DIGITALIZATION OF DLR UNMANNED AERIAL SYSTEM PLATFORM “PROTEUS” FOR SIMULATION OF MORPHING AND FLIGHT MECHANICS

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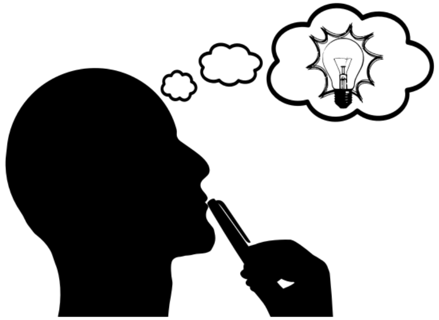
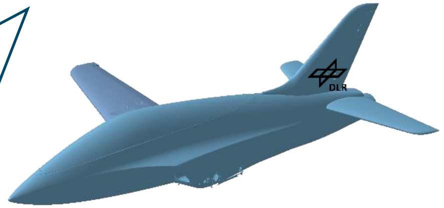
DLR

Outline

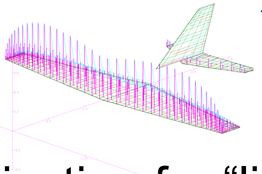


Motivation/Idea

Scalability with UAS



Digitalization of geometry



Digitalization for “live” calculation

Outlook

Motivation for wing shape adaption

- Adaption of wing „shape“ in different flight states
- Nearly everything what is imageable at aircraft wing was morphed:
  - Camber
  - Span
  - Sweep
  - Twist
  - Oblique
  - …
- Unique benefit, but is a comparison within one category is challenging
- Since 2000s more unmanned systems are tested

Barbarino S, Bilgen O, Ajaj RM, Friswell MI, Inman DJ. A Review of Morphing Aircraft. *Journal of Intelligent Material Systems and Structures*. 2011;22(9):823-877. doi:10.1177/1045389X11414084

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  - A320 Model (Clean Sky 2 by ONERA, NLR, CIRA)

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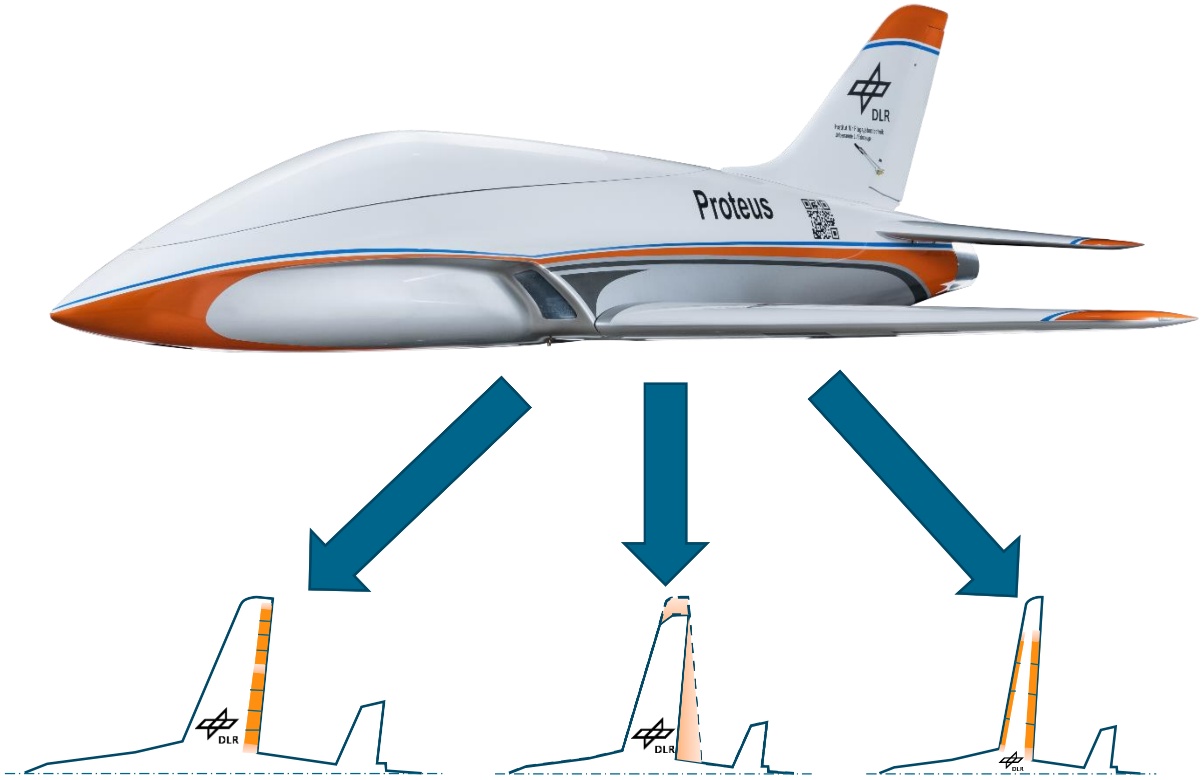
- Still expensive models due to scaled model

