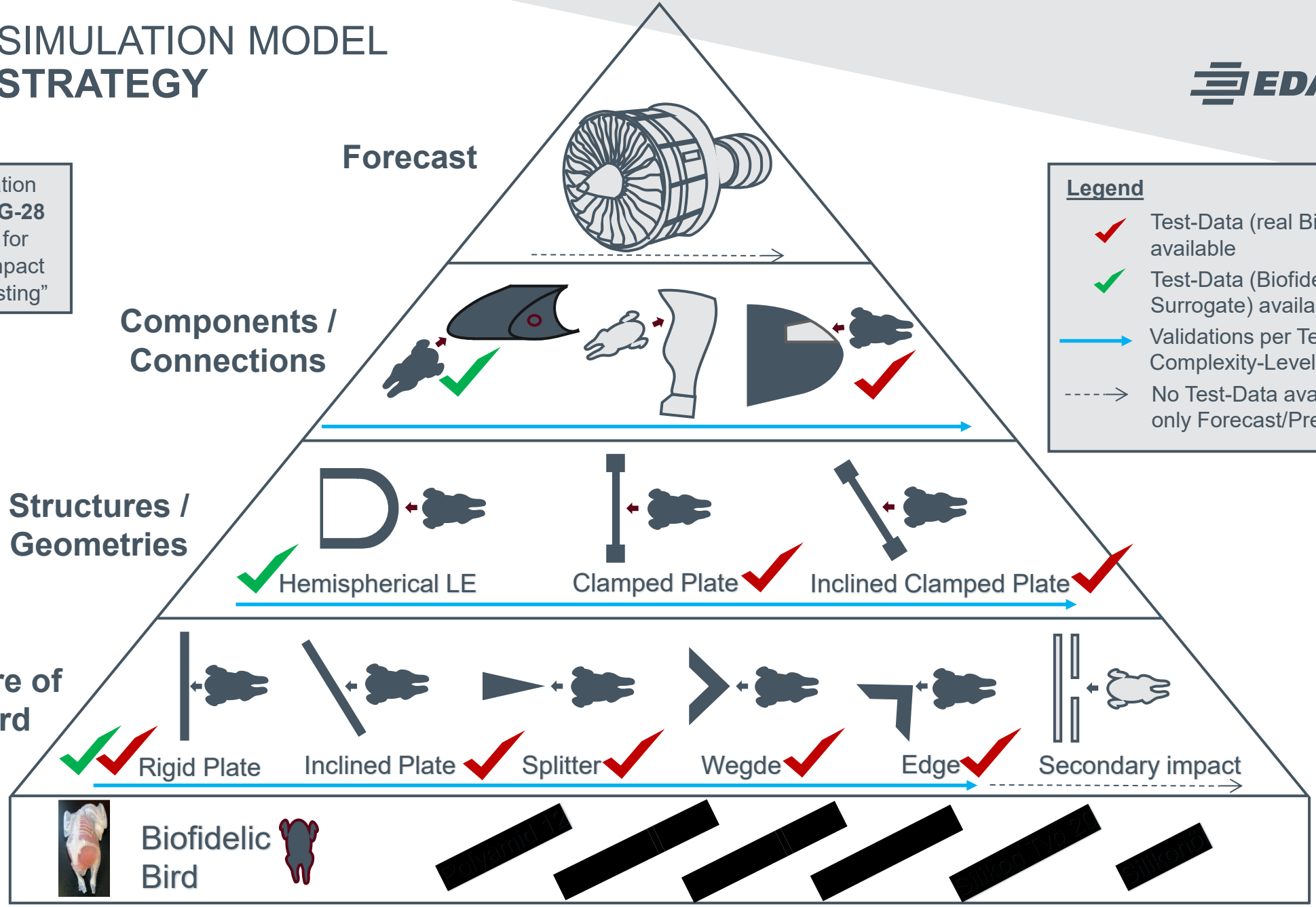






BIRDSTRIKE SIMULATION MODEL
VALIDATION STRATEGY

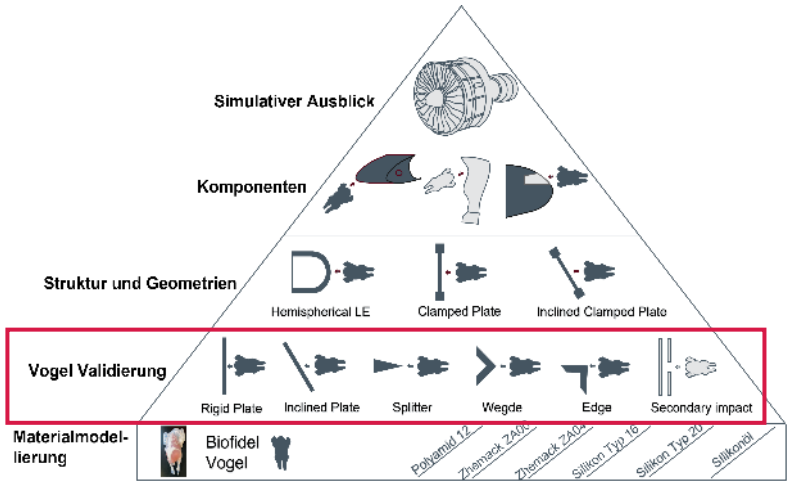
Based on validation pyramid of **SAE G-28** working Group for „Simulants for Impact and Ingestion Testing"



Legend

- Test-Data (real Birds) available
- Test-Data (Biofidelic Bird-Surrogate) available
- Validations per Test-Complexity-Level
- No Test-Data available, only Forecast/Prediction

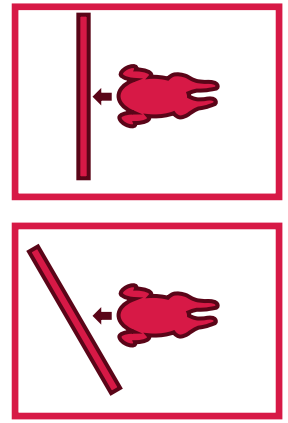
BIRDSTRIKE SIMULATION MODEL
LEVEL 1 VALIDATION



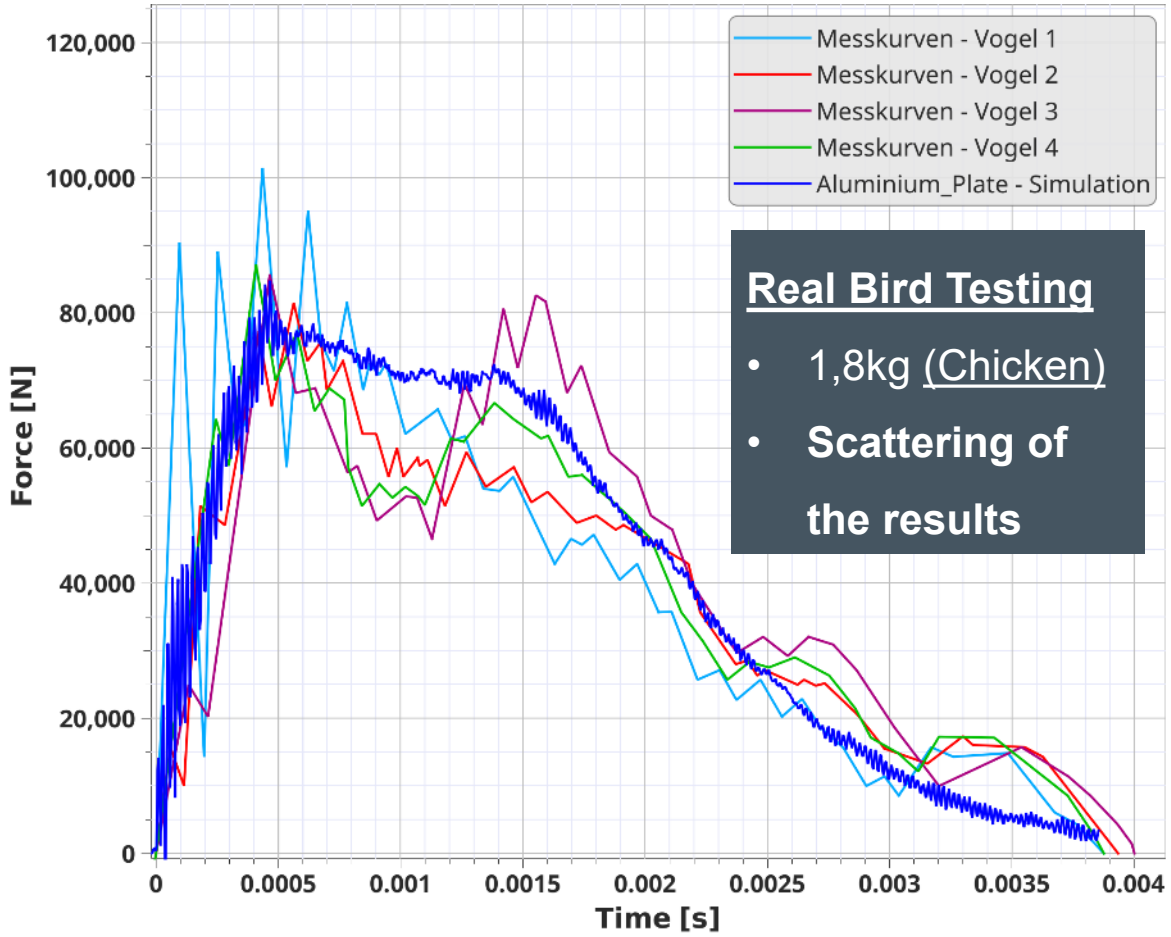
Rigid Plate	Inclined Plate	Splitter	Wegde	Edge
Materials: Structures are fully rigid				
Velocities: 85m/s 90m/s	**Velocity:** 125m/s	**Velocity:** 69m/s	**Velocity:** 106m/s	**Velocity:** 125m/s

