DEVELOPMENT OF A SHORT & MEDIUM RANGE AIRCRAFT CONFIGURATION FOR AEROELASTIC INVESTIGATIONS USING CPACS-MONA

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DLR

Motivation 1/3

Expectations for a next transport aircraft configuration

- Aerodynamics: High aspect ratio wing
- Structures: High structural flexibility
- Material: Carbon fiber and metal material
- Propulsion: SAFs, LH2 technology, …
- Size: 200PAX plus (up to 250PAX single class) for short and mid range → Sales figures show that Airbus A321 overtakes Airbus A320 in the meantime (Airbus A321the “middle” of the family?)

Motivation 2/3

Scale of the design step for a next aircraft configuration

- Revolutionary step versus evolutionary step
- History shows mainly evolutionary steps regarding the principle design (e.g. Airbus A330 → Airbus A350, family development of Airbus A320, Boeing 737, Boeing 777)
- Nine years development time of Airbus A350 (announcement in 2004, maiden flight in 2013)
- A new aircraft to be built in high quantities should smoothly fit into current environment (airport, operational aspects, maintenance)

Motivation 3/3

Application of a new aircraft configuration for aeroelastic analysis

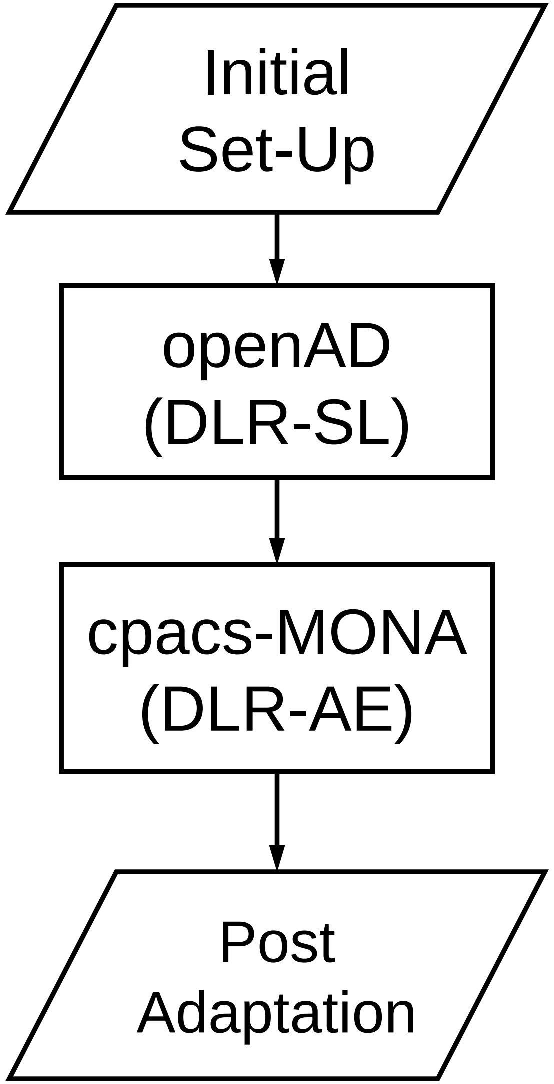
- Expected higher flexibility due to better utilization of the material impacts the field of aeroelasticity (loads, flutter, control surface efficiency)
- Development of controller to avoid flutter within the aeroelastic stability envelope
- Provision of an aircraft configuration including structural and aerodynamic models project WISDOM*

WISDOM, LuFo VI-2 project, 2022-2025: Demonstration of flutter controller on a mechatronic rig for a potential next transport aircraft configuration with high aspect ratio wing and high structural flexibility (project partner DLR, Liebherr Aerospace, Diehl Aerospace, FFT Produktionssysteme und TU-Berlin)

Overview

- Derivation of a new aircraft configuration based on the motivation
- Principal design process
- Analytical equations and statistics based conceptual design synthesis
- Parametric aeroelastic design process (loads analysis / structural design)
- Start configuration
- Results
- Summary and outlook

Design Process



- First guess, further development of an initial conceptual design approach

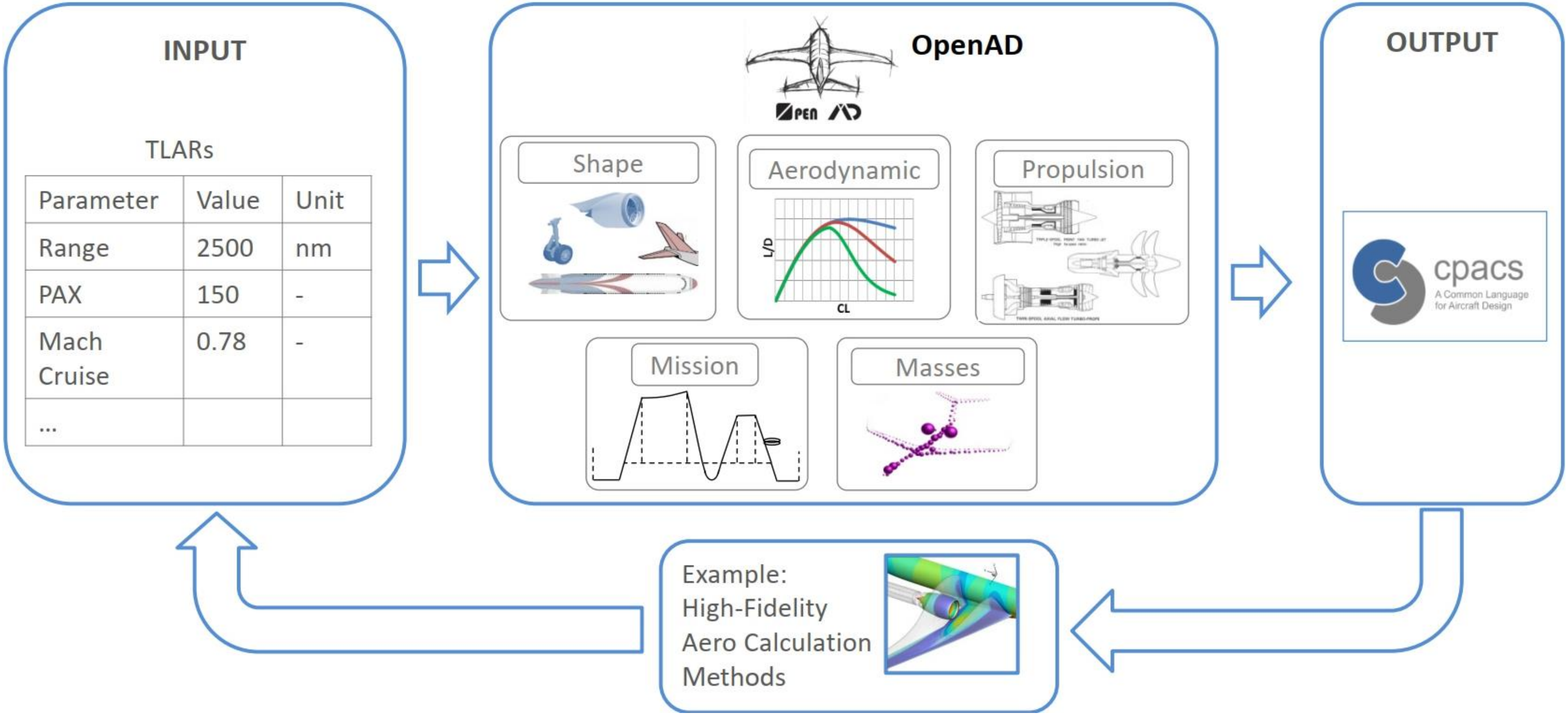
- Conceptual design synthesis (analytical functions, statistics) If needed modifications and re-run
- Result: e.g. aircraft configurational design, mass breakdown