Proteus as scaled flight testing platform

- Commercially available model aircraft
  - MTOW 25 kg (later up to 70kg)
  - Span of 2.5 m
  - V_{max} 300 km/h
  - Material: GFRP
- Experimental investigation also for high risk technology possible due to low cost model
- Knowledge of model is vital for scaled flight tests



What make sense to scale with Proteus?

Class	Name	MTOW	Example
A	Airplane	> 20 000 kg	Boeing 737, Airbus A320, Embraer E190, Fokker 70, Dash 8Q-400
B	Airplane	14 000 kg – 20 000 kg	Bombardier DHC-8-300, ATR 42
C	Airplane	5 700 kg – 14 000 kg	Learjet 45, Beech King Air 350
E	Single-engine airplane	≤ 2 000 kg	Cessna C172, Piper PA-28
F	Single-engine airplane	2 000 kg – 5 700 kg	Pilatus PC12, Antonov AN-2, Cessna C208
G	Multi-engine airplane	≤ 2 000 kg	Piper PA-34, Diamond DA-42
H	Rotorcraft		EC 135, EC 145
I	Multi-engine airplane	2 000 kg – 5 700 kg	Beechcraft King Air 200, Piper PA-42, Beech Baron 58
K	Motor glider		Grob G 109, Scheibe Falke
L	Airships		Zeppelin NT
M	Ultra-light airplane	< 600kg	FK 9, Ikarus C42, Shark Aero UL
N	Ultra-light glider		ProFe Banjo, Windward Performance SparrowHawk
O	Hot air balloon		GEFA-Flug AS 105 GD
P	Unmanned Aircrafts		DJI Mavic Air, Yuneec Typhoon H3
D-1234	Gliders		LS4, K 8, ASK 13, ASK 21, Discus

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similar planform

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Equal certification specification

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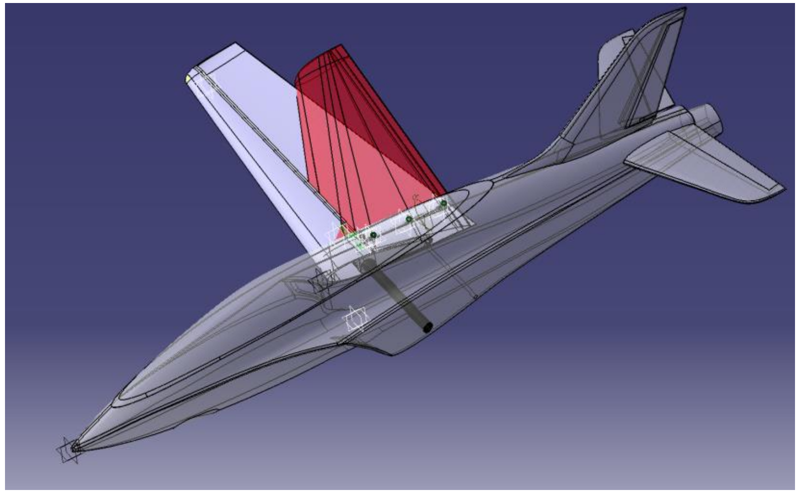
Possible aircraft classes for scalability

