4th SCAD –
Symposium on Collaboration in Aircraft Design

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25.11.2014

Overview

- Introduction: Bottlenecks in Airframe Development
  - Gap Analysis
- Technology Road Map
  - Current State of Integrated Process
  - Scope of Development (24 Months)
- Summary

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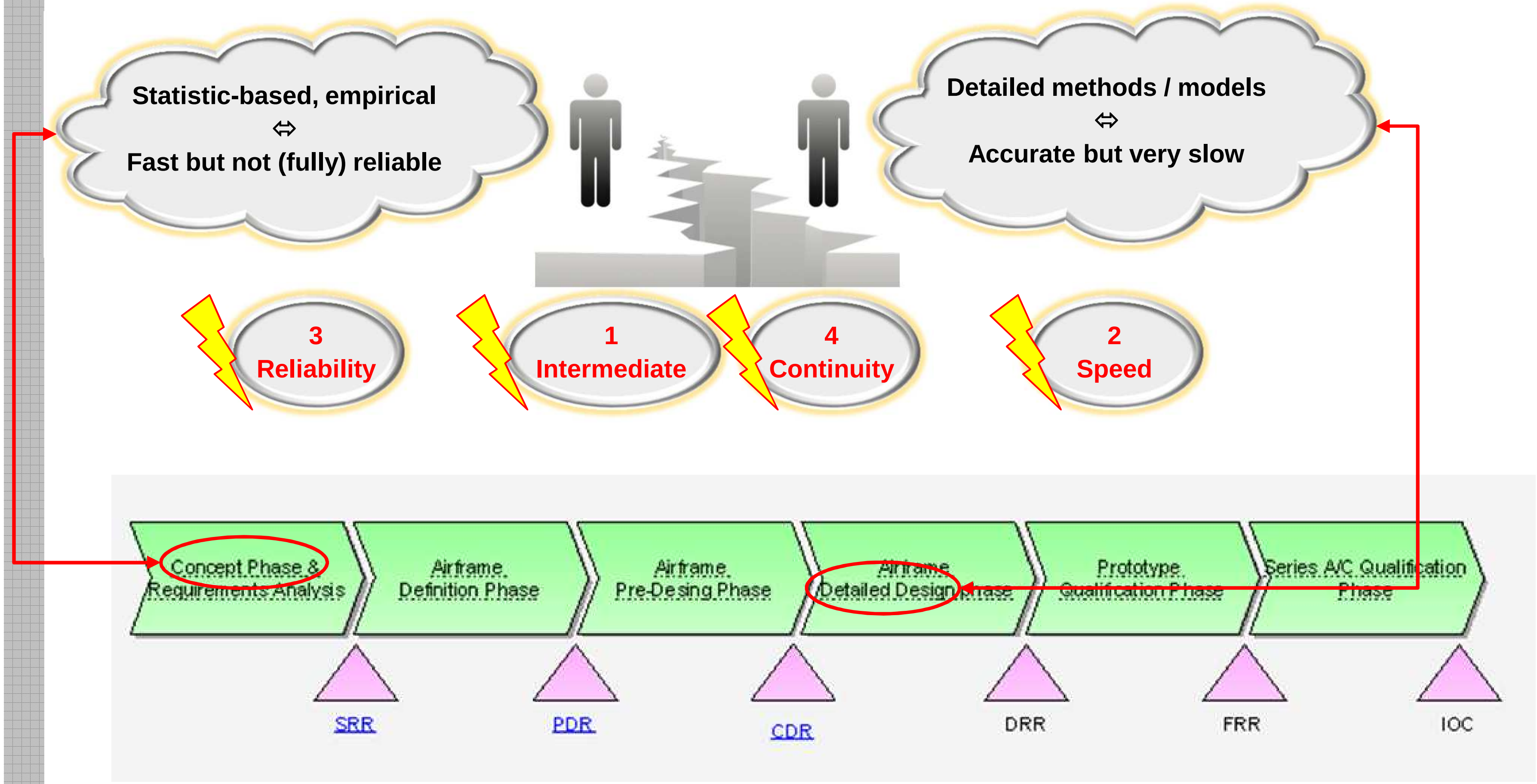
Bottlenecks in Airframe Development

- Gap Analysis



Gap Analysis

Due to

- Limited fidelity i.e. reliability of assessment during concept design phase
- Gap between „Conceptual Design“ and „Detailed Design“
  - Tools and methods and models
  - Limited intermediate analysis capabilities (mainly used during multidisciplinary optimisation)
- Detailed analysis models require too much time

Following high priority gaps have to be closed:

1) Intermediate level analysis (fast and accurate methods, 80% solution)
2) Fast analysis and model generation also in Detailed Design
3) Reliable assessment in Conceptual Design through numerical analysis
4) Continuity in assessment (methods, models) between Conceptual and Detailed Design (multi-fidelity approach)