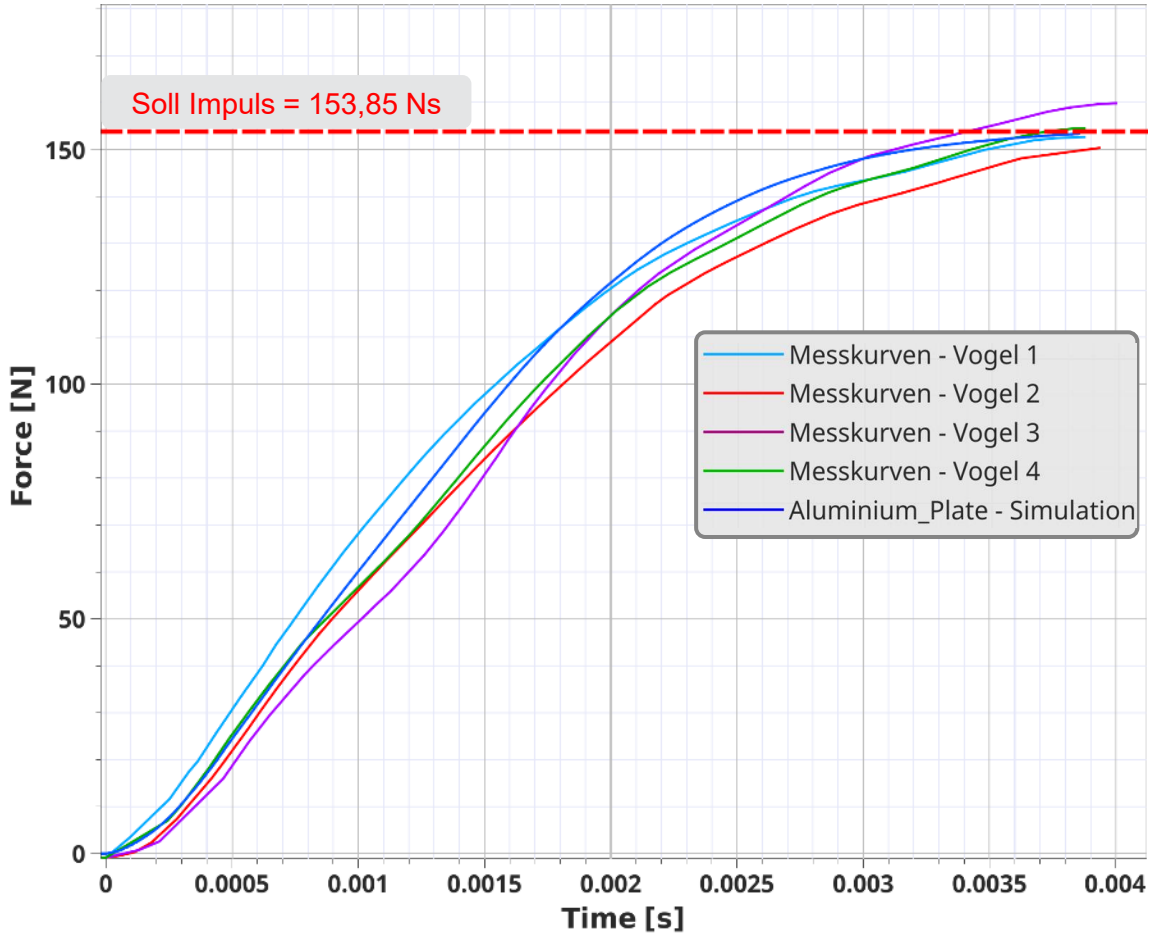
BIRDSTRIKE SIMULATION MODEL
LEVEL 1 VALIDATION

Numerical Simulation of Impact bird against rigid flat plate and rigid edge for bird splitting analysis



BIRDSTRIKE SIMULATION MODEL
LEVEL 1 VALIDATION

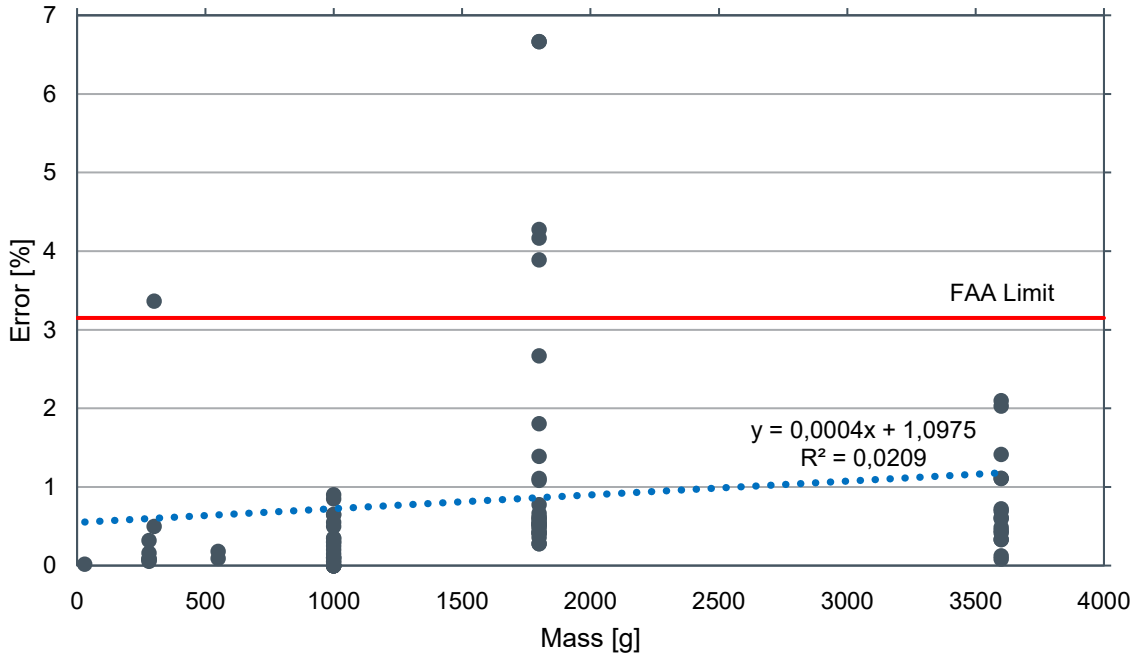




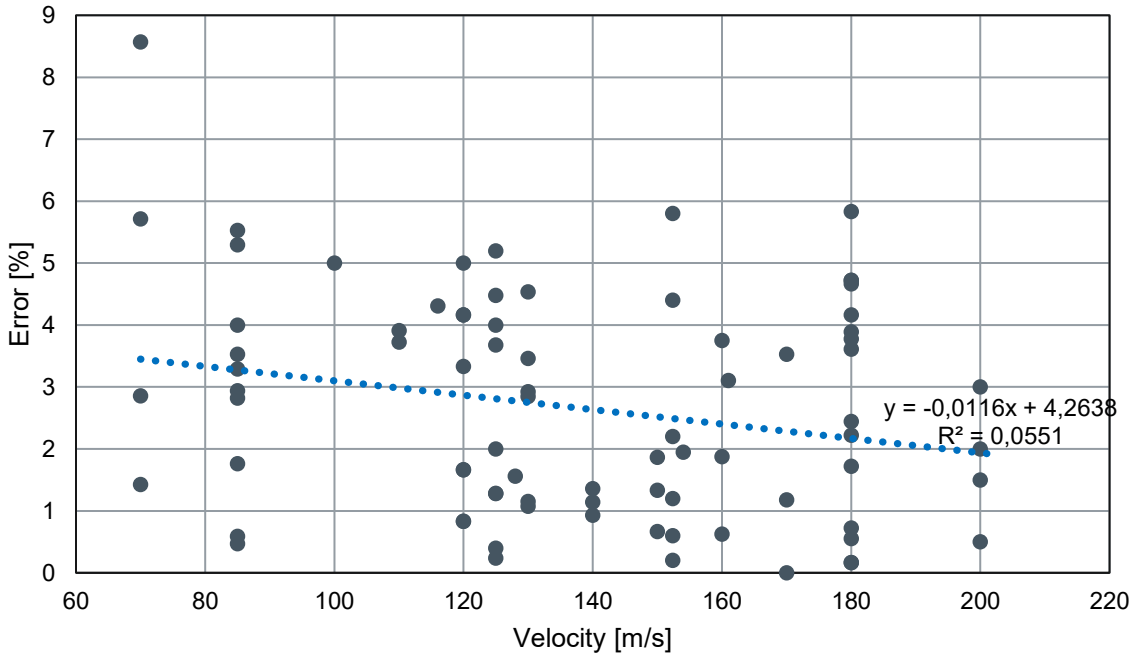
BIRDSTRIKE SIMULATION MODEL
LEVEL 1 VALIDATION

$$p = m \cdot v, \qquad F = \frac{m \cdot v}{t}, \qquad t = \frac{l}{v}$$

Percentage Mass-Error



Percentage Velocity-Error

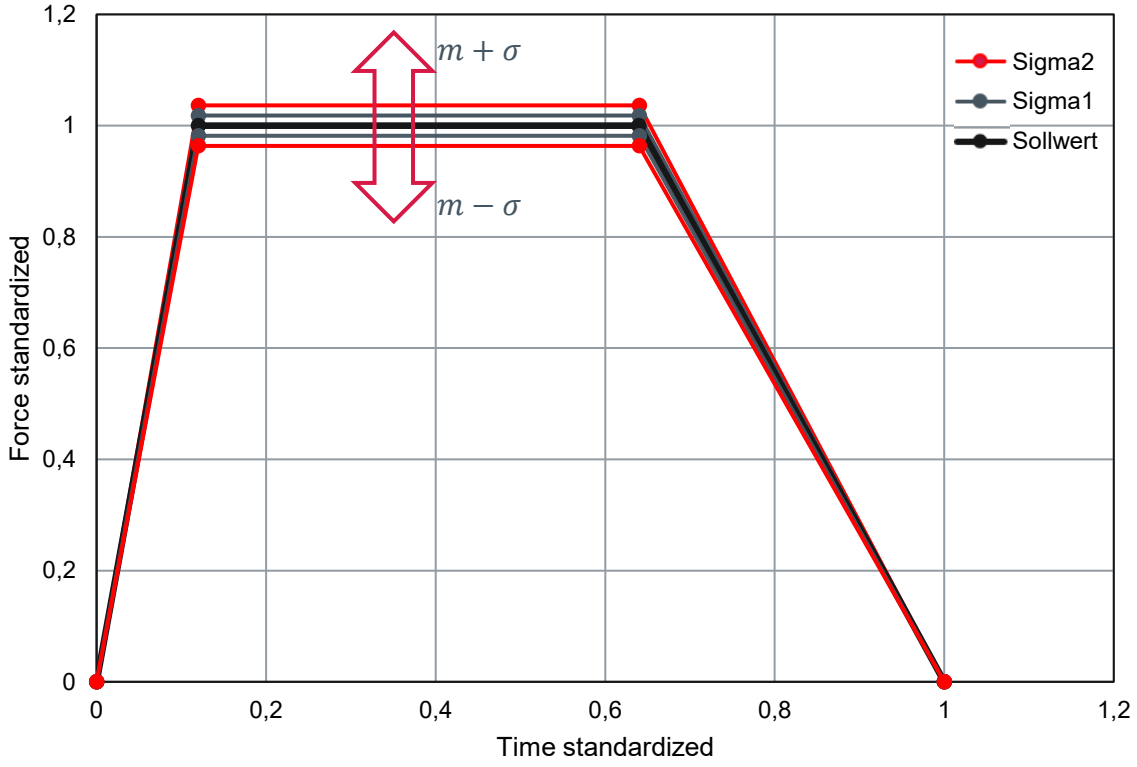


- ASTM F330-21 für „Bird Impact testing“ allow a mass error of max. 3,15% and a velocity measurign deviation of max. 2%
- Different Birdstrike Test-Facilities indicate an absolute error of ± 5 – 7 m/s, therefore the percentage velocity-error is lower at higher velocities