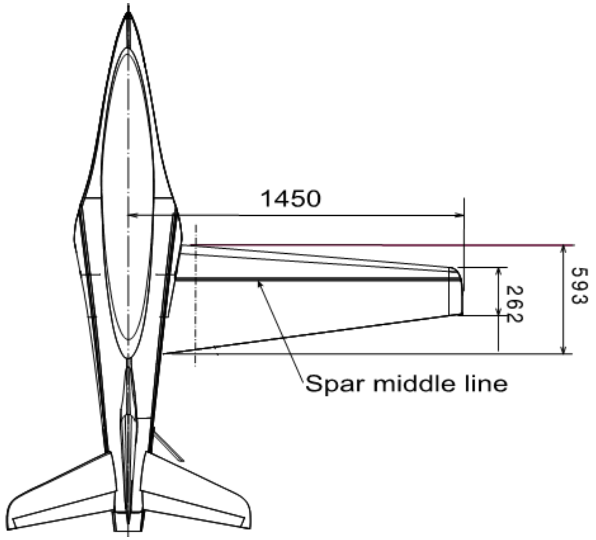
Class	Example	MTOW [kg]	Wing area [m²]	Span [m]	Rectangular wing	Trapezoid wing	Sweep	Velocity [km/h]
A	Boeing 737, Airbus A320, Embraer E190, Fokker 70	> 20 000 78 000 (A320)	> 28 121 (A320)	> 29 36 (A320)	-	X	X	Transonic
B	ATR 42	14 000 –20 000	54.5	24.57	-	X	-	560
C	Learjet 45	5 700 –14 000	29	14.57	-	X	X	860
E	Cessna C172, Beechcraft G58	≤ 2 000	13.1 – 16.2	10.92 – 16.8	X	X	-	~300 – 400
F	BNG Defender 2T-4s	2 000 – 5 700	32.61	16.15	X	-	-	
M	AL3C-100 EuropaXS	< 600	16.6 9.5 – 14	10.82 8 – 14.4	X	-	-	~300
D-1234	Antares E 23	290-680	9 – 12	15 – 23	X	X	-	320

- Aerodynamic effects for aircrafts with MTOW <5.7 t are properly scalable
- Focus with Proteus in first step on classes E, F, M und D-1234 with same wing loading
- Scalability to categories to A, B, C is more complex (e.g. transonic effects) and cannot properly investigated with UAS

Wing planform of Proteus

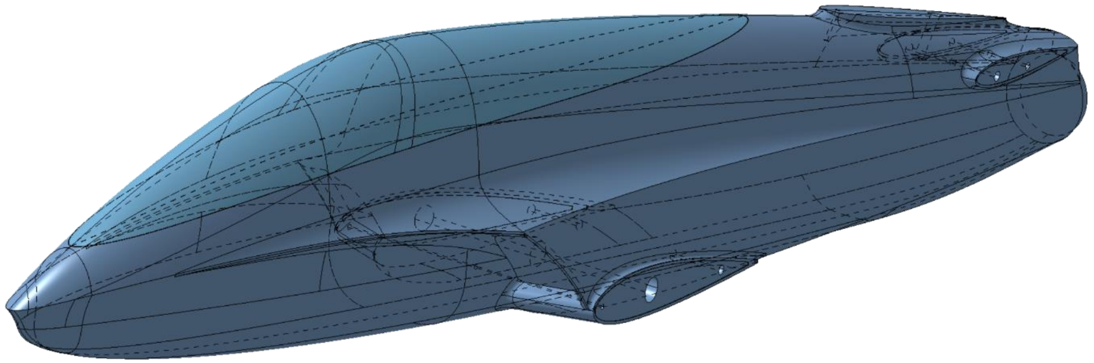
- Model aircraft is designed for aerobatics (red shape)
- Initial span of 2.5 m does not fit for loading by ~60 kg / m² per wing
- Reduce sweep and extend span for general aviation aircrafts
- Heavier fuselage required (70kg)
- Digitalization only of fuselage and empennage required for simulation