- Preliminary loads analysis / structural design process including aeroelasticity
- Aeroelastic loads and physics based simulation models for the complete aircraft (e.g. structure)

- For LuFo VI-2 project WISDOM adaptation of the structure to achieve required flutter characteristics

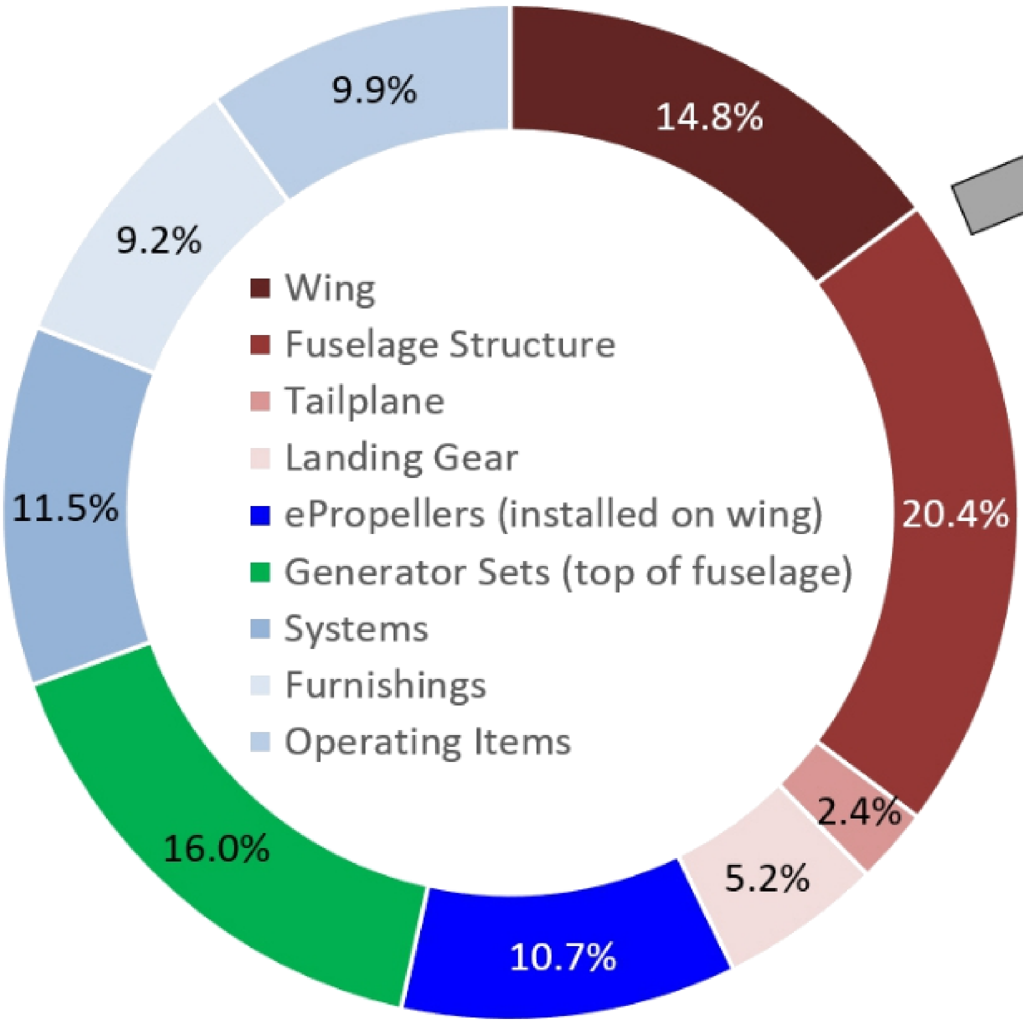
CPACS dataset, the interfacing dataformat

OpenAD – Conceptual Design

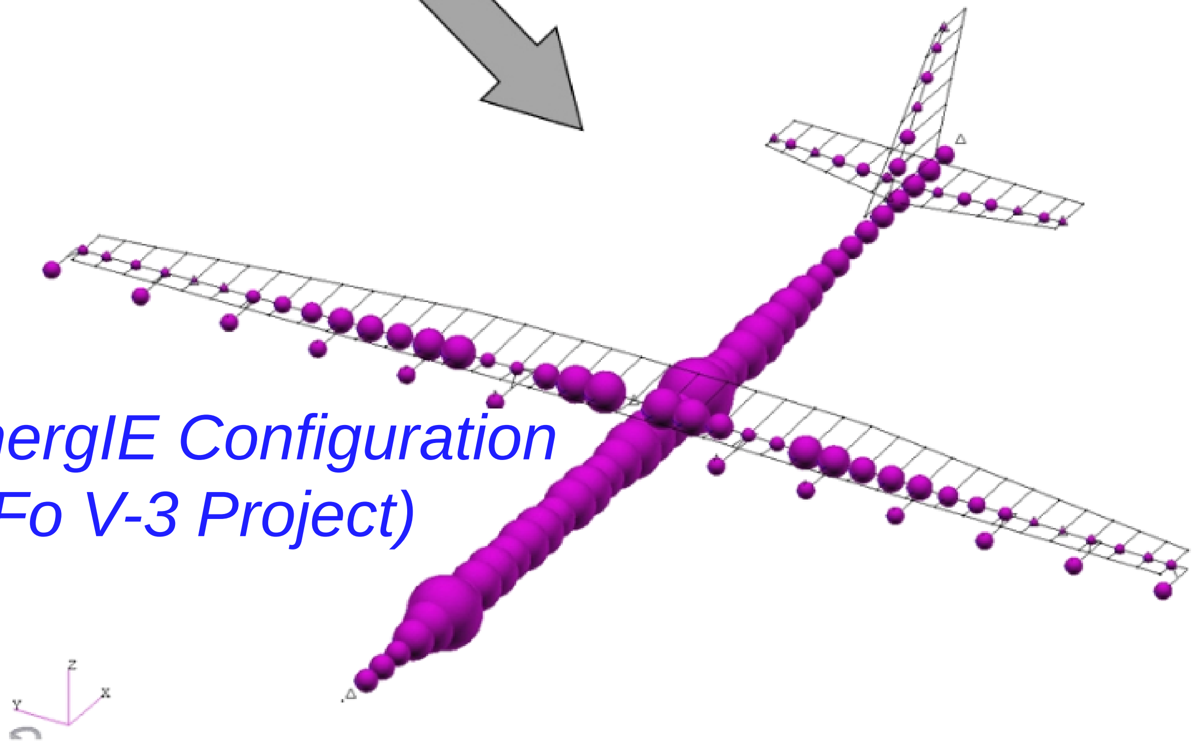


Parameter	Value	Unit
Range	2500	nm
PAX	150	-
Mach Cruise	0.78	-
...		

