INVESTIGATION ON AEROELASTIC CHARACTERISTICS DUE TO STRUCTURAL AND GEOMETRICAL VARIATIONS FOR AN SMR AIRCRAFT CONFIGURATION USING CPACS-MONA

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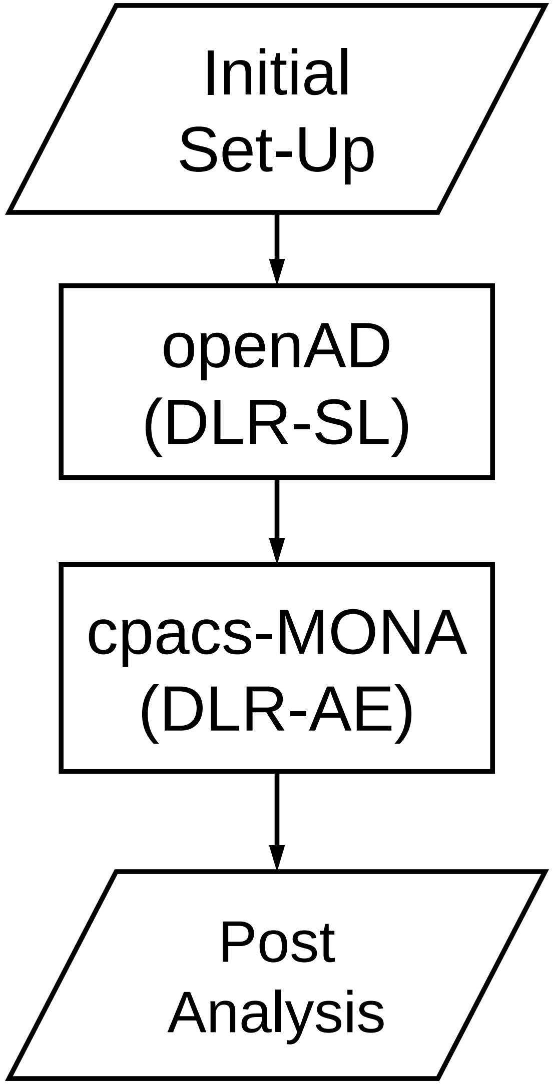
DLR

Overview

- Principal parametric design process
- Analytical equations and statistics based conceptual design synthesis
- Parametric aeroelastic design process (loads analysis / structural design)
- D2AE configuration
- Parameter study regarding flutter characteristics
- Summary and outlook

Parametric 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 (flutter check)
- Aeroelastic loads and physics based simulation models for the complete aircraft (e.g. structure)

- Parameter study

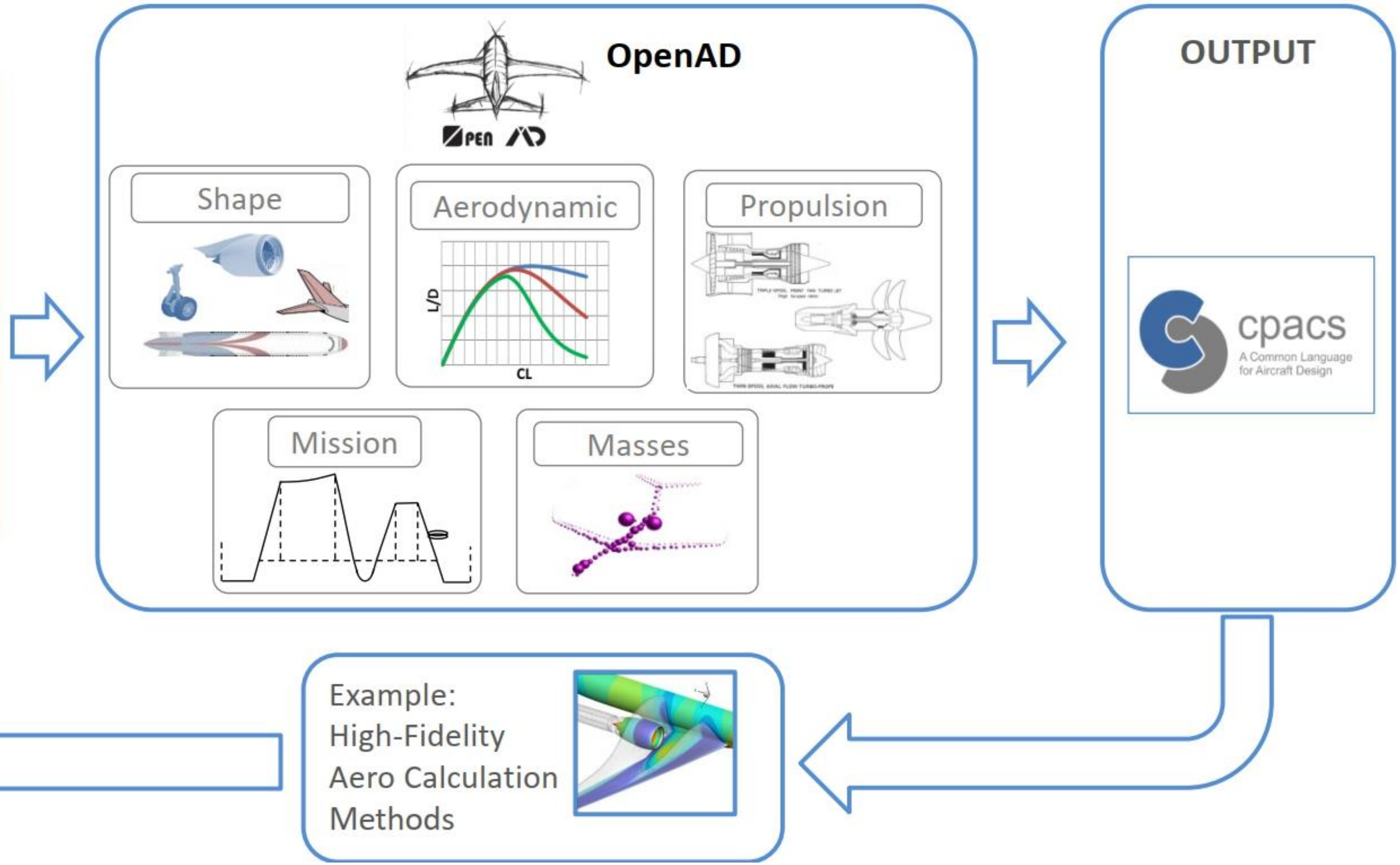
CPACS dataset, the interfacing dataformat

