POTENTIAL AND LIMITATIONS WITHIN CONCEPTUAL AIRCRAFT DESIGN FOR THE OPTIMIZATION OF A FLEXIBLE WING WITH AND WITHOUT LOAD ALLEVIATION

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Bundesministerium für Wirtschaft und Klimaschutz
aufgrund eines Beschlusses des Deutschen Bundestages

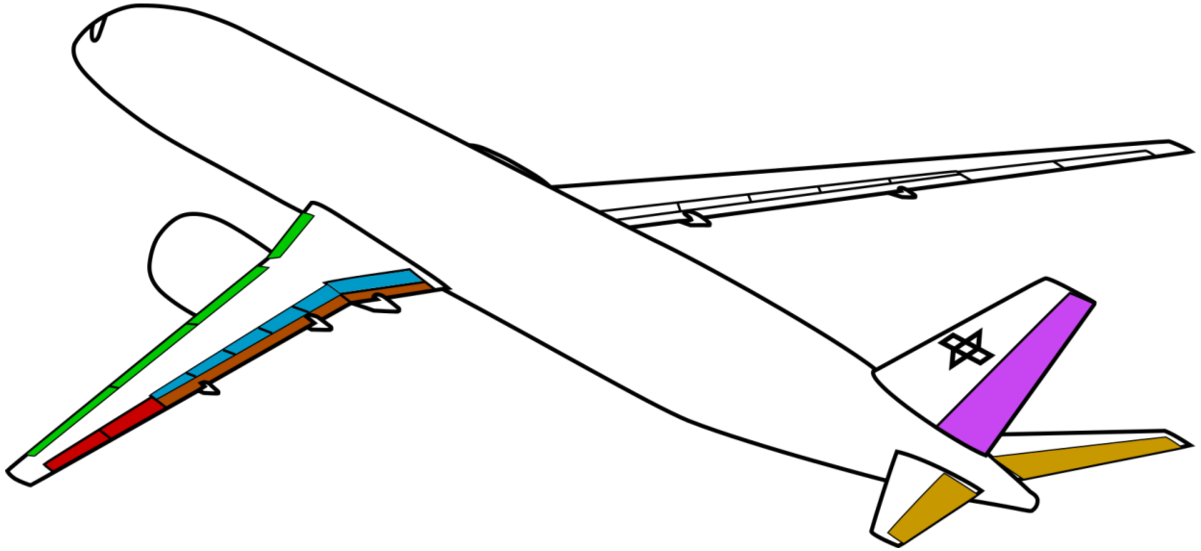
DLR

Outlook

- **Methodology** of the Process

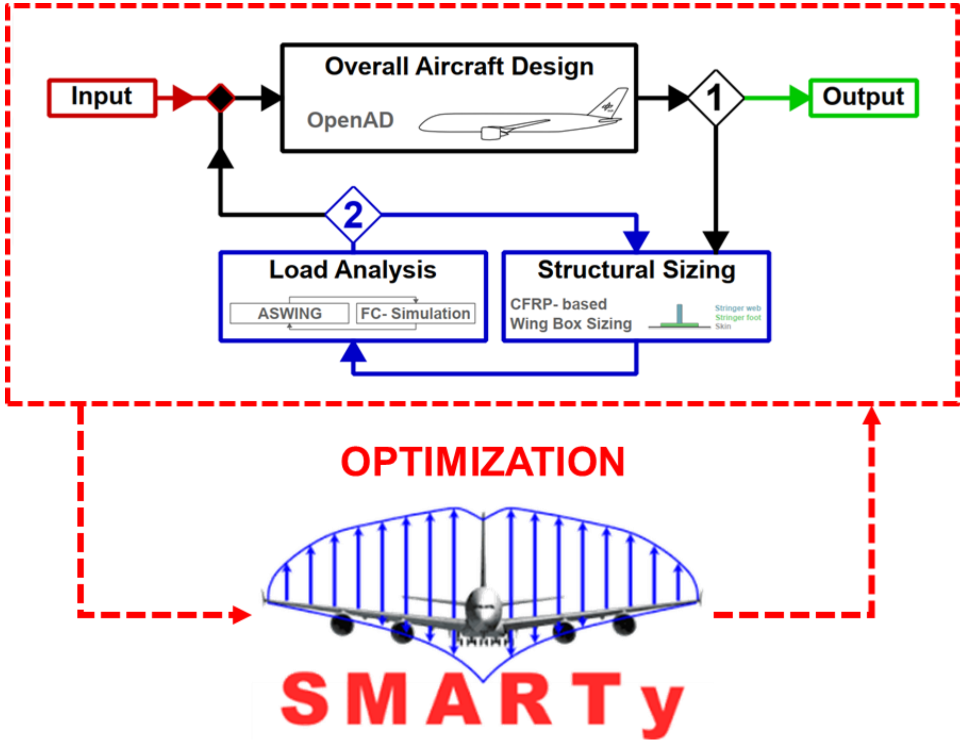
- **Results** for a Long Range Aircraft

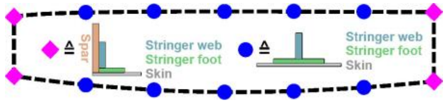
- **Summary** and Outlook



Overview Design Process

- OAD- Framework with **aeroelastic wing design**
  - ***Aeroelastic simulation*** (ASWING – Lifting Line and non-linear beam)
  - ***CFRP- design*** (Wingbox - constant topology)