OpenAD - Exemplatory Result Mass Breakdown



cpacs
A Common Language for Aircraft Design

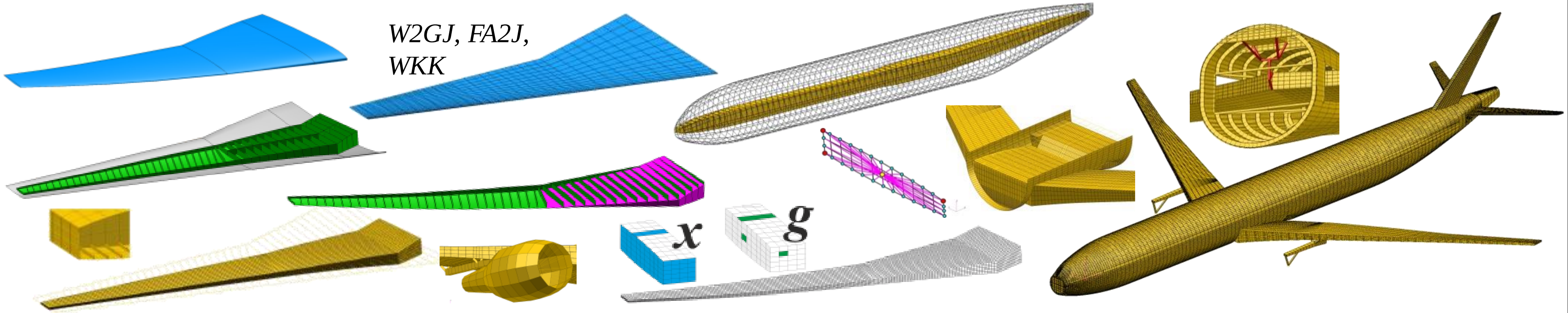


SynergIE Configuration (LuFo V-3 Project)

Finite Element Model – Mass Model Part

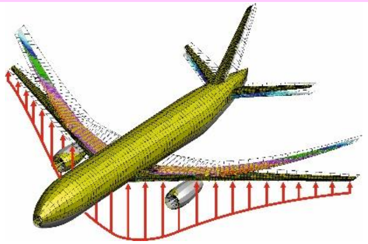
MONA – Parameterized Models Loads & Structural Design

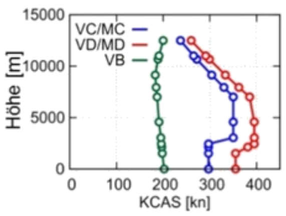
Parametric Set-Up of Simulation and Optimization Models (ModGen)

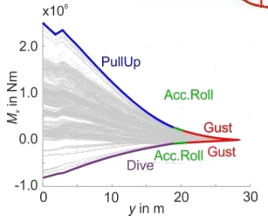


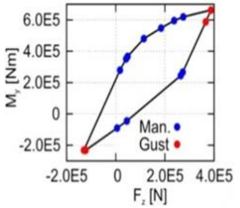
Loads Analysis (e.g. MSC Nastran)

- Maneuver
- Gust
- Continuous turbulence
- Ground and landing
- With and without control



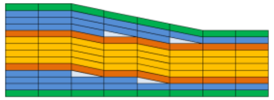




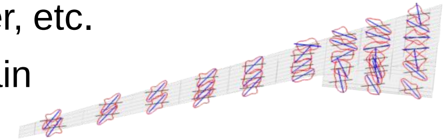


Structural Optimization (MSC Nastran)

$Min\,\{f(\boldsymbol{x})|\boldsymbol{g}_j(\boldsymbol{x}) \geq 0\}$

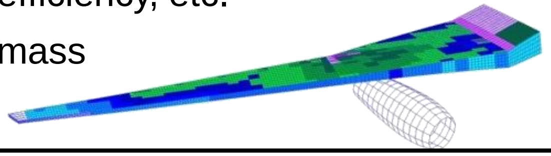


$\boldsymbol{x}$: skin thickness,
lamination parameter, etc.



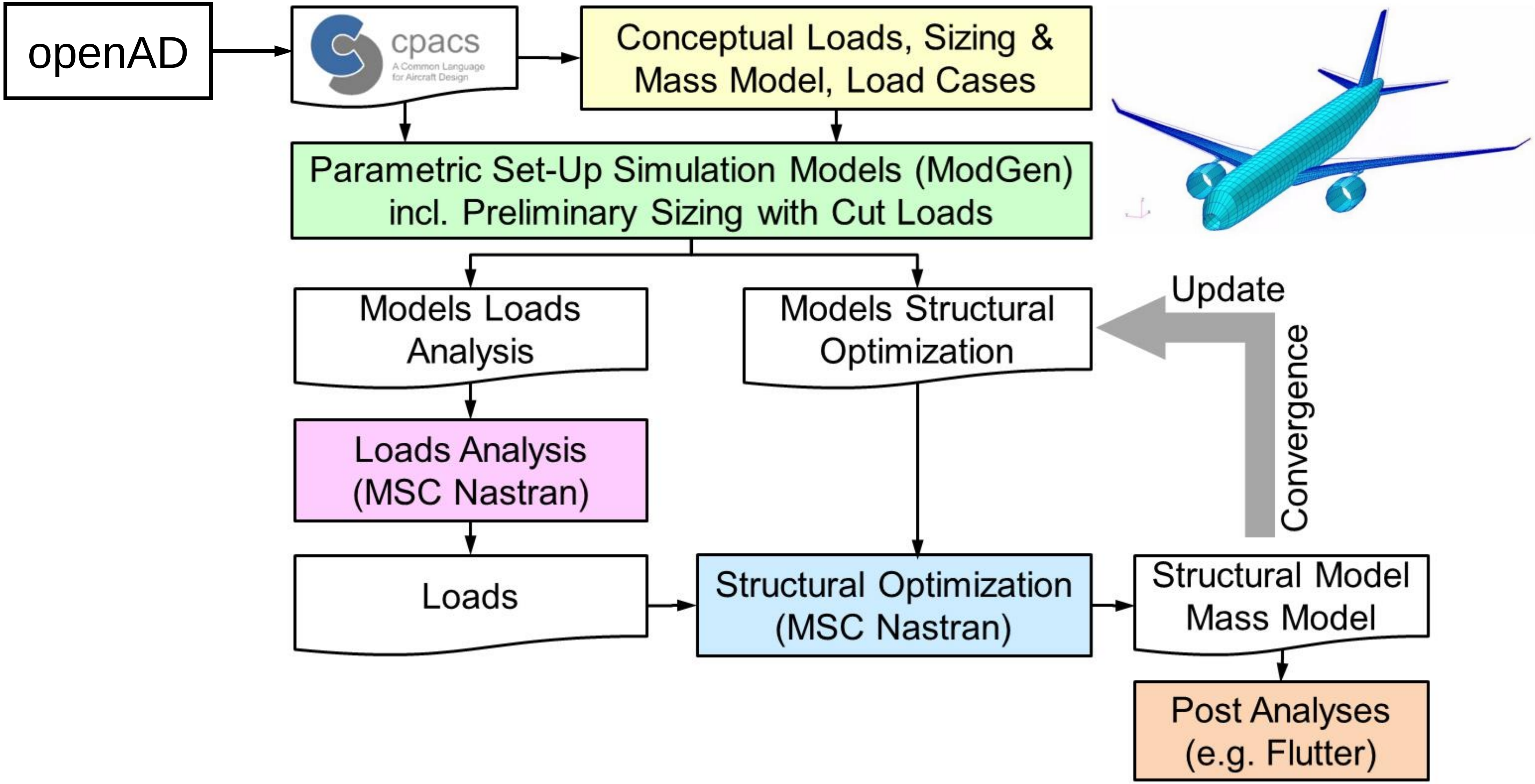
$\boldsymbol{g}$: stress, buckling, strain
control surface
efficiency, etc.