OpenAD – Conceptual Design

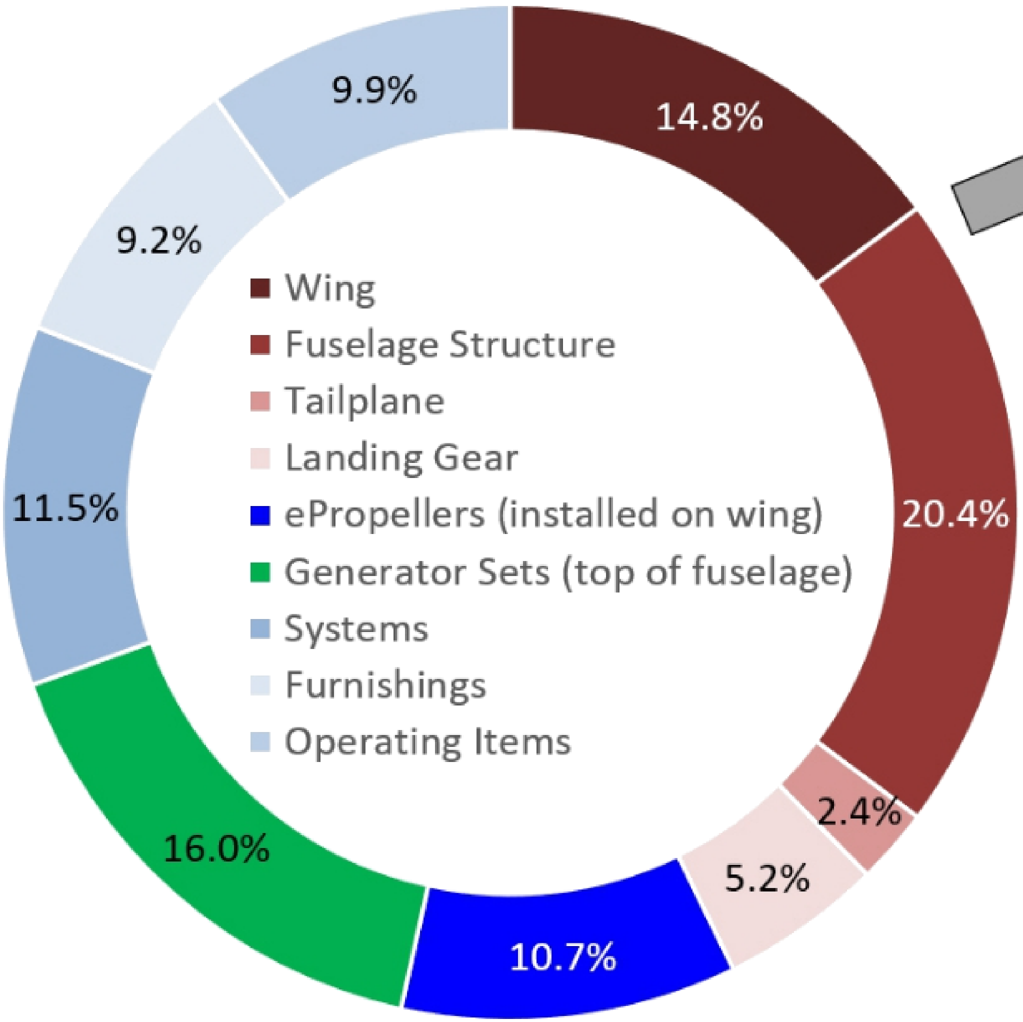
INPUT

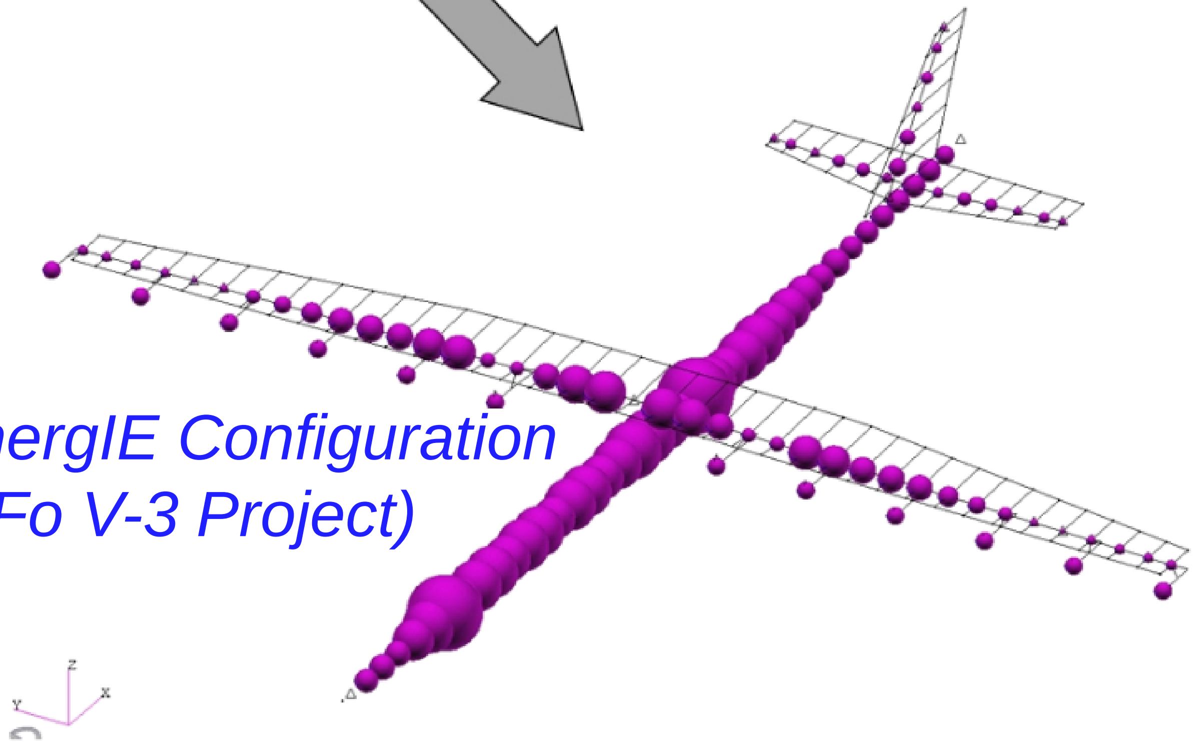
TLARs

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



OpenAD - Exemplatory Result Mass Breakdown



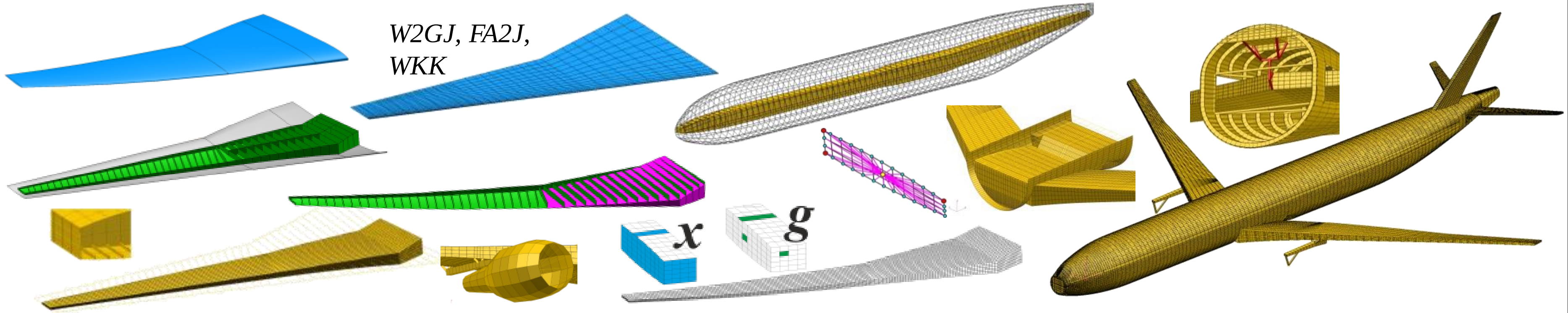


SynergIE Configuration (LuFo V-3 Project)

Finite Element Model – Mass Model Part

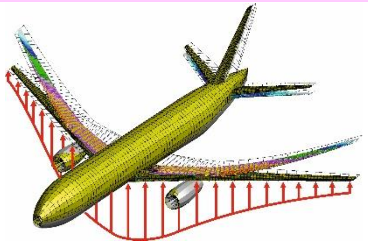
MONA – Parameterized Models Loads & Structural Design

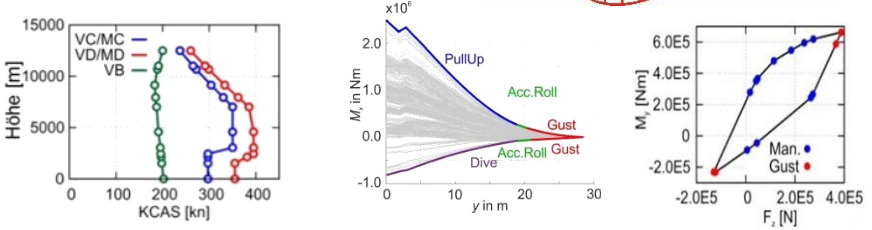
Parametric Set-Up of Simulation and Optimization Models (ModGen)



Loads Analysis (e.g. MSC Nastran)

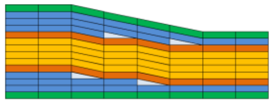
- Maneuver
- Gust
- Continuous turbulence
- Ground and landing
- With and without control



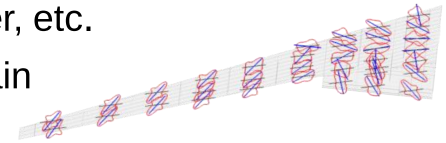


Structural Optimization (MSC Nastran)

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

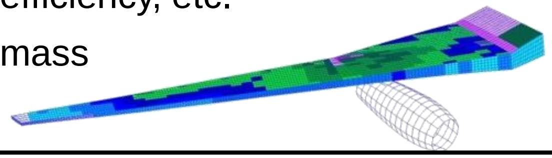


$\boldsymbol{x}$: skin thickness,
lamination parameter, etc.



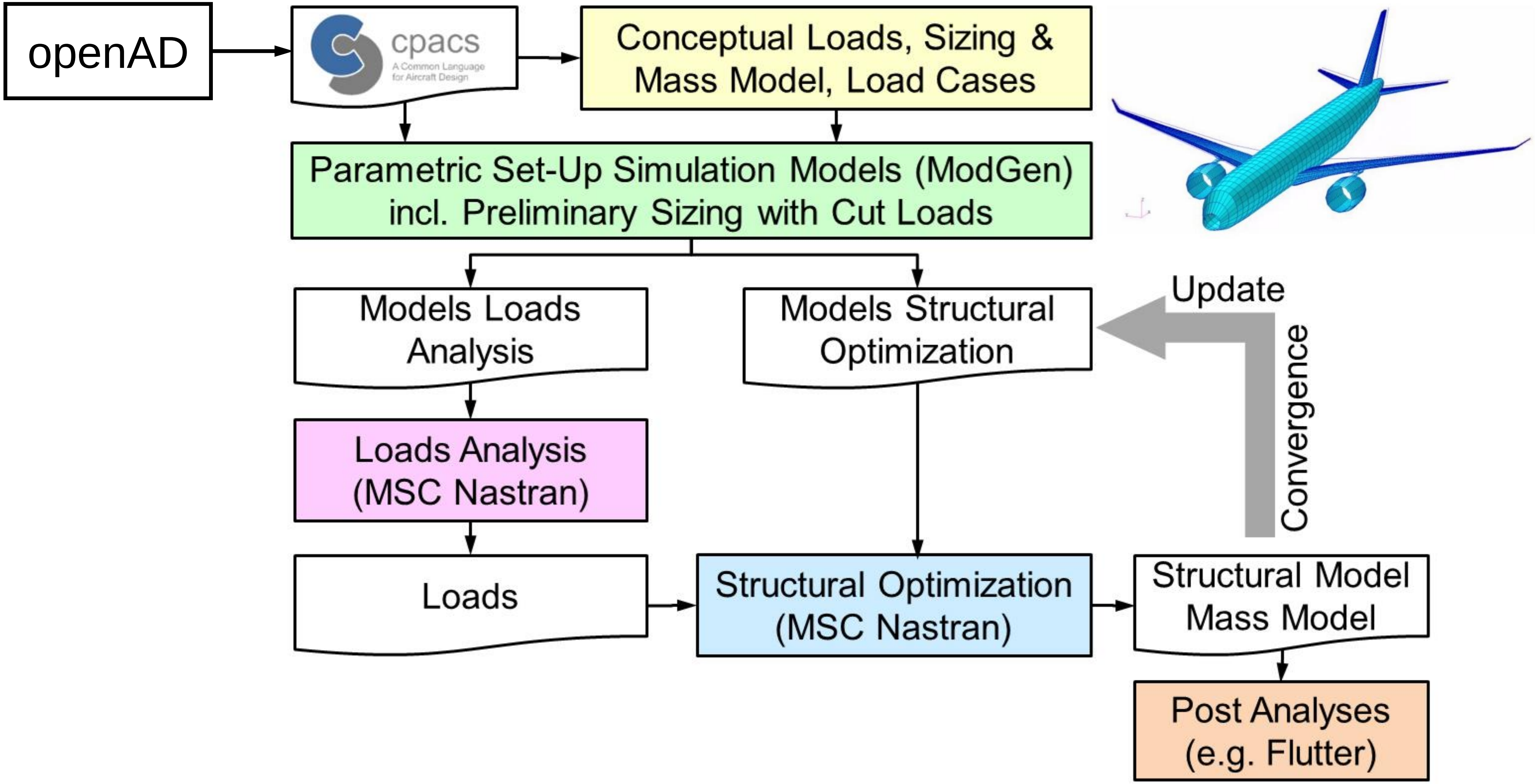
$\boldsymbol{g}$: stress, buckling, strain
control surface
efficiency, etc.

f: mass



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

cpacs-MONA – Parametric Aeroelastic Design Process



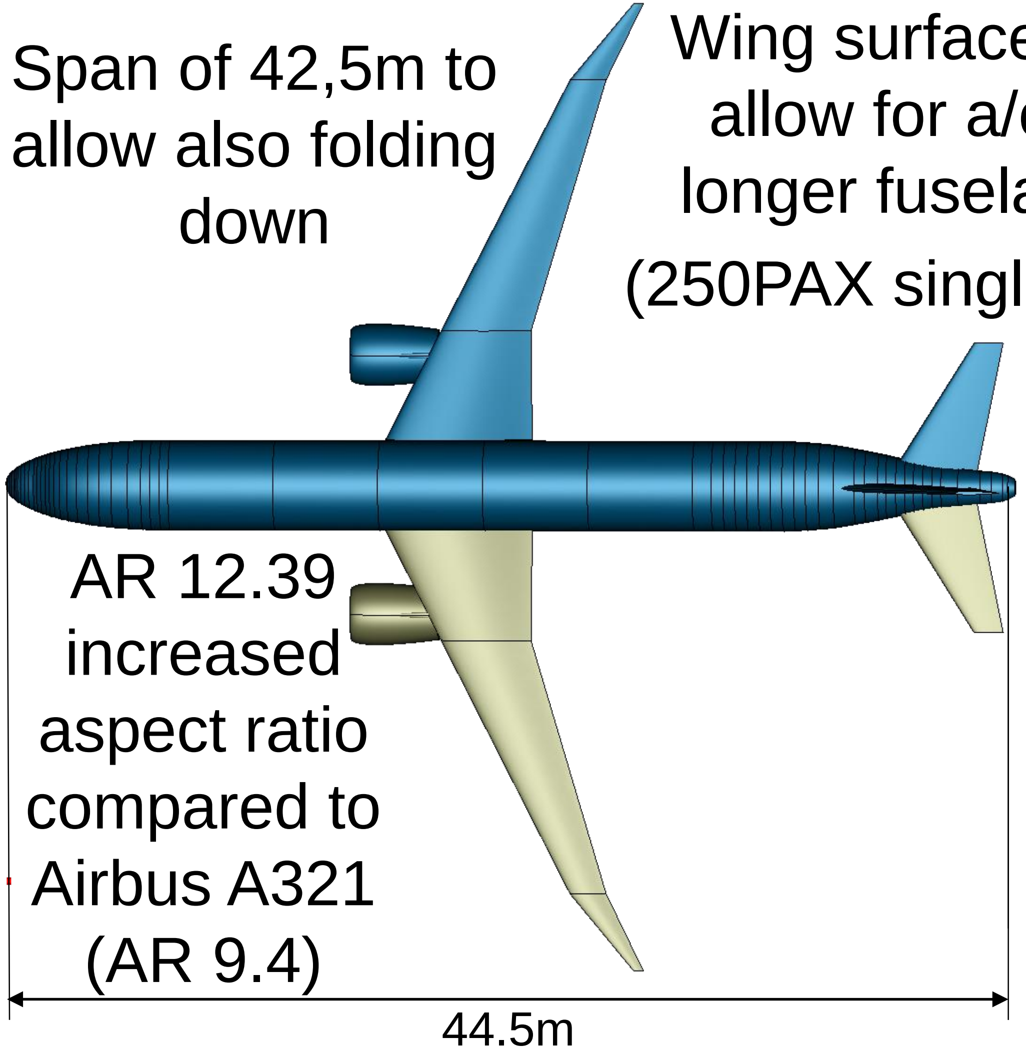
Results openAD – View of the D2AE Configuration

(CPACS Visualization with TiGL Viewer)