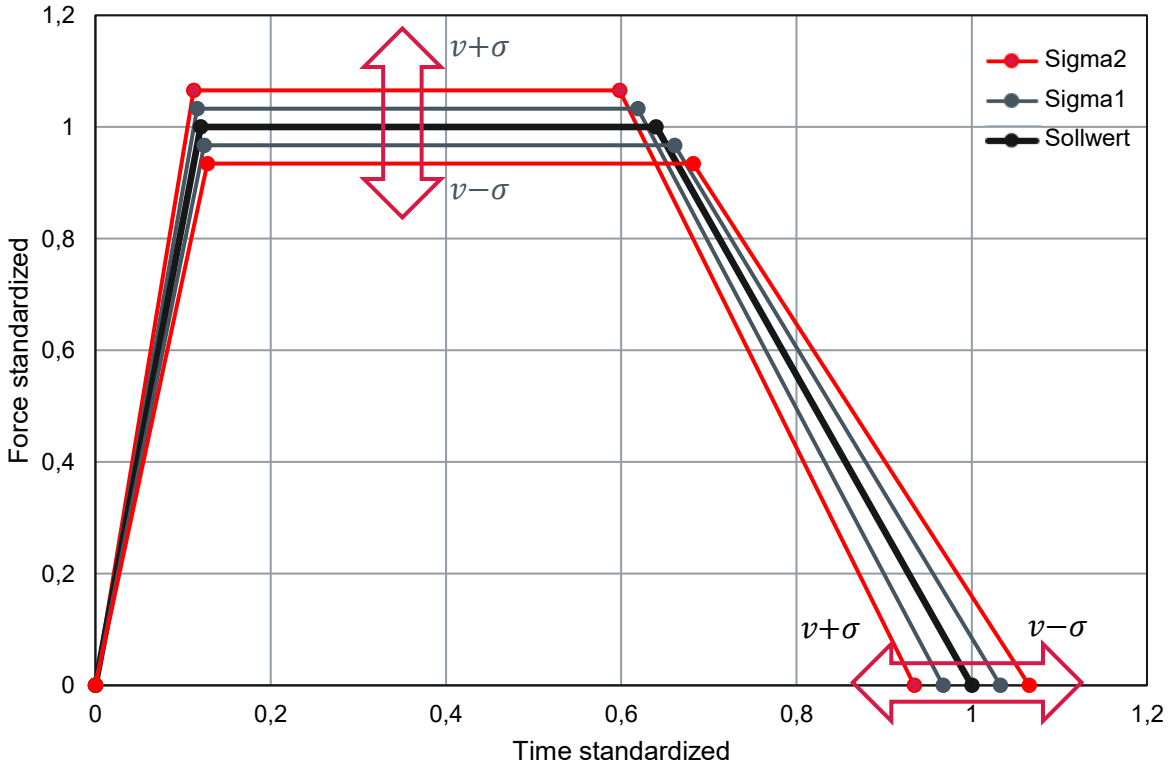
BIRDSTRIKE SIMULATION MODEL
LEVEL 1 VALIDATION

$$p = m \cdot v, \qquad F = \frac{m \cdot v}{t}, \qquad t = \frac{l}{v}$$

Effect of Mass-Error



Effect of Velocity-Error

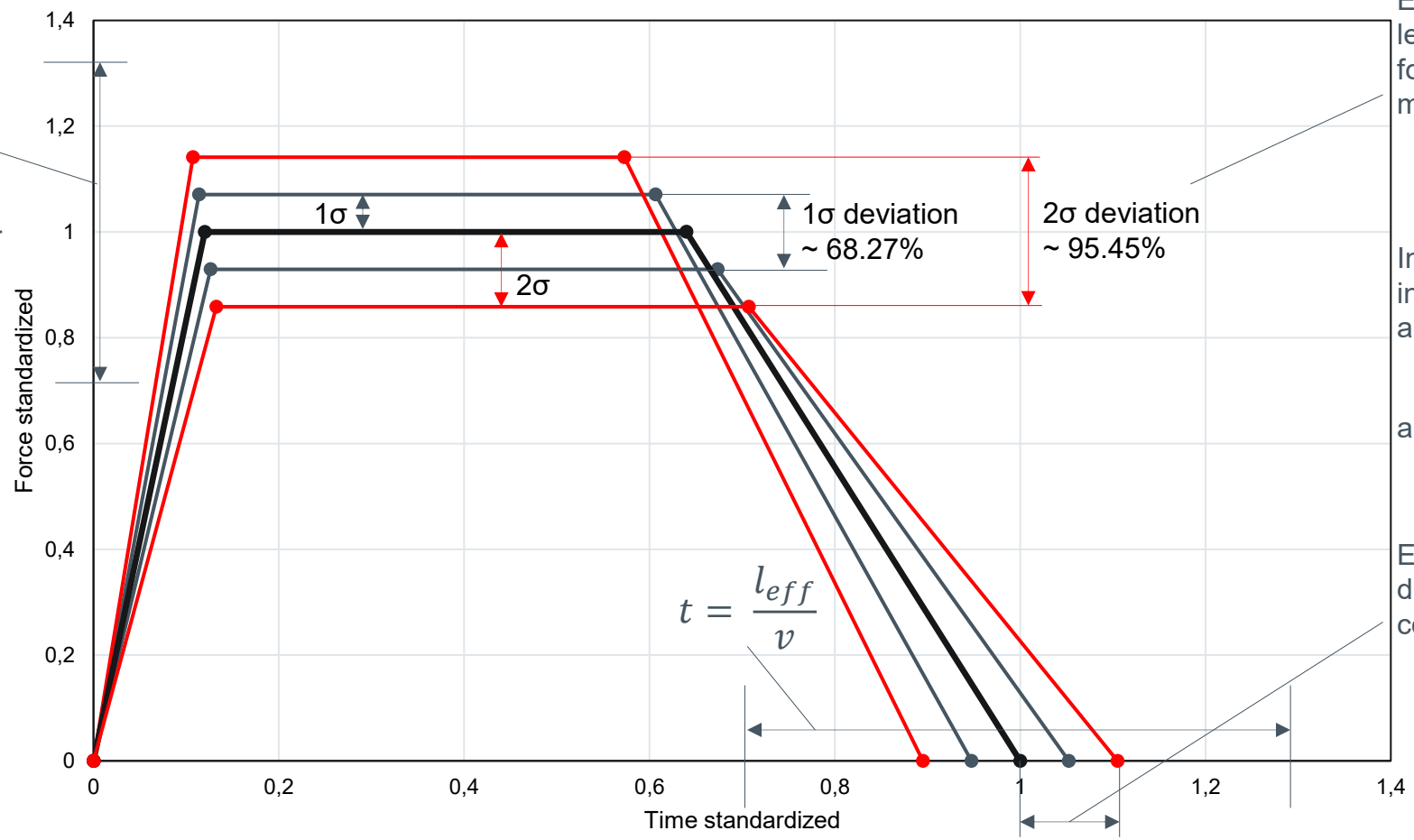


BIRDSTRIKE SIMULATION MODEL
LEVEL 1 VALIDATION

Dimensionless Force-Time-History

Error range in the force that would be additionally increased by deviations in the length

$$F = \frac{m \cdot v}{t} = \frac{m \cdot v^2}{l_{eff}}$$



Errors in velocity and mass lead to differences in the force derived from the momentum:

$$p = m \cdot v, \quad F = \frac{m \cdot v}{t}$$

In addition, a measurement inaccuracy of the tests of approx.:

$$v = 2\%$$

and

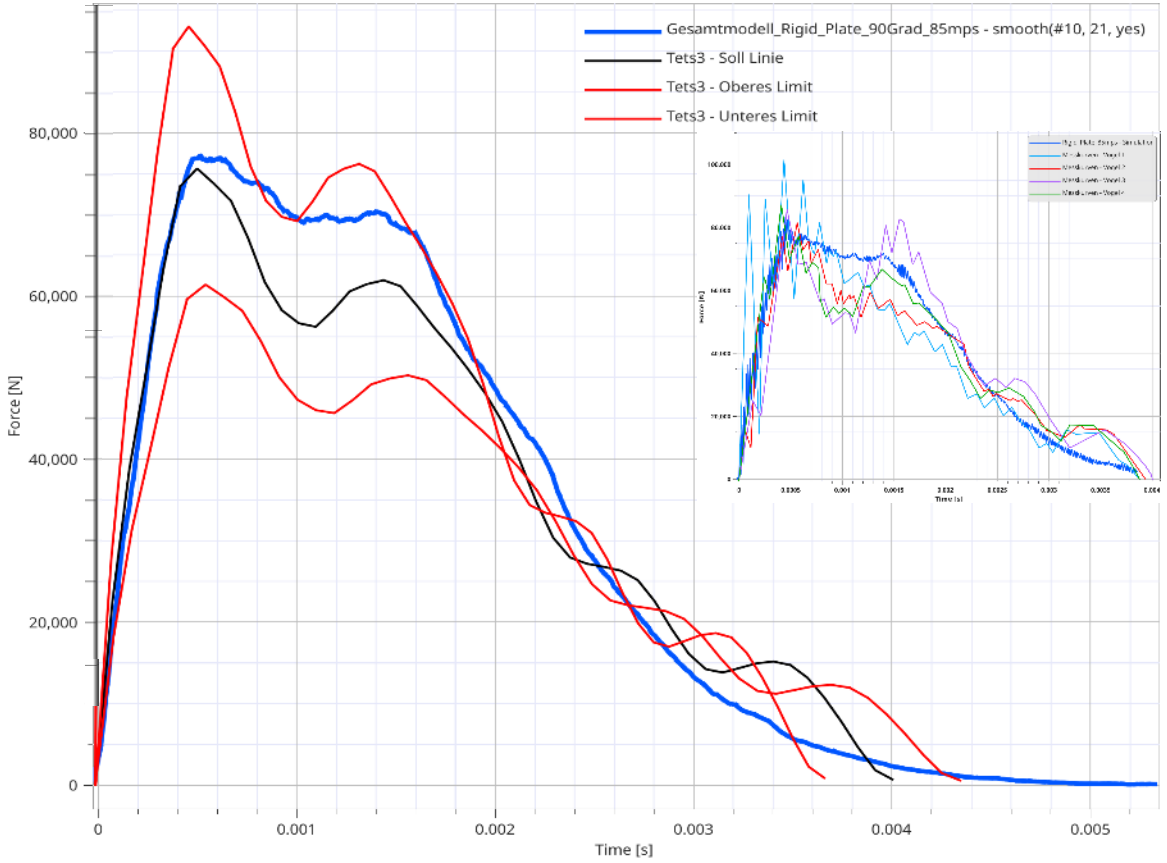
$$m = 1.8g$$

Error in speed leads to differences in time if a constant length is assumed

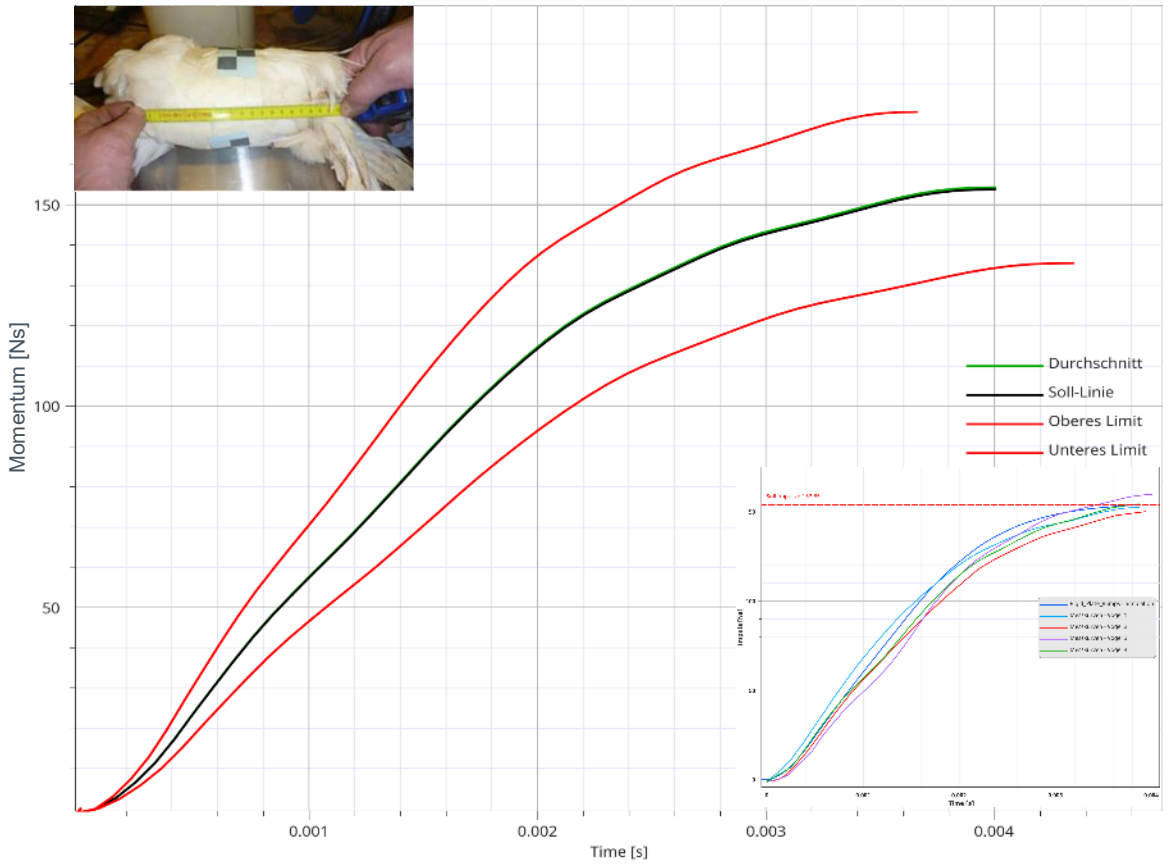
$$t = \frac{l_{const.}}{v}$$

BIRDSTRIKE SIMULATION MODEL
LEVEL 1 VALIDATION

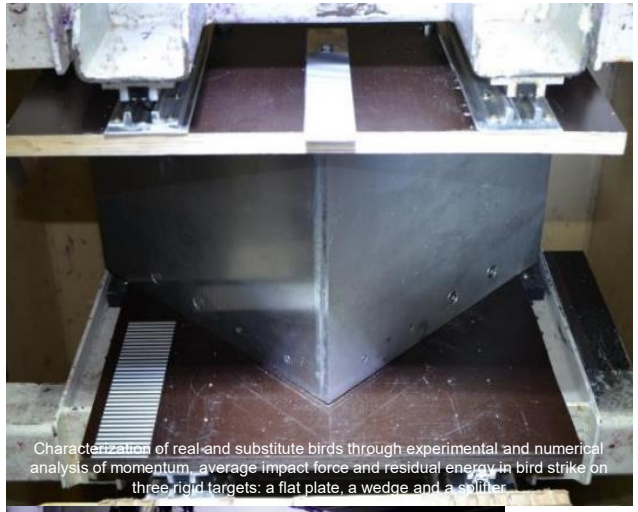
Force-Time Confidence Interval



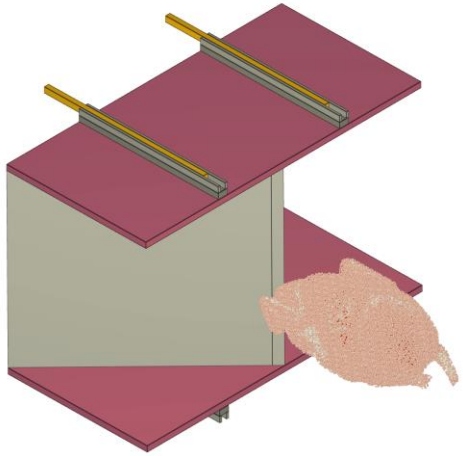
Momentum-Time Confidence Interval

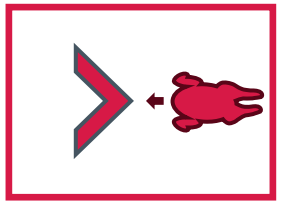


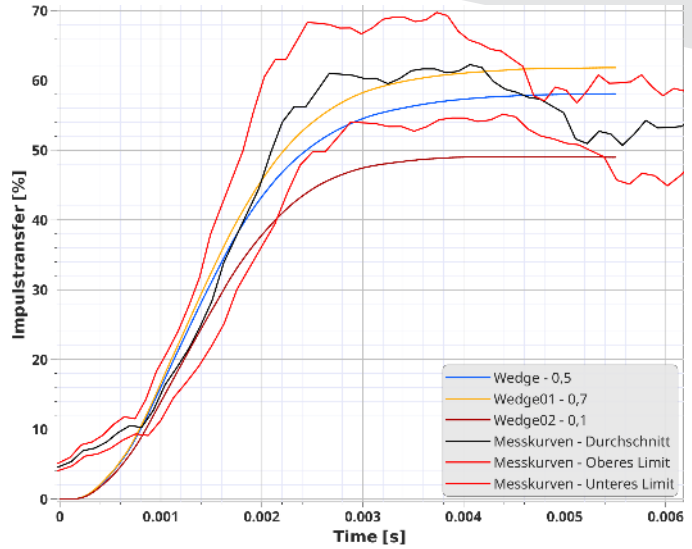
BIRDSTRIKE SIMULATION MODEL
LEVEL 1 VALIDATION

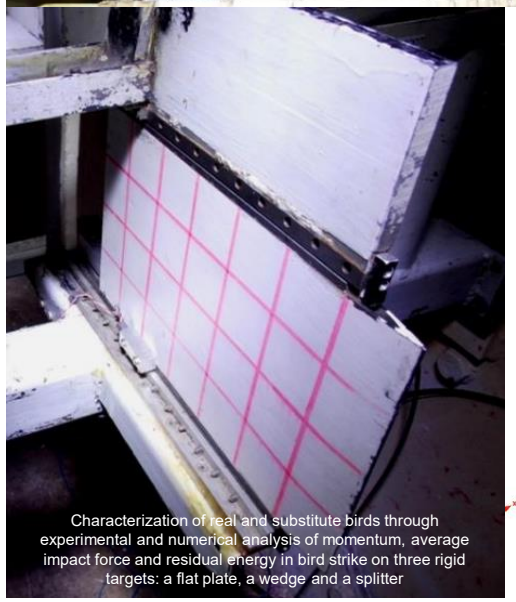


Characterization of real and substitute birds through experimental and numerical analysis of momentum, average impact force and residual energy in bird strike on three rigid targets: a flat plate, a wedge and a splitter

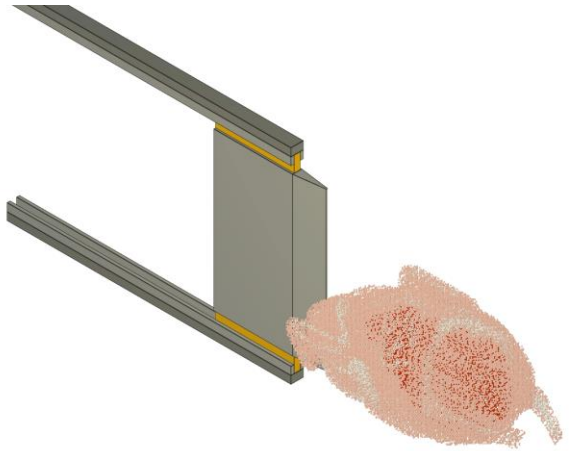


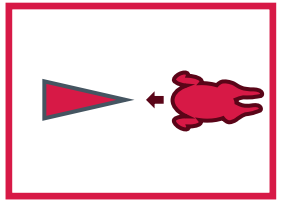


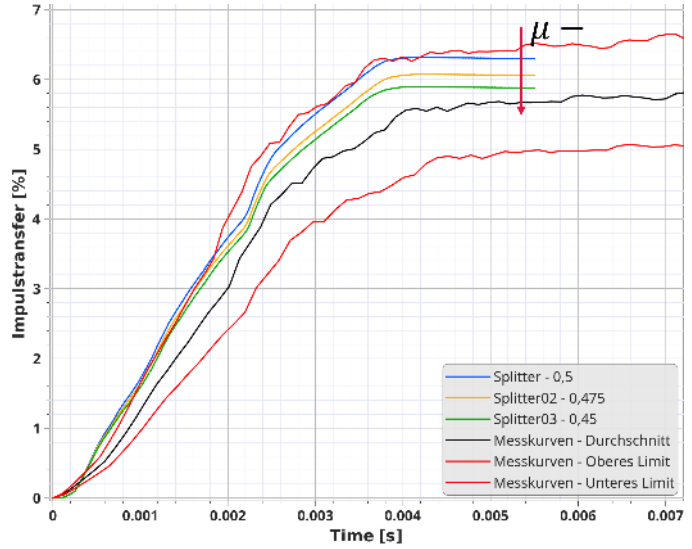




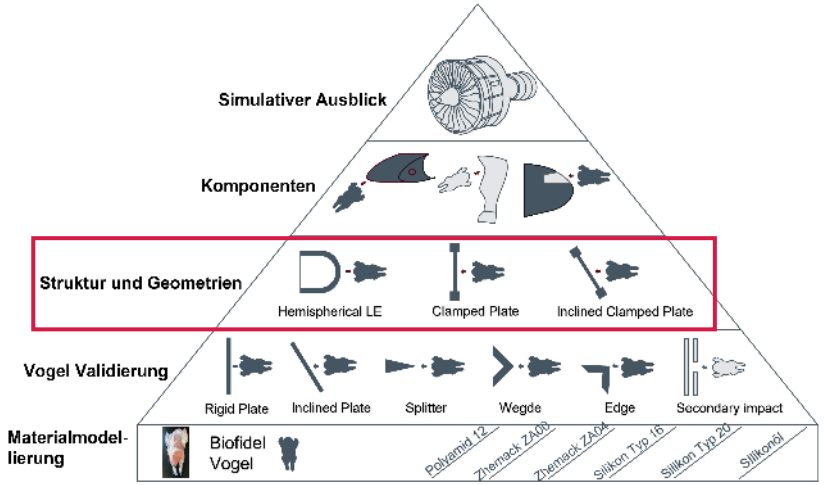
Characterization of real and substitute birds through experimental and numerical analysis of momentum, average impact force and residual energy in bird strike on three rigid targets: a flat plate, a wedge and a splitter





