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Preliminary Design for Flexible Aircraft in a Collaborative Environment

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Outline

- Scope: Enhancing Overall Aircraft Design (OAD)

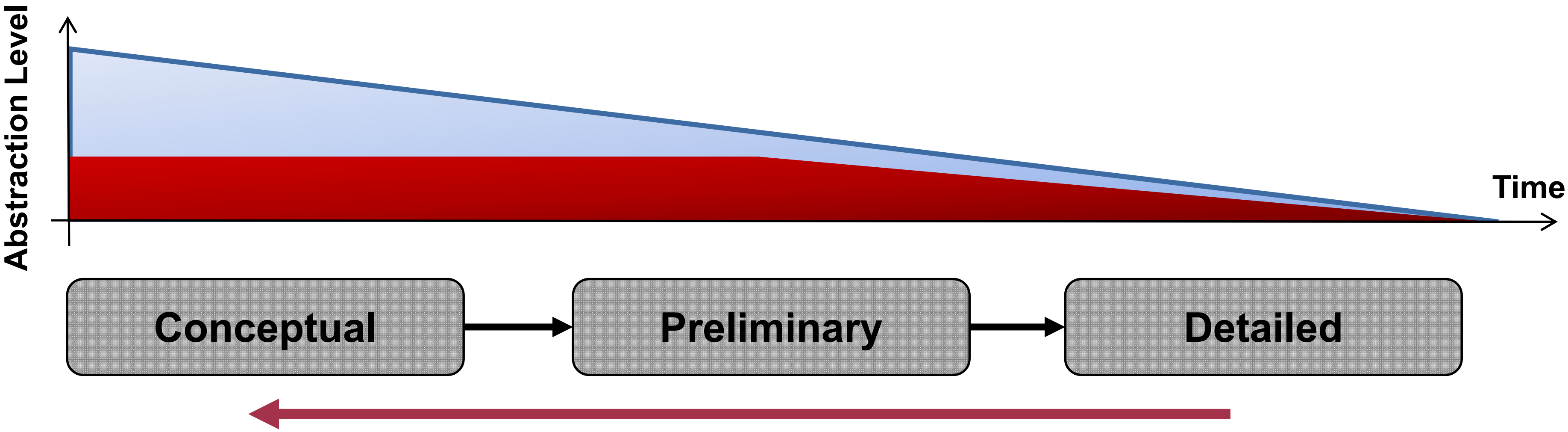
- Collaborative Design and Optimization Environment
    - DLR centralized data model and design framework

- Enabling physics based OAD
    - Design and disciplinary analysis modules integrated
    - OAD Workflow development

- Study Cases
    - Conventional aircraft
    - Boxwing configuration

- Conclusions and Outlook

Overall Aircraft Design
Exploring novel design space



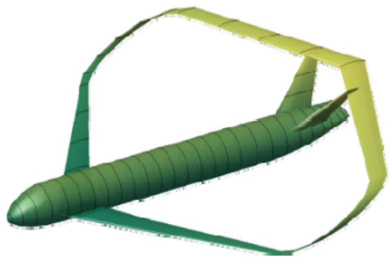
- Visions and Scenarios demand the extension of the current design space
  - No data/knowledge available at the early stage (no handbook methodologies)
  - But effective physics based model available to assess new Technologies

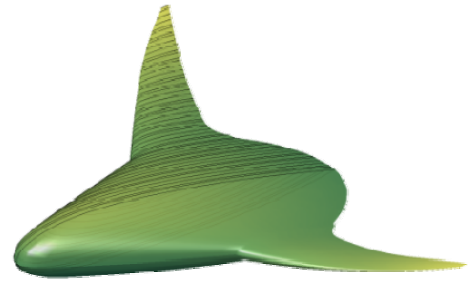
Shift to the early stages

Unconventional OAD in pre-design

Unconventional configurations:

- Highly disciplinary coupled designs
- Unexpected behaviour
- MDO solution required





How to enable the pre-design of novel configurations?

Enhancing preliminary design requires:

- Physics based analysis (many modules are already available)
- Collaborative design approach with specialists in OAD (Overall Aircraft Design)
- Automation of the design process, and cross-disciplinary management

