EXACT public symposium

STRUCTURAL WING AND FUSELAGE DESIGN

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Content

- Motivation
- Methods
- Configurations
- Assessment of loads, wing and fuselage mass
- Summary

Motivation
EXploration of electric Aircraft Concepts and Technologies

Conceptual study for environment-friendly flight

<u>Goals:</u>

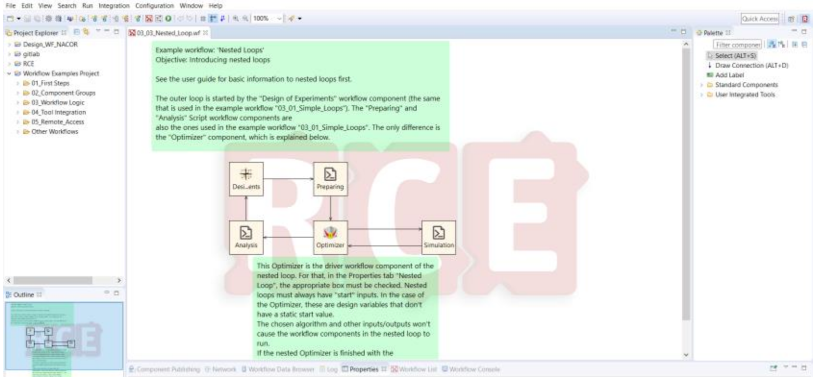
- identify **aircraft concepts** and **enabling technologies** for climate neutral flight
  - propulsion system concepts considering batteries, fuel cells and hydrogen

➢ expertise from different areas necessary

➢ wide design space studies of aircraft concepts

- a lower level of detail but high computational efficiency is required for fast overall aircraft design (OAD)
- analytical methods are used for structural sizing – more detailed than empirical handbook methods

Methods

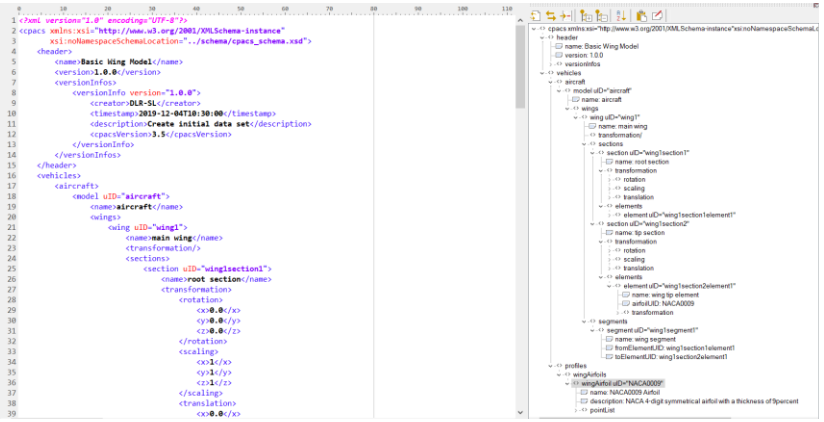


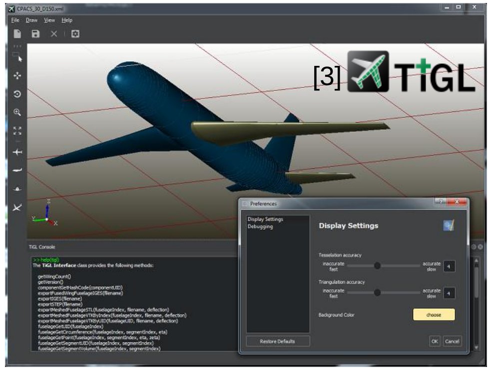
RCE used for integration of tools in a multidisciplinary workflow for overall aircraft design (OAD)

RCE [2]