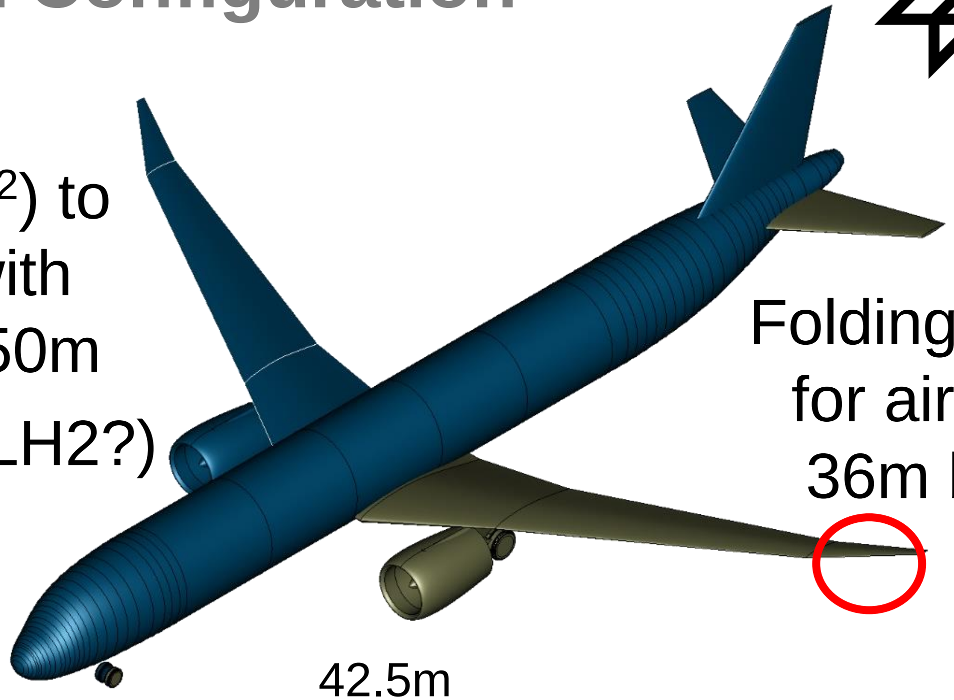
Span of 42,5m to allow also folding down

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

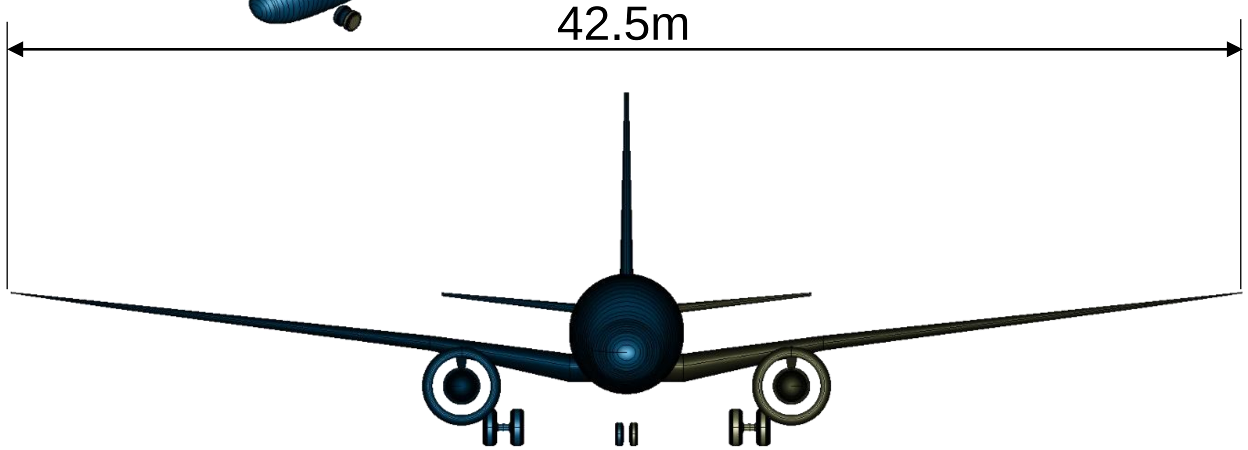
(250PAX single aisle or LH2?)



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



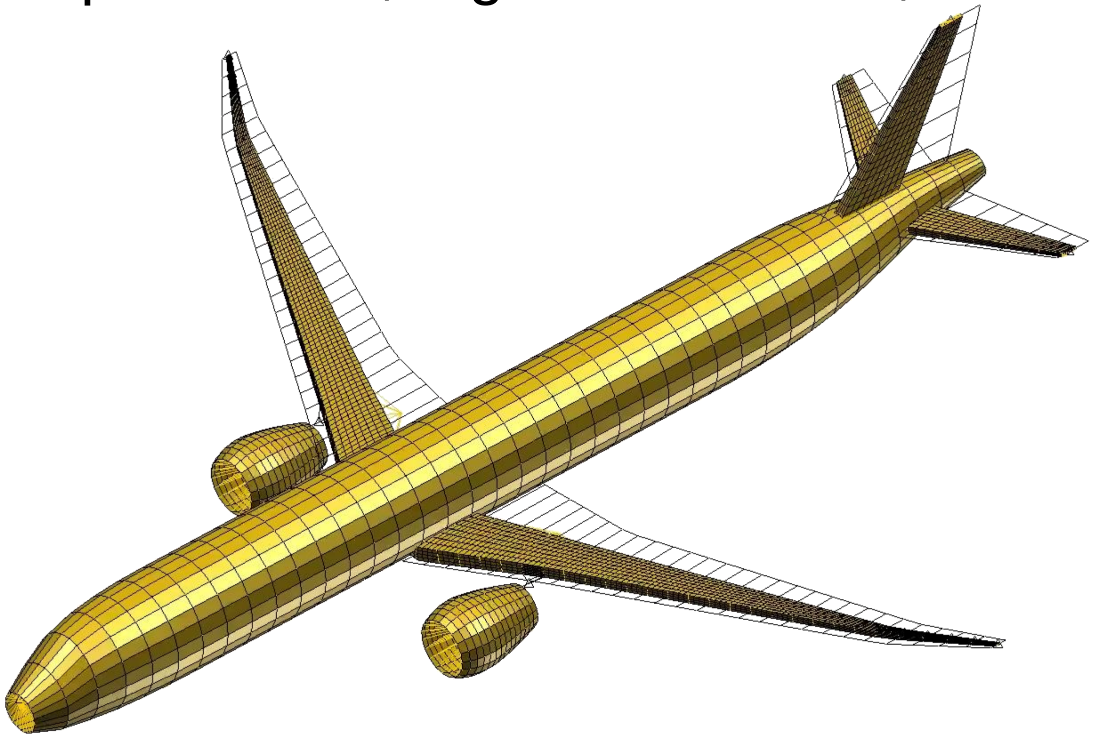
Folding wing for airport 36m box

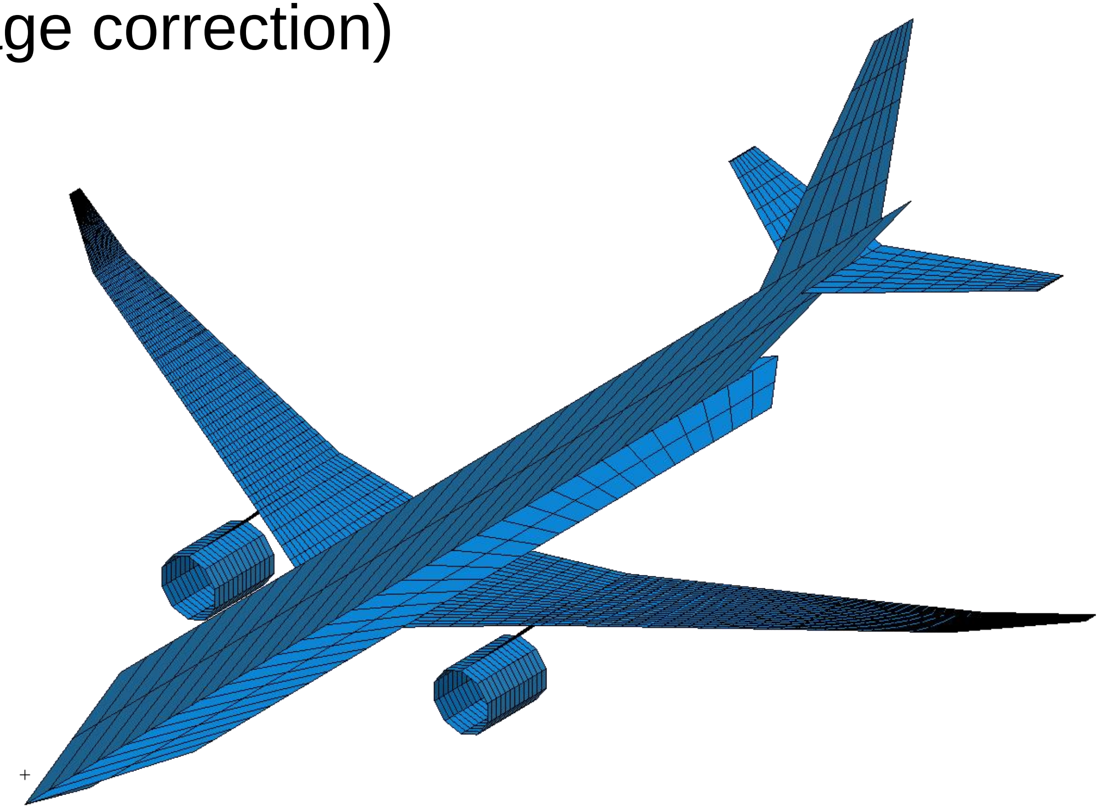


Root chord enlargement to keep main landing at the wing

Result cpacs-MONA – Structural and Aerodynamic Model

- Structural model as finite element model for the complete aircraft (MSC Nastran)
- Finite element model with separate 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)