- Optimization strategy
  - ***Surrogate*** Based Optimization (**SMARTy-** Toolbox)
    - Initial **Halton** Point DoE (min. 900 design points)
    - **Kriging** as surrogate model
    - Stepwise optimization





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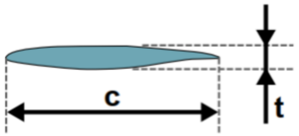
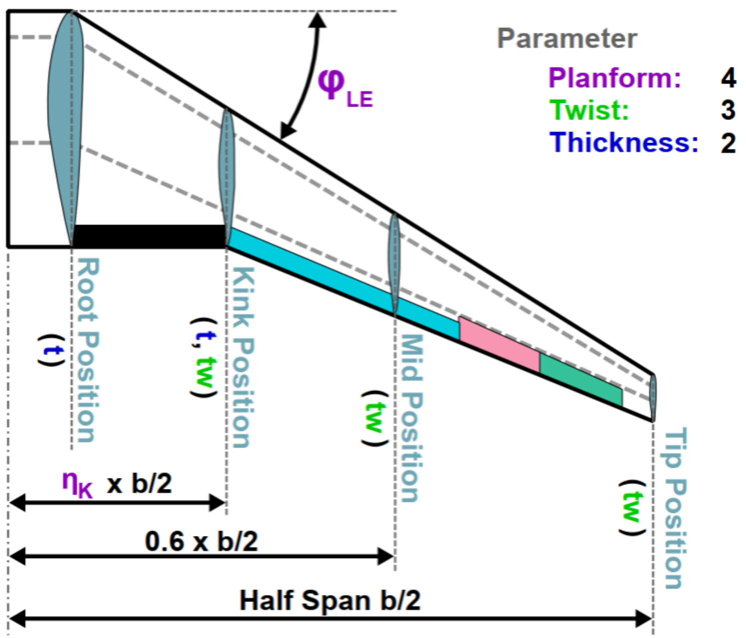
Design Space and Load Cases

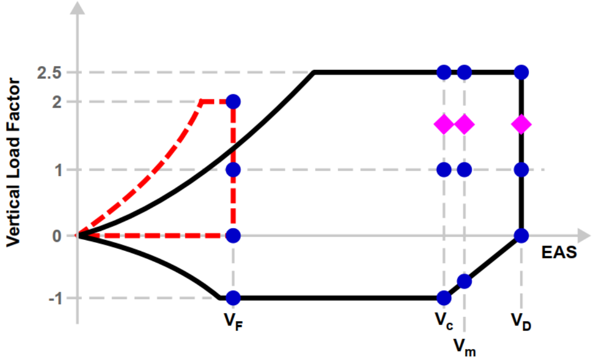
- **9** dimensional design space
- **Target function:** *combined* Block Fuel (related to transport work)
  - **3** different missions
- **16** maneuver load cases
- **24** gust load cases
  - Dynamic 1-Cos cases with FCS
  - Constant short-term oscillation behaviour