f: mass

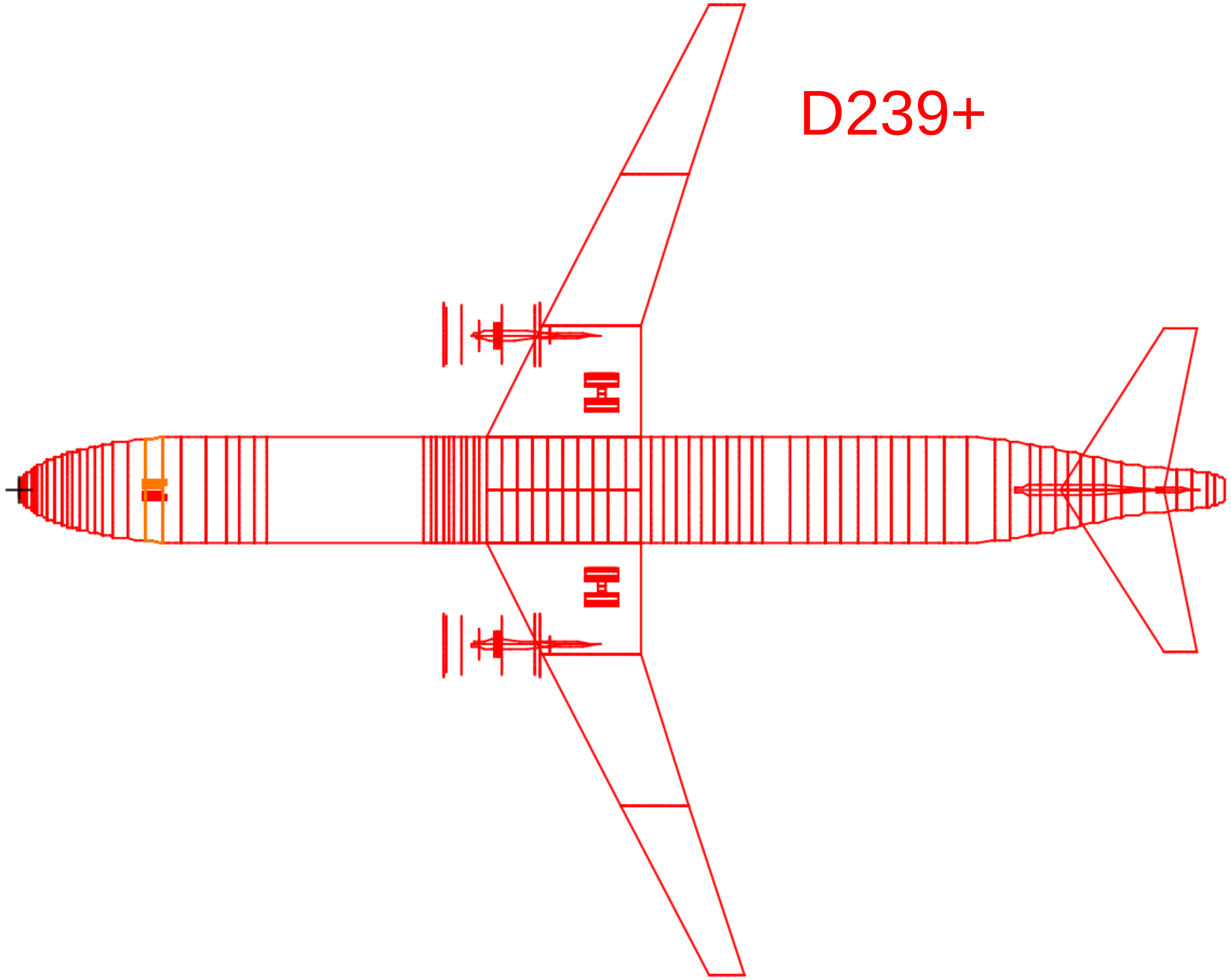


MONA: DLR-AE design process, main computer programs ModGen und MSC Nastran

cpacs-MONA – Parametric Aeroelastic Design Process



Start Configuration D2AE – Based on D239+ (DLR-SL)
(Techonology 2035)

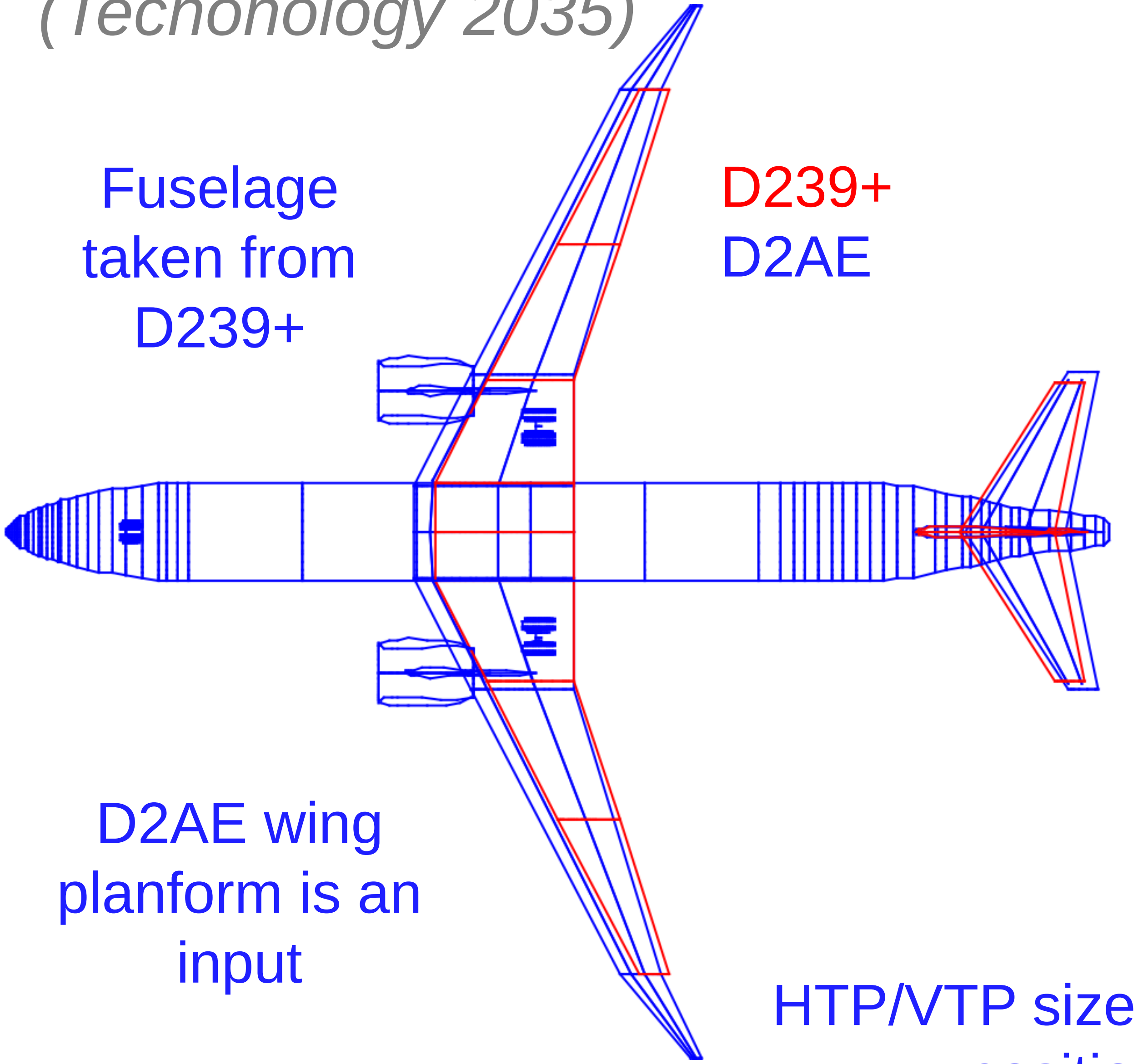


TLARs D239+

Design Range	[nm]	2500
Design PAX (single class)	[-]	239
Mass per PAX	[kg]	95
Design Payload	[kg]	25000
Max. Payload	[kg]	25000
Cruise Mach number	[-]	0.78
Max. operating Mach number	[-]	0.8
Max. operating altitude	[ft]	40000
TOFL (ISA +0K SL)	[m]	<2200
Rate of Climb @ TOC	[ft/min]	>300
Approach Speed (CAS)	[kt]	136
Wing span limit	[m]	<36
Alternate Distance	[nm]	200
Holding Time	[min]	30
Contingency	[-]	3%

Start Configuration D2AE – Based on D239+ (DLR-SL)
(Techonology 2035)