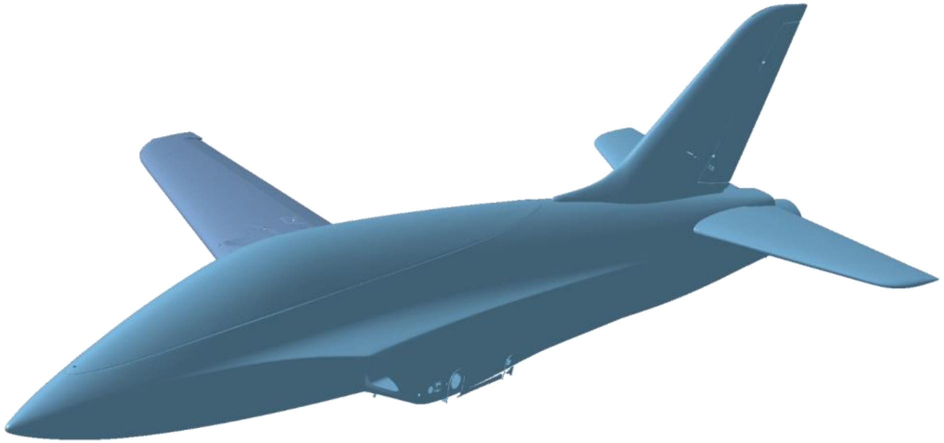
Geometrical digitalization of fuselage

- Manufacture provide CAD model fuselage
- High divergence of shape between model and reality (e.g. compare nose)
- Manufacture update only the molds
- Decision for new surface scanning in order to get proper data