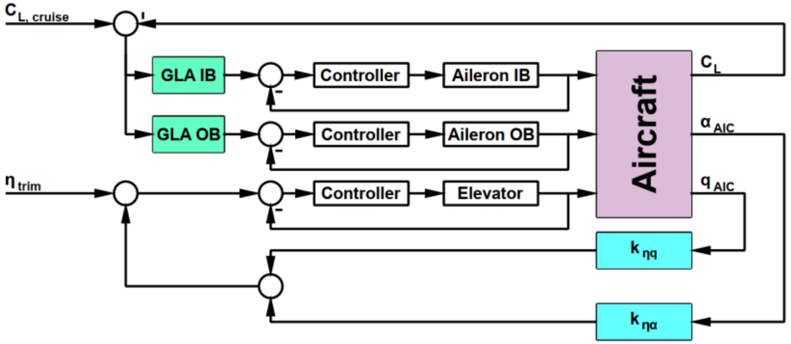


$AR = b^2 / S_{ref}$

$TR = c_{tip} / c_{root}$

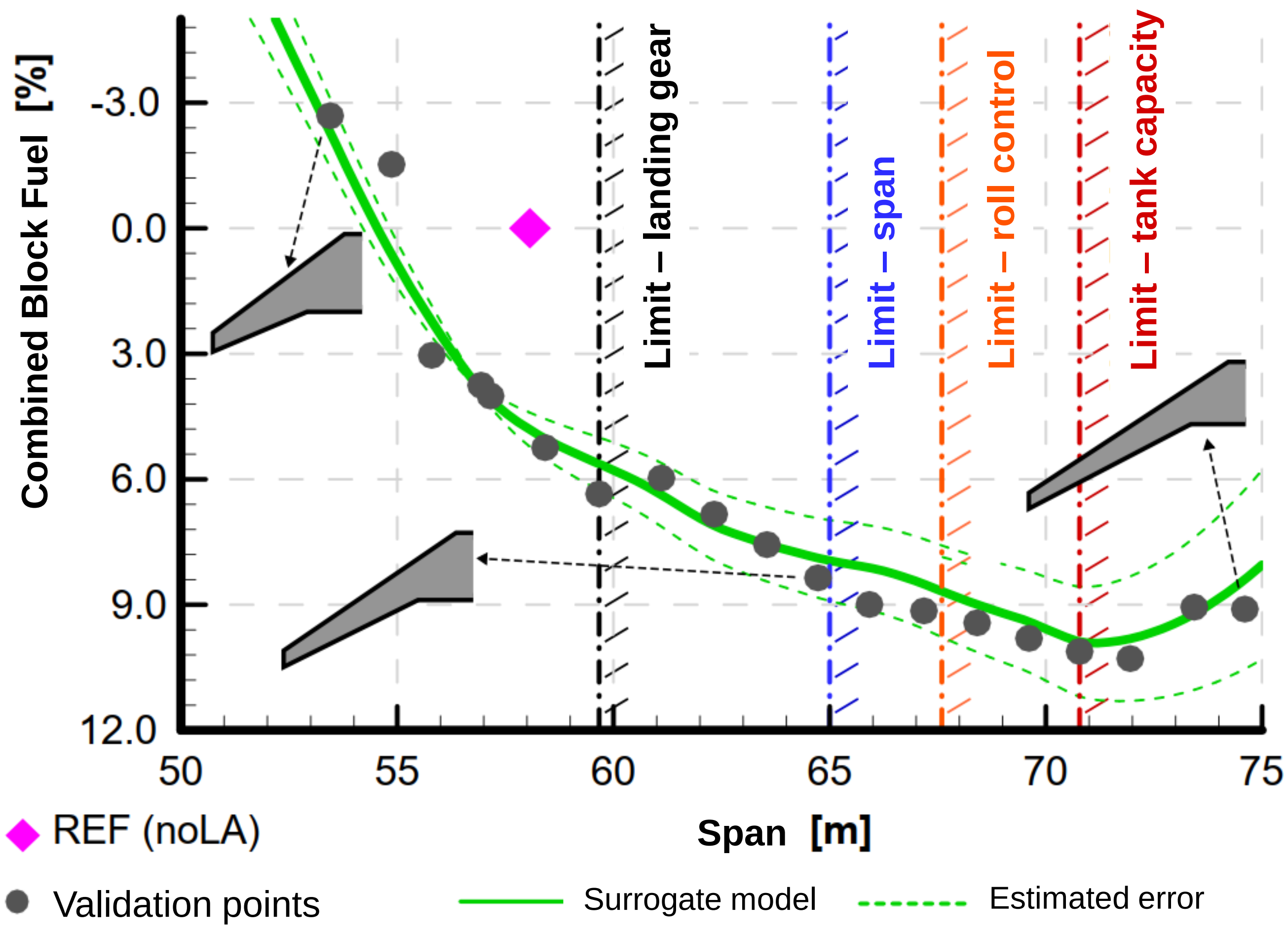






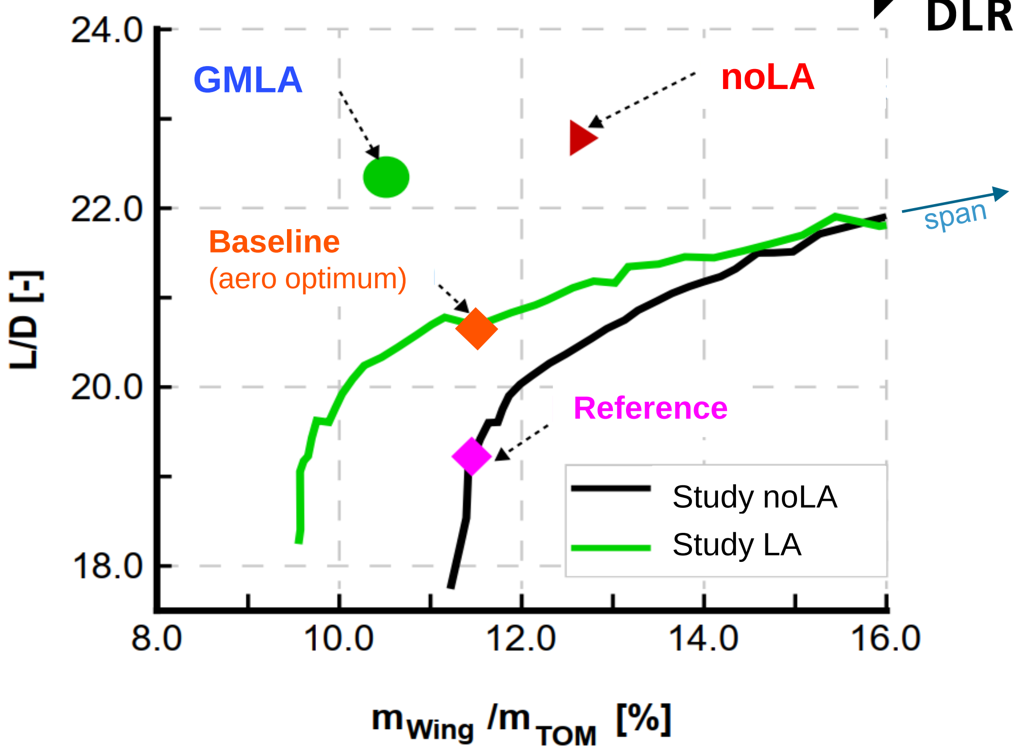
Results of pre-study (wing span)