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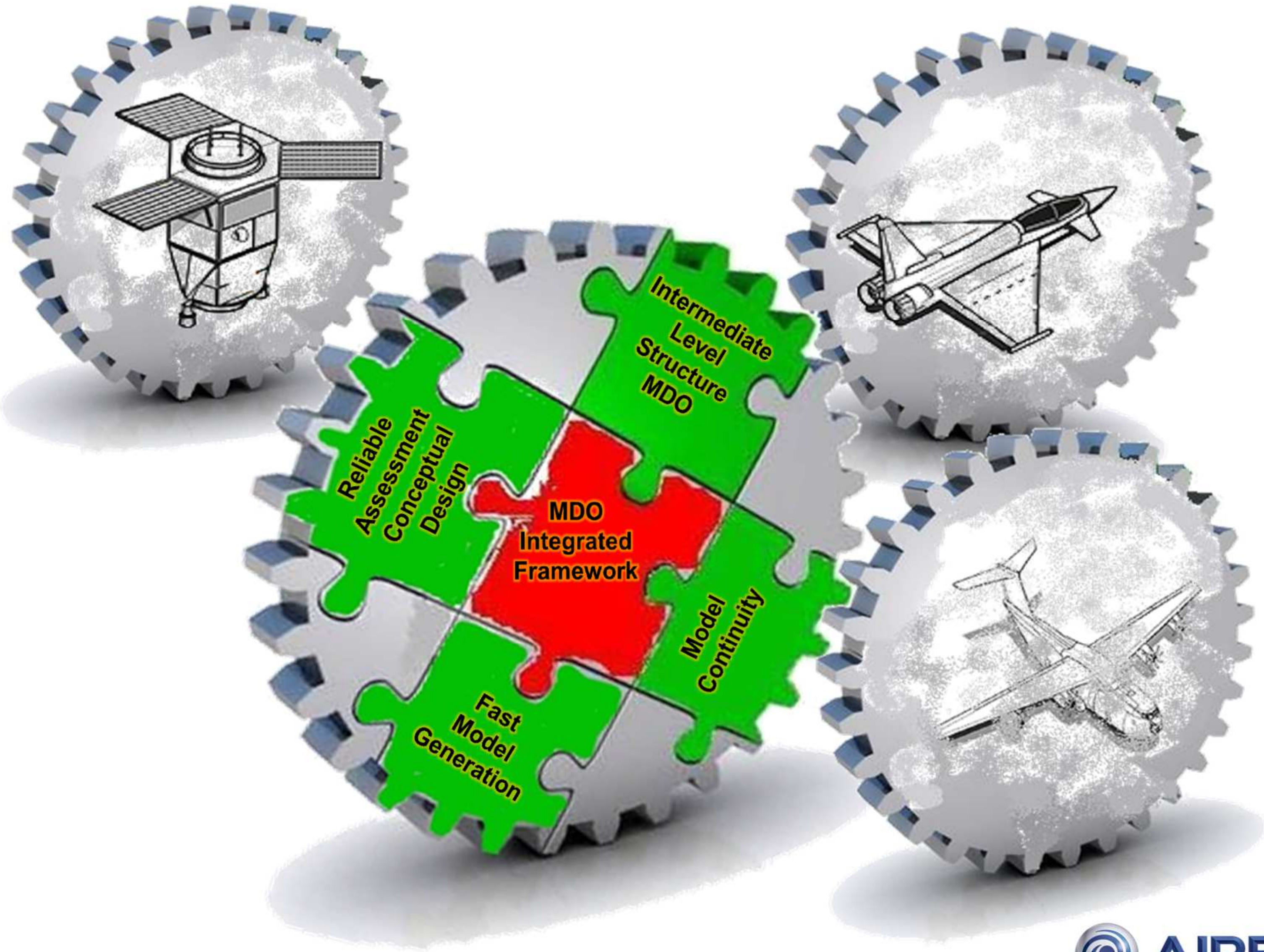
Technology Road Map



Summary

- For the sake of high-performance and affordable aircraft Airbus Defence & Space has identified following development demand
  1) Intermediate level analysis (fast and accurate methods, 80% solution)
  2) Fast analysis and model generation in Detailed Design
  3) Reliable assessment in Conceptual Design
  4) Continuity in assessment (methods, models) between Conceptual and Detailed Design
- The technology road map foresees an integrated multidisciplinary development process assisted by a decentral / distributed IT framework
  - Based on central parametric geometry model (Descartes)
  - Loose coupled competence tools
  - Central MDO data management
  - Multi-fidelity numerical analysis and optimisation environment
  - „numerical Conceptual Design
  - Fast and reliable exploration of design space assisted by MDO