- Remote Component Environment

Methods



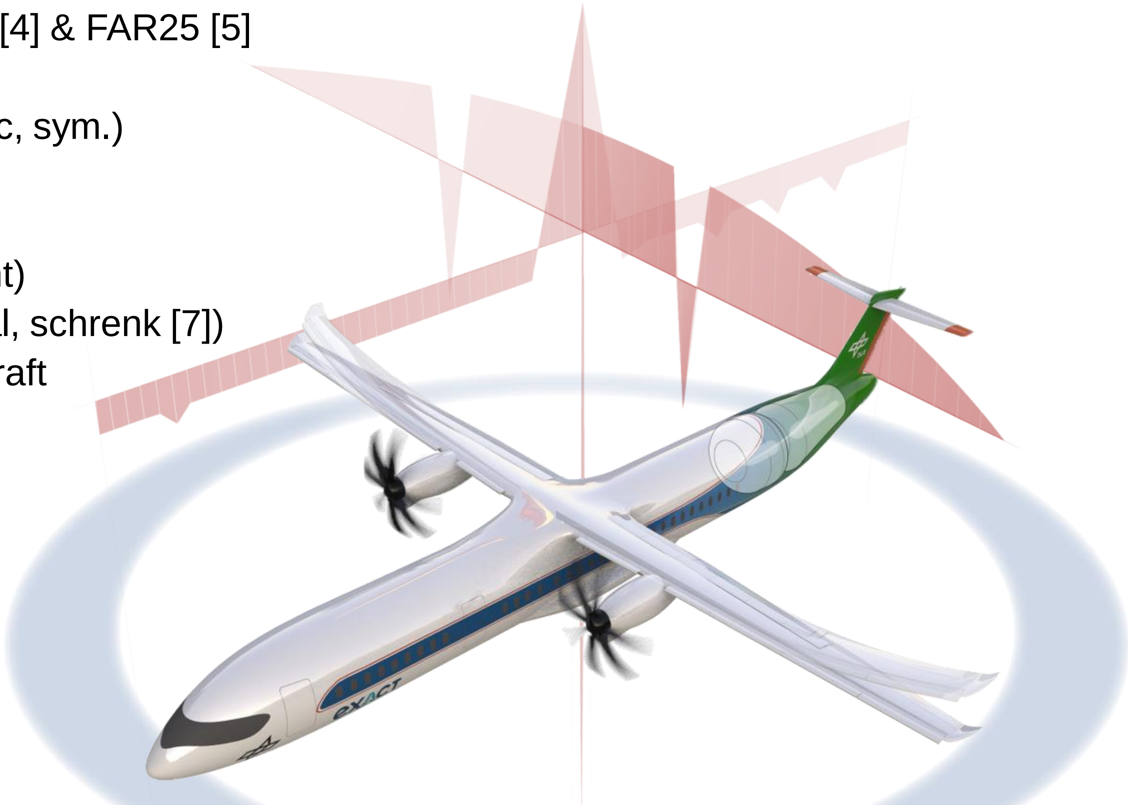


CPACS used for data exchange between tools

- Common Parametric Aircraft Configuration Schema

Methods

- CPACS minimal input – rigid aircraft
- load cases in accordance to CS25 [4] & FAR25 [5]
  - flight loads
    - manoeuvre (quasi-static, sym.)
    - gust (Pratt [6])
  - ground and landing loads
- mass model (volumetric, area, point)
- lift distribution (elliptical, trapezoidal, schrenk [7])
- load factor and acceleration of aircraft

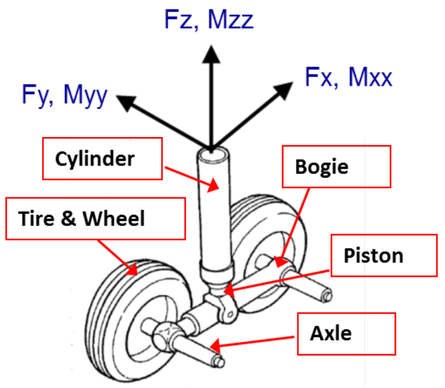


RCE [2]

LOADzero

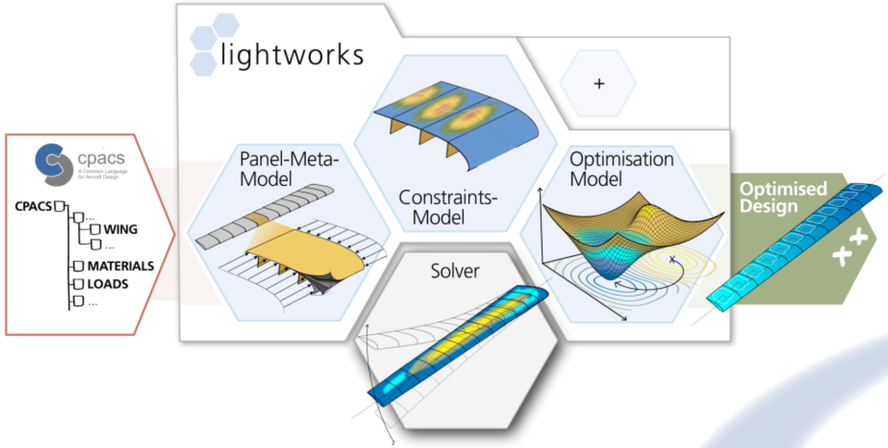
➢ loads estimation

cpacs [1]