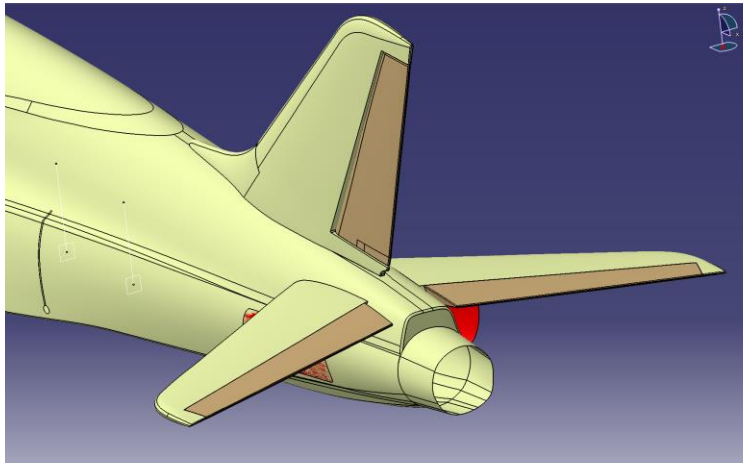
Surface scan

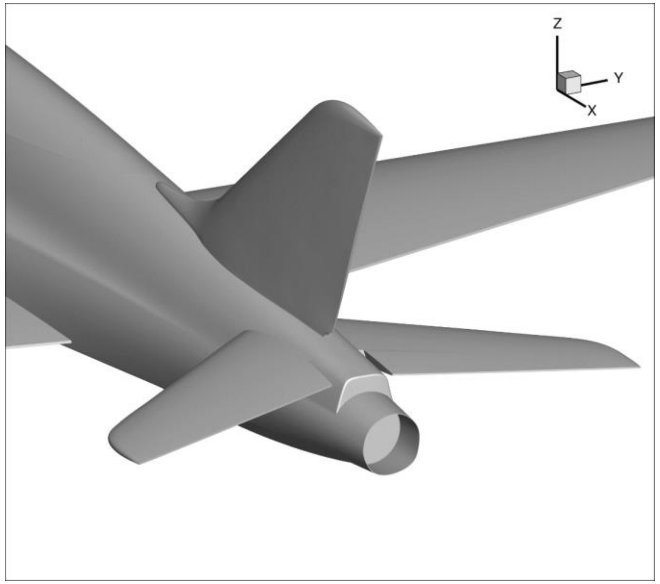
- Surface measurement with stereolithographic camera system
- Complete scan of fuselage incl. tail
- Measurement points needs to be re-worked to surfaces for proper mesh generation



Re-modelling of tail

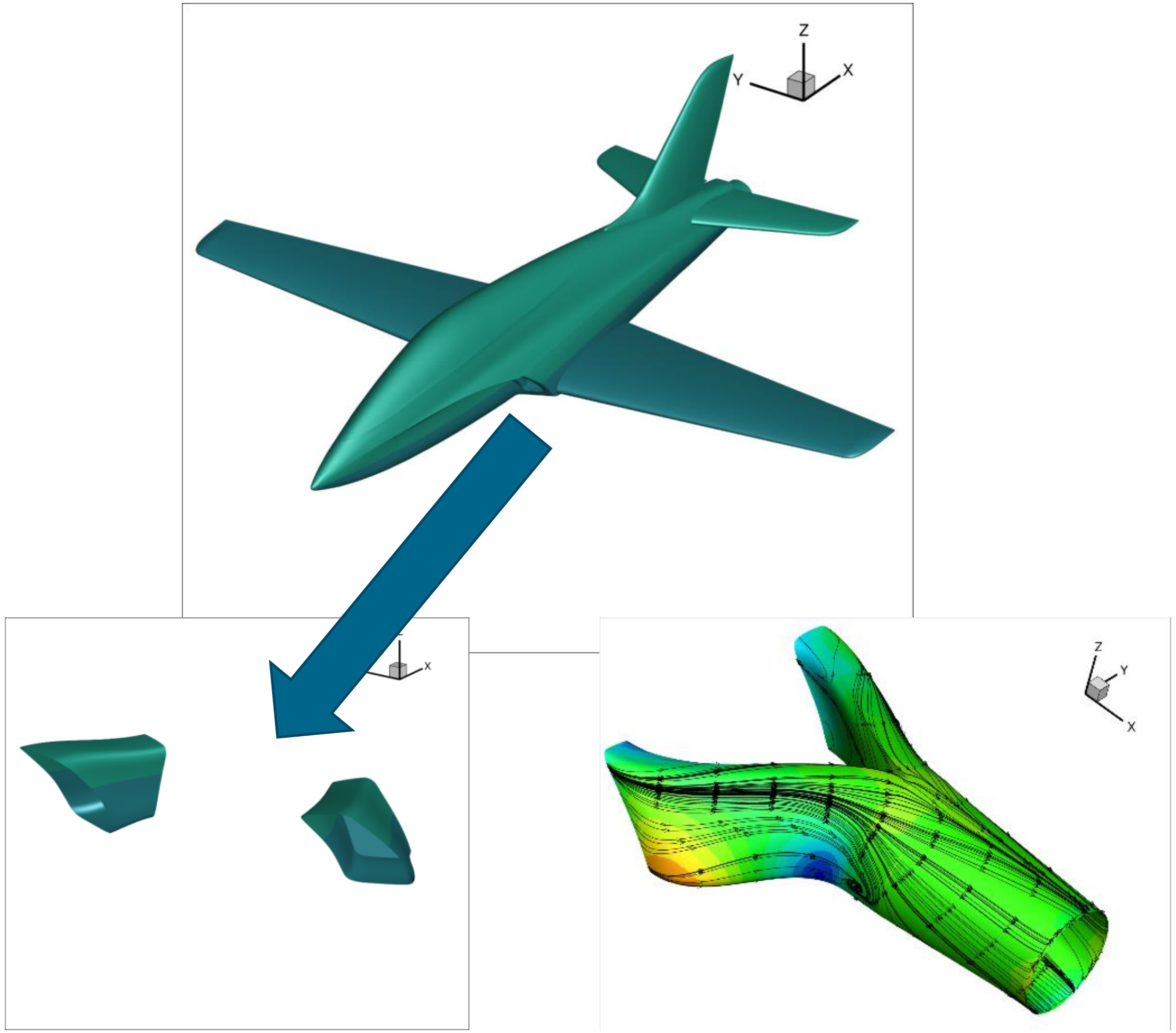
- Discrete surfaces on horizontal and vertical stabilizer
- Simplification to reduce mesh elements for aerodynamic simulation
- Introduce sharp edges at trailing edges to have fast converging results (flow separation at edges)
- Divergence to real model expected, but tail is not changed