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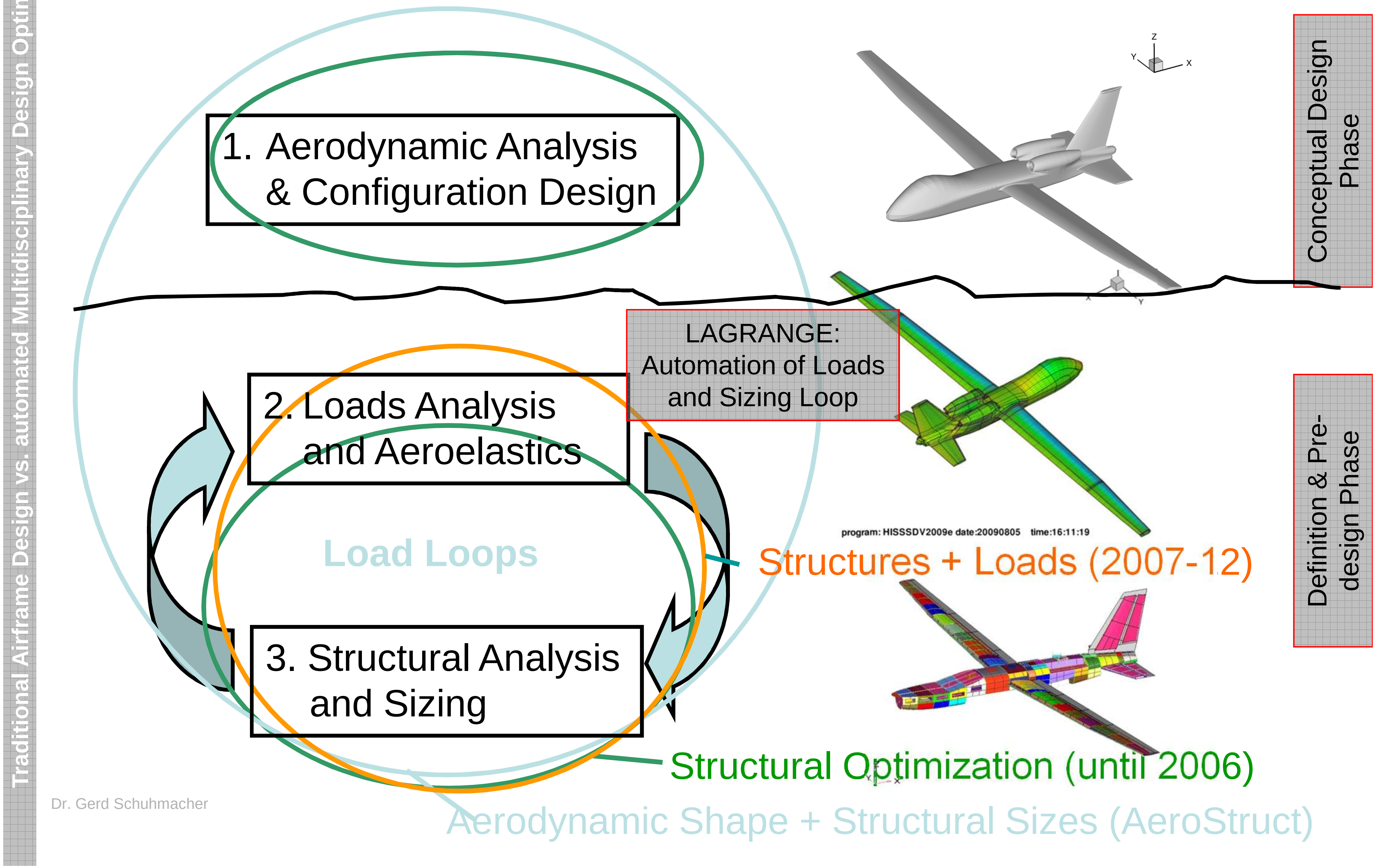
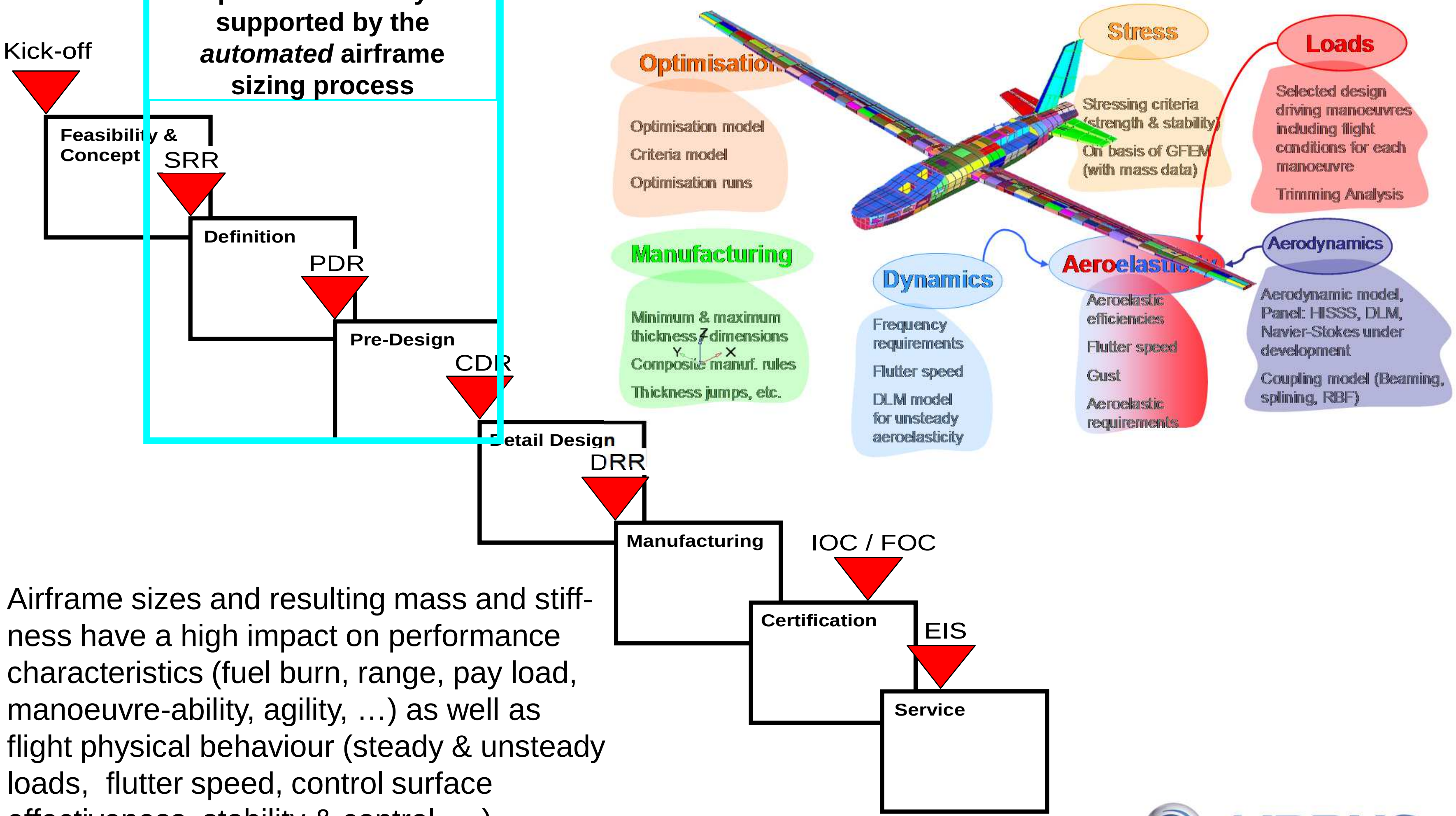
Intermediate Level
Structure MDO