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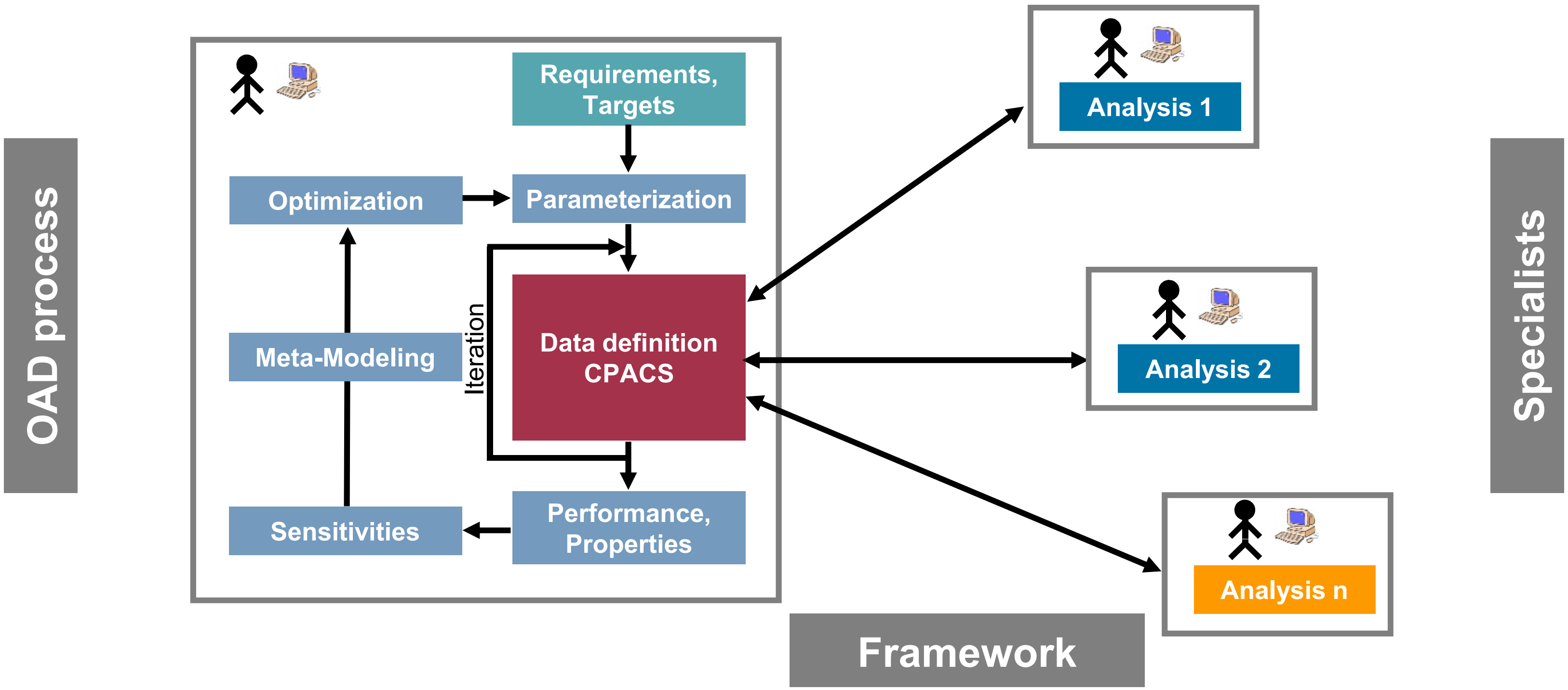
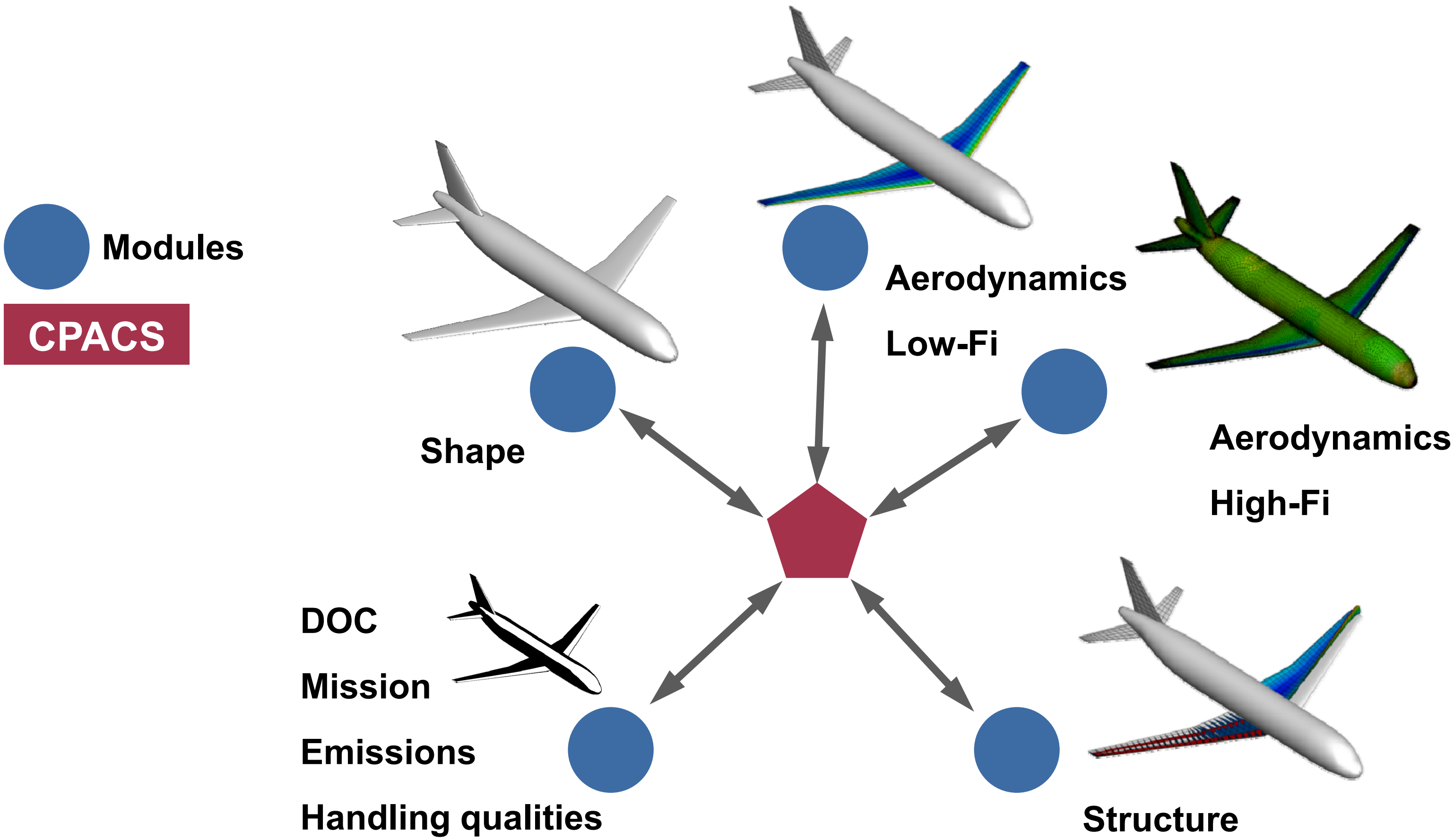
Collaborative Design Environment



- Integration of modules developed by disciplinary specialists.
- A common namespace defined by DLR **CPACS** data format
- Design Framework for workflow orchestration
- Beyond tools: A system of distributed competencies.