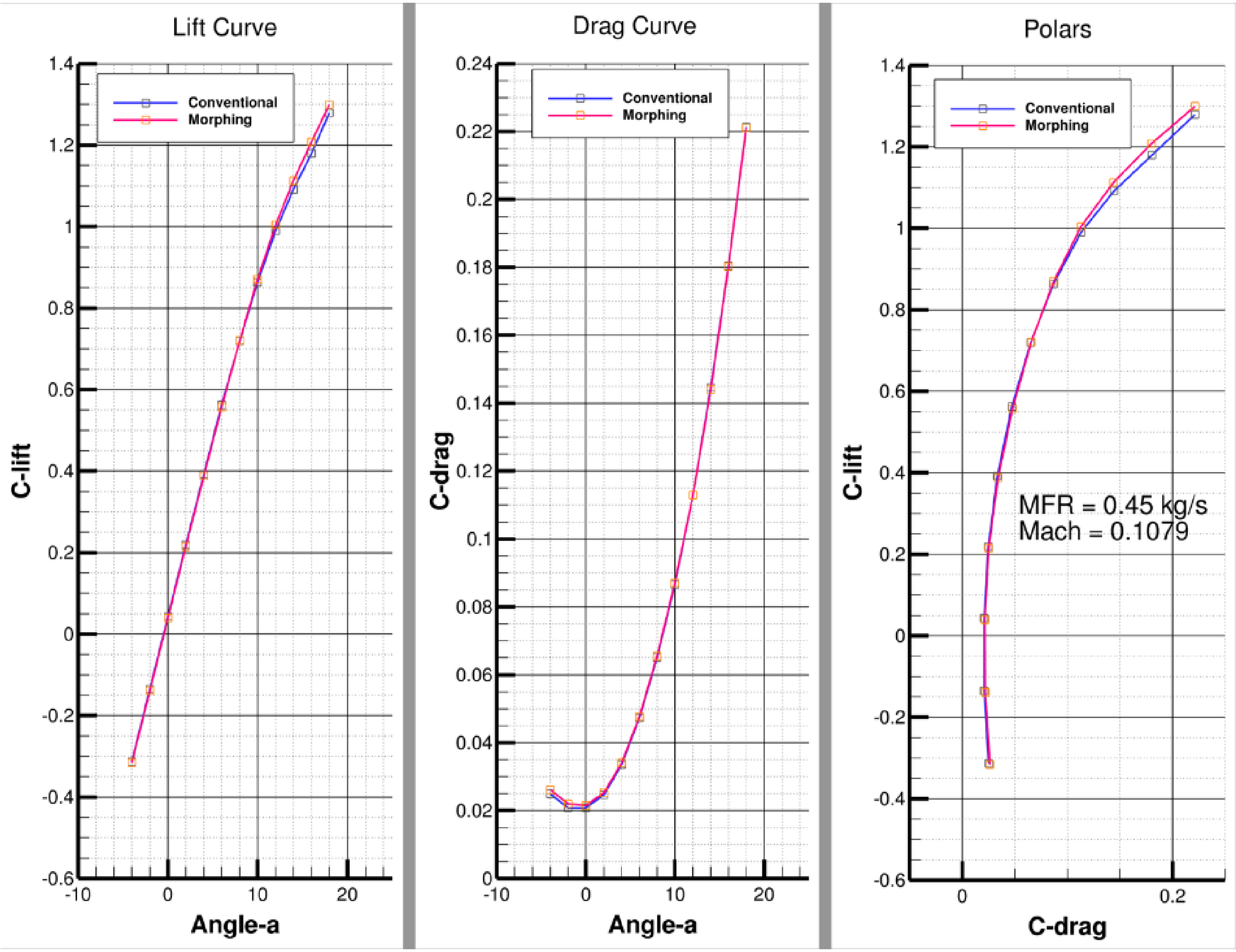


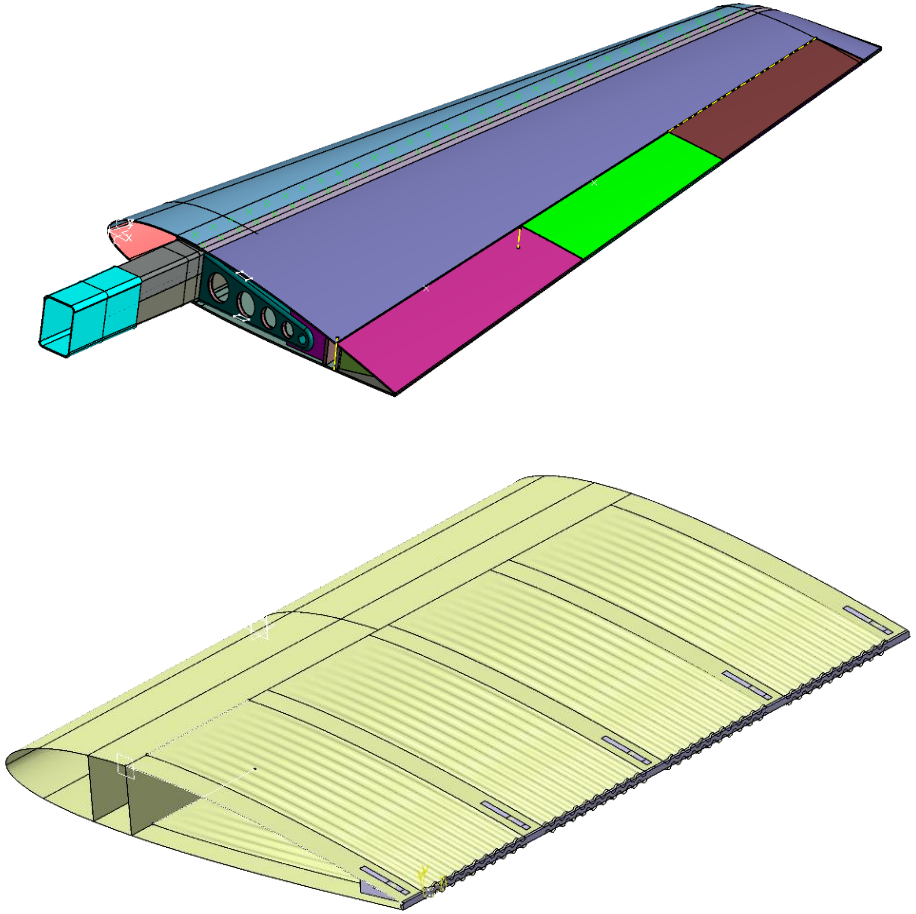
Issues with air intake

- Smaller intakes compared to real aircraft
- Numerical difficulties due to the flow separation occurring too downstream within the inlet channel
- Channel is originally quite short
- Channel extension for inlets inside the UAS
- Validation of flow characteristics at intakes need to be done