Automation of the Global Airframe Development Process



Automation of the Major Airframe Sizing Phases

Disciplines integrated into the Automated Airframe Sizing Process performed by LAGRANGE



Airframe sizes and resulting mass and stiff-ness have a high impact on performance characteristics (fuel burn, range, pay load, manoeuvre-ability, agility, …) as well as flight physical behaviour (steady & unsteady loads, flutter speed, control surface effectiveness, stability & control, …)

Three Pillars of Optimisation

- Multidisciplinary structure optimisation (variable structure & variable loads)

Analysis Model

HISSS

FEM

Linear Statics

Linear Dynamics

Steady Aeroelastics

Unsteady Aeroelastics

Criteria Model

Strength (diverse models depending on failure criteria)

Analytical buckling analysis (also theory 2nd order)

Local stability analysis (for critical parts of cross-section), crippling

Displacements (stiffness requirements)

Constraints for natural frequencies

aeroelastic requirements (steady, unsteady): efficiencies, flutter, etc.

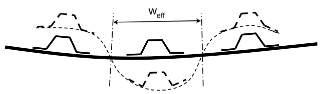
Manufacturing constraints

Constraints for trimmed flight and landing manoeuvres

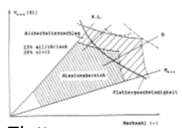
$$\varepsilon_{allow}^{tens} = +yyyy\mu s$$

$$\varepsilon_{allow}^{comp} = -xxxx\mu s$$

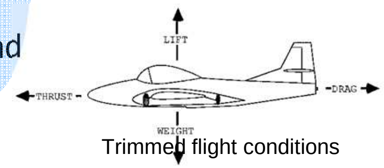
Damage Tolerance & Repairability



Skin & Column Buckling



Flutter



Trimmed flight conditions

Optimisation Model

Parametric model defining the design variables:

- Cross-sectional area of bars (sizing)
- Thickness of shell or membrane elements (sizing)
- Ply thickness of composites (sizing)
- Fibre orientation in composite stacks (angles)
- Coordinates of FE nodes (shape)
- Coordinates of control points (CAD, NURBS)
- Trimming variables (angles of attack)