Fuselage taken from D239+



D2AE wing planform is an input

TLARs D2AE

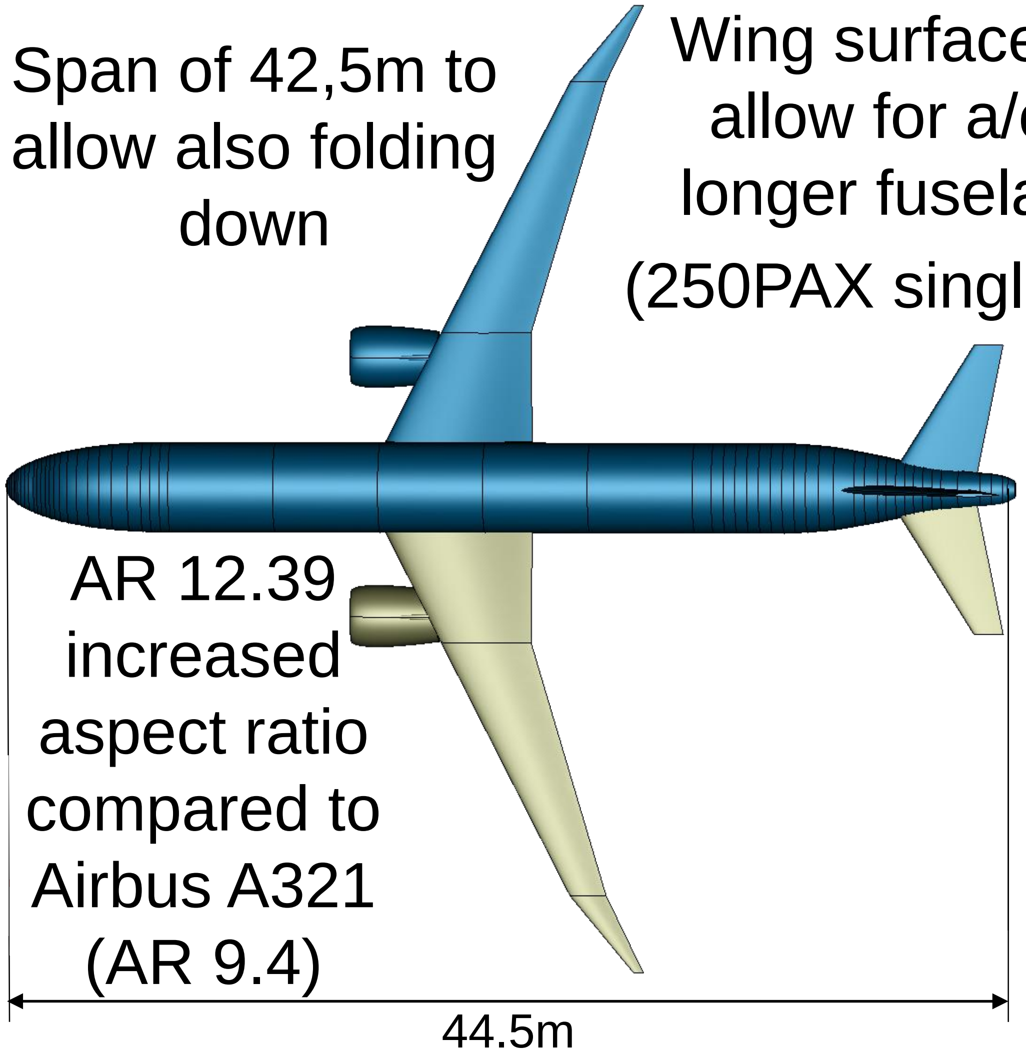
Design Range	[nm]	2500
Design PAX (single class)	[-]	239
Mass per PAX	[kg]	95
Design Payload	[kg]	25000
Max. Payload	[kg]	25000
Cruise Mach number	[-]	0.78
Max. operating Mach number	[-]	0.8
Max. operating altitude	[ft]	40000
TOFL (ISA +0K SL)	[m]	<2200
Rate of Climb @ TOC	[ft/min]	>300
Approach Speed (CAS)	[kt]	136
Wing span limit	[m]	42.5
Alternate Distance	[nm]	200
Holding Time	[min]	30
Contingency	[-]	3%

HTP/VTP size and position, and landing gear position estimated by openAD

Results openAD – View of the D2AE Configuration

(CPACS Visualization with TiGL Viewer)

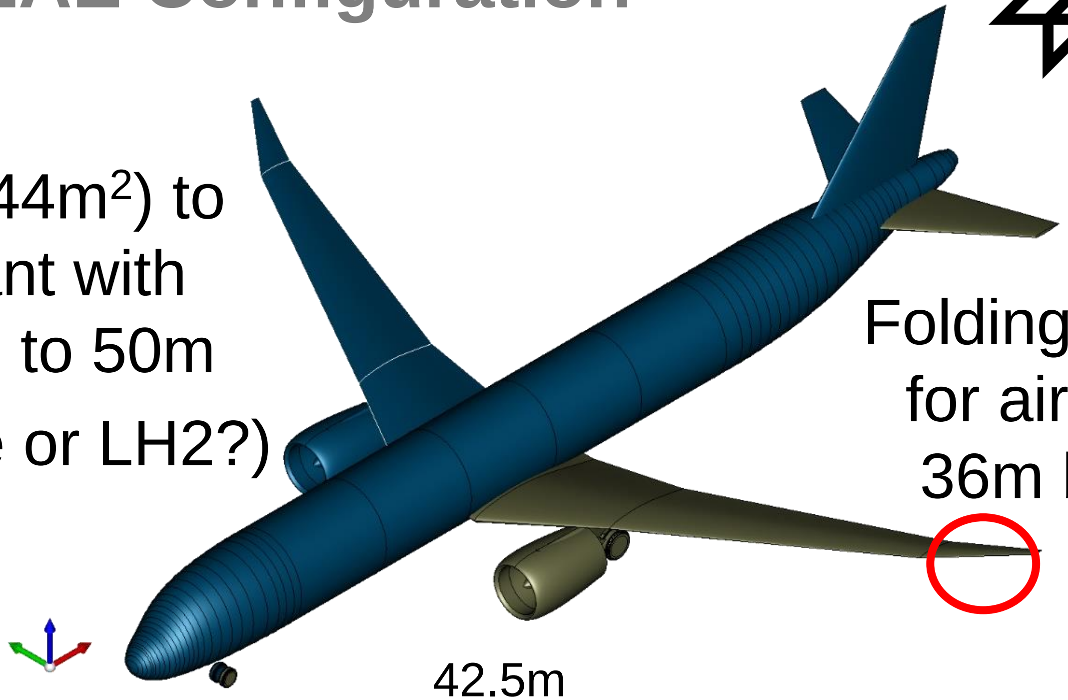
Span of 42,5m to allow also folding down



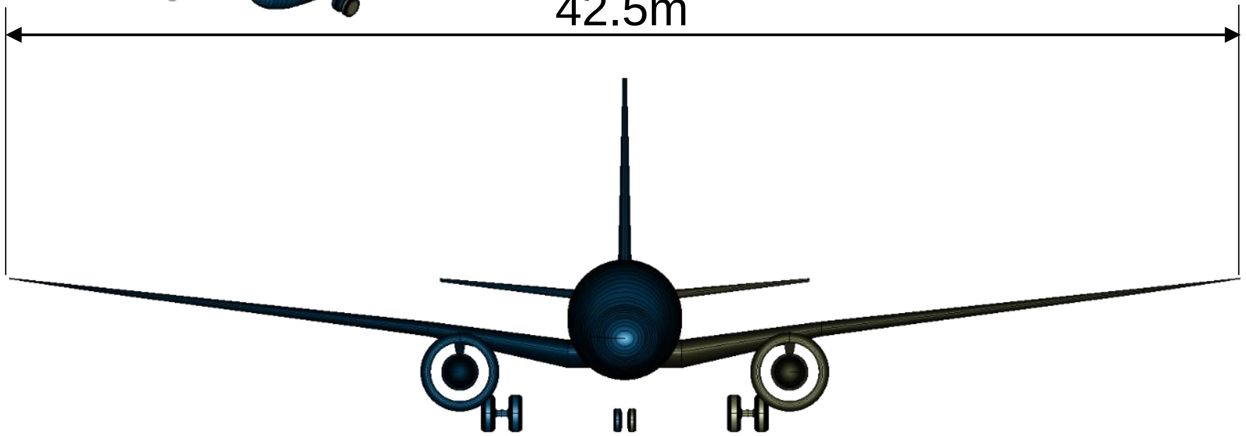
AR 12.39 increased aspect ratio compared to Airbus A321 (AR 9.4)

Wing surface of (144m²) to allow for a/c variant with longer fuselage up to 50m

(250PAX single aisle or LH2?)