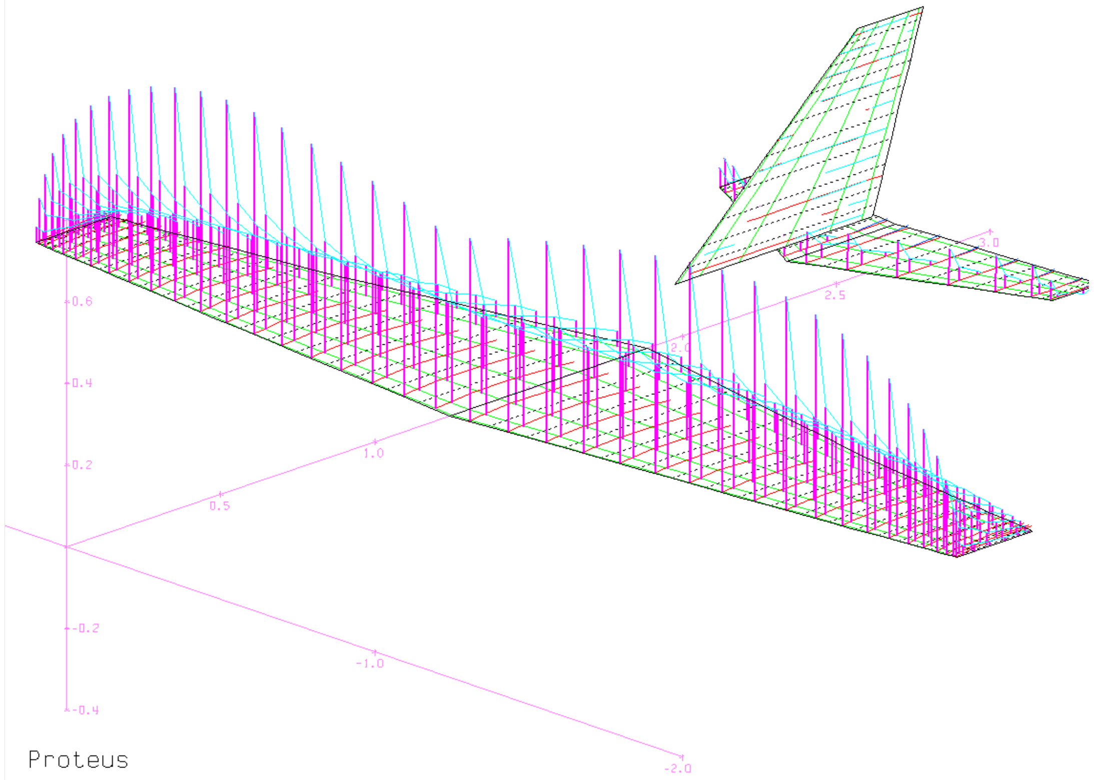
Comparison of Proteus in cruise condition with morphing and conventional wing





Digitalization of fuselage for live aerodynamic calculation

- Wing will be equipped with trailing edge morphing concept with 10 actuators per wing
- Concept will be used in combination with reinforced learning controller
- “Live” (low-fidelity) calculation of aerodynamic forces & moments in combination of UAS moments of inertia



Moments of inertia for fuselage

- Determination of moments of inertia around pitch, yaw and roll axis
- Simple approach to calculate moments out of oscillating behavior
- Round table is equipped with springs
- Tracking of equipment mass and position for overall moments of inertia

Conclusion and outlook

- Proteus UAS could be a proper scaling platform for general aviation aircrafts as well as estimation of novel systems on fuel efficency
- Geometrical digitalization of UAS depends on details (e.g. intakes, tail)
- Live (low-fidelity) calculation for flight control system required and determined
- Flight test in 2025 with morphing system and reinforced learning algorithm

Thank you for your attention.