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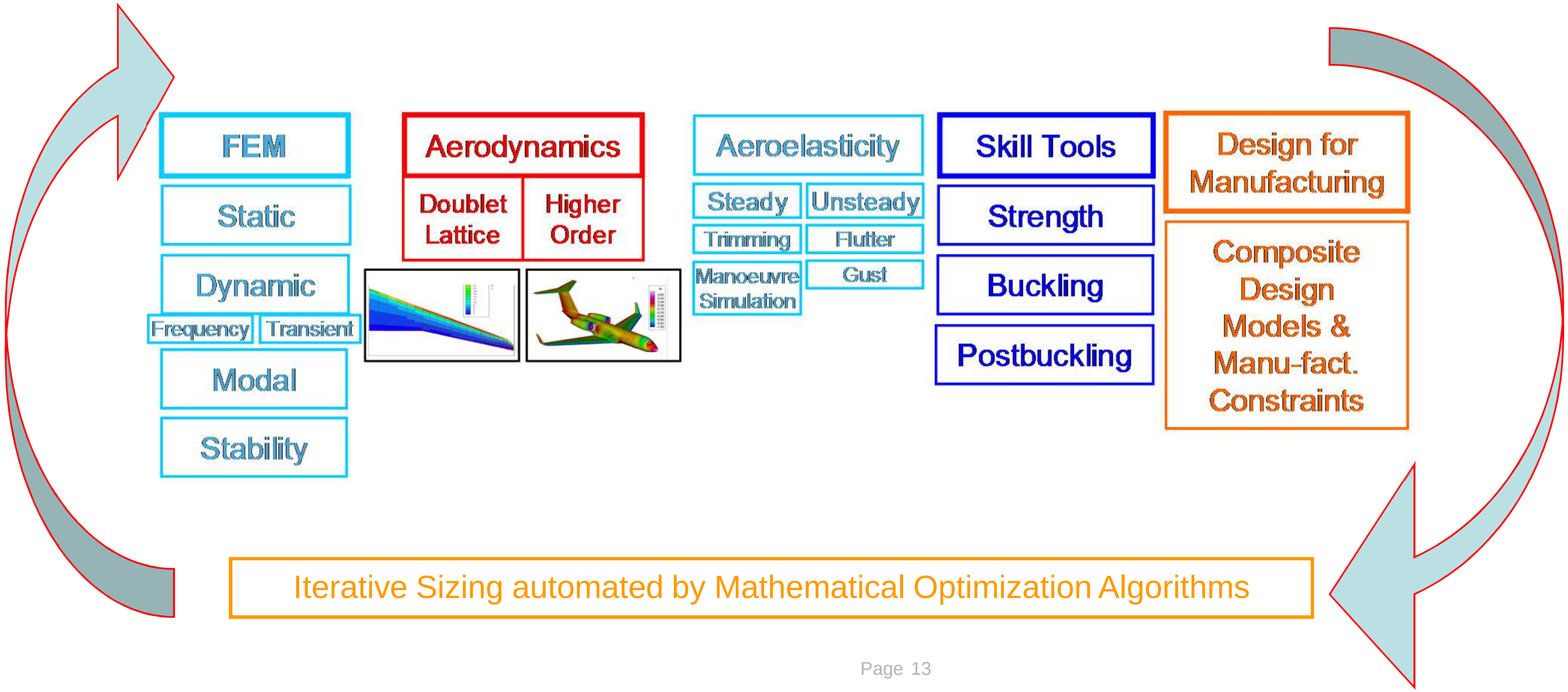
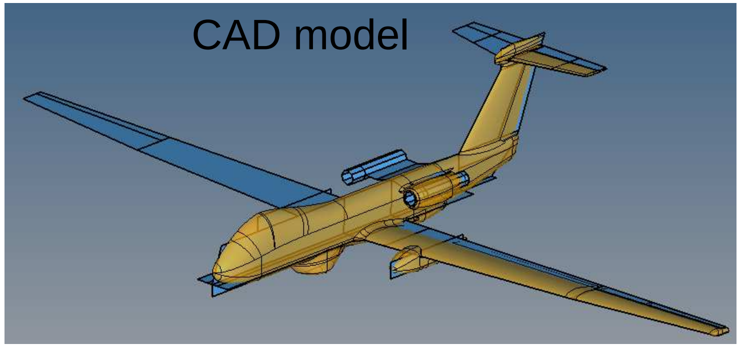
Integrated & Automated Sizing by LAGRANGE

LAGRANGE is an Airbus DS software which ***combines the traditional airframe analysis tools*** (loads, dynamics, stress, manufacturing etc.) with mathematical optimization methods ***in order to automate the structural development and sizing process***. This results in an ***"integrated, and highly efficient design process"*** in contrast to the traditional ***"iterative, subsequent processes of single disciplines".***