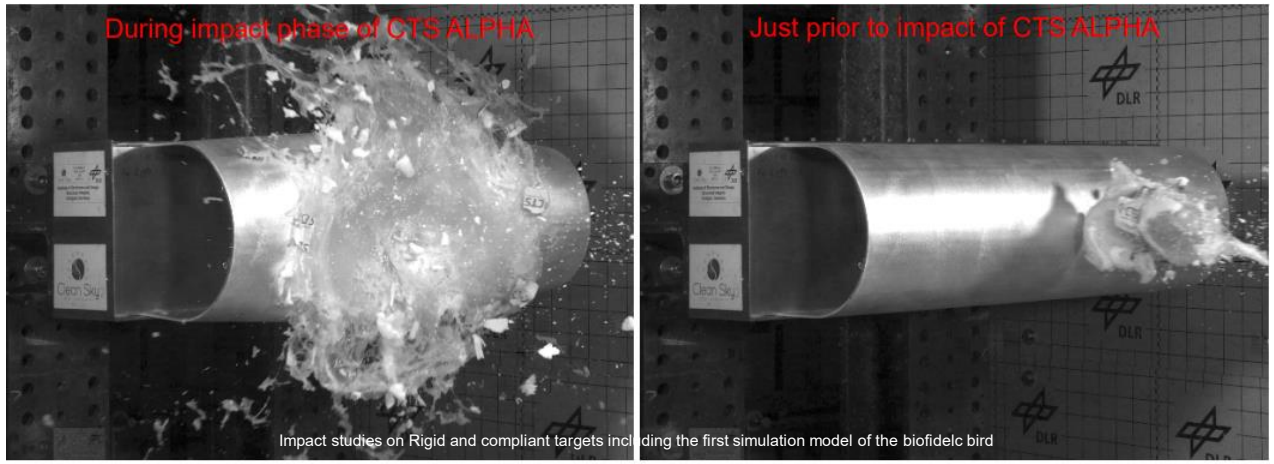


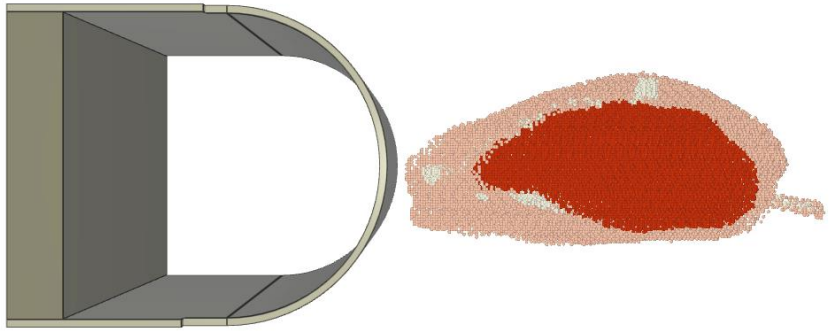
BIRDSTRIKE SIMULATION MODEL
LEVEL 2 VALIDATION

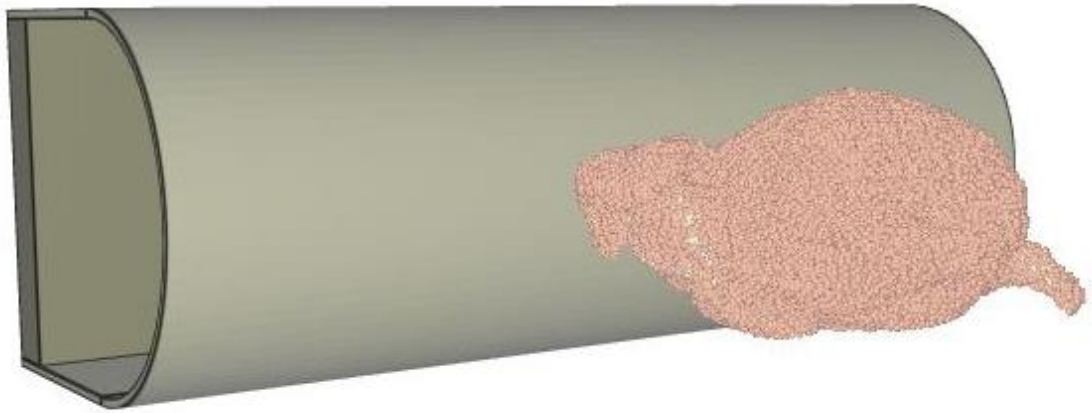


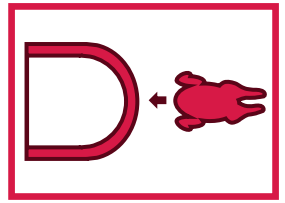
Hemispherical LE	Clamped Plate	Inclined Clamped Plate
	Configurations: Mono-plate Layered structure	**Configurations:** Mono-plate Double-plate Layered glass
Material: Al 2024T3	**Materials:** Al 2024 T3 C45E4 AlSi7Mg0,5 TC4	**Materials:** Al 2024 T3 Glass TPU&SG Composite TORAY PC Makrolon
Velocity: 110m/s	**Velocities:** 69m/s, 70m/s, 120m/s, 138m/s, 149m/s, 170m/s, 180m/s, 195m/s	**Velocity:** 110m/s, 130m/s, 150m/s, 155m/s
		Angles: 45°, 30°

BIRDSTRIKE SIMULATION MODEL
LEVEL 2 VALIDATION





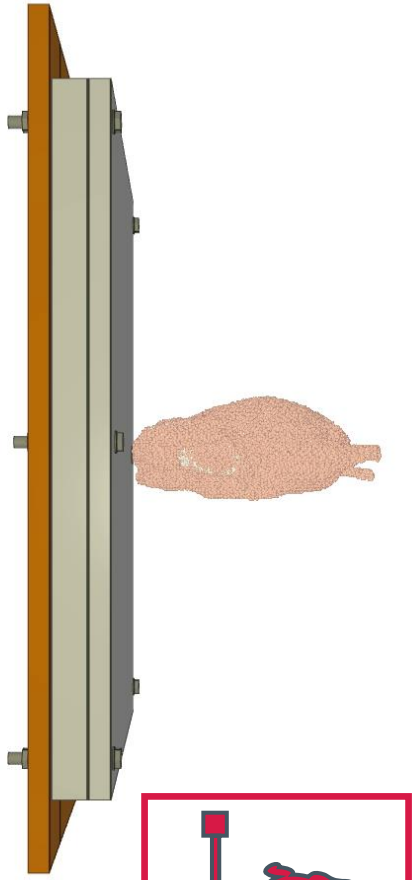


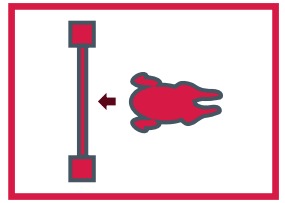


BIRDSTRIKE SIMULATION MODEL
LEVEL 2 VALIDATION

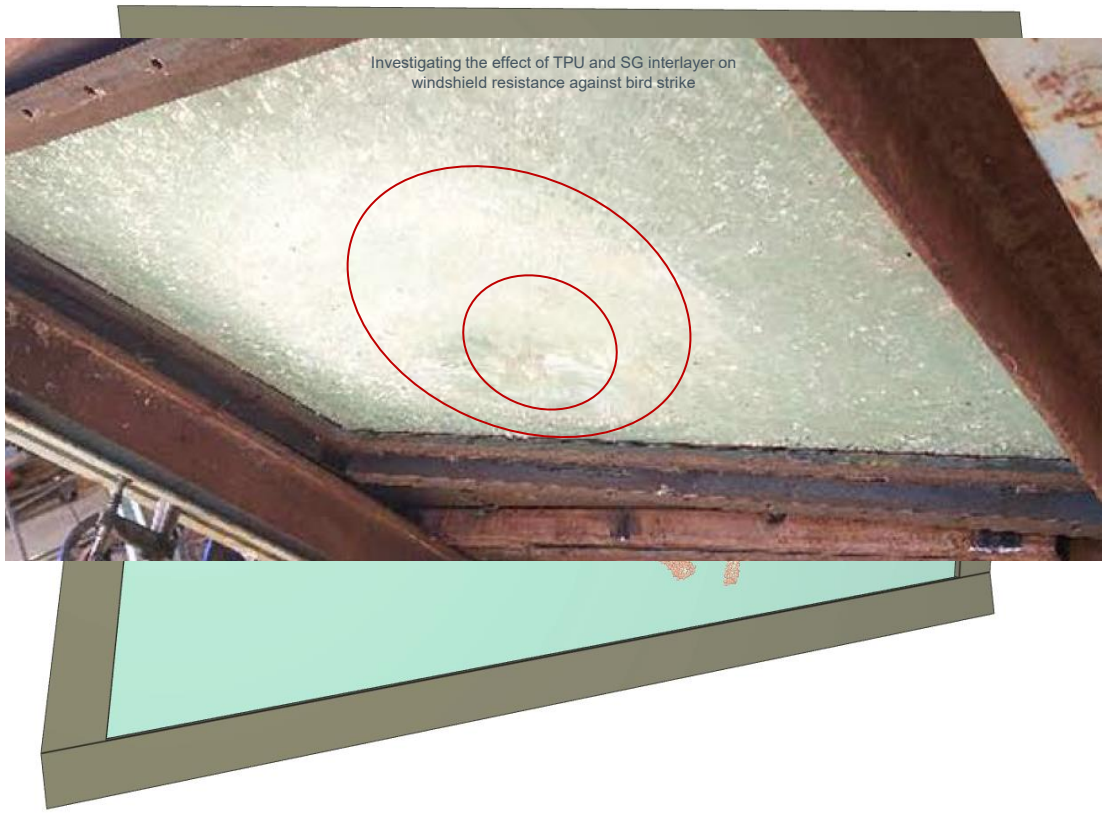
A numerical model for
bird strike of aluminium foam-based sandwich panels