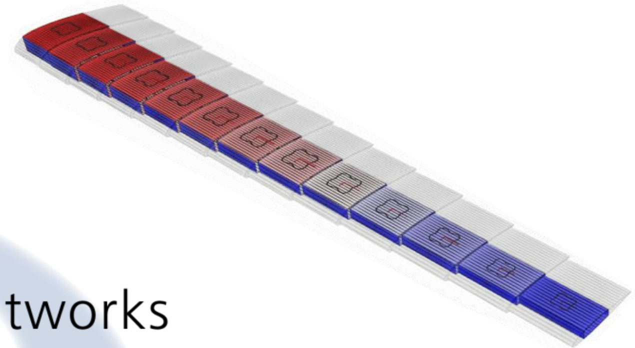


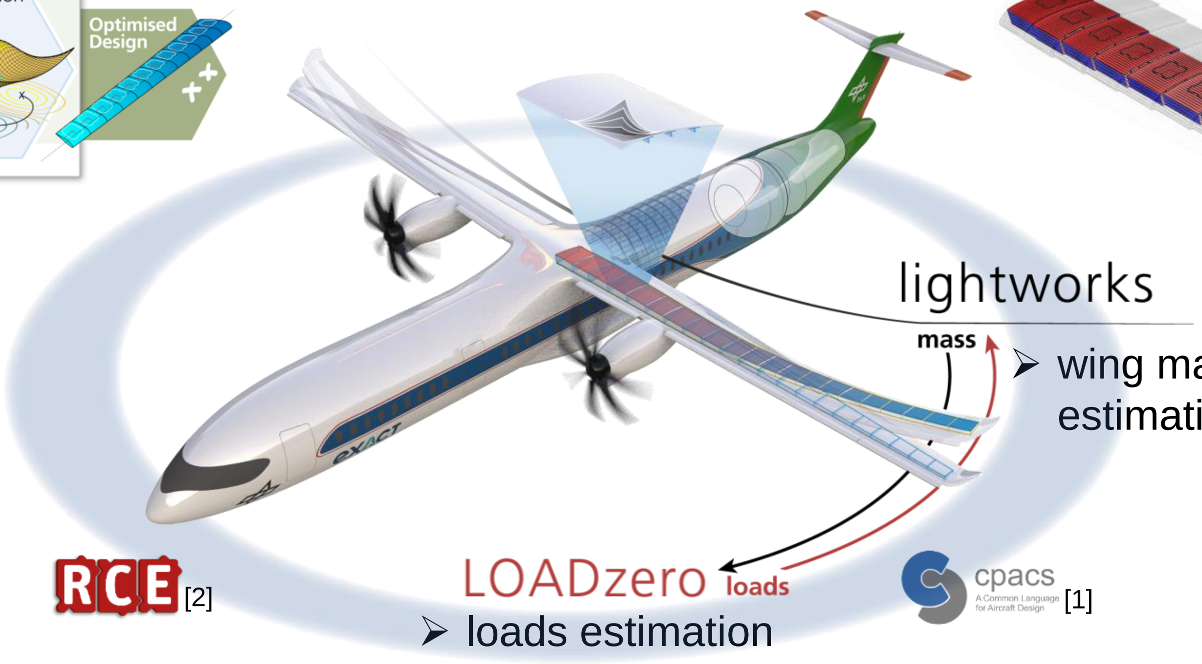
Methods

- Gradient-based structural design with flexible configuration options of the optimisation problem



- Gradient-based optimization derives optimal structural solution but computationally expensive
- Gradients: ~2h, Fully stress design: ~8min





➢ wing mass estimation

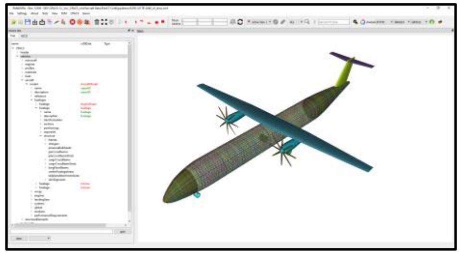
➢ loads estimation

Methods

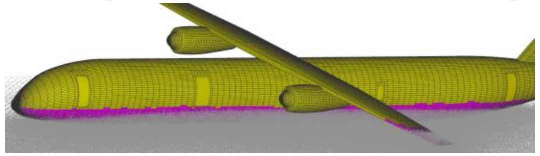
PArametric **N**umerical **D**esign and **O**ptimization **R**outines for **A**ircraft

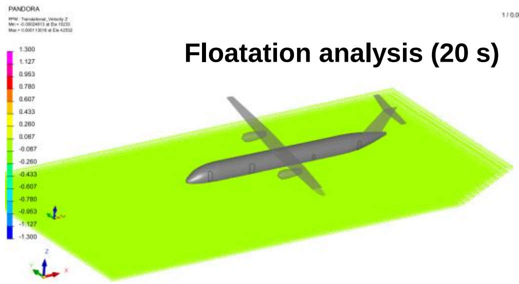
CPACS

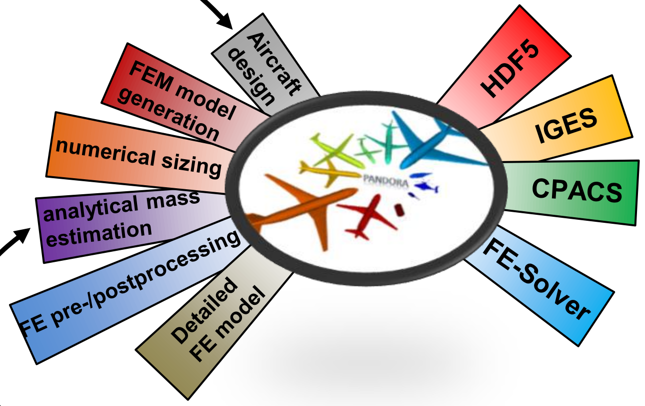
- create aircraft
- define aircraft structure



Floatation analysis using FPM (Finite Pointset Method)