Multidisciplinary Analysis and Automated Sizing by LAGRANGE

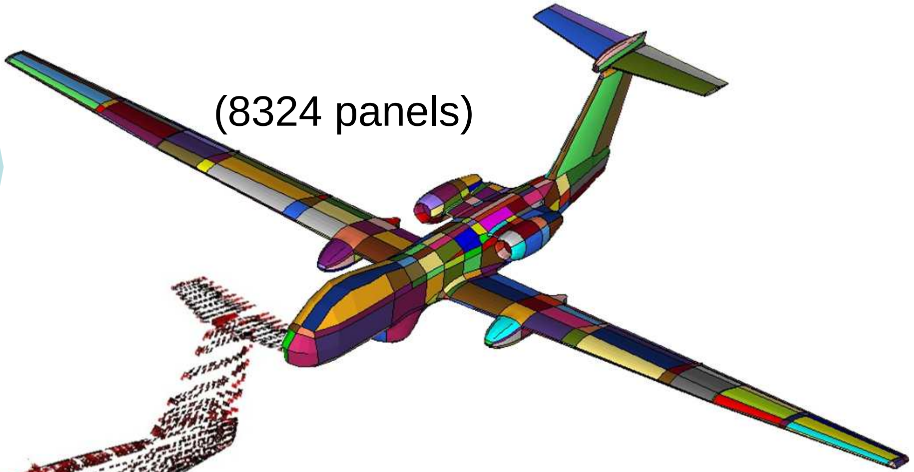


Example: Multidisciplinary Analysis Models of a UAV



CAD model

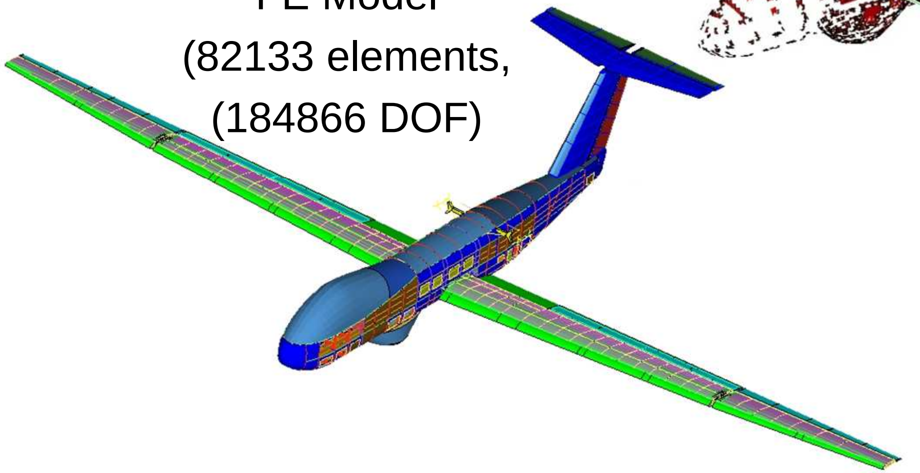
Aerodynamic Panel Model
for steady state manoeuvres

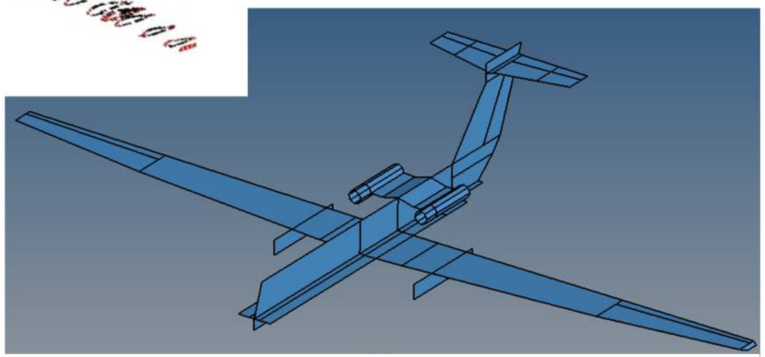


(8324 panels)

Aero-Structural Coupling Model
(Beaming)

FE Model
(82133 elements,
(184866 DOF)



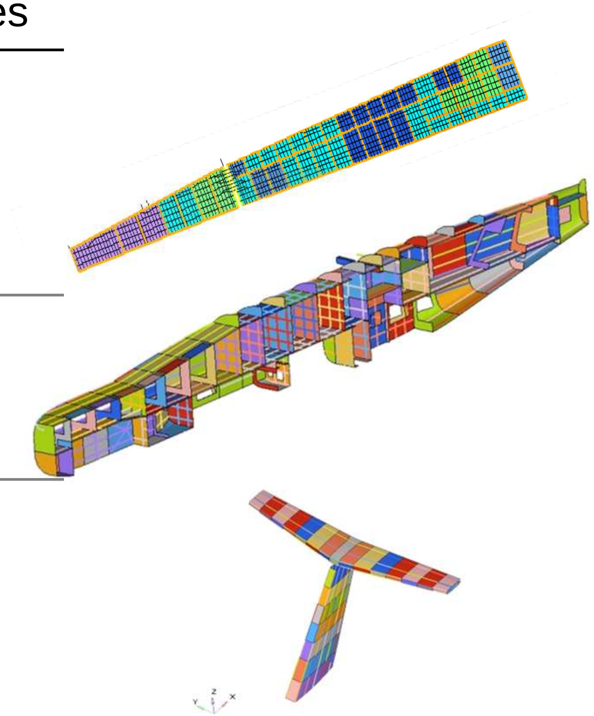


Aerodynamic DLM model (unsteady
state: gust, flutter)