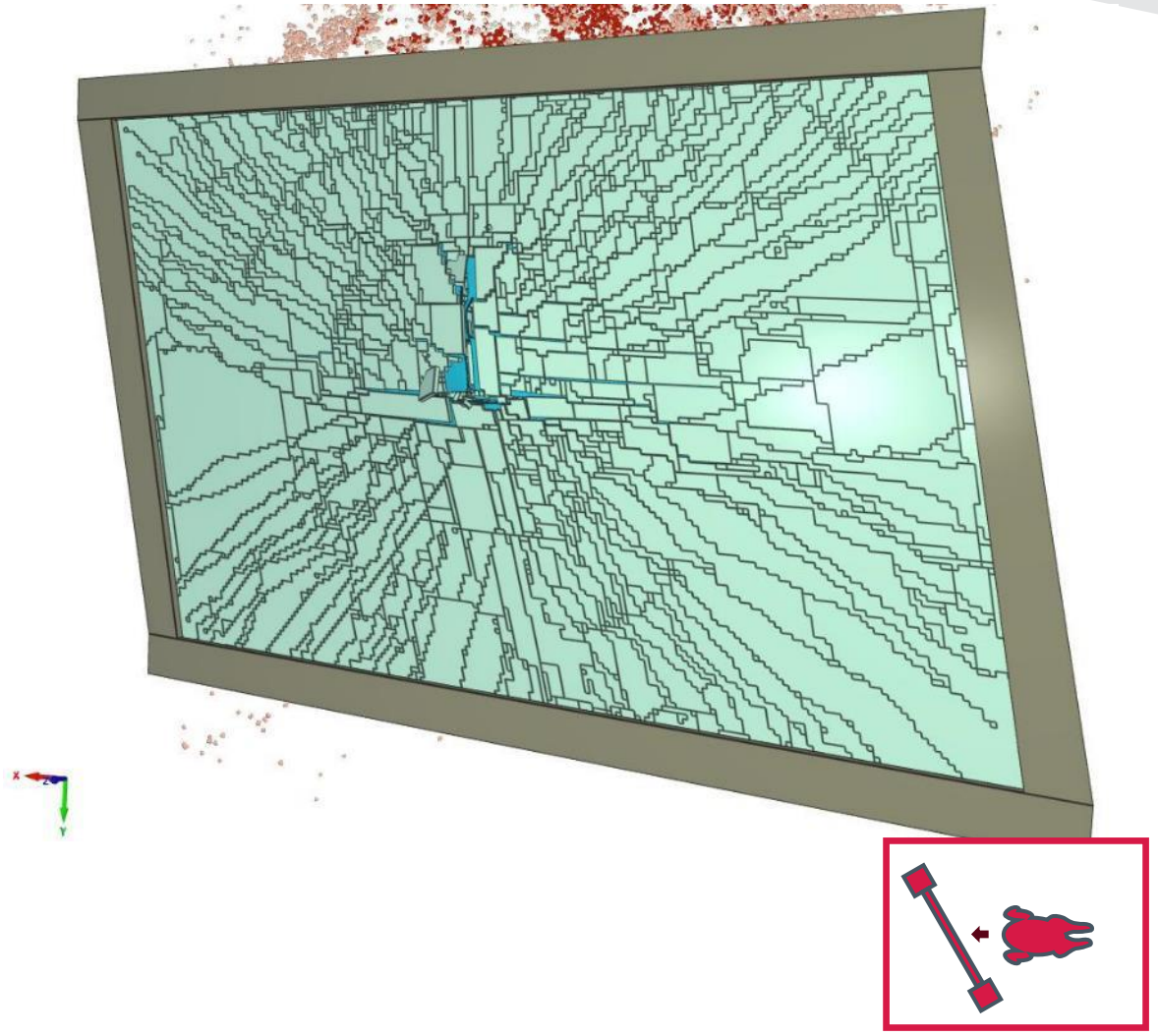
A numerical model for
bird strike of aluminium foam-based sandwich panels



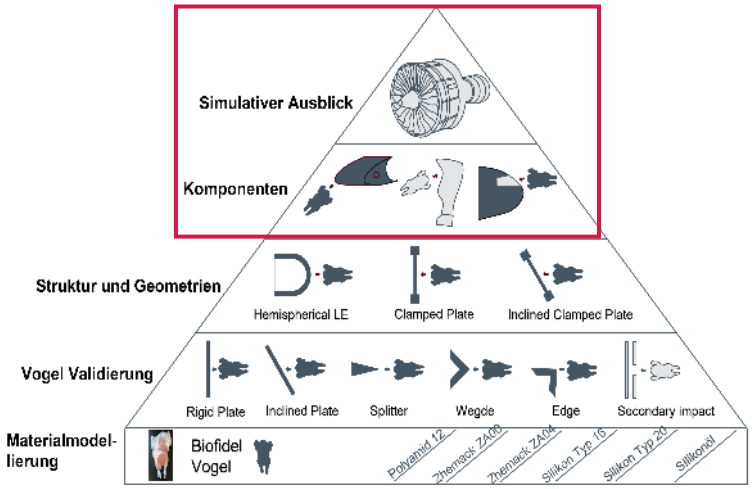


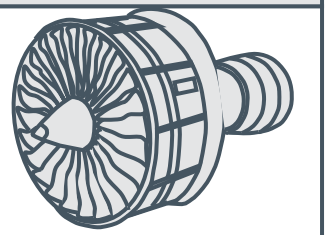
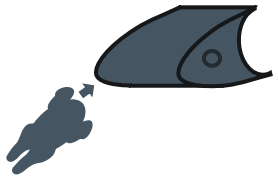
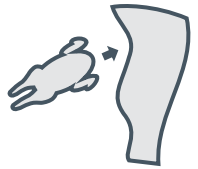
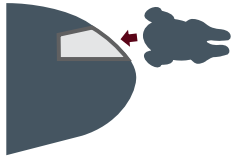
BIRDSTRIKE SIMULATION MODEL
LEVEL 2 VALIDATION





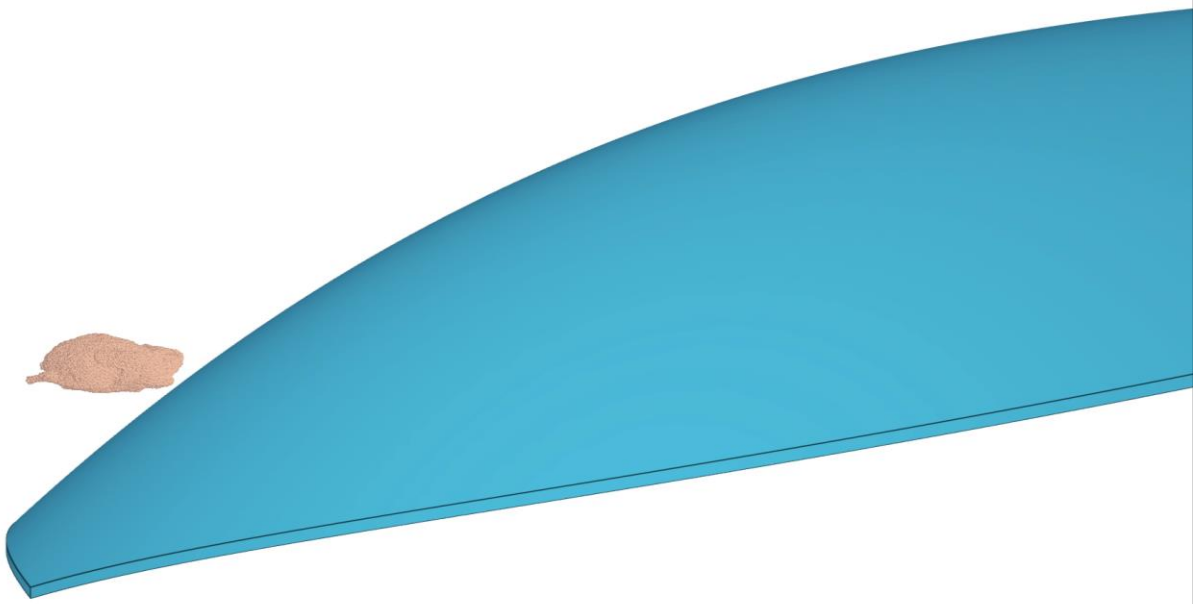
BIRDSTRIKE SIMULATION MODEL
LEVEL 3 VALIDATION AND FORECAST

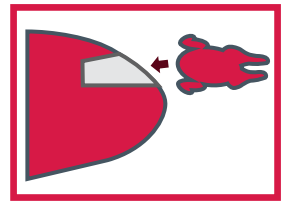


Configuration: Military Jet Engine EJ200	**Configurations:** Elevator of a Boeing 737 (Between and on rib structure)	**Configurations:** Fan Blade Compound of a Turbofan-Engine	**Configuration:** Cockpit L-39NG
			
Materials: Fully-Rigid	**Material:** Al 2024 T3	**Material:** Titan TC4	**Material:** Polycarbonate
Velocity: 250m/s	**Velocity:** 180m/s	**Velocity:** 110m/s	**Velocities:** 110m/s 130m/s 150m/s 155m/s
Engine-RPM: 20.000 1/min		**Engine-RPM:** 2.500 1/min	