Folding wing for airport 36m box



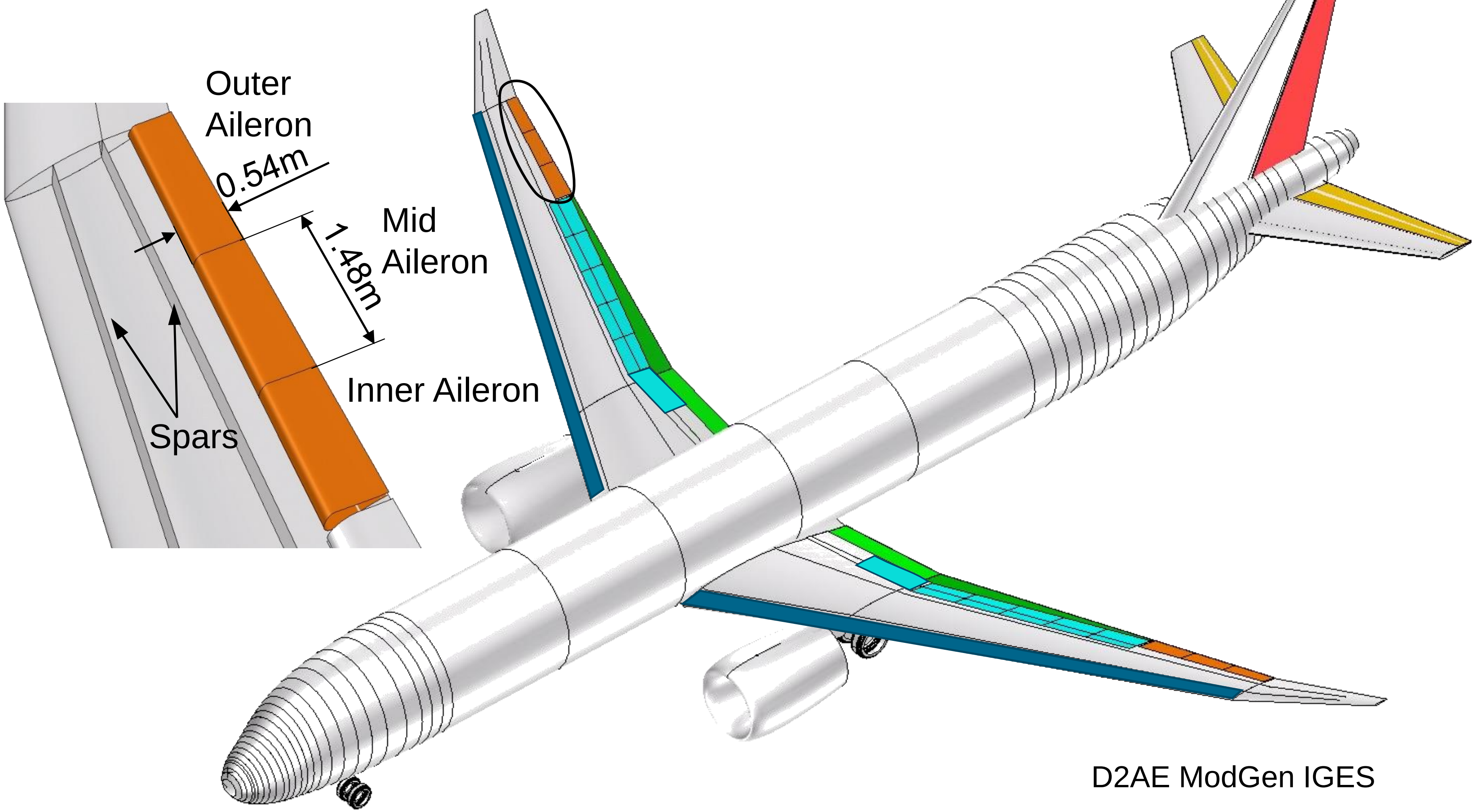
Root chord enlargement to keep main landing at the wing

D2AE Control Surfaces

Freeze Control Surface Layout in LuFo VI-2 Project WISDOM

Control Surfaces:

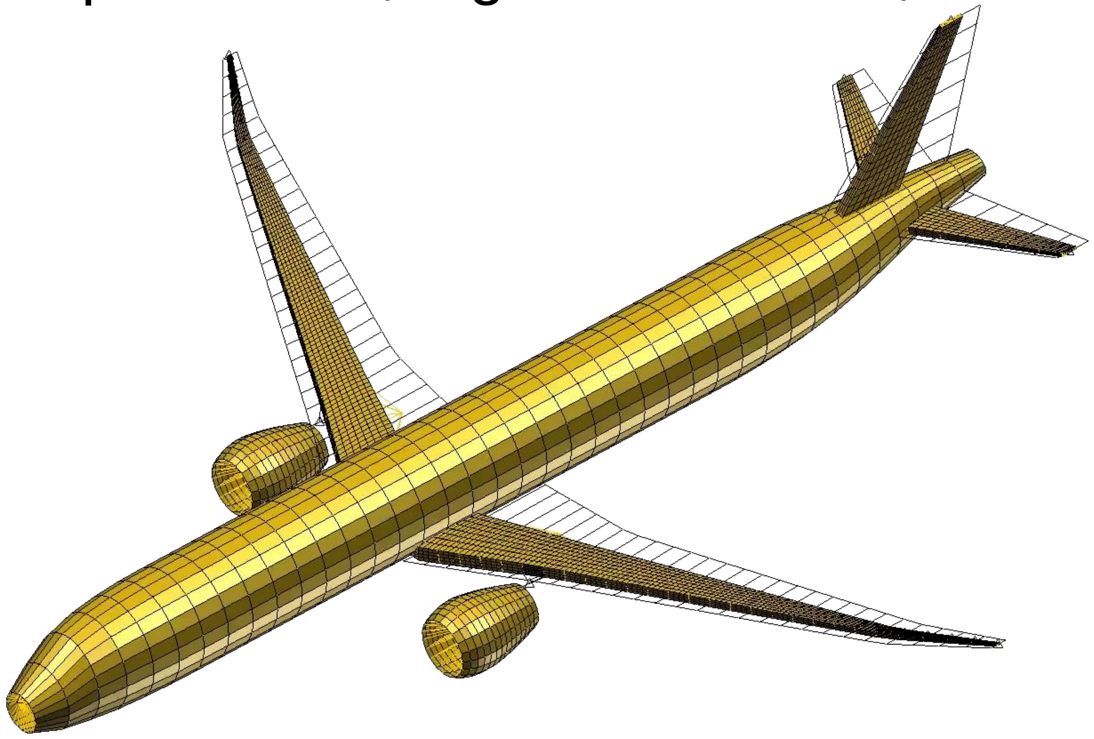
• Inner Flap	
• Outer Flap	
• Inner Aileron	
• Mid Aileron	
• Outer Aileron	
• Spoiler	
• Elevator	
• Rudder	
• Slats	