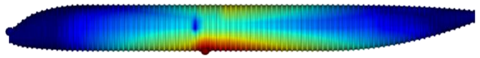




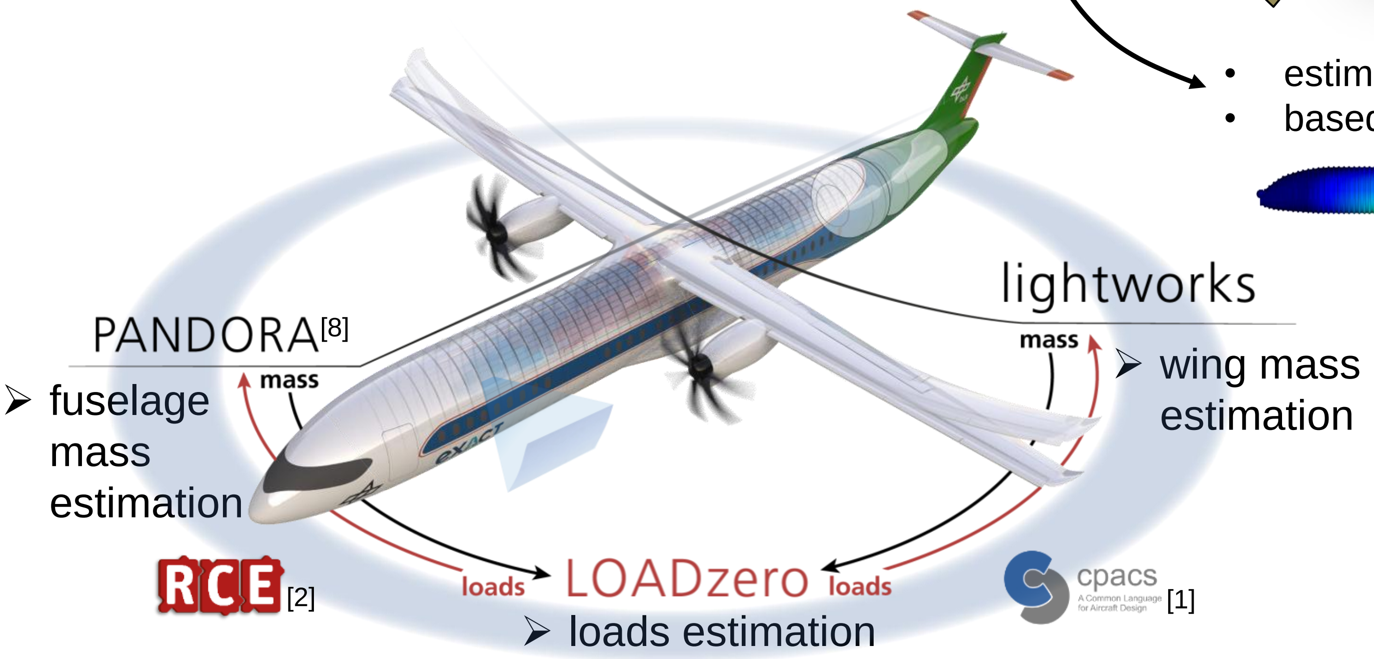


analytical

- estimate structural mass
- based on Barlow's formula



runtime: ~1min

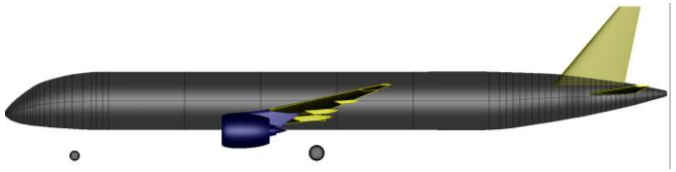


Configurations short range

- fuel tanks require space with a margin for systems and maintenance
- typical integration of LH2 tanks in the rear of the fuselage for manageable shifts in centre of gravity i.e. moderate tank size
- volumetric kerosene mass within wing due to LH2 is absent

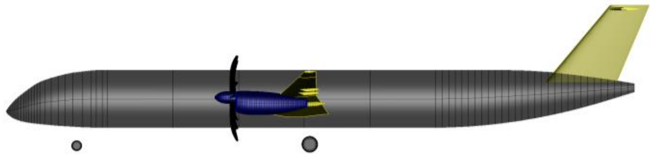
	short range
Design range [NM]	1500
Design PAX	250
Entry Into Service	2040

- Turbofan SynFuel / Fossil Kerosene



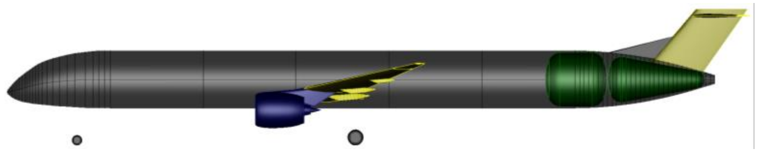
OEM: 47.7 t
MTOM: 80.83 t
Fuselage length: 46.85 m

- Turboprop SynFuel / Fossil Kerosene



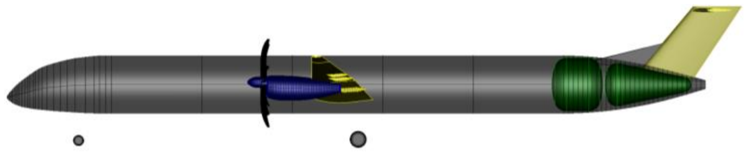
OEM: 44.9 t
MTOM: 75.99 t
Fuselage length: 45.19 m