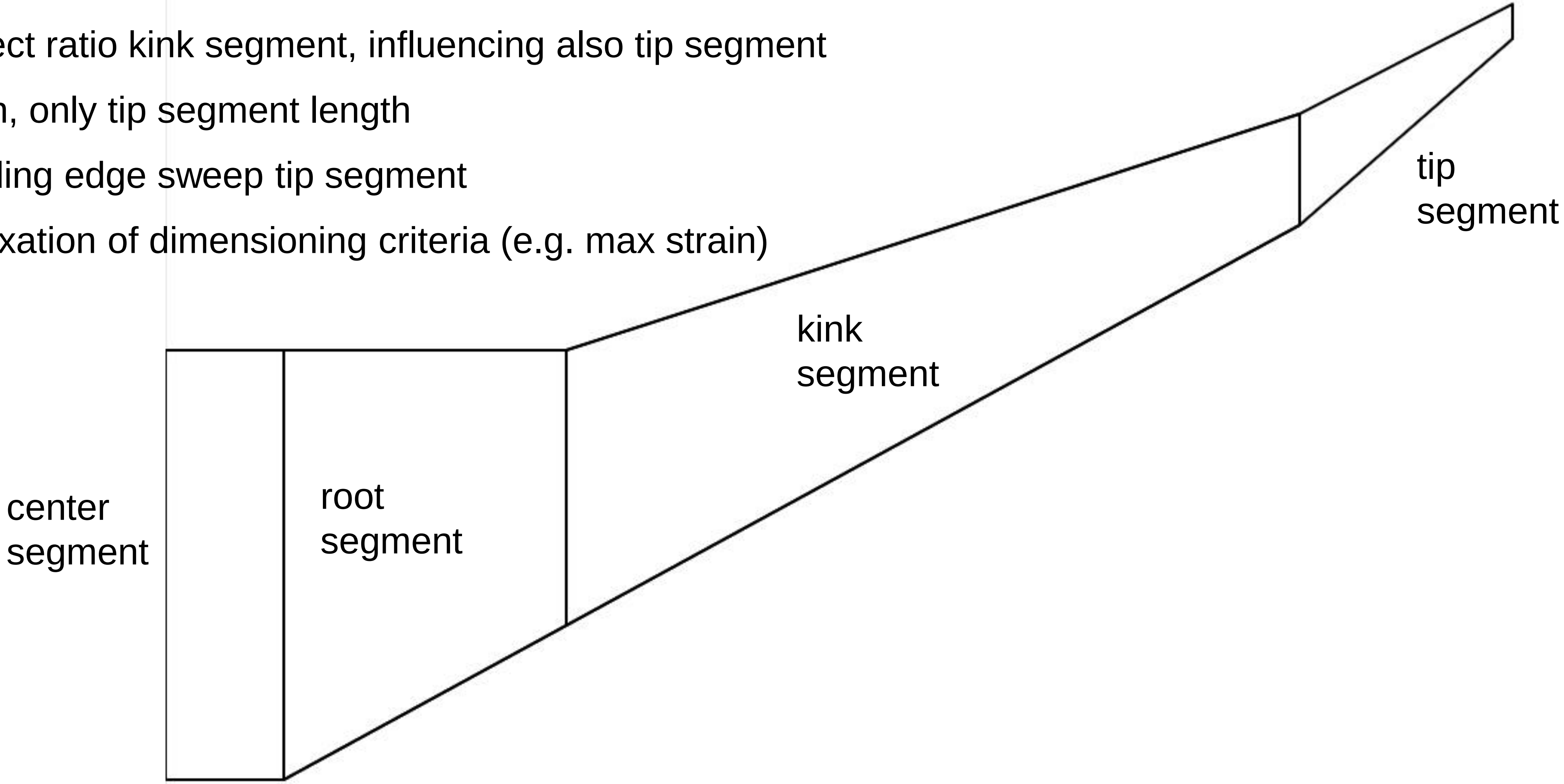




Parameterstudy – Selected Parameter

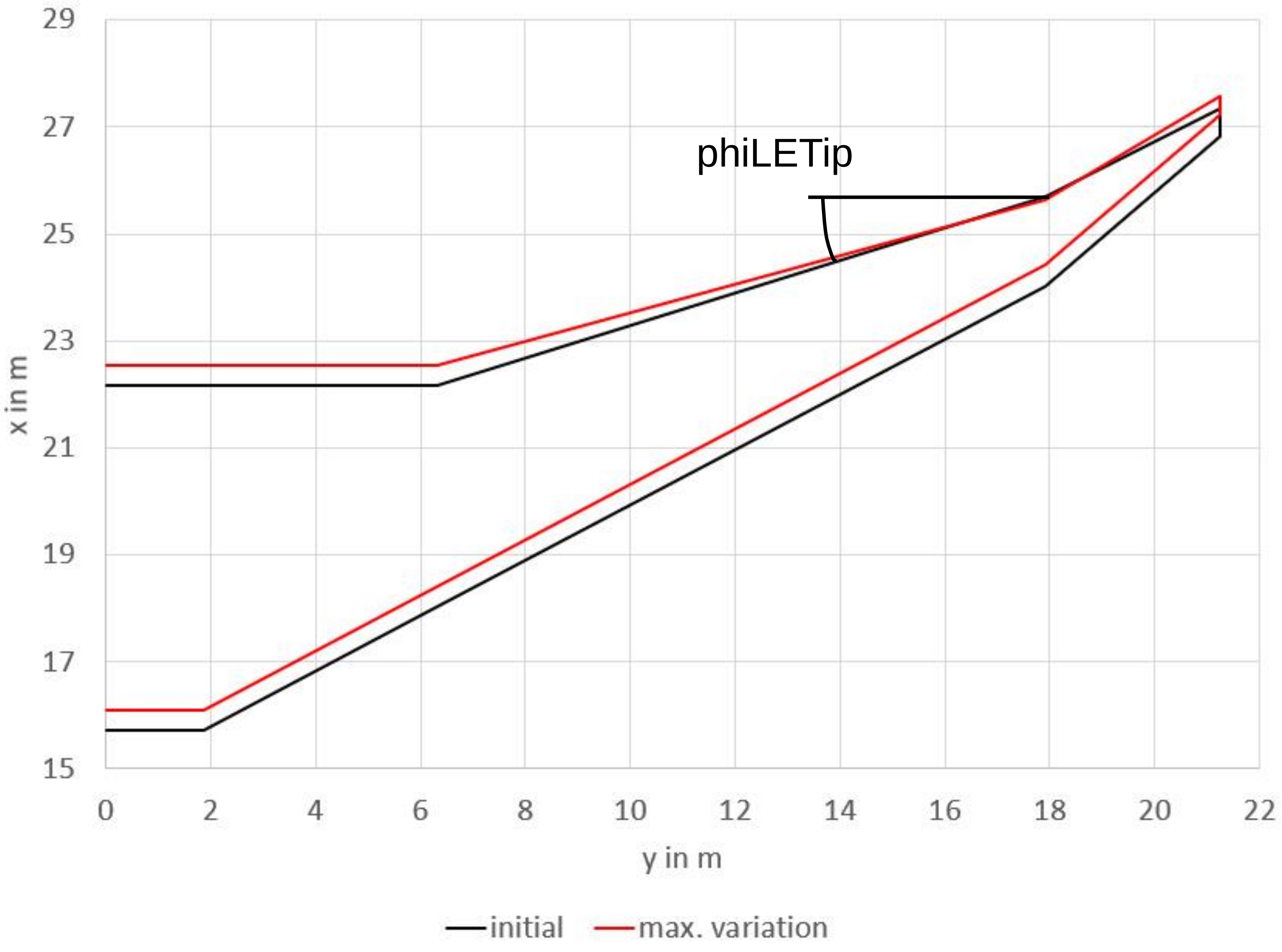
Selected planform parameter of the wing

1. Aspect ratio kink segment, influencing also tip segment
2. Span, only tip segment length
3. Leading edge sweep tip segment
4. Relaxation of dimensioning criteria (e.g. max strain)



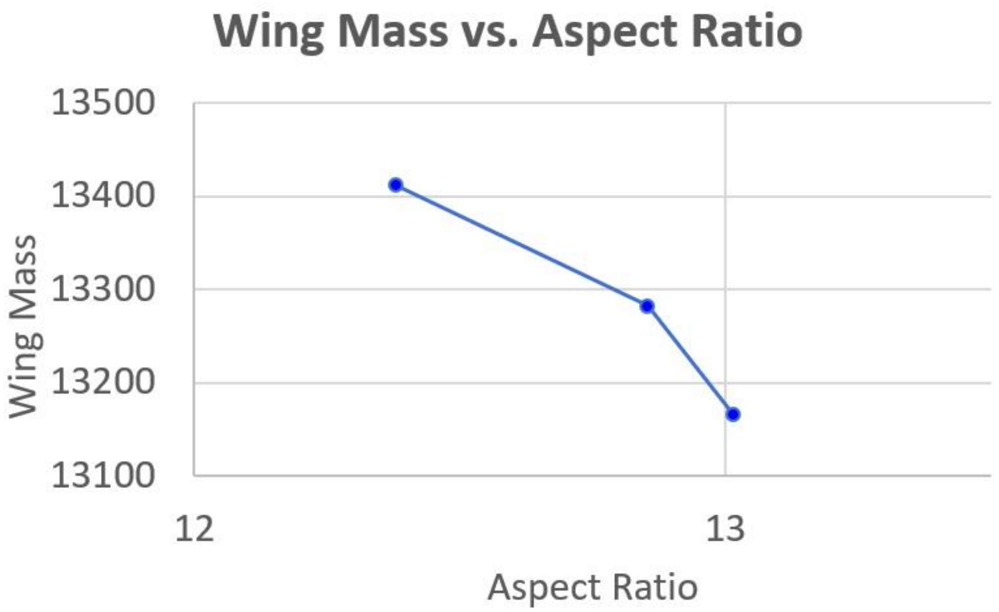
Parameterstudy – 1. Aspect Ratio Kink Segment

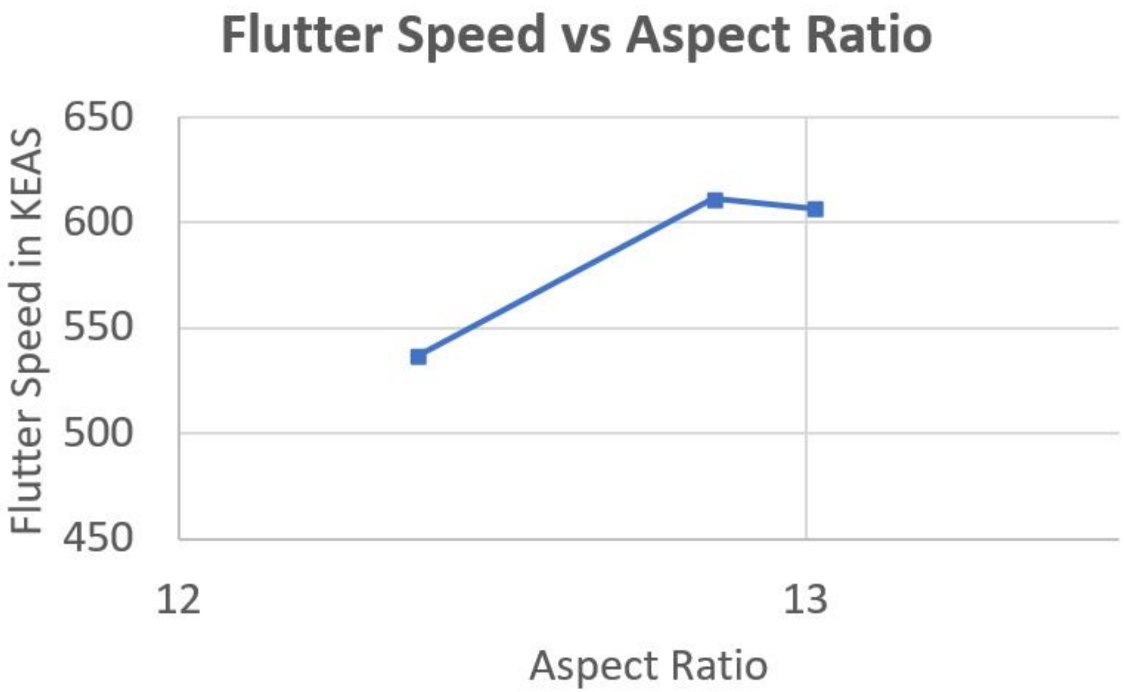
- Three Variations
- Aspect ratio of kink segment due to trailing edge sweep of kink segment
- Range of trailing edge sweep from
- shift of wing position of openAD → further investigation