Parametric model (Design Variables)

Full Parametric Model

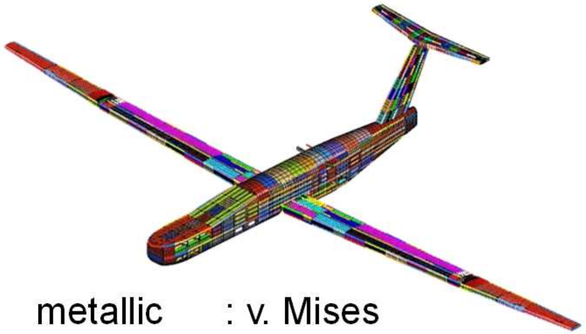
Component	Design Parameter	No. Design Variables
Wing	Skin: composite ply thicknesses Stringers: height and ply thicknesses Spars: cap cross-sectional areas, web thickness	372
Fuselage	Skin: metallic skin thicknesses Metallic shear walls, frame, longeron thicknesses	358
Empennage	Skin: composite ply thicknesses Stringers: height and ply thicknesses Spars: cap cross-sectional areas, web thickness	241
Total		**971**



Criteria Model

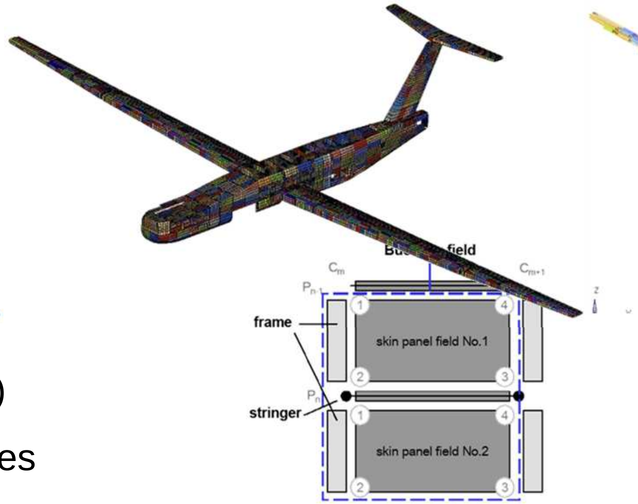
- Strength & Stability Criteria Model:

Strength | **Stability**

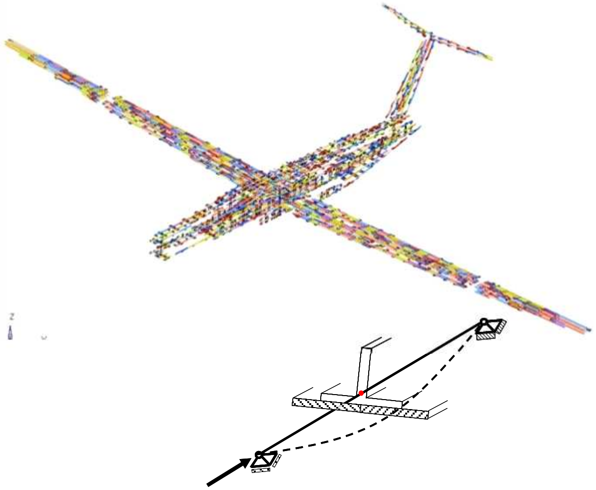


metallic : v. Mises
composites: maximum strain
(Damage Tolerance)

21915 constraints * 132 load cases



2743 Skin & shear wall buckling fields



1227 Column buckling fields (incl. local buck& crippling)

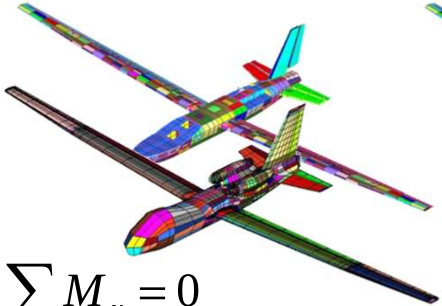
2.892.780 strength constraints 598.278 buckling constraints