- Turbofan Mild-Hybrid LH2



OEM: 55.3 t
MTOM: 82.58 t
Fuselage length: 50.57 m

- Turboprop Mild-Hybrid LH2

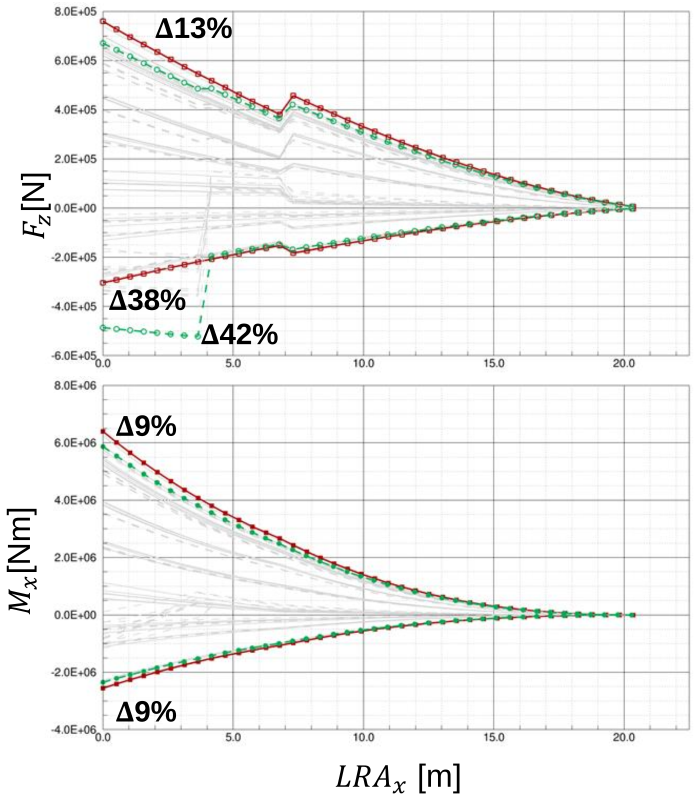


OEM: 51.0 t
MTOM: 77.60 t
Fuselage length: 49.38 m

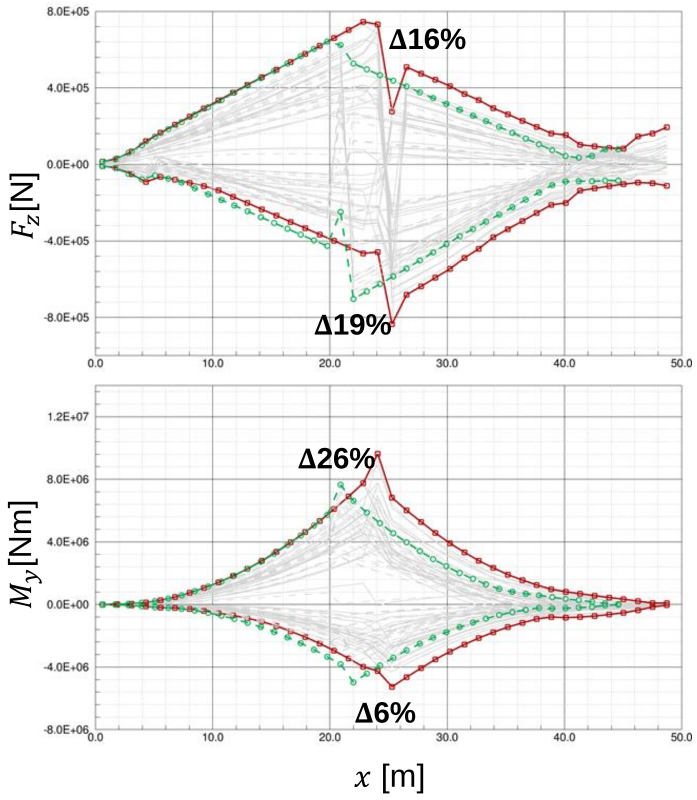
- How does the conceptual loads and mass estimation change when LH2 is used?