Paramterstudy – Aspect Ratio Kink Segment / Results

Results wing mass and flutter speed

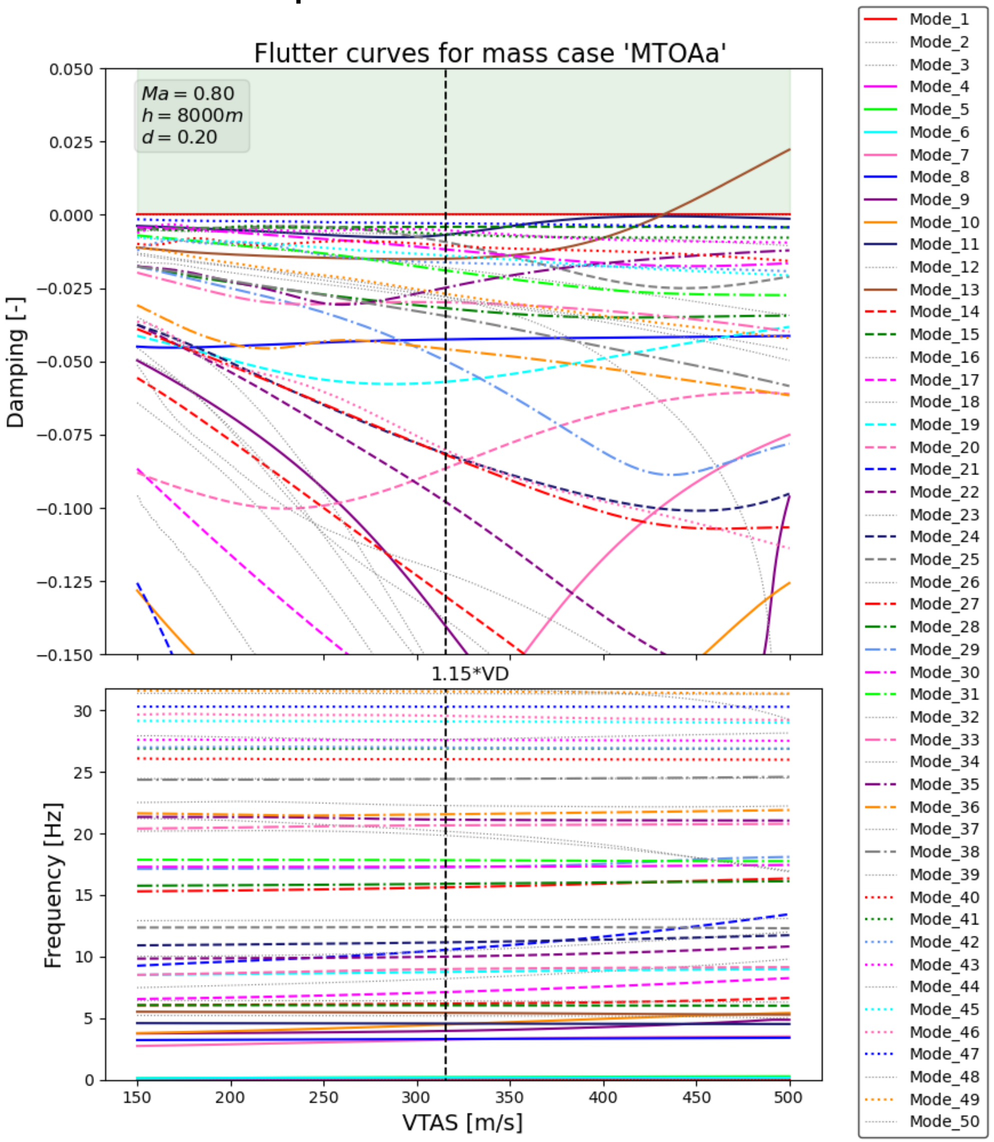




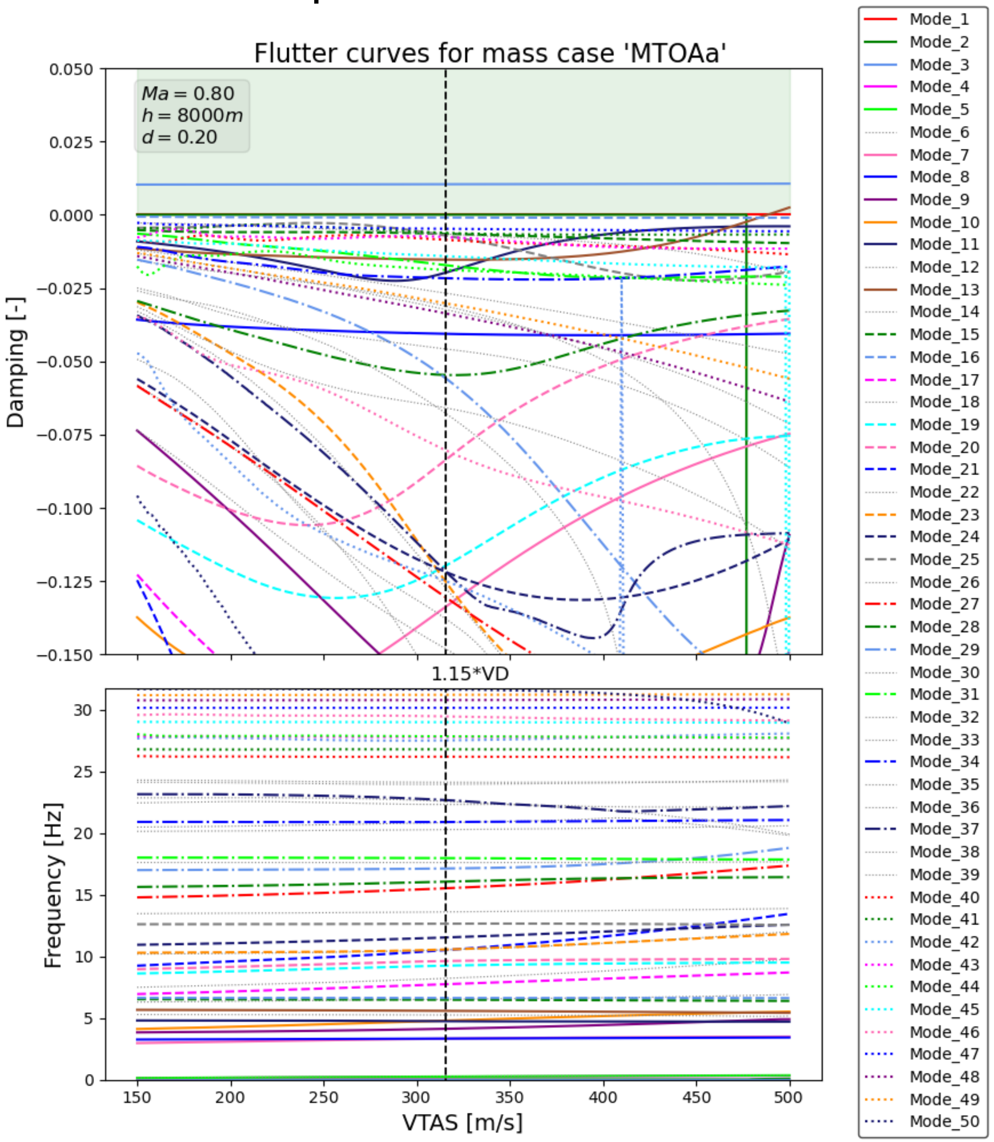
Paramterstudy – Aspect Ratio Kink Segment / Results

- Increase of flutter speed
- Flutter mode coupling the same

Aspect Ratio 12.38

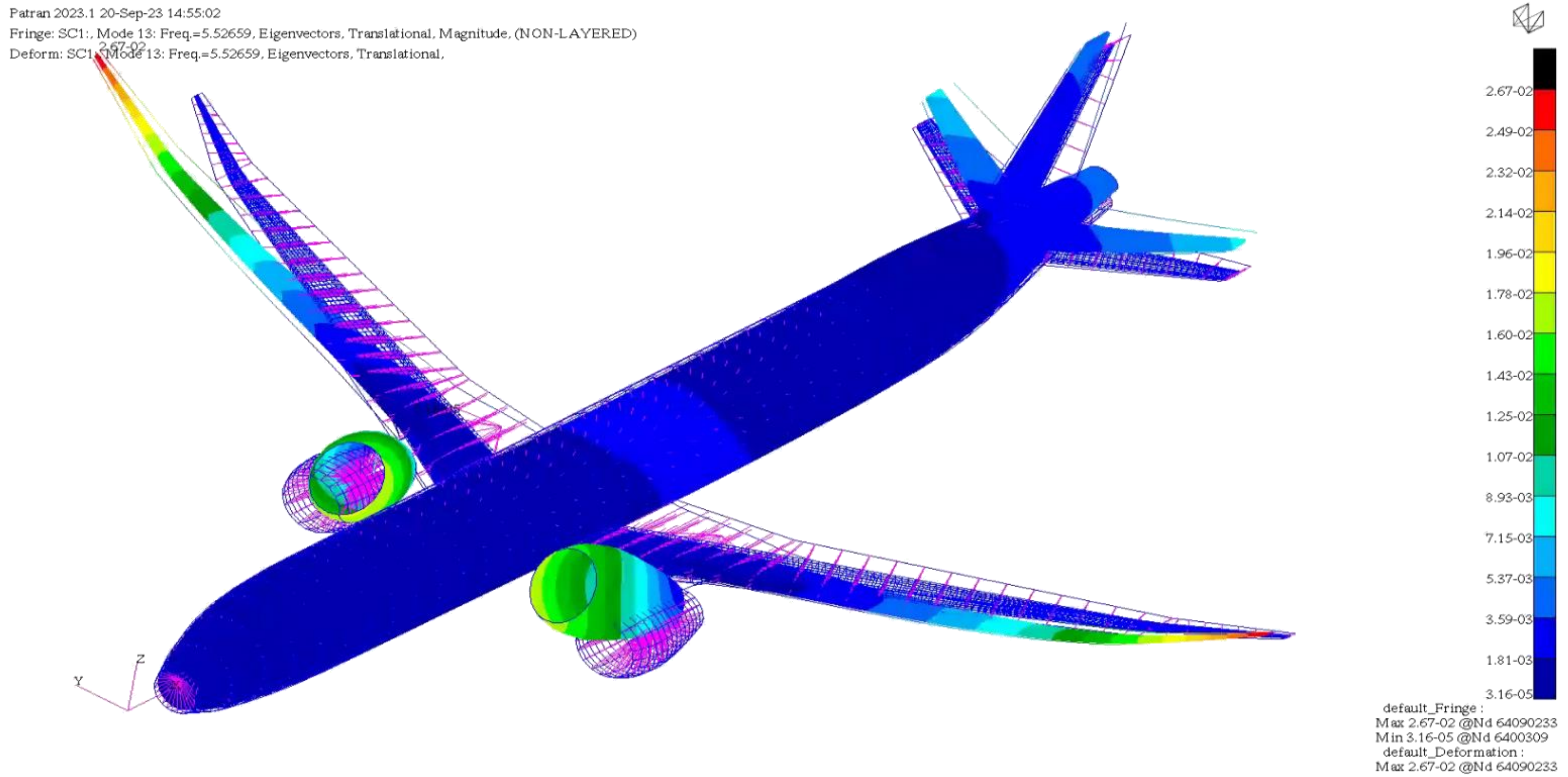


Aspect Ratio 13.01



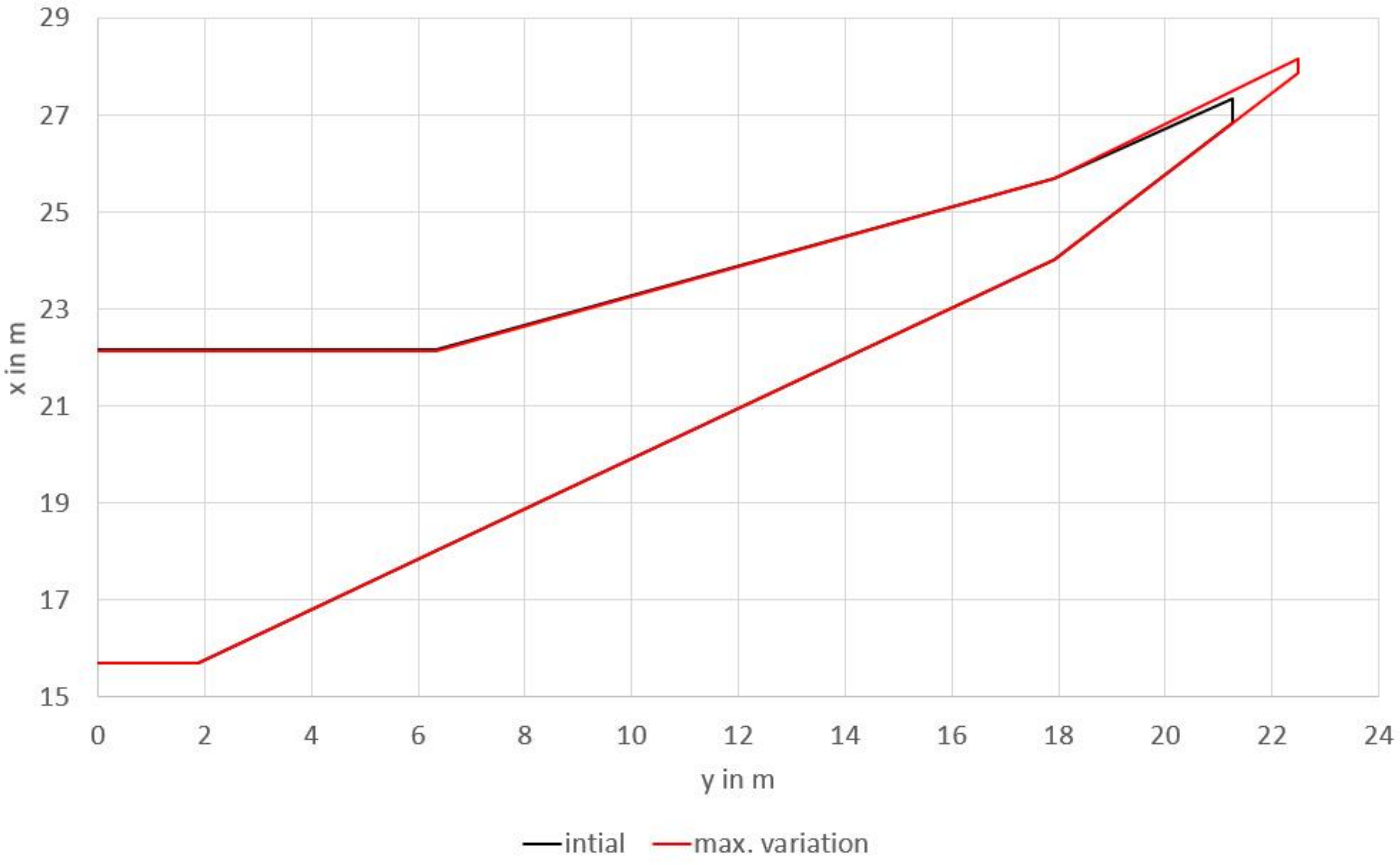
Paramterstudy – Aspect Ratio Kink Segment / Results