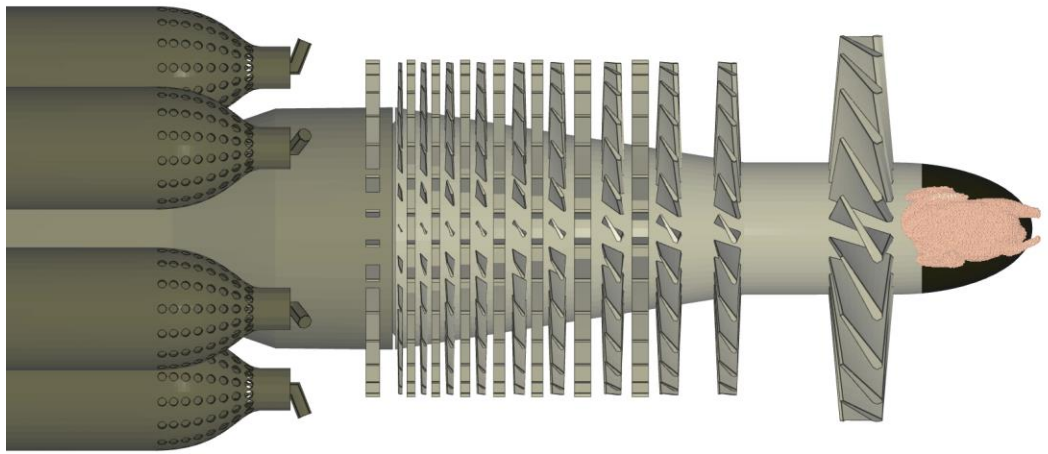
BIRDSTRIKE SIMULATION MODEL
LEVEL 3 VALIDATION AND FORECAST

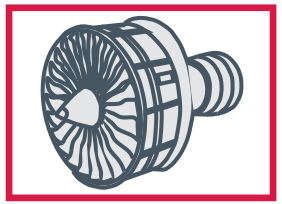
Cockpit L-39NG

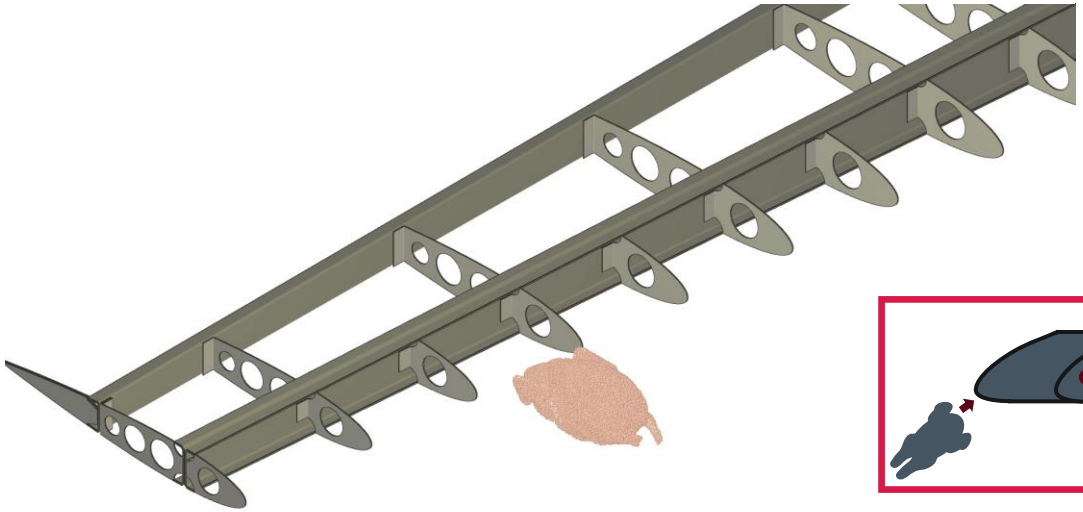




BIRDSTRIKE SIMULATION MODEL
LEVEL 3 VALIDATION AND FORECAST

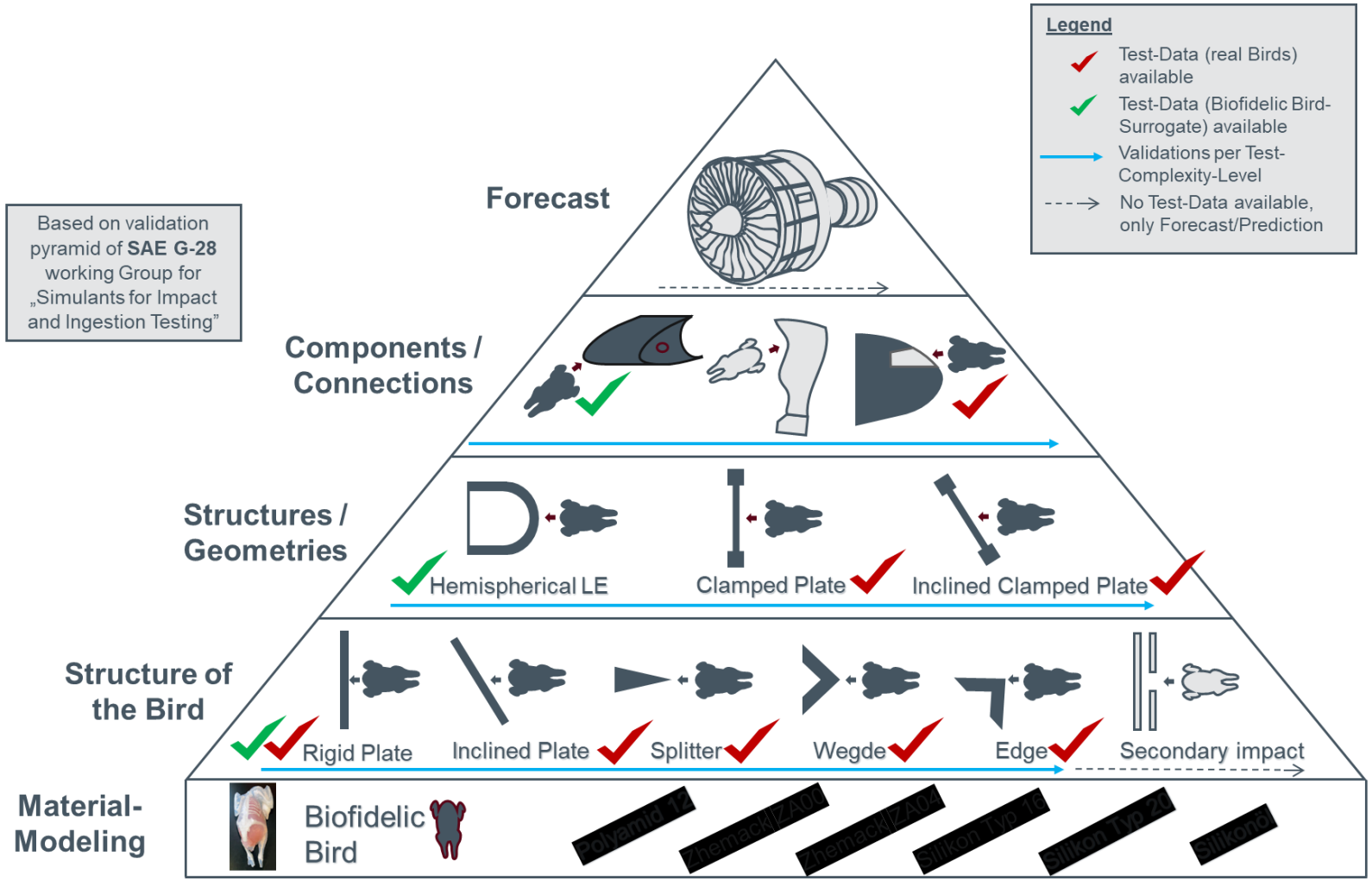


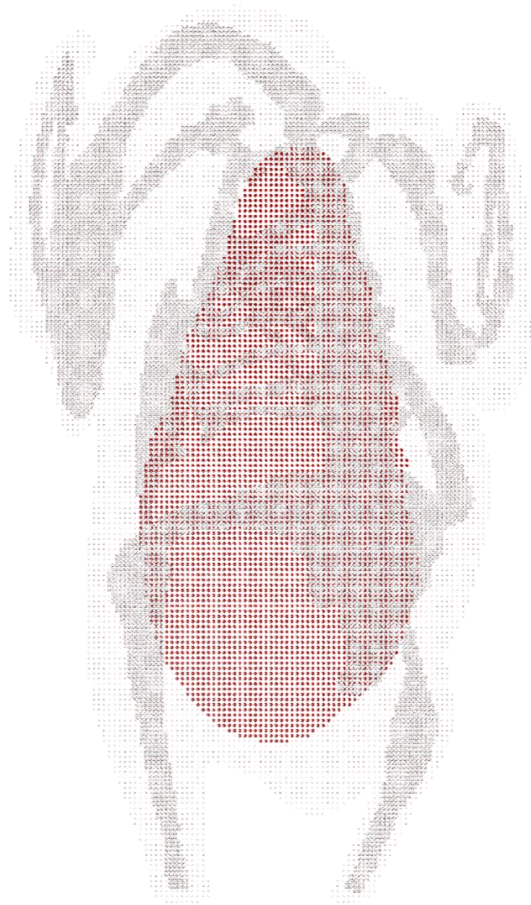




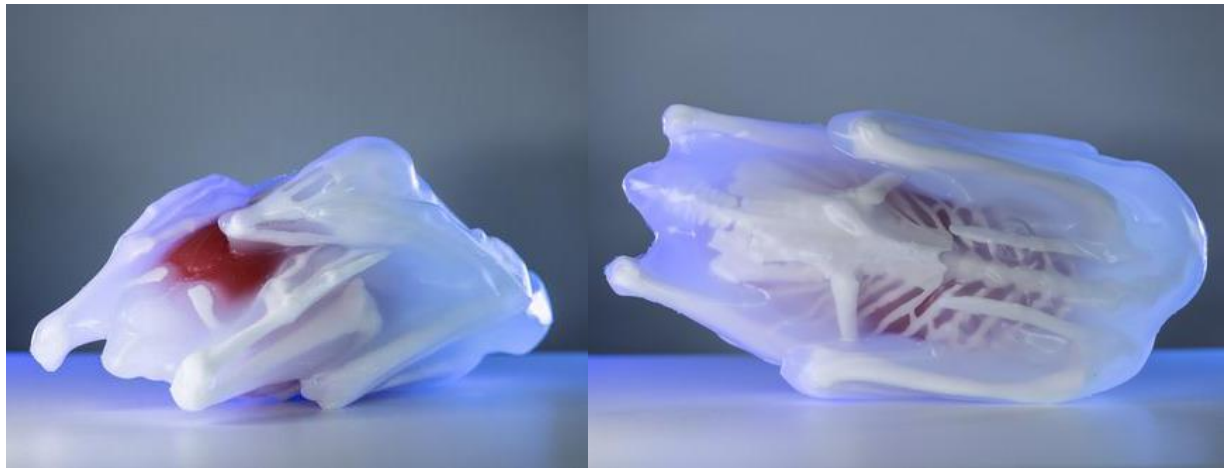
BIRDSTRIKE SIMULATION MODEL
VALIDATION

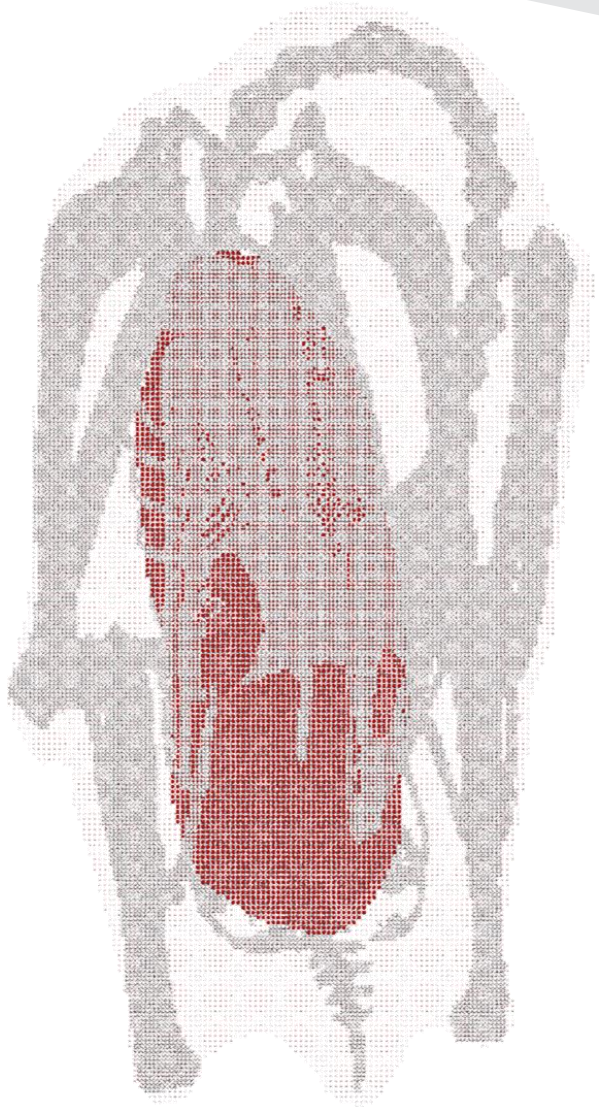
Based on validation pyramid of **SAE G-28** working Group for „Simulants for Impact and Ingestion Testing"