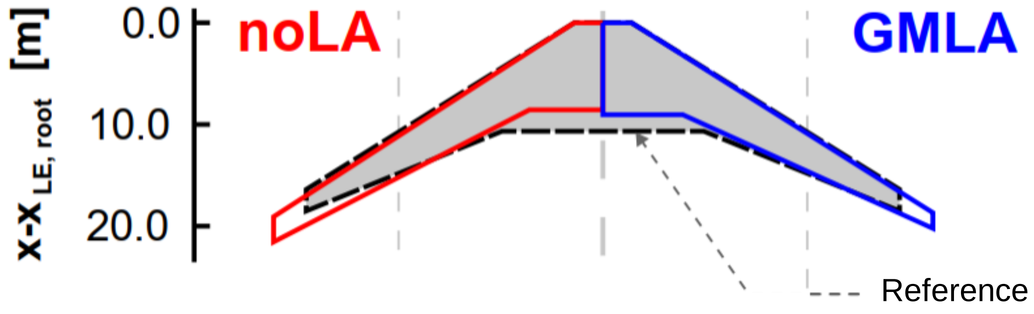
- Planform variation rational
  - Constant absolute kink position (→ engine/VTP)
  - Constant sweep of 50% line (→ wave drag)
  - Constant outer taper ratio (“limited” tip chord)
- Study provides additional validation
  - Surrogate model fits simulation data well
  - Estimated error increases towards the edge
- Limits consideration
  - Landing gear limit constrains design space too much
  - Neglecting this limit for further optimizations
- Local Minimum
  - Expectation: Optimization yield more than 10 %
  - Optimum should have higher span than the reference



Optimum with and without Load Alleviation

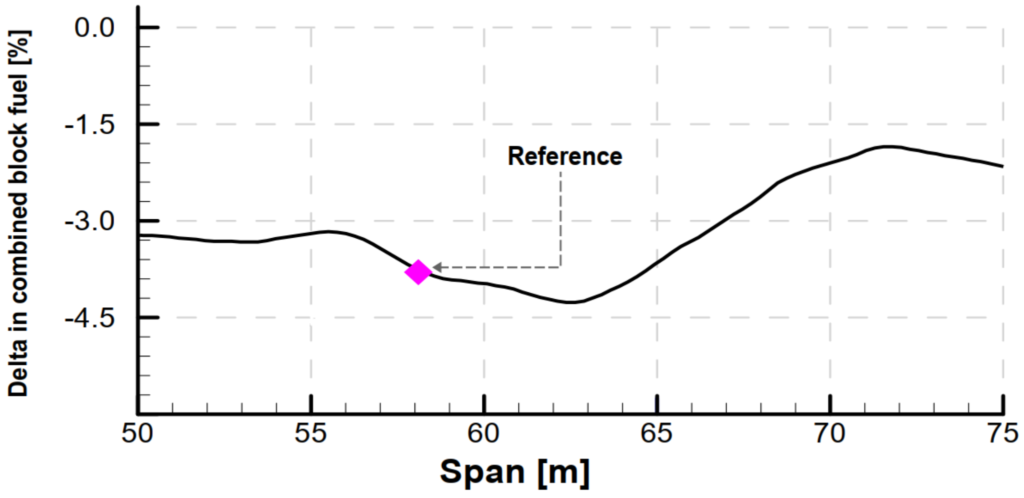
- Span study
  - At first strong increase of L/D
  - Towards higher AR → dominating increase in rel. wing mass
  - Further increase of L/D is limited
- Optima separate mainly in rel. wing mass
  - GMLA cases have reduced wing mass but also lower L/D
  - Constraints reduce wing mass and L/D
- Both planforms tend to a higher aspect ratio
  - The optimization reduces kink position to cl-max dependent minimum
  - Main difference between configurations is the taper ratio
  - Different wing position!