Contributing mode to flutter: Mode Nb13 @ 5.53 Hz



Parameterstudy – Span Tip Segment

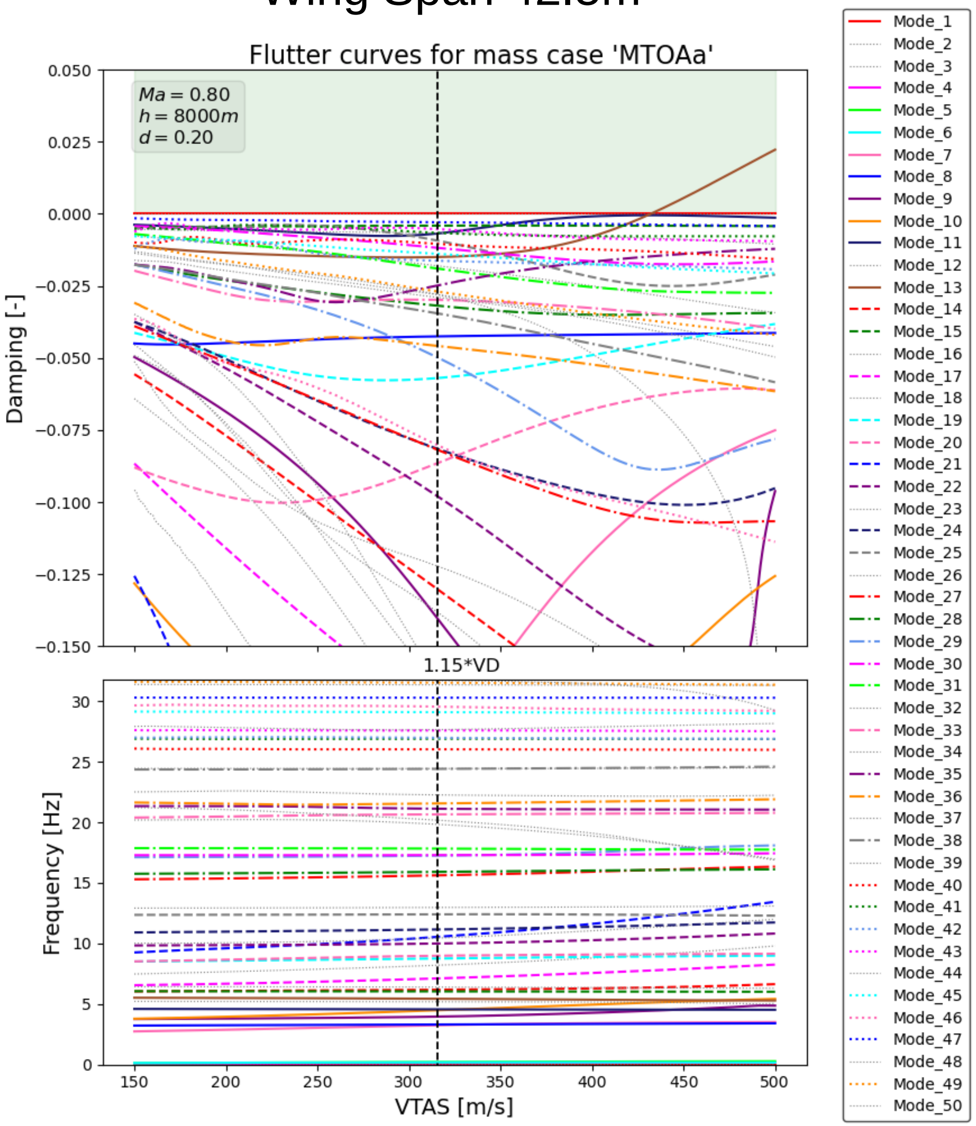
- Two Variations
- Span for 42.5m up to 45 m
- Length tip segment from 3.45m up to 4.6m
- Leading edge sweep constant
- Slight adaptation of trailing edge sweep to avoid too short tip chord
- No shift of wing position of openAD



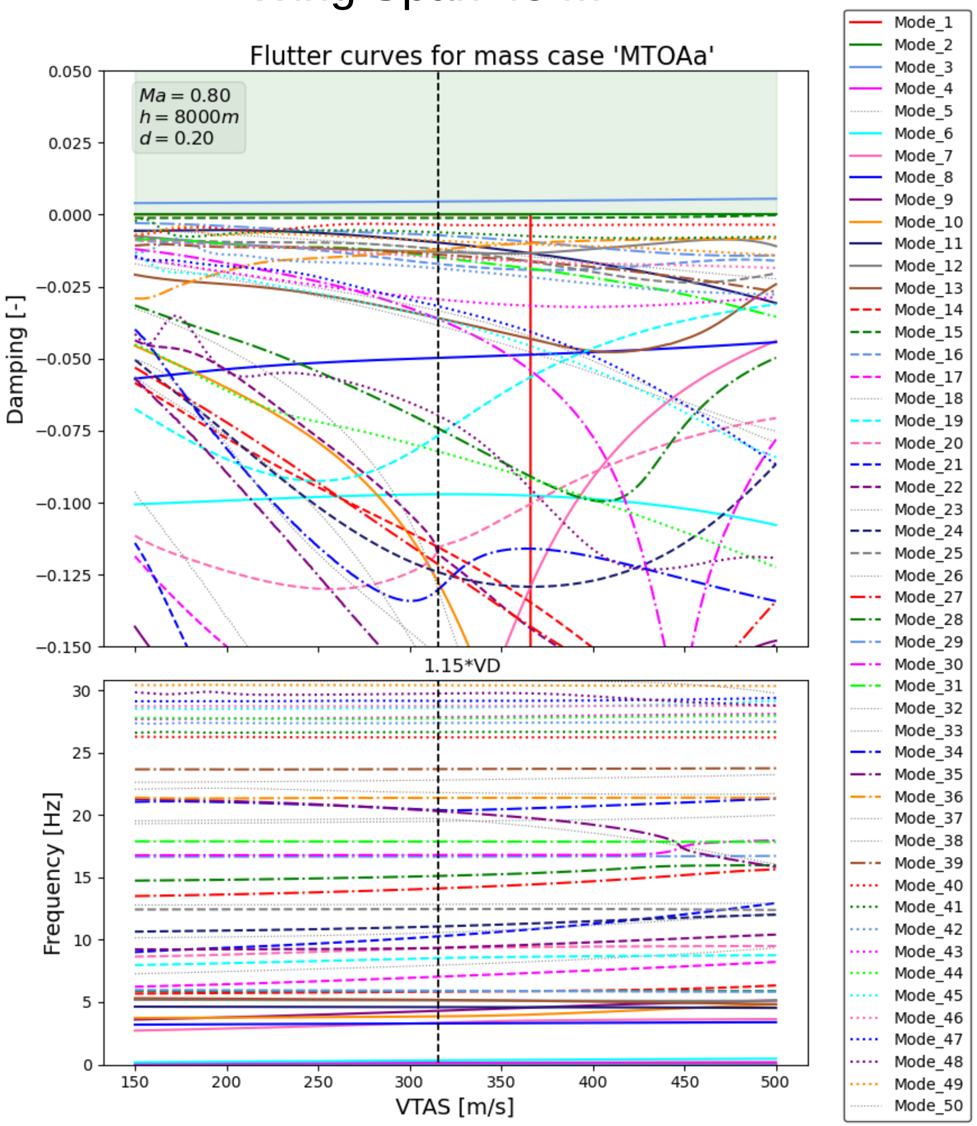
Paramterstudy – Span Tip Segment / Results

- Increase of flutter speed
- Increase of wing mass by 14%
- 1st Flutter mode of 45m wing no engine/pylon contribution