BIRDSTRIKE SIMULATION MODEL
ALPHA® BIRDSTRIKE-SURROGATE (GOOSE)

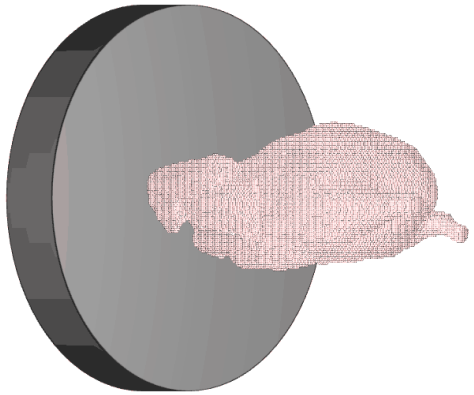


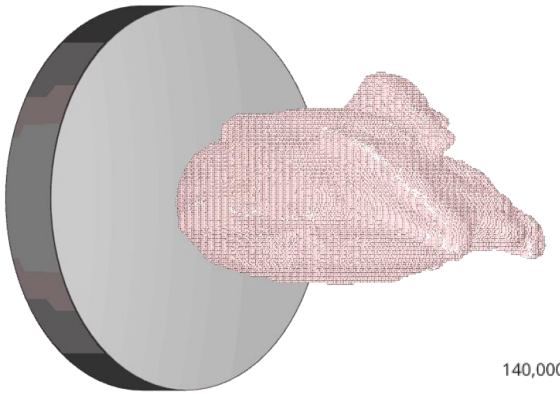


Alpha® Birdstrike-Surrogate (Goose)

- 3,6kg
- Based on CT-Scan of a prepared Goose
- Inner soft organs
- Skeleton structure (slightly simplified)
- Outer muscular tissue

BIRDSTRIKE SIMULATION MODEL
ALPHA® BIRDSTRIKE-SURROGATE (GOOSE)



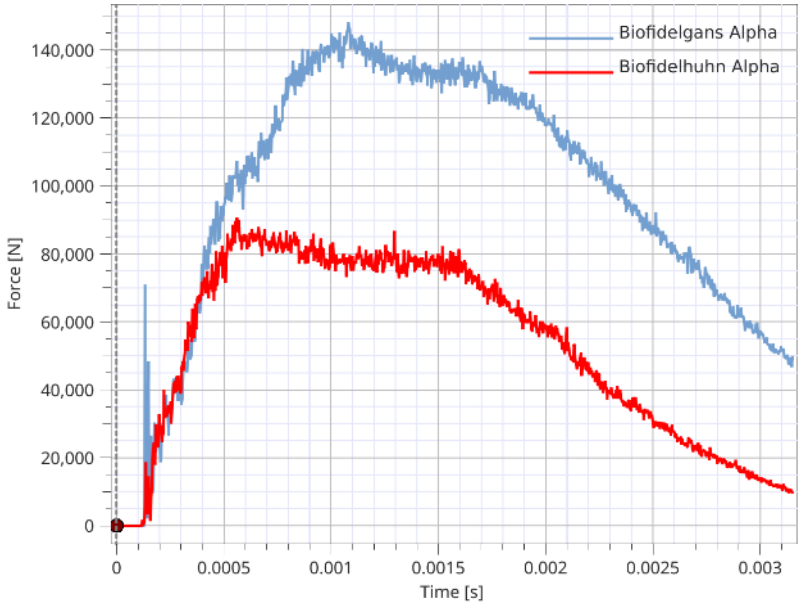


1,8kg

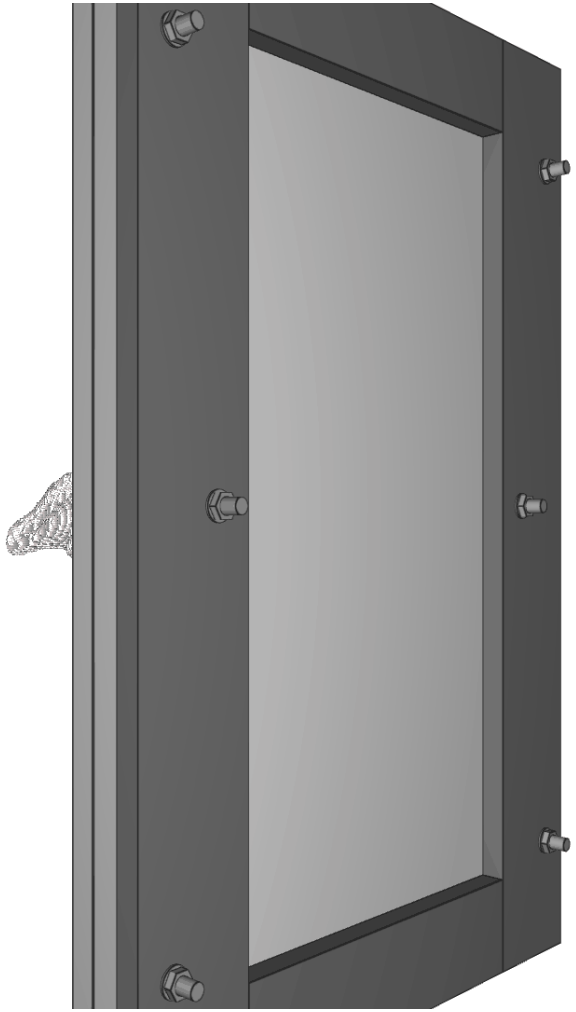
3,6kg

Alpha® Birdstrike-Surrogate (Chicken vs. Goose)

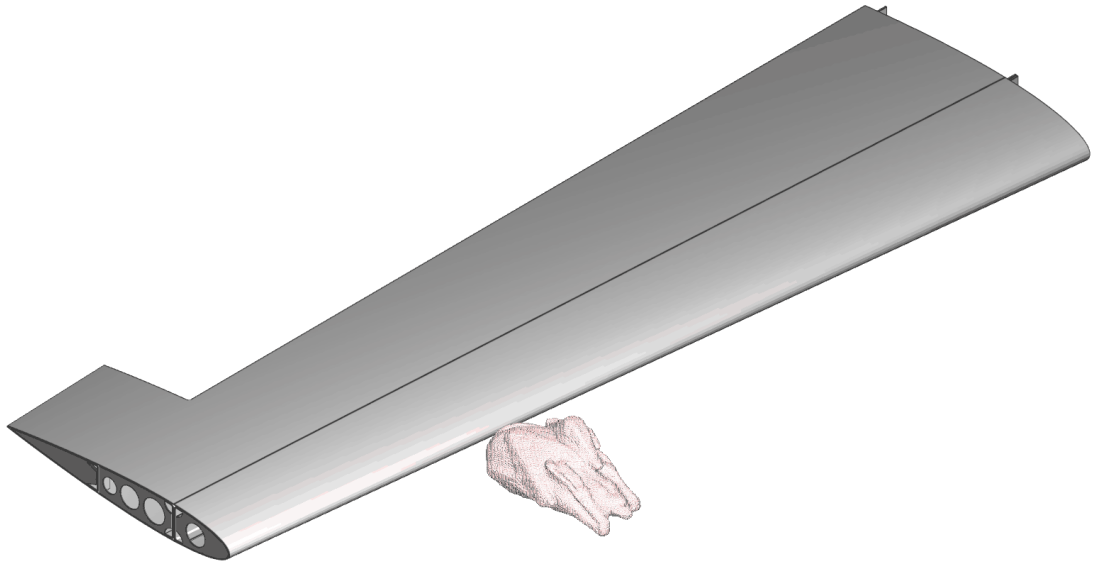
Same characteristics in Force-Time History

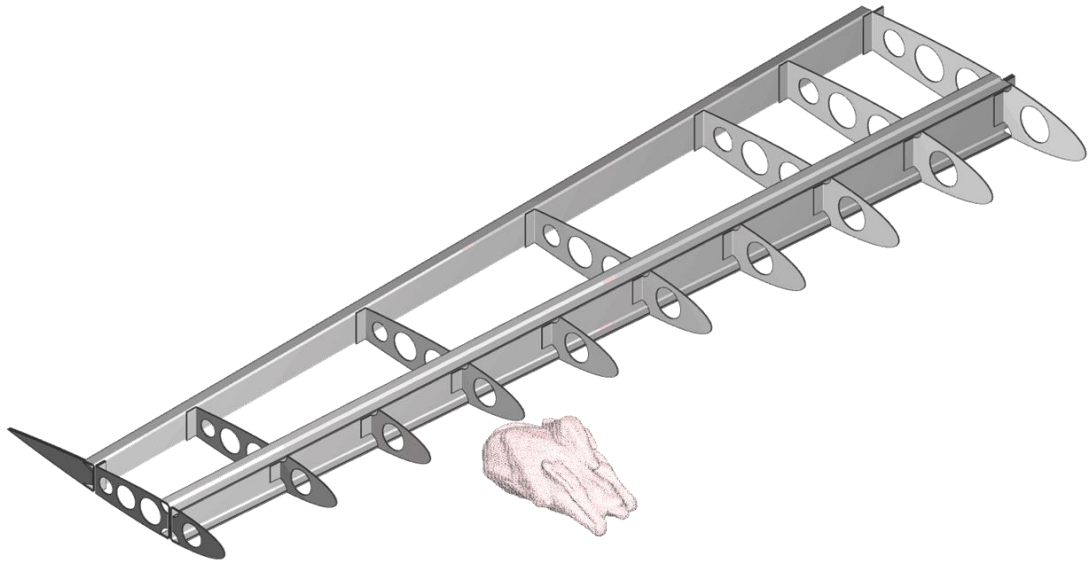


BIRDSTRIKE SIMULATION MODEL
ALPHA® BIRDSTRIKE-SURROGATE (GOOSE)



BIRDSTRIKE SIMULATION MODEL
ALPHA® BIRDSTRIKE-SURROGATE (GOOSE)





THANK YOU.

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Project Leader Defence
Blast & Ballistic Simulation