Total: 3.497.174 constraints

Criteria Model

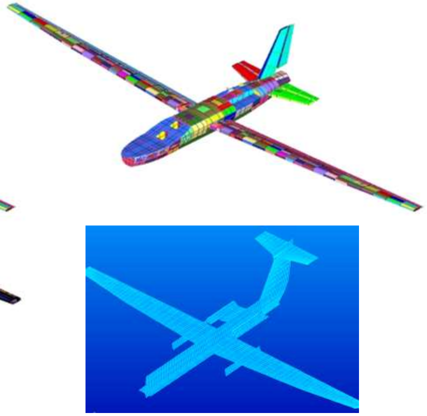
Criteria Model

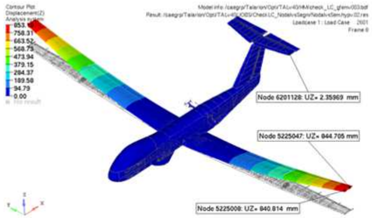
Flight-Physics	Flutter	Displacement	Manufacturing

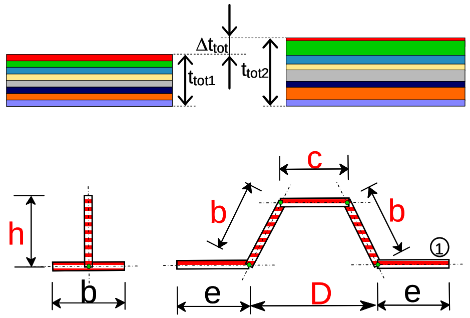


$$\sum M_x = 0 \quad \sum M_y = 0 \quad \sum M_z = 0$$

$$\sum Y = 0 \quad \sum Z = 0$$







5 constraints / load case

7 load cases

Displacement constraints

35 constraints

7 flutter constraint / Altitude / mass configuration

1 constraints

6116 manufacturing constr.

Additional 6160 constraints

Totally 3,503,334 constraints

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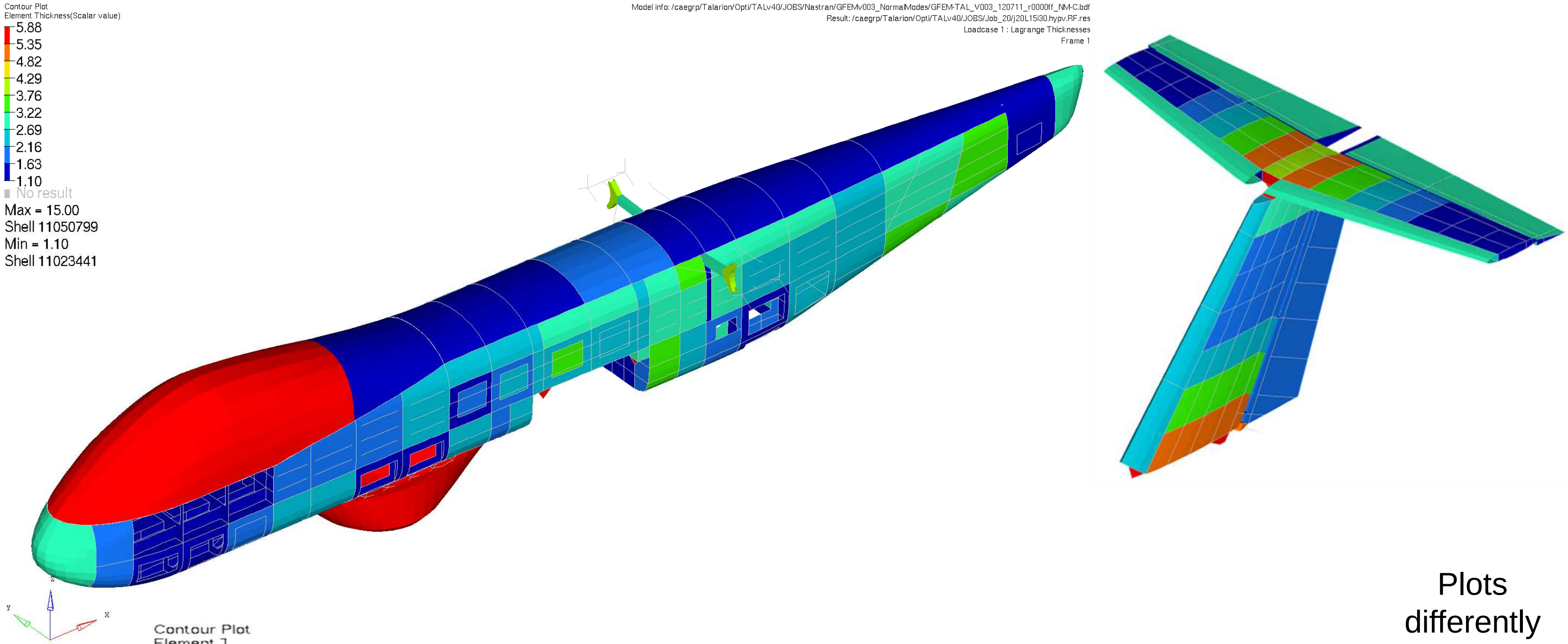