Wing Span 42.5m

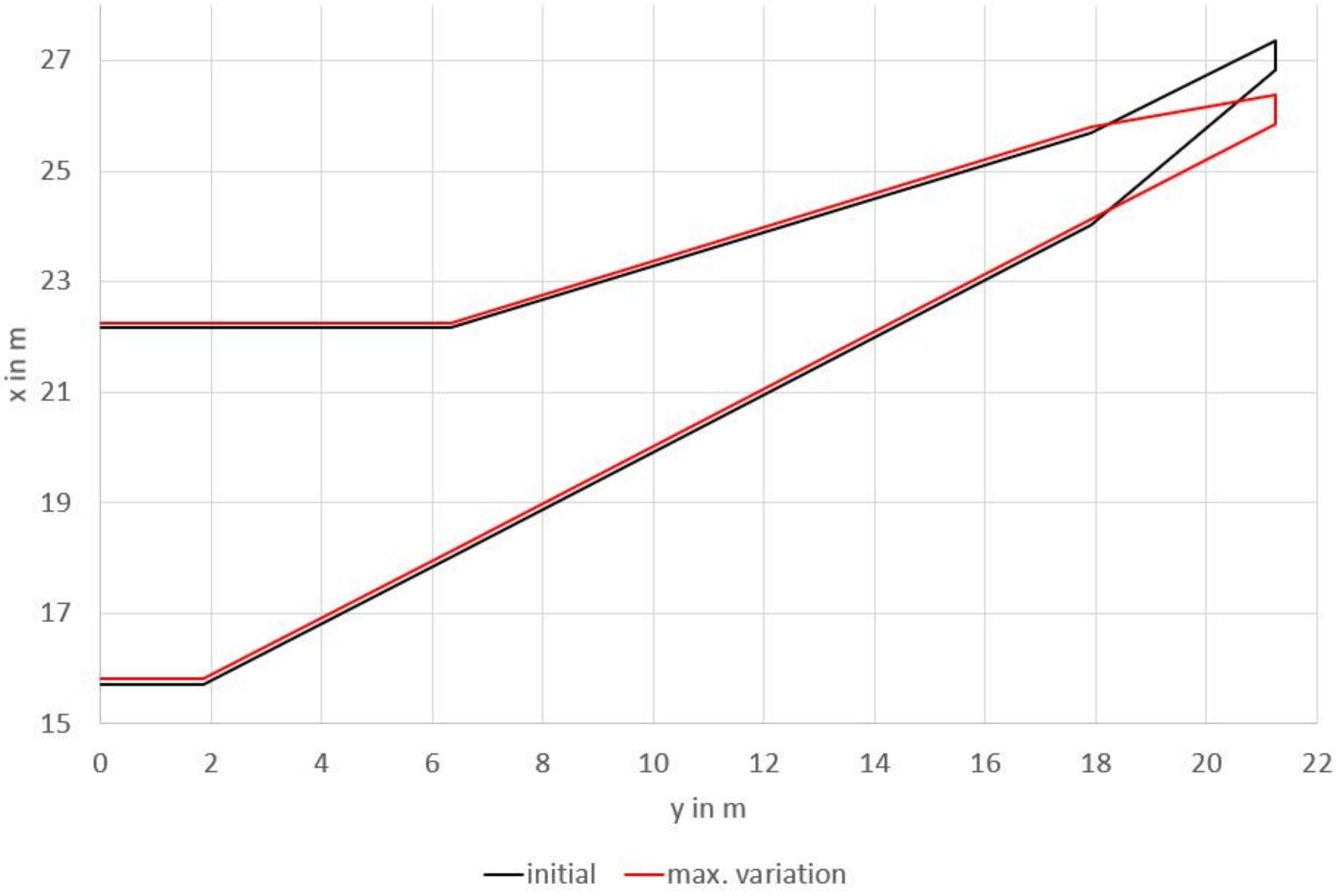


Wing Span 45 m



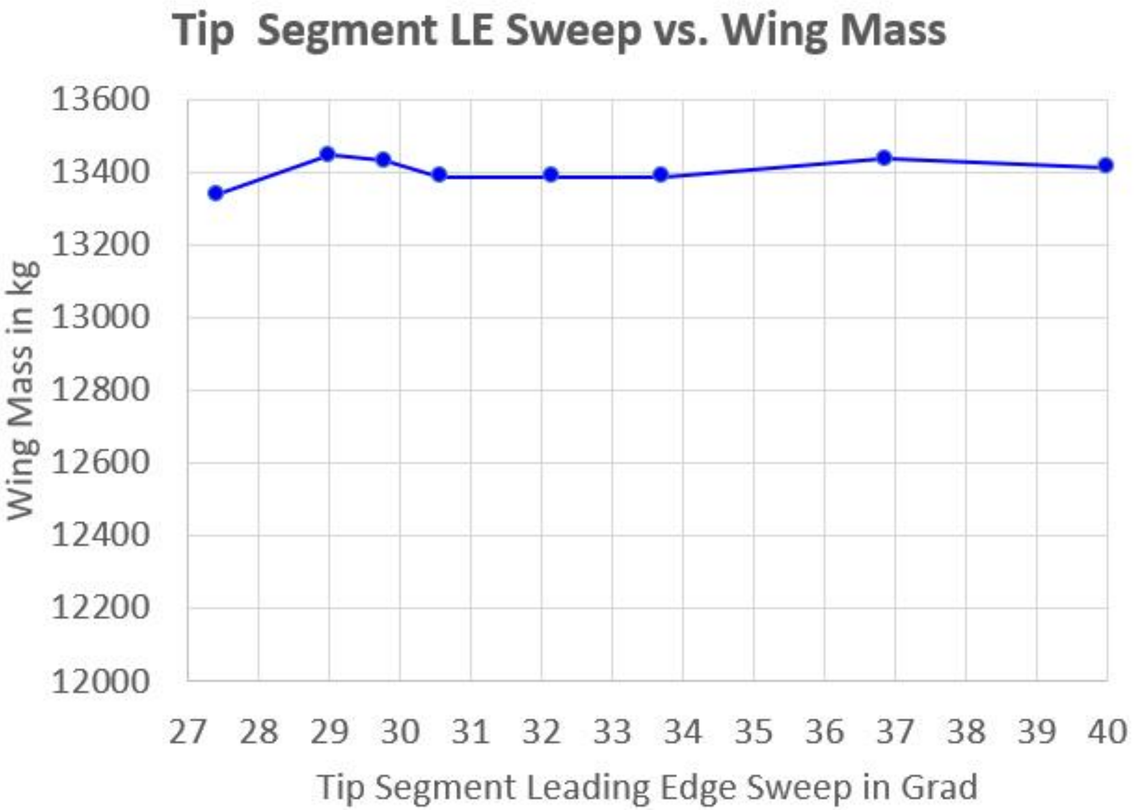
Parameterstudy – Tip Segment LE Sweep

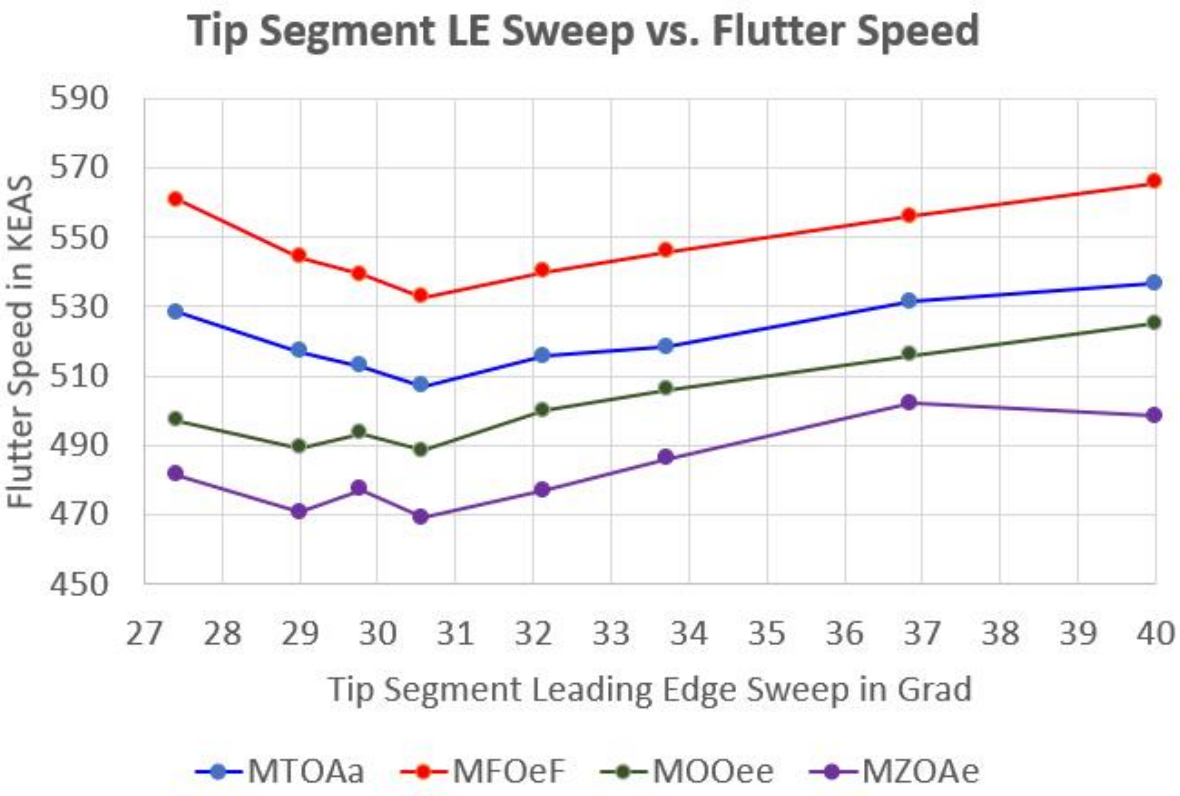
- Eight Variations
- Leading edge sweep tip segment
- Aspect Ratio of tip segment constant
- Leading edge sweep constant
- Slight adaptation of trailing edge sweep to avoid too short tip chord
- No shift of wing position of openAD



Paramterstudy – Tip Segment LE Sweep / Results

Results wing weight, flutter speed

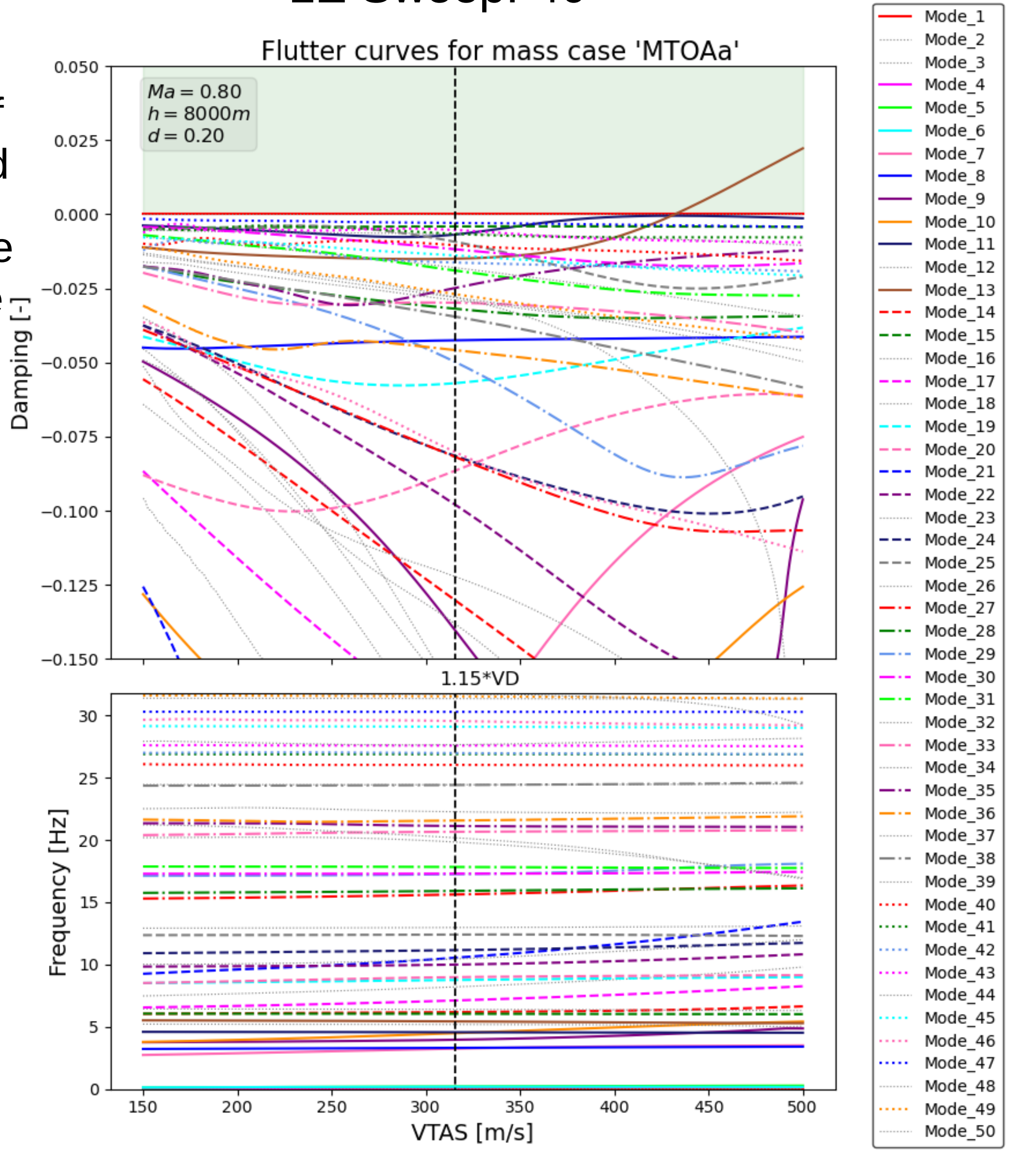




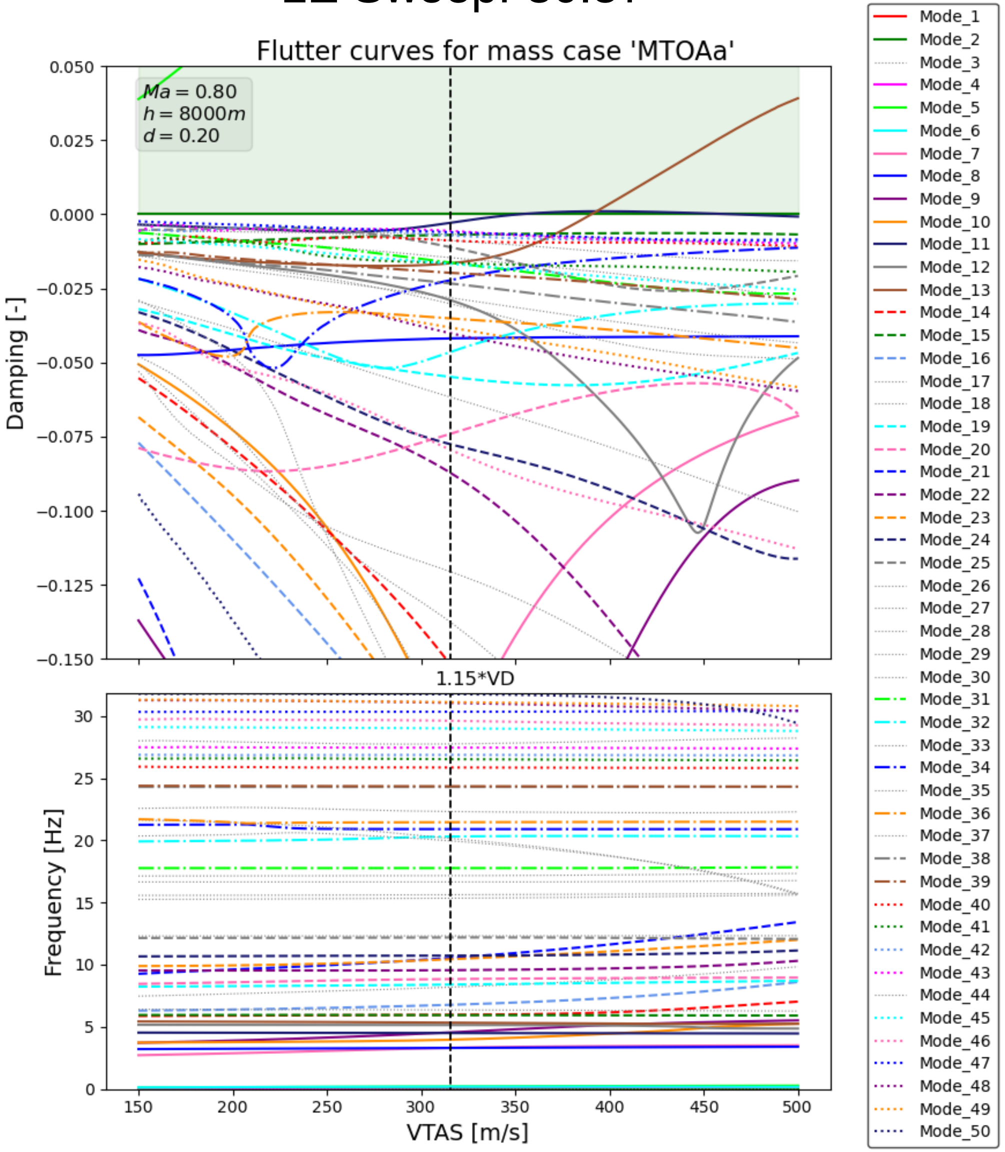
Paramterstudy – Tip Segment LE Sweep / Results