CPACS

Common Parametric Aircraft Configuration Schema



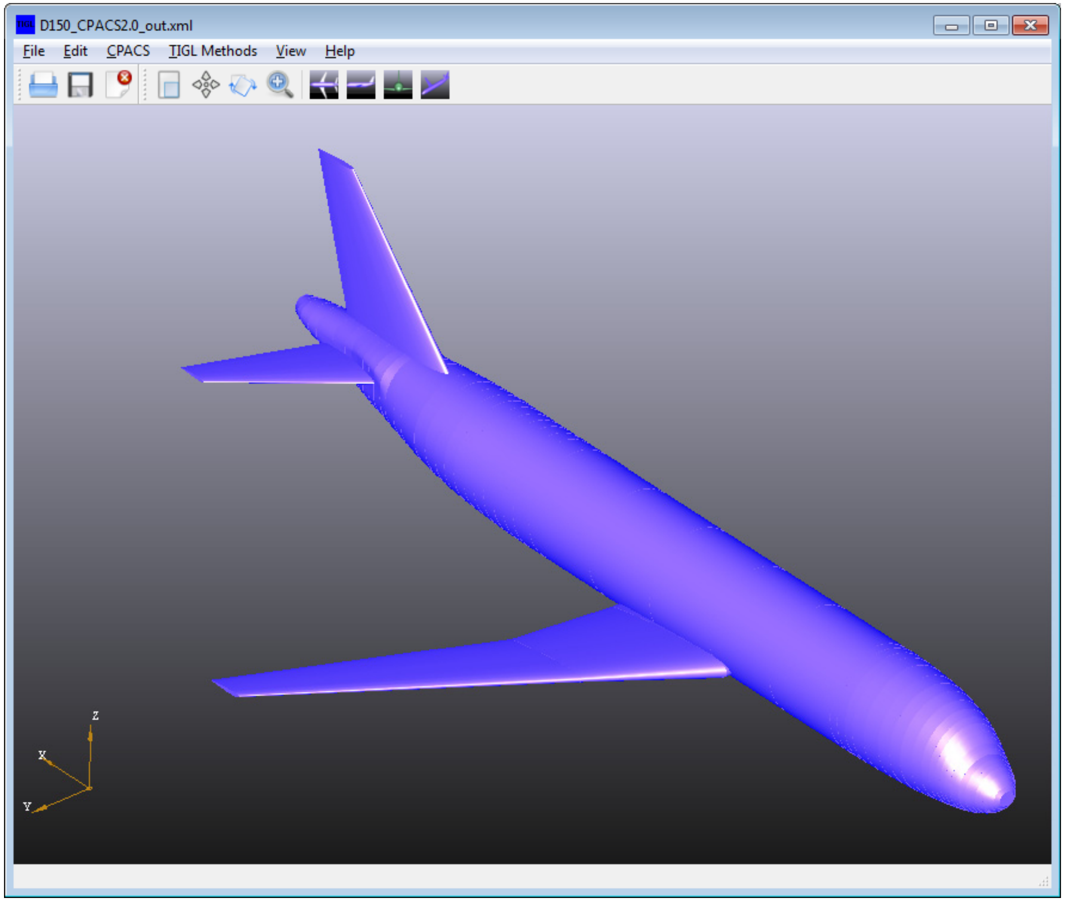
a CPACS file…

- **Hierarchical** schema definition (xml-structure data format)
- **Product** and **process** information
- Standard within DLR (since 2005)
- External Partners

- Multi-scale, containing data on:
    - Aerodynamics
    - Structures
    - Mission
    - Climate
    - Fleets

- Open source:

http://code.google.com/p/cpacs/

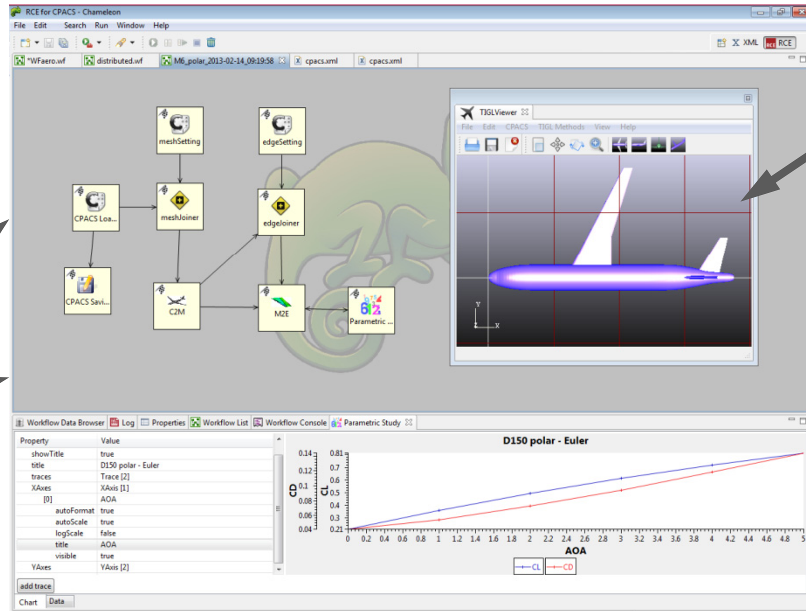


…the same CPACS file!

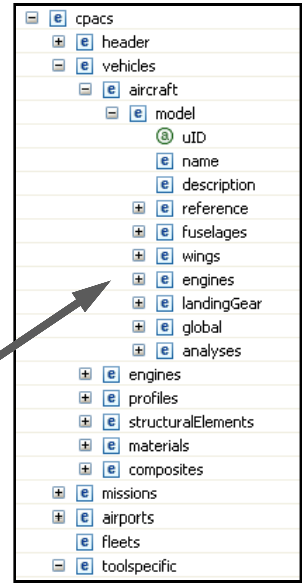
Design Framework RCE
Remote Component Environment

- Decentralized system
- Workflow development
- Distributed architecture
- DLR developed
- Open source

Tools remain on owners‘ servers. Exchange of input and output in CPACS format via the network.