Assessment of loads, wing and fuselage mass Comparison Turboprop

wing loads comparison



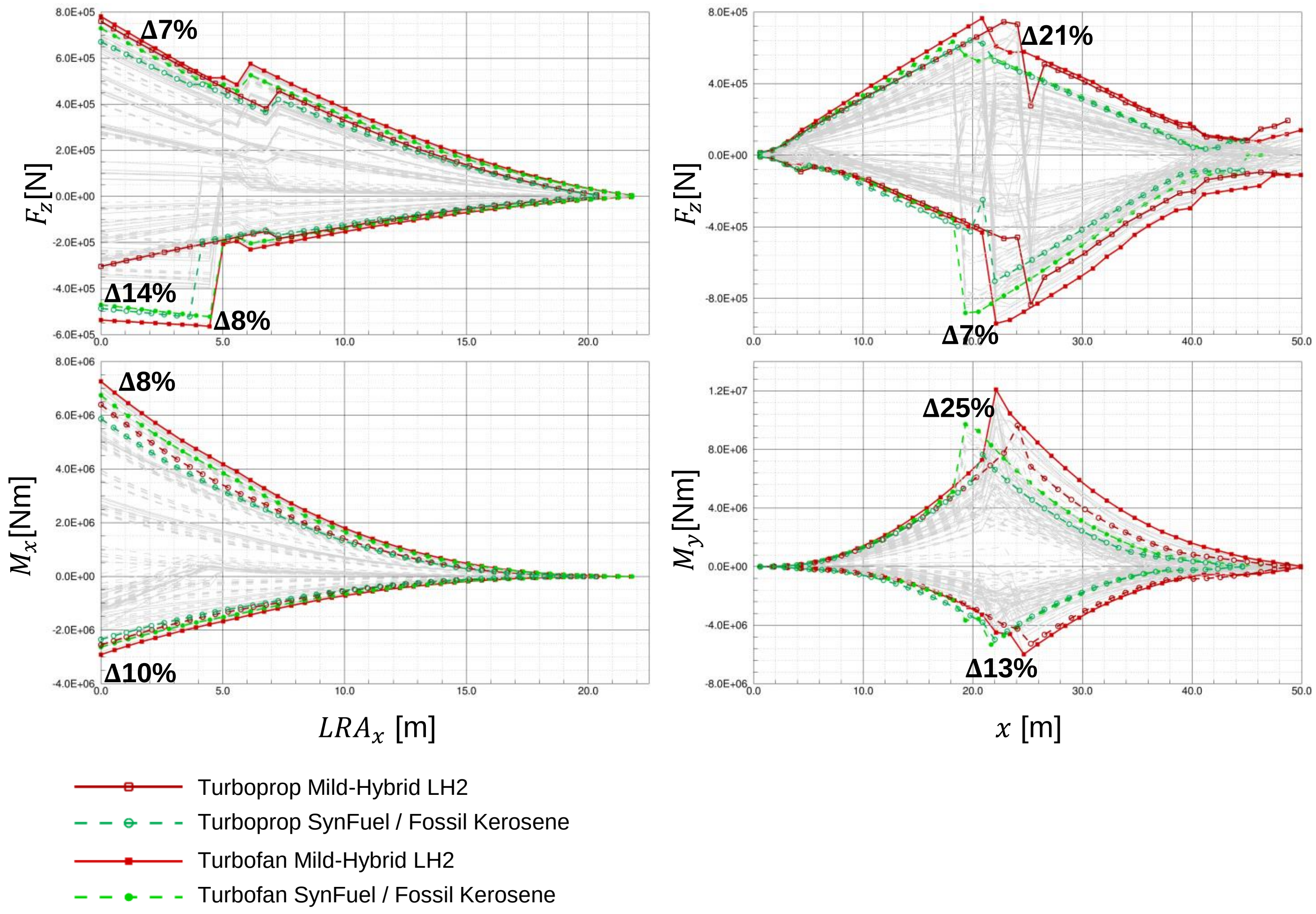
fuselage loads comparison



Turboprop Mild-Hybrid LH2
Turboprop SynFuel / Fossil Kerosene

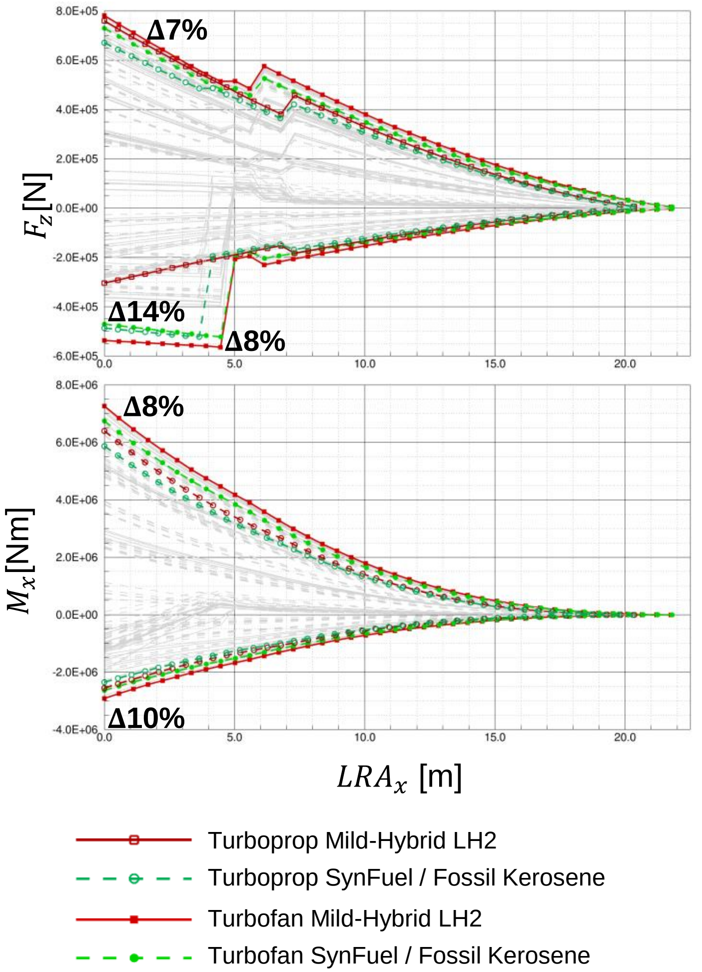
Assessment of loads, wing and fuselage mass Comparison Turbofan