Optimum with and without Load Alleviation

- Potential of **active** load alleviation (based on surrogate model analysis)
  - Additional benefit of active load alleviation
  - Dependent on the AR/span
  - For more flexible wings and higher spans the potential is reduced

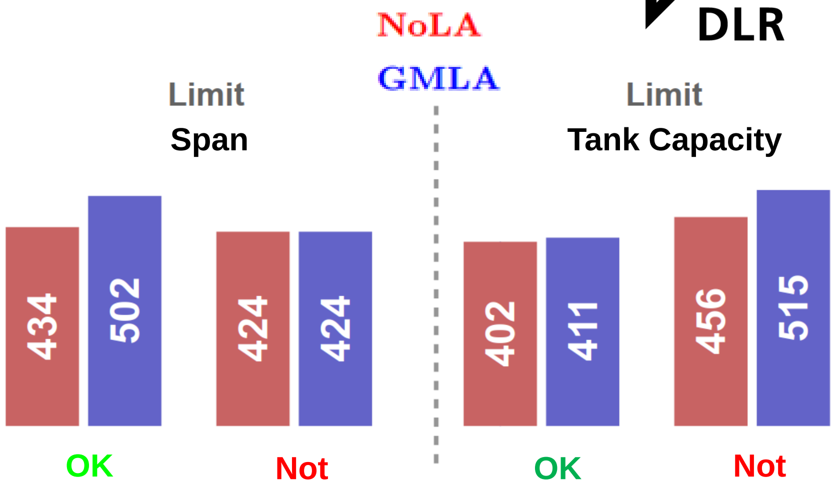


- „Breakdown“ of the up 20 % block fuel savings (REF)
  - Twist optimization ~ 3.0 %
  - t/c optimization (no further BCs) ~ 4.1 %
  - Synergetic combination (Baseline) ~ 9.0 %
  - Active load alleviation span dependent ~ 1.6 – 4.5 %
  - Wing planform optimization up to 9.3 %

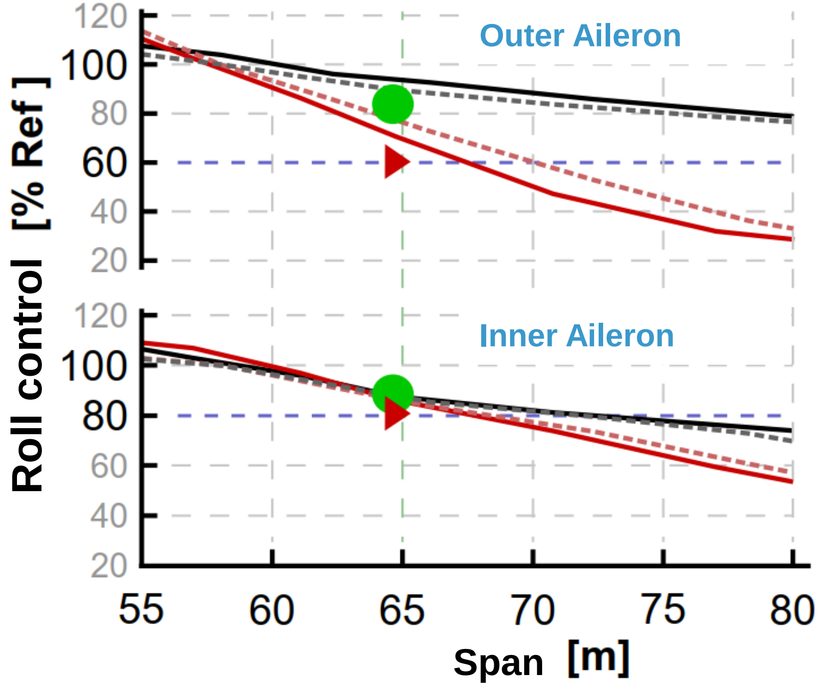
A/C Design	Comb. Block Fuel $[10^{-4} km^{-1}]$	To Baseline [%]	To noLA [%]
Reference	2.0431		
Baseline	1.8598	⊙	
NoLA	1.6703	-10.19	⊙*
GMLA	1.6438	-11.61	-1.59

Discussion of Boundary Conditions (Limits)

- GMLA **increases** the number of valid designs
  - Total: 91.4 % compared to 84.7 % for noLA
  - Span limit: 502 / 434 (+16 %)
  - Tank capacity limit: 411 / 402 (+2 %)