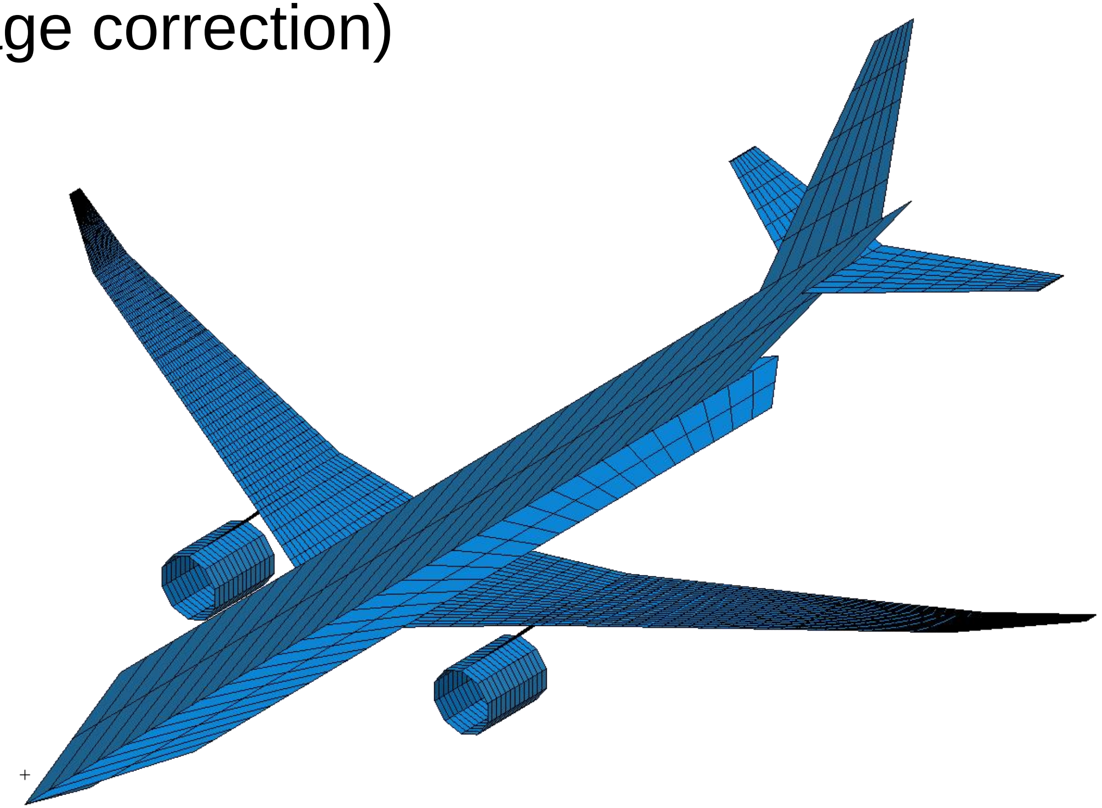


D2AE ModGen IGES

Result cpacs-MONA – Structural and Aerodynamic Model

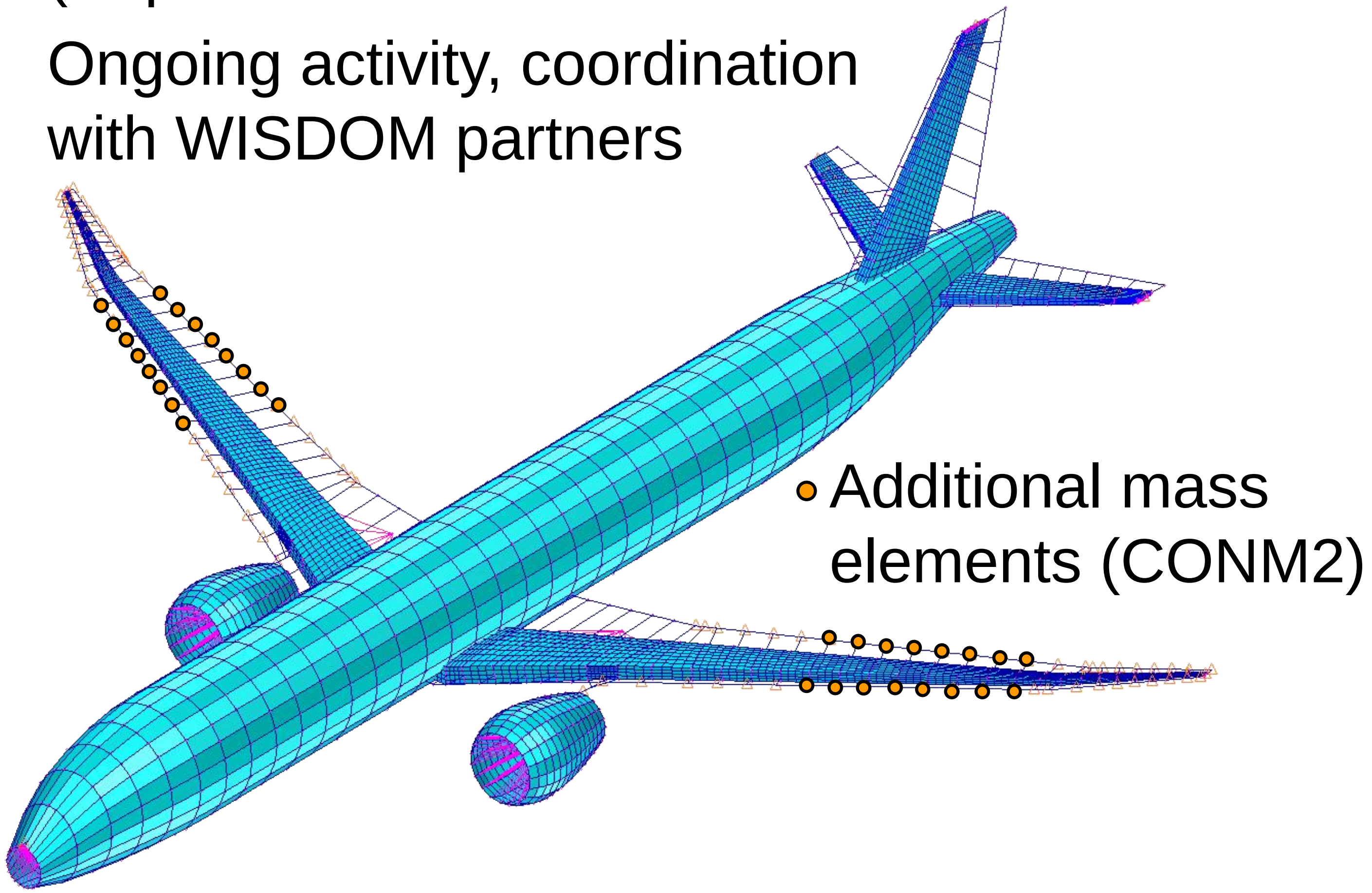
- Structural model as finite element model for the complete aircraft (MSC Nastran)
- Finite element model with seperate modelling of stiffness and mass
- Mass model available for various mass configurations
- Aerodynamic Model as Doublet Lattice model (already 1st corrections implemented, e.g. camber data, fuselage correction)