wing loads comparison | **fuselage loads comparison**

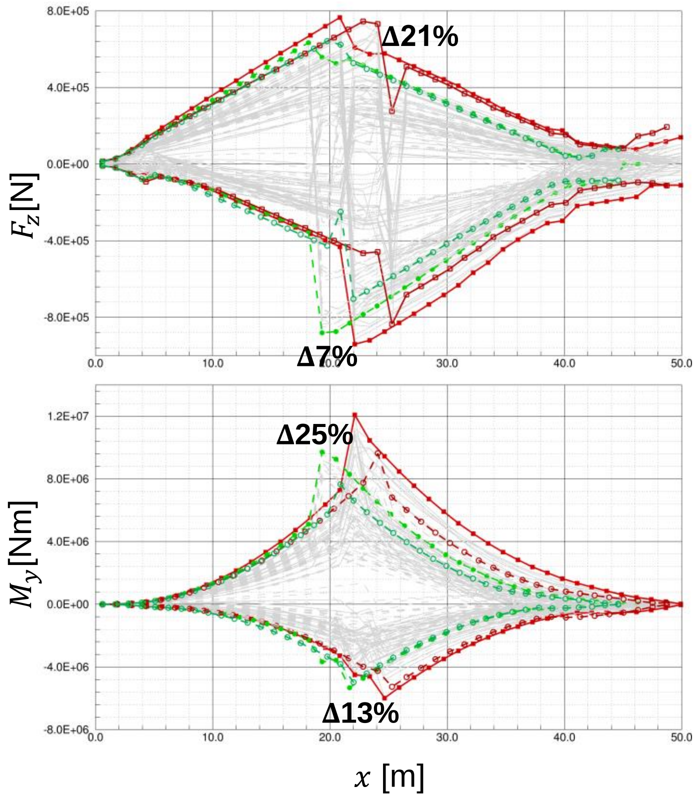


Assessment of loads, wing and fuselage mass
Comparison wing mass

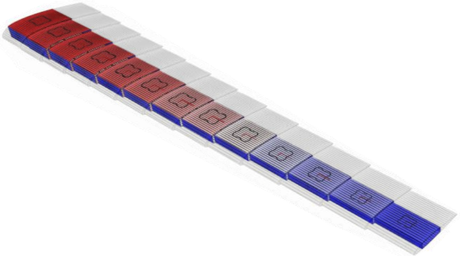
wing loads comparison



fuselage loads comparison

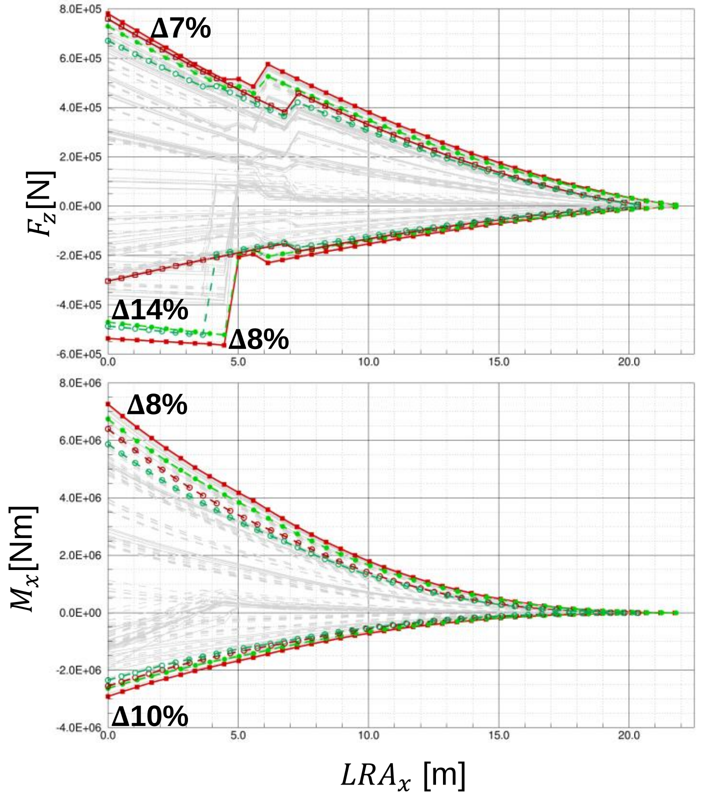


Aircraft	wing mass [kg]
Turboprop Mild-Hybrid LH2	7127.6
Turboprop SynFuel / Fossil Kerosene	7001.7
Comparison TP	1.8%
Turbofan Mild-Hybrid LH2	8981.4
Turbofan SynFuel / Fossil Kerosene	8477.4
Comparison TF	6.0%

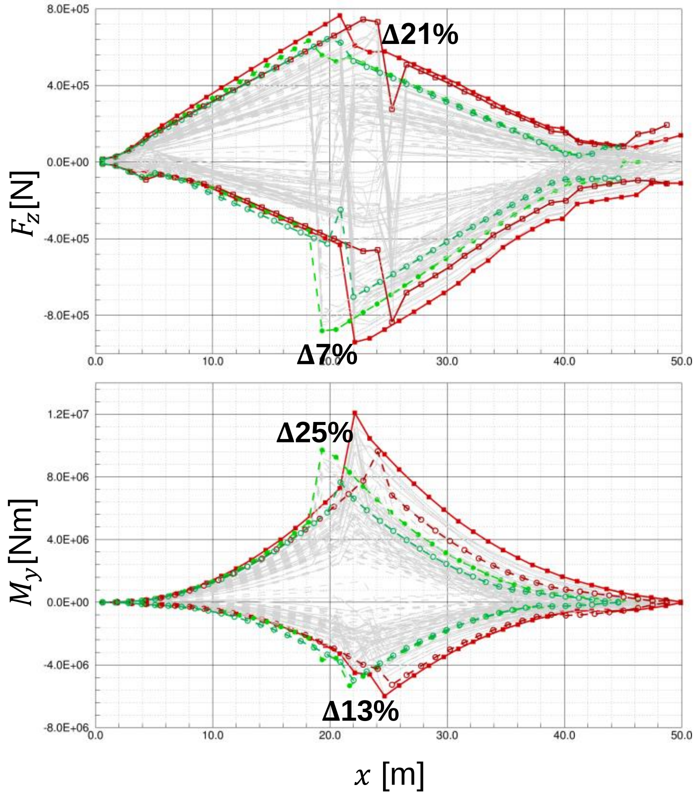


Assessment of loads, wing and fuselage mass
Comparison fuselage mass

wing loads comparison

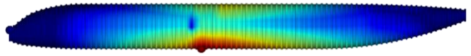


fuselage loads comparison



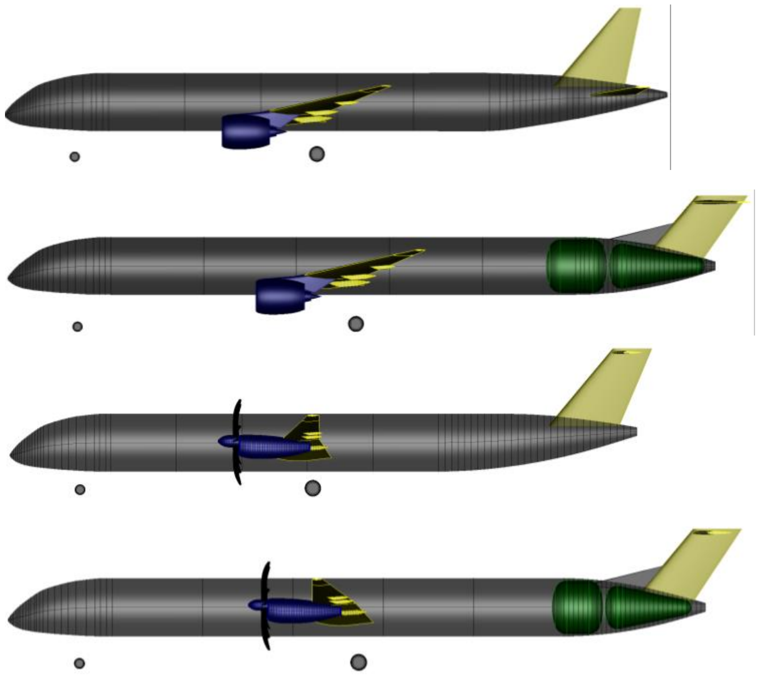
Turboprop Mild-Hybrid LH2
Turboprop SynFuel / Fossil Kerosene
Turbofan Mild-Hybrid LH2
Turbofan SynFuel / Fossil Kerosene