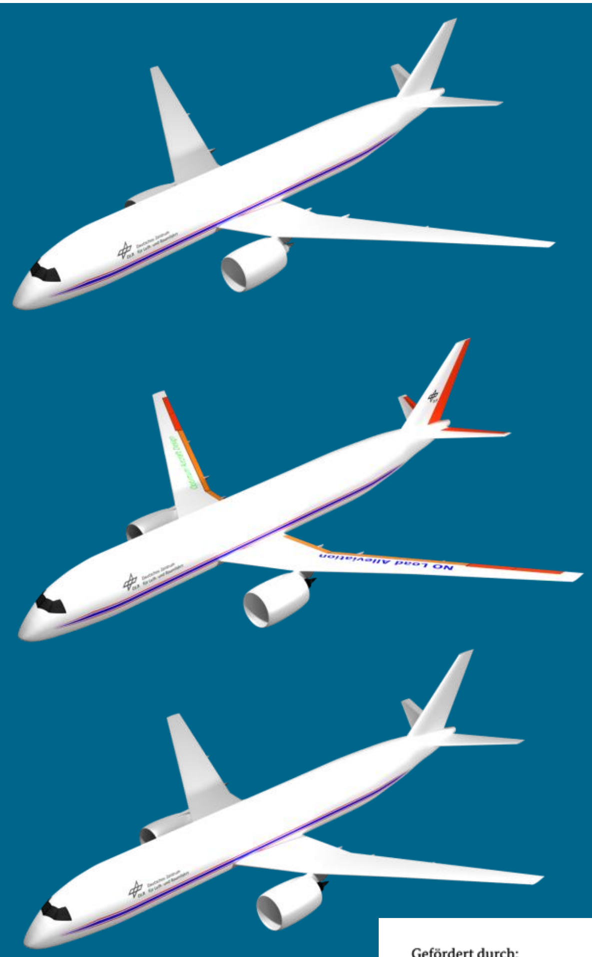


- Roll control (**schwarz**: rigid, **rot**: flexible)
  - From dynamic bank-to-bank roll maneuver
  - Reduced roll control due to flexibility
  - Earlier limit defined as 60% outer AIL und 80% inner AIL
  - Here no aileron reversal (high torsional stiffness design)



Summary

- Successful, physics-based integration of LA in conceptual aircraft design
  - Creation and validation of surrogate models
  - Fundamental trends can be shown based on 1-D studies
  - Active load alleviation has a span (flexibility) dependent influence
- Optimum with GMLA **11.6%** Optimum noLA **10.2%** → Why?
  - Larger wing allows for more inboard kink position (condition: successful 2.5g case)
  - **Overall aircraft effects** → Empennage sizing
- So why load alleviation in conceptual aircraft design?
  - Keep the possible **design space less restricted** by more and more limits
  - Keep the **aircraft mass** lighter → overall advantages including costs
  - Handle **transonic flow** at the outer wing, in particular during pull-up