CPACS



Modules

DEE Initiator
Conceptual OAD

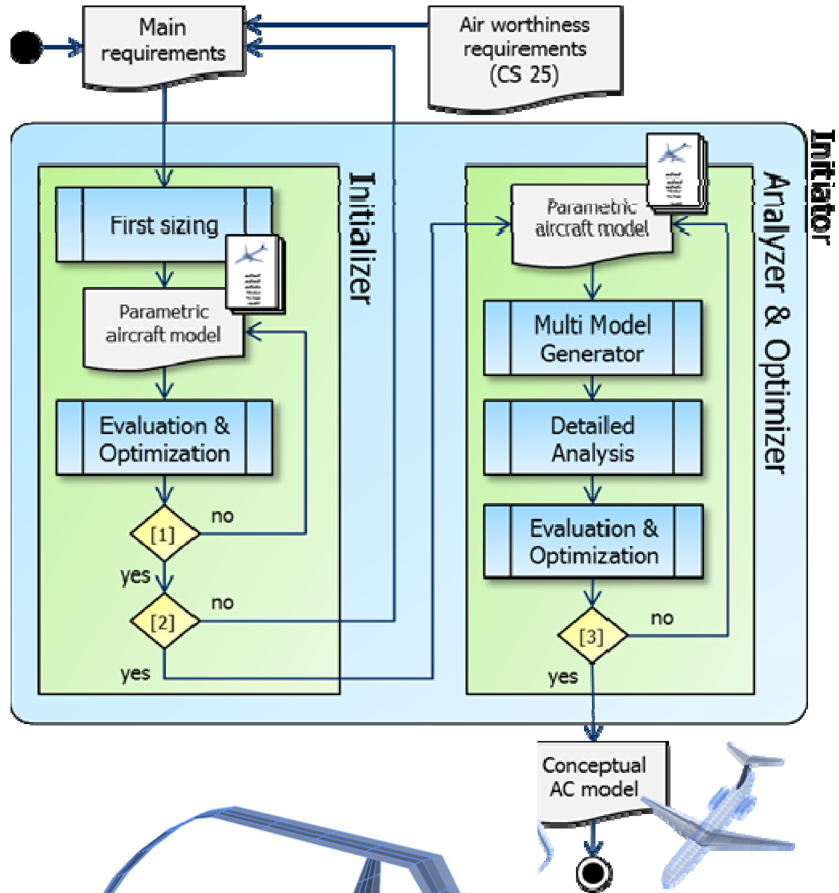
- Conceptual design code

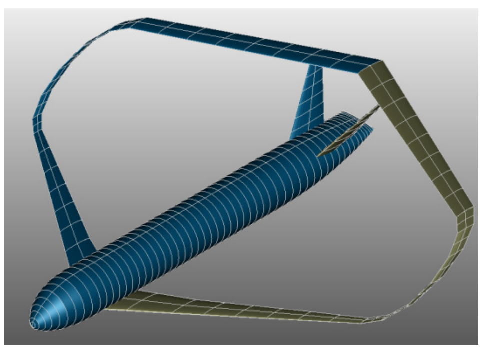
- Developed at TU Delft

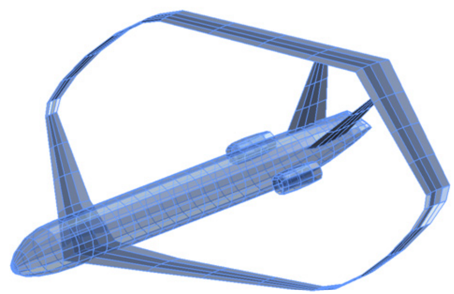
- Conventional and Unconventional

- Consists of three separate modules-
    - Initializer
    - Analyzer
    - Optimizer

- CPACS compatible

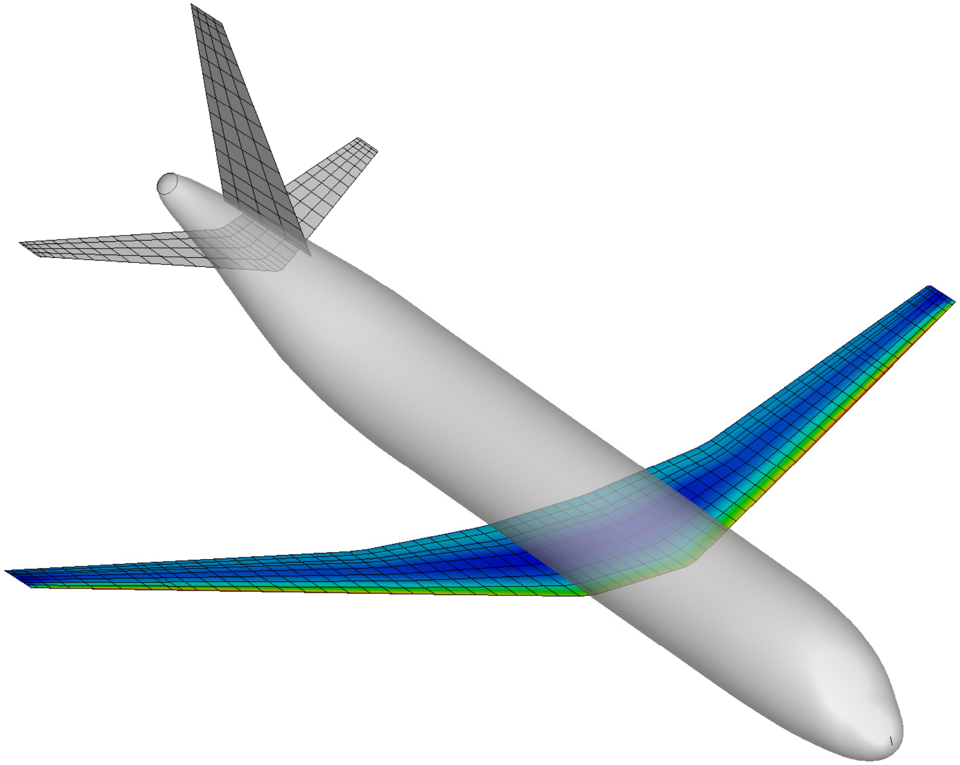






Aerodynamics Module
Aerodynamics Design

- Physics based aerodynamics module
- Automated generation lattice mesh for lifting surfaces
- AVL VLM solver for induced drag
- Additional components for estimation of wave and friction drag



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Aeroelastic Engine
Structural Analysis

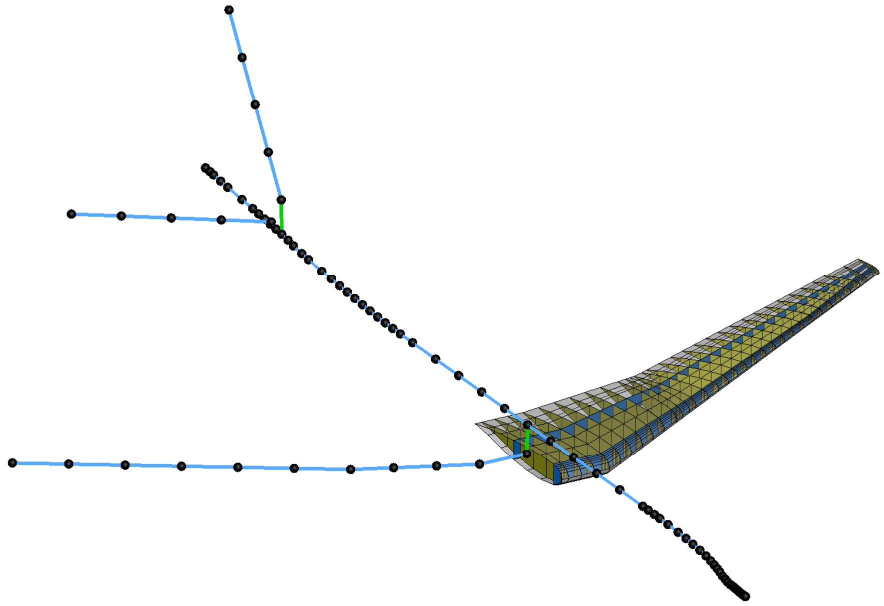
Automated Generation of FE models:
Multi-level approach:

Level-1

- FE beam formulation
- Distributed masses

Level-2

- FE shell formulation
- Hybrid Models



The module provides
- Internal static and dynamic FEA solver or exporting of macros for commercial FEA
- Sizing process for the primary structures

Aeroelastic Engine
FSI coupling

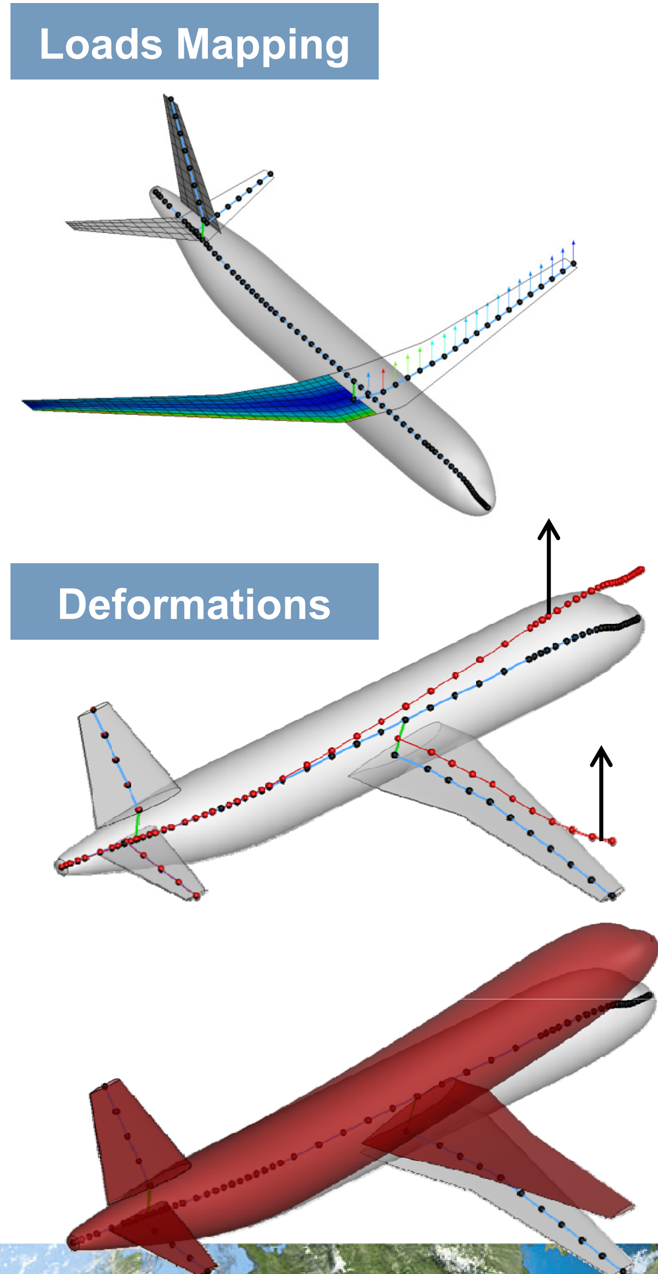
Collaborative design oriented:

- **Loosely coupled**

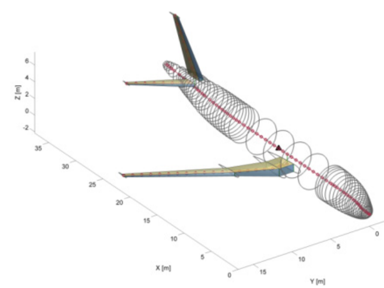
- Aerodynamics loads mapping (aero lattice → FE nodes)

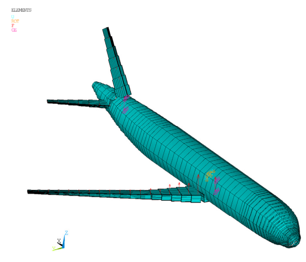
- Structural displacements deformations (FE nodes → aero lattice or geometry)

- Coupling kernel based on a modular set of interpolation schemas (e.g. RBF)