- Decrease of flutter speed
- Flutter mode coupling the same

LE Sweep: 40°



LE Sweep: 30.57°



Paramterstudy – Relaxation Dimensioning Criteria / Results

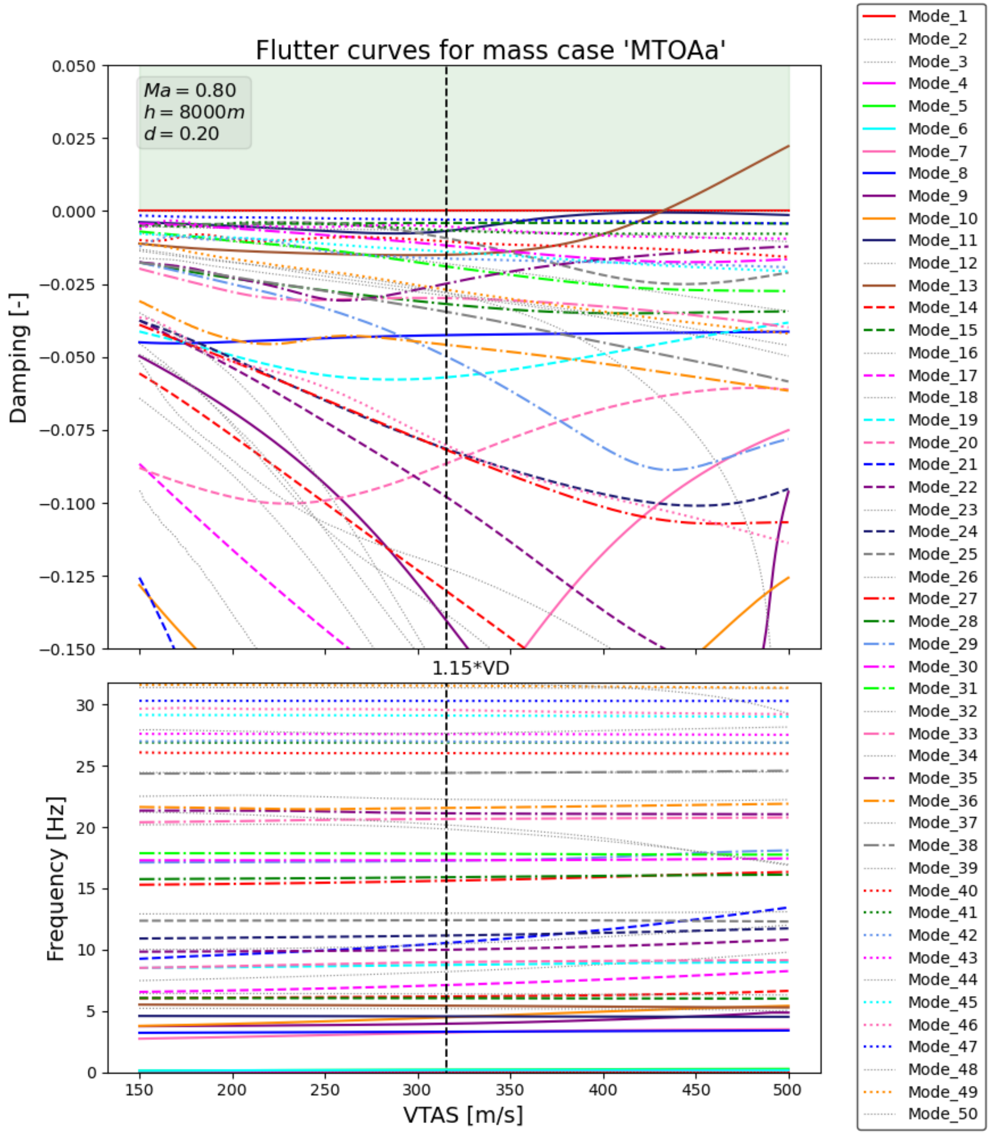
Dim. Criteria

- Max strain $4.0^{-3} \rightarrow 6.0^{-3}$
- Min strain $3.5^{-3} \rightarrow 5.25^{-3}$
- Shear strain $8.0^{-3} \rightarrow 12.0^{-3}$

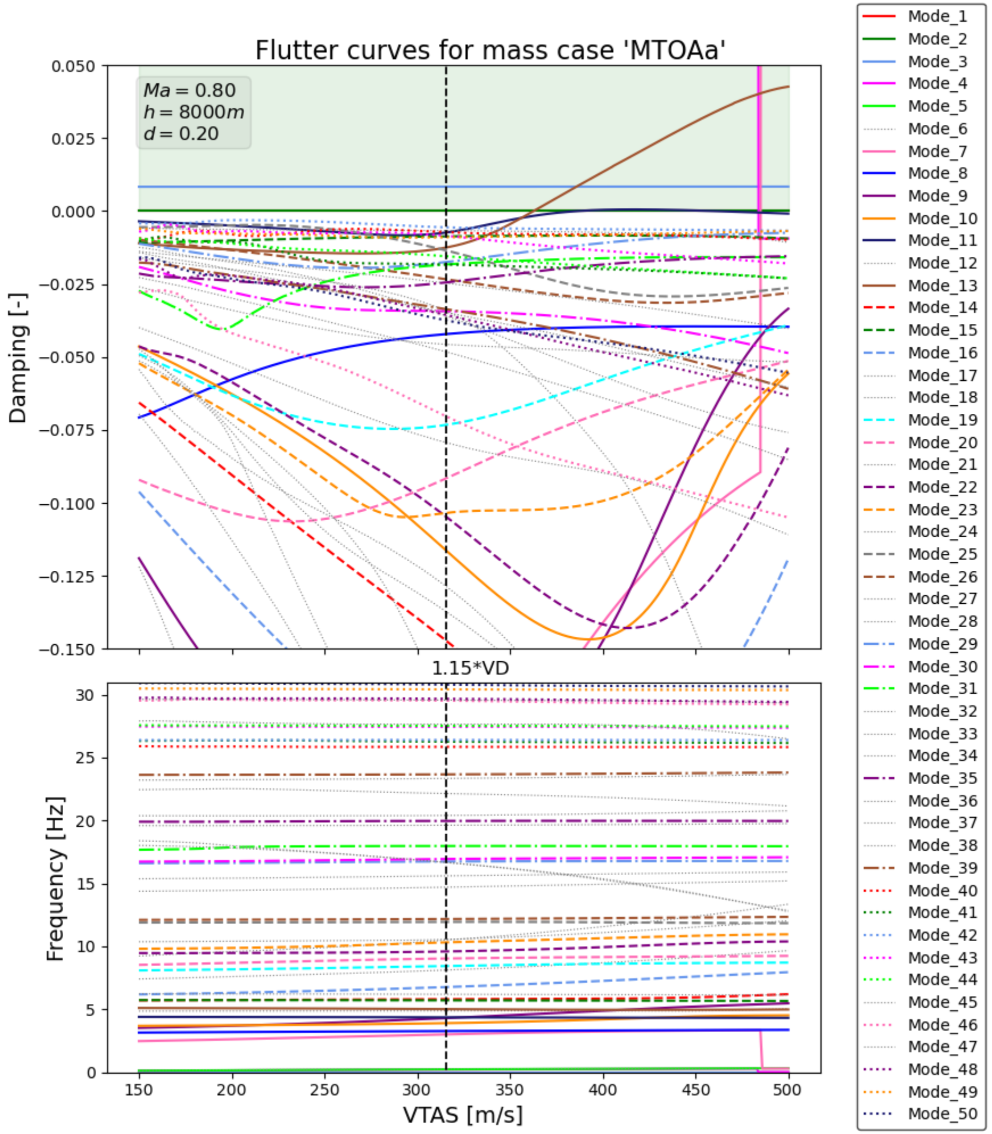
Results

- Decrease of flutter speed
- Reduction of wing mass by 14%

Initial



Relaxed Dim. Criteria

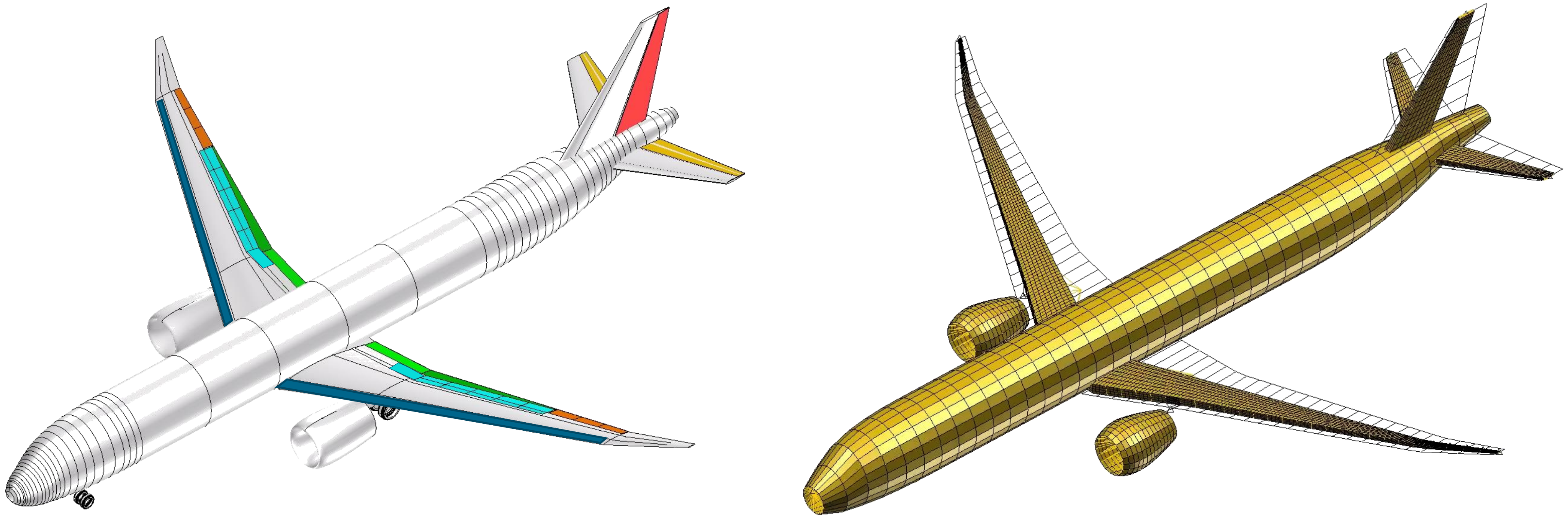


Summary and Outlook

- Brief introduction of the D2AE configuration
- Presentation of openAD/cpacs-MONA conceptual/preliminary aeroelastic design process for D2AE configuration
- Parameter study regarding flutter characteristics

- More detailed understanding of the flutter characteristics regarding the planform parameters and structural criteria

Thank you very much for your attention!



D2AE – developed @ DLR-AE