Funding

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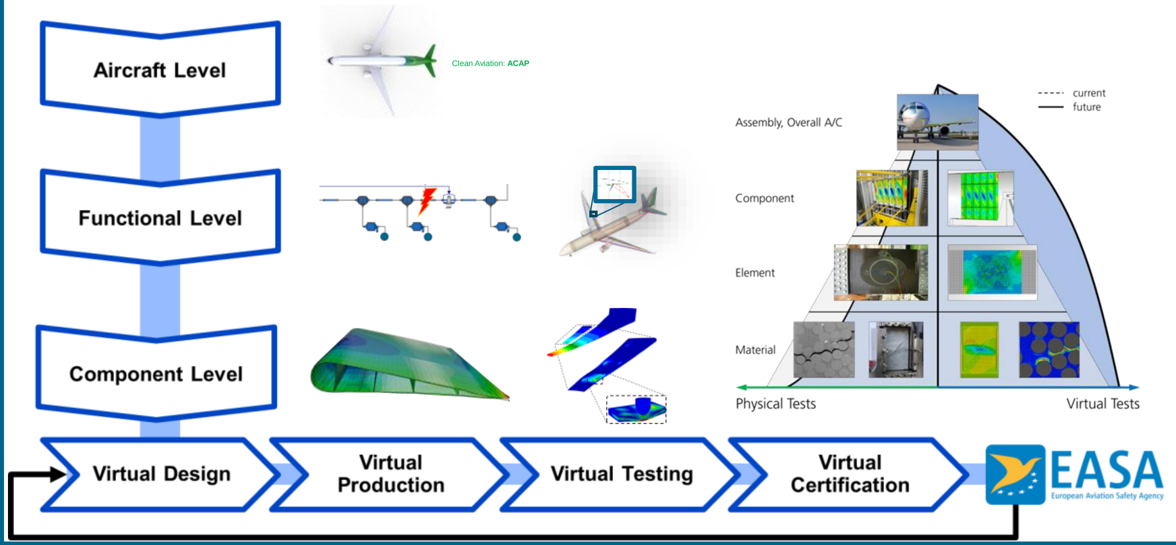
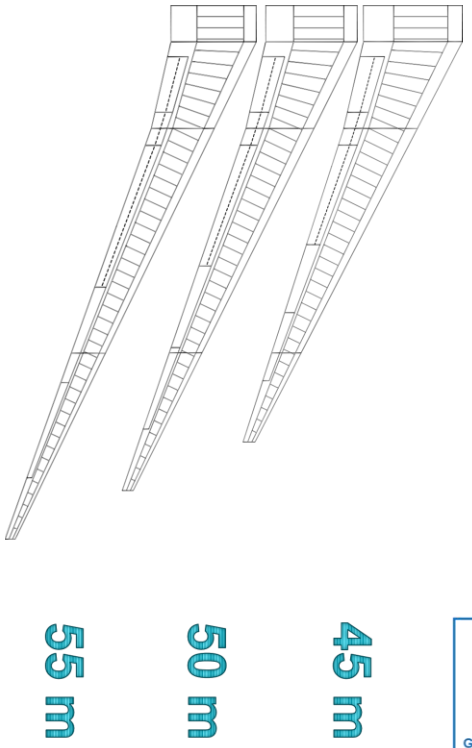
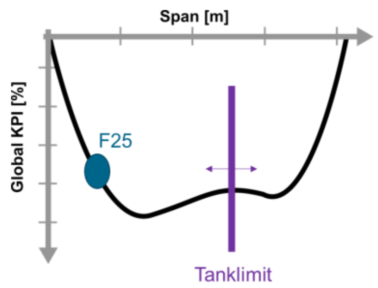
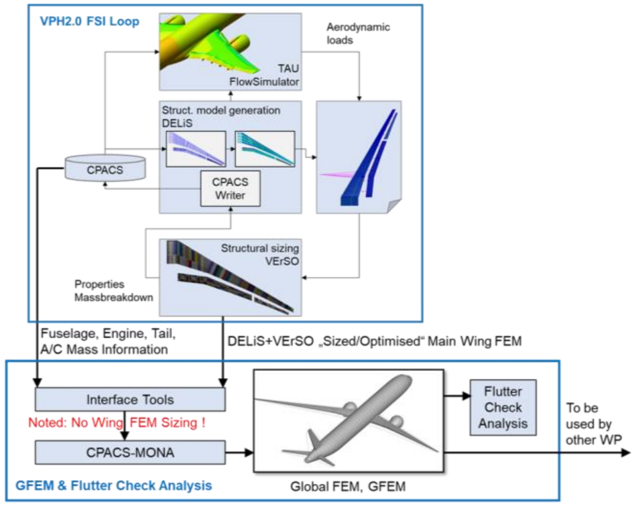
Outlook: Clean Aviation Project UP Wing WP 1

- Optimization of HAR-SMR wing (Baseline: 45m)
- Including digital End-to-End process (horizontal integration)
  - Virtual Product House (VPH) in Bremen (Focus: Moveables)
- OAD- Link for global KPI trade-curve (vertical integration)
  - cooperation with Clean Aviation: **ACAP**









The European UP Wing project: Developing and maturing technologies for an high aspect ratio wing

Bruno Stefes
Airbus (Germany)

→ **Friday, Session 5**

CLEAN AVIATION
Co-funded by the European Union