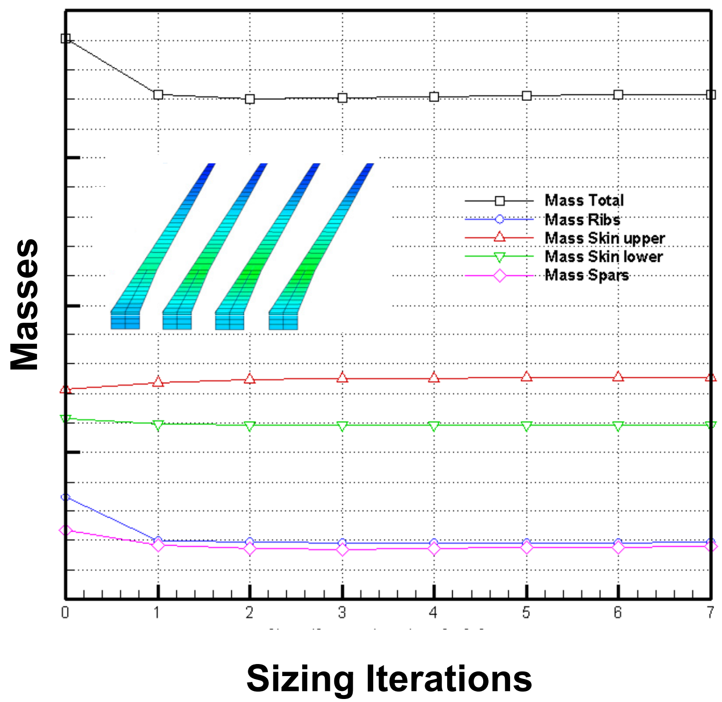


Disciplinary Analysis
Aero-Structural Sizing

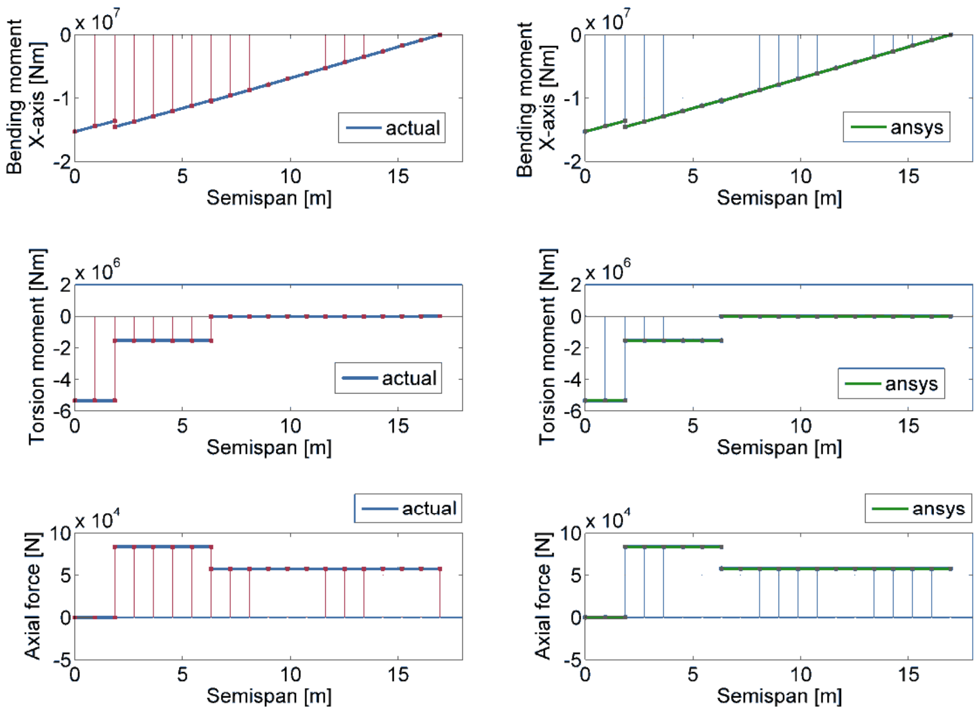




Iterative Sizing



Internal forces



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Workflow Development
OAD process

3 phases workflow:

1) Initial Synthesis:
- Initialize the aircraft design
- Conceptual OAD tool

2) Physics based analysis:
- Aero-structural sizing loop
- Aircraft performance evaluation Rigid and Flexible (flexibility loop)

3) Multifidelity synthesis:
- Physics based values replace conceptual calculations
- New OAD synthesis

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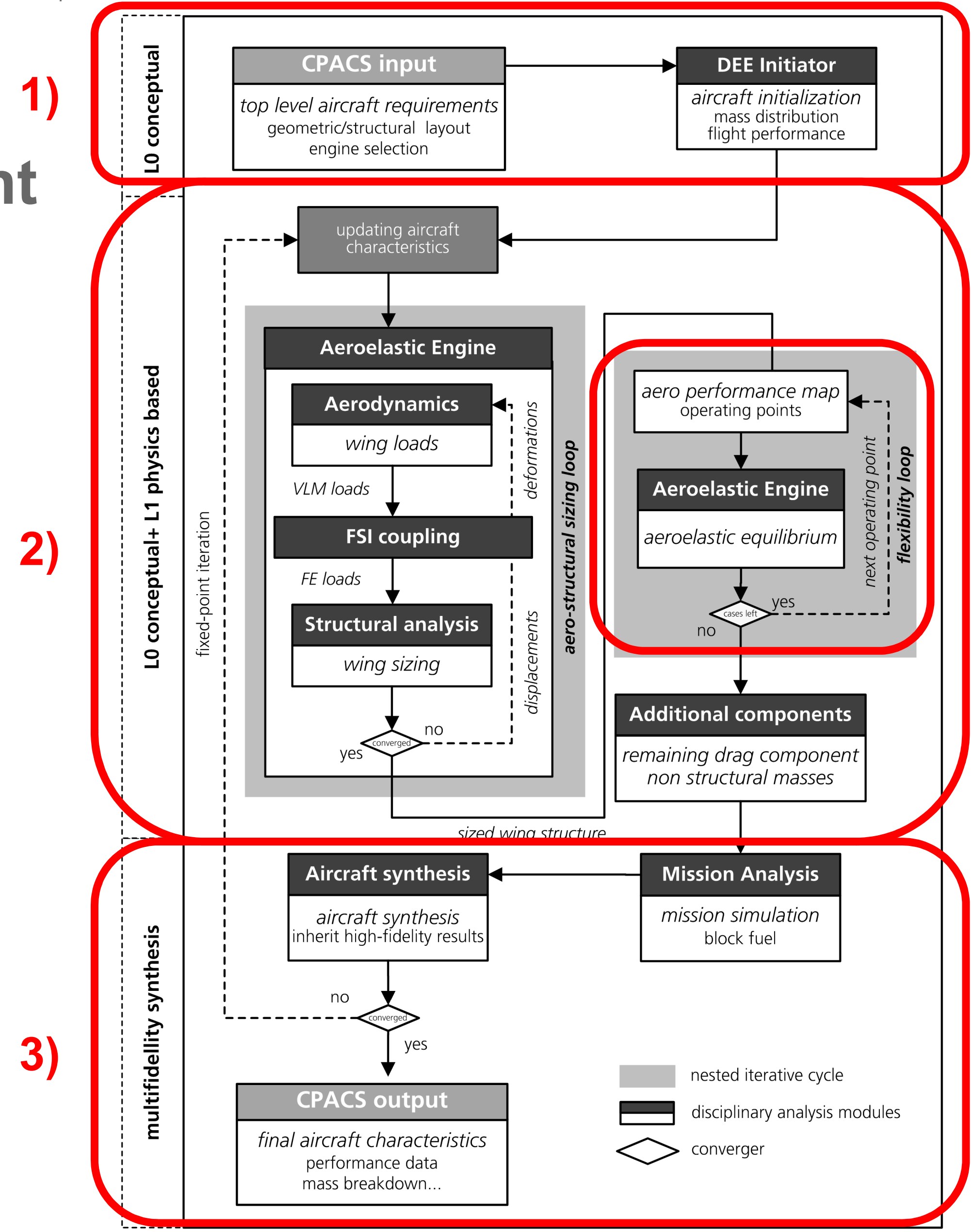
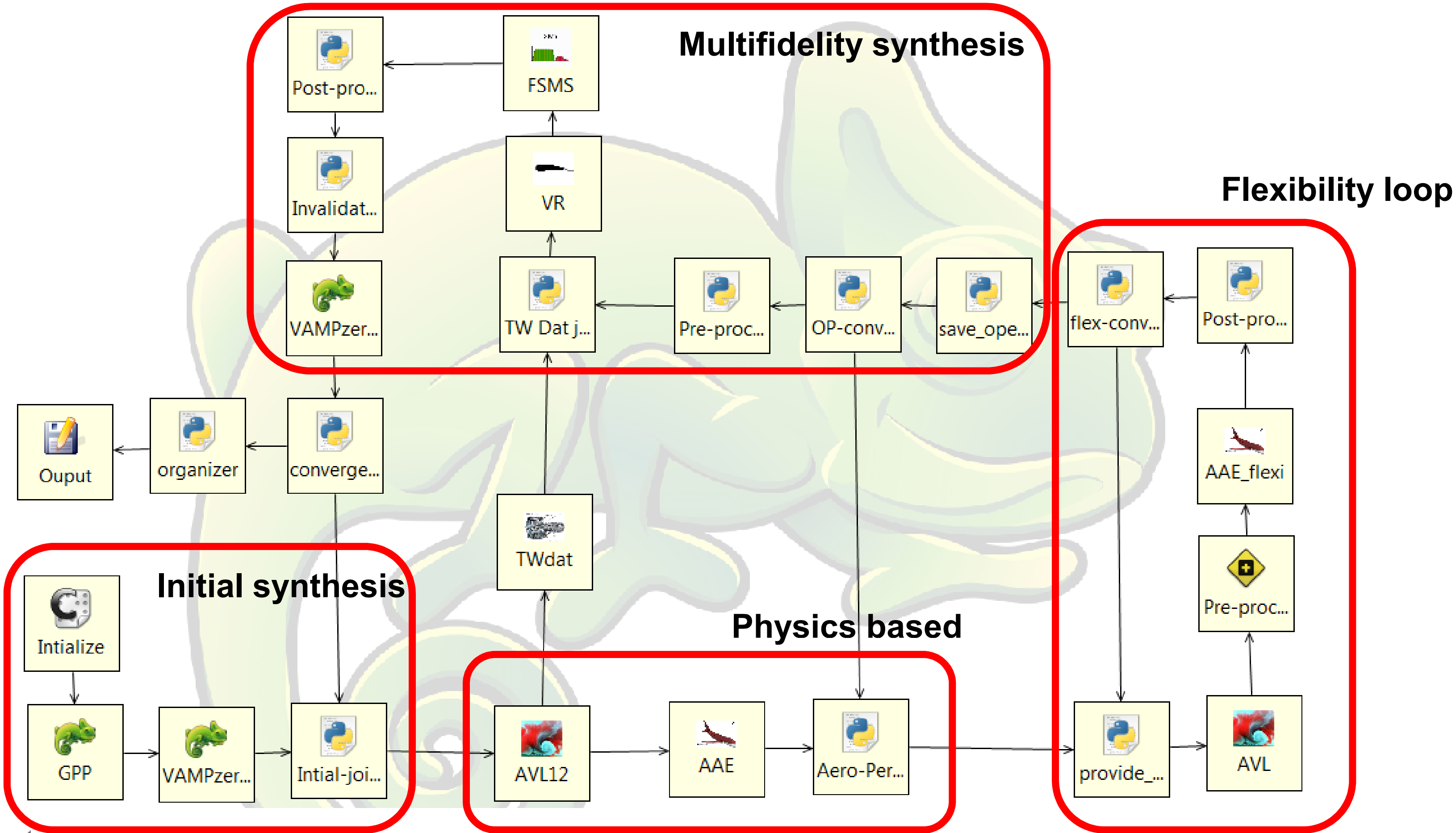