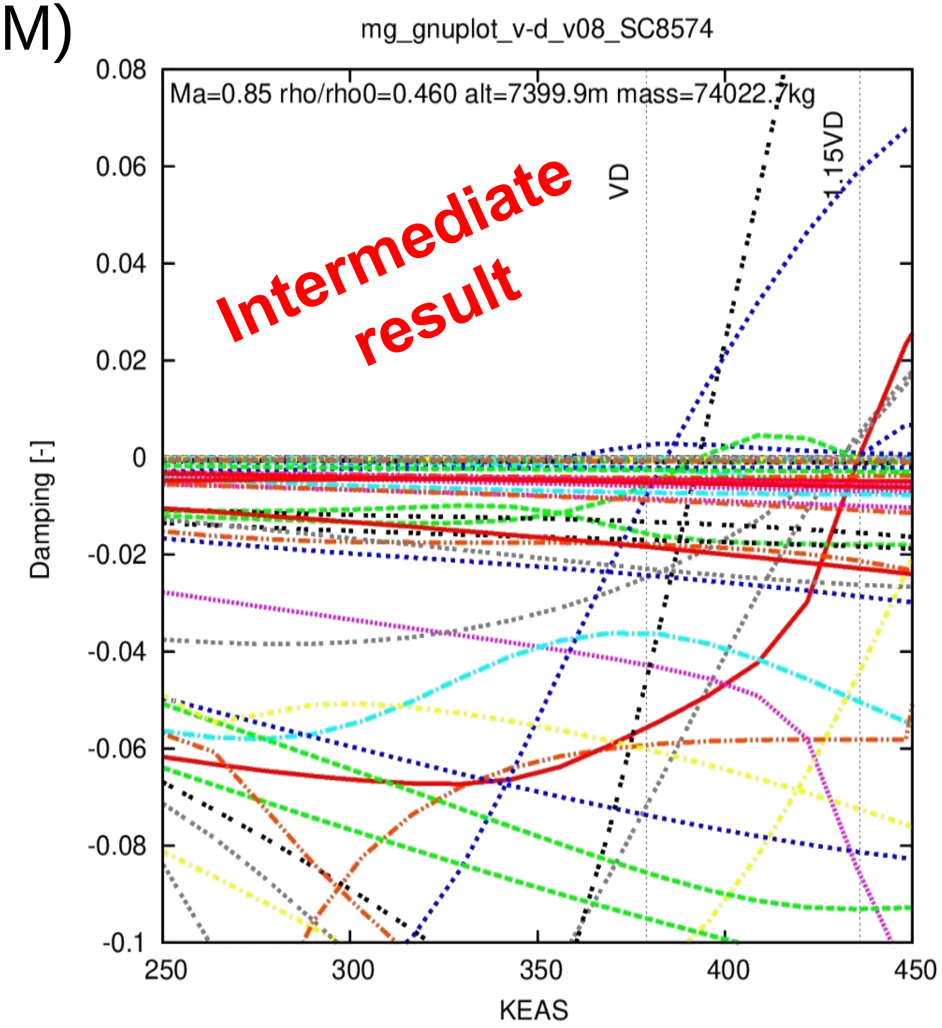




D2AE: Adaptation FEM – Masses @ LE und TE (for WISDOM)

- Adaptation to achieve flutter between design diving speed VD und 1.15*VD
- 1st torsional mode (sym./antiysm) down to 11Hz, flutter frequency about 7 Hz (requirement from available actuators in WISDOM)
- Ongoing activity, coordination with WISDOM partners



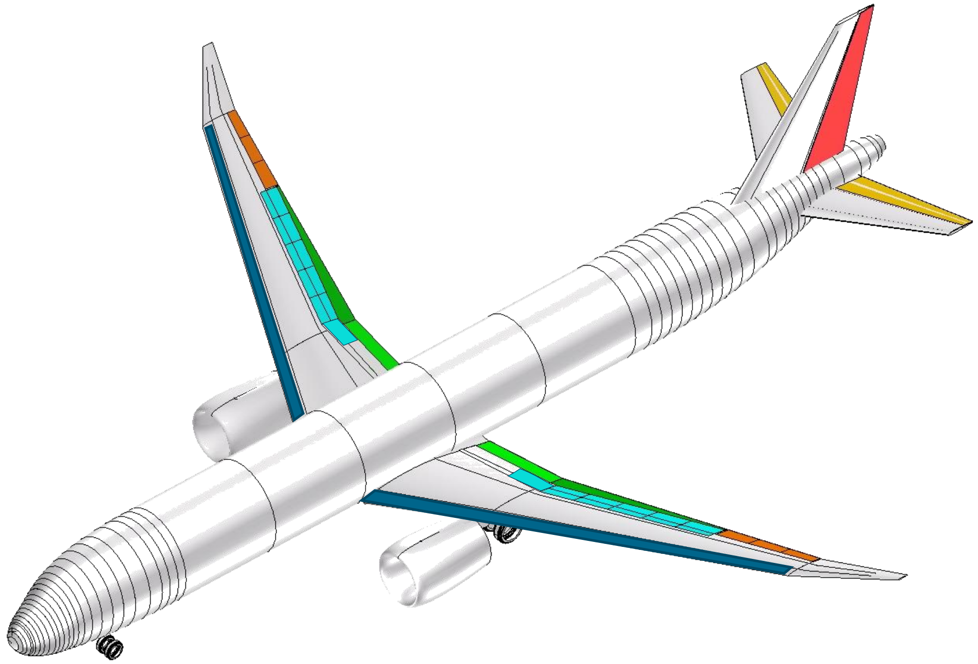


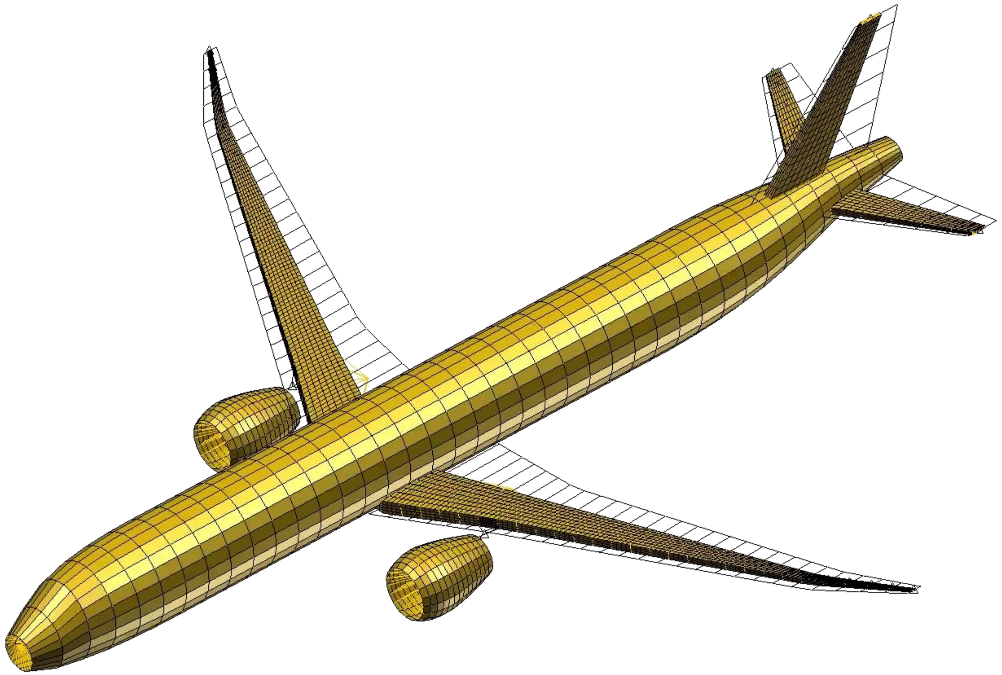
Summary and Outlook

- Introduction of the D2AE configuration as potential new transport aircraft configuration following an evolutionary approach
- Presentation of openAD/cpacs-MONA conceptual/preliminary aeroelastic design process for D2AE configuration
- Adaptation of the structural model to achieve required flutter characteristics

- Further development of the D2AE configuration of aeroelastic and aero-servoelastic applications (e.g. for loads and flutter control)
- Gradual progress to incorporate CFD aerodynamics

Thank you very much for your attention!





D2AE – developed @ DLR-AE