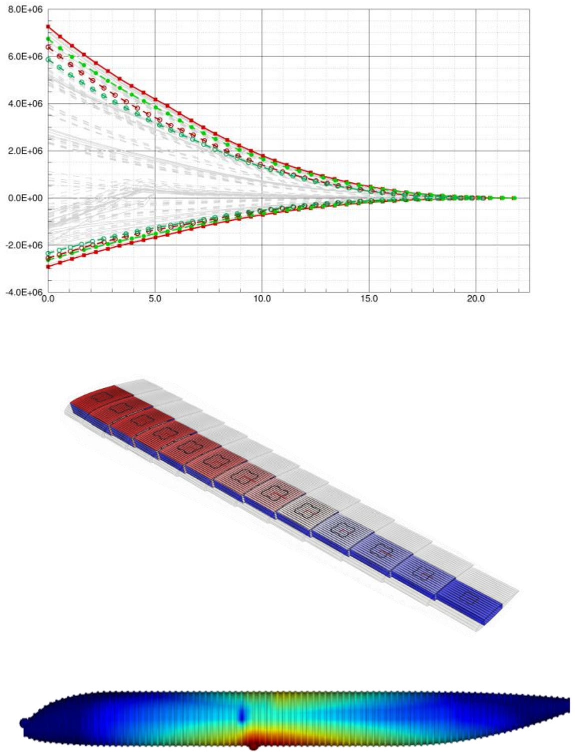
Aircraft	fuselage mass [kg]
Turboprop Mild-Hybrid LH2	13399.7
Turboprop SynFuel / Fossil Kerosene	12220.0
Comparison TP	9.7%
Turbofan Mild-Hybrid LH2	13865.3
Turbofan SynFuel / Fossil Kerosene	12636.1
Comparison TF	9.7%



Summary

methods	configurations	results





Impressum

Topic:	**Structural wing and fuselage design**
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Institutes:	Institute of Aeroelasticity
	Institute of Structures and Design
	Institute of Lightweight Systems
Credits:	Alle Bilder „DLR (CC BY-NC-ND 3.0)“

References

[1] M. Alder, E. Moerland, J. Jepsen and B. Nagel. Recent Advances in Establishing a Common Language for Aircraft Design with CPACS. Aerospace Europe Conference 2020, Bordeaux, France, 2020.

[2] Brigitte Boden, Jan Flink, Niklas Först, Robert Mischke, Kathrin Schaffert, Alexander Weinert, Annika Wohlan, and Andreas Schreiber. "RCE: an integration environment for engineering and science." SoftwareX 15 (2021): 100759. https://doi.org/10.1016/j.softx.2021.100759.

[3] Siggel, M., Kleinert, J., Stollenwerk, T. et al.: TiGL: An Open Source Computational Geometry Library for Parametric Aircraft Design. Math.Comput.Sci. (2019). https://doi.org/10.1007/s11786-019-00401-y

[4] Certification Specifications and Acceptable Means of Compliance for Large Aeroplanes CS-25, Amendment 11, European Aviation Safety Agency, 2011.

[5] https://aviation-regulations.com/part/25

[6] Pratt K. H., “A Revised Formula for the Calculation of Gust Loads”, NACA TN-2964, 1953

[7] Schrenk, O., “Ein einfaches Näherungsverfahren zur Ermittlung von Auftriebsverteilungen längs der Tragflügelspannweite”, Mittelung der Aerodynamischen Versuchsanstalt, Göttingen, 1940

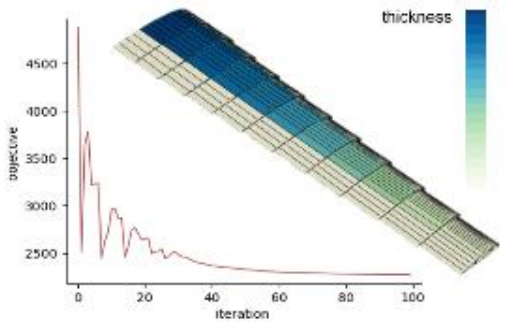
[8] M. Petsch, D. Kohlgrüber and J. Heubischl, “PANDORA – A python based framework for modelling and structural sizing of transport aircraft”, EASN-CEAS, Glasgow, Scotland, 2018.


PANDORA
mass
lightworks
mass
RCE [2]
loads
LOADzero
loads
cpacs
A Common Language for Aircraft Design [1]

BACKUP

Assessment of wing mass

Aircraft	Turbofan SynFuel / Fossil Kerosene	Turbofan Mild-Hybrid LH2	Comparison
span	42	42	0%
area	220	232	5.5%
wing mass	8477.4	8981.4	6.0%
wingbox mass	5074.5	5290.7	4.3%
ribs mass	440.6	478.1	8.5%
shells mass	3941.9	4077.6	3.4%
spars mass	691.9	735.0	6.2%



Assessment of fuselage mass

Aircraft	Turbofan SynFuel / Fossil Kerosene	Turbofan Mild-Hybrid LH2	Comparison
length	46.85m	50.57m	7.9%
mass	12636.1	13865.3	9.7%
mass / length	269.7 kg/m	274.18 kg/m	1.6%
struc mass	6650.9	8076.0	21.4%
bulkhead mass	194.4	356.4	83.3%
skin panels mass	3834.8	4613.5	20.3%
stringers mass	1917.4	2306.7	20.3%
frames mass	704.3	799.4	13.5%