Workflow Development
OAD process



Design Case I
Conventional configuration OAD

Test configuration:
- TLAR defined in a Design challenge launched in December 2012

TLAR	
Range (nm)	2000
Mach cruise	0.79
PAX	190

Aero-Structural analysis:
- 2.5g pull-up maneuver
- Static strength sizing
- Isotropic material
- Fixed structural layout
- Rigid / Flexible trim and performance

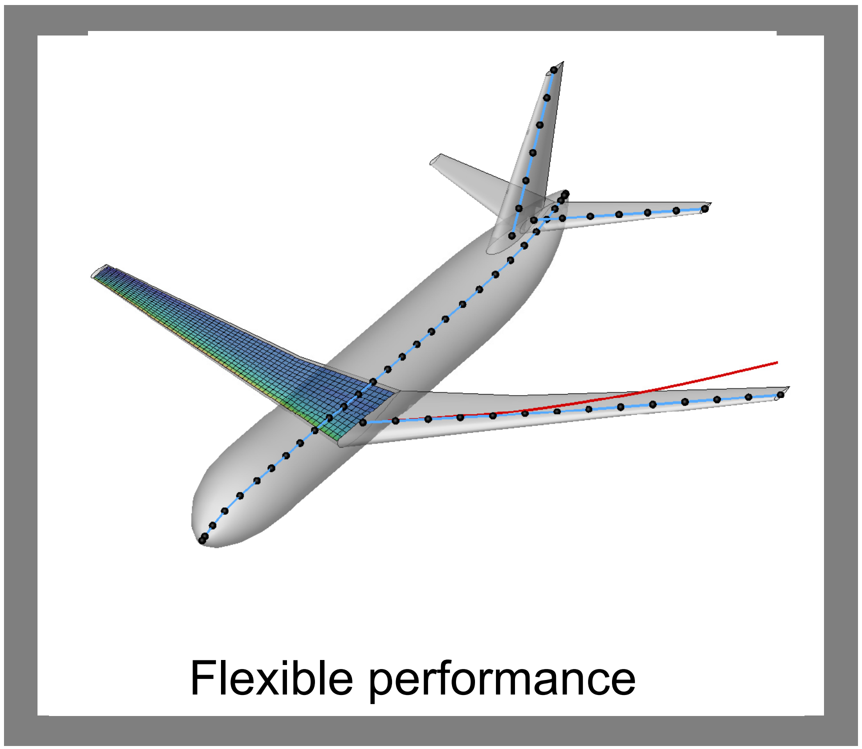
3 OAD design process modes:

***L0 design process*:**
- Only conceptual aircraft design

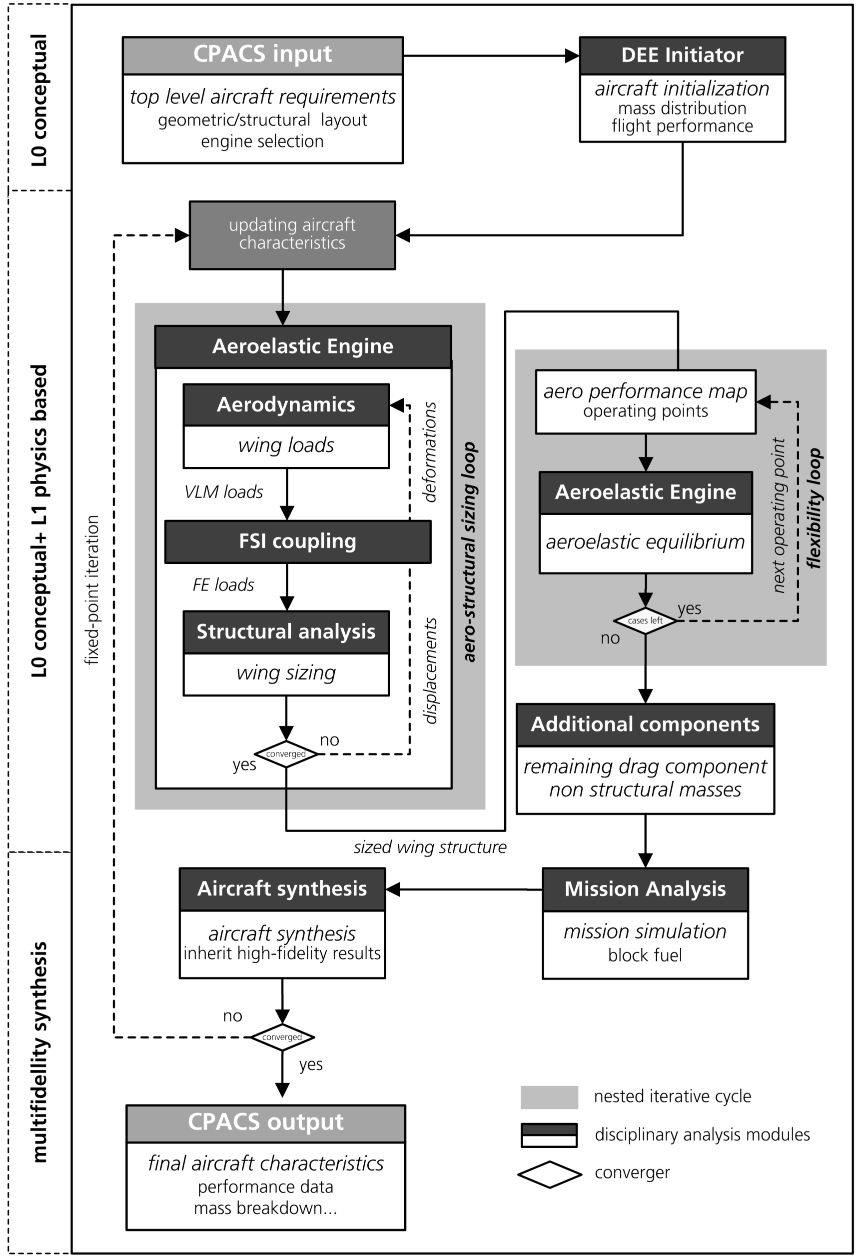
***L1 Rigid design process*:**
- Conceptual and physics based design
- Aero-structural sizing, rigid performance

***L1 Flexible design process*:**
- Conceptual and physics based design
- Including flexibility loop

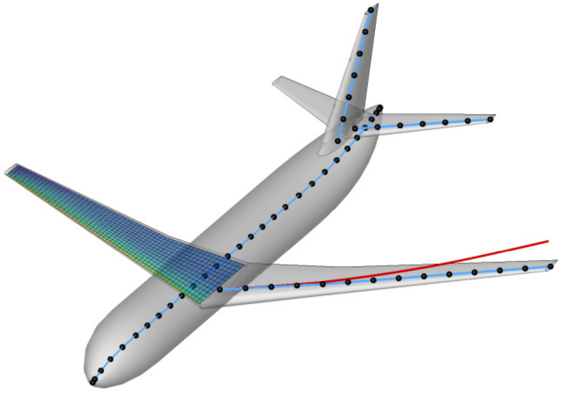
Design Case I
Conventional configuration



Flexible performance

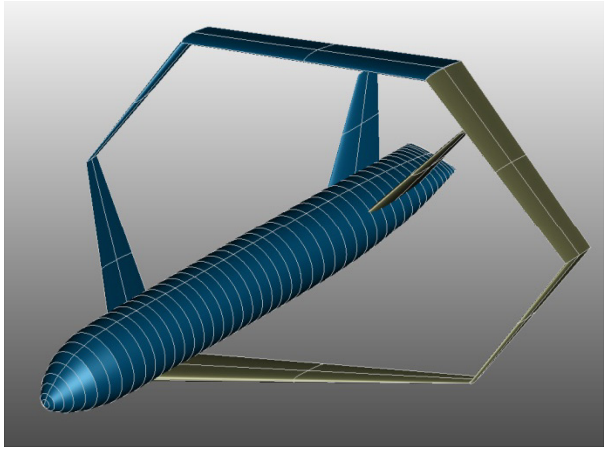


Design Case I
Results



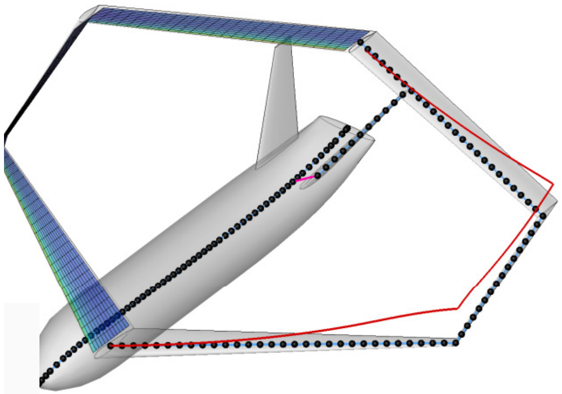
OAD	Conceptual L0 Initial OAD
mTOM [kg]	83145.7
mFM [kg]	18947
OEM [kg]	45198

Design Case II
Results



- Unconventional boxwing OAD (ref. TLAR Pisa)
- Same approach conventional

OAD	Conceptual L0
	Initial
mTOM [kg]	245551
mFM [kg]	77474
OEM [kg]	126327



Conclusions and Outlook

- Collaborative design approach for aircraft in pre-design
  - Enabling physics based analysis
  - Focus on flexibility effects

- Integration of distributed physics based modules
  - Analysis starting from an initial OAD synthesis model
  - Disciplinary modules for aero-structural design and new synthesis
  - Flexibility loop influence

Design cases:
- Conventional aircraft behaves as expected
- Care has to be considered with the unconventional aircraft case

- Outlook:
  - Adopt the approach for design and optimization applications

Thank you for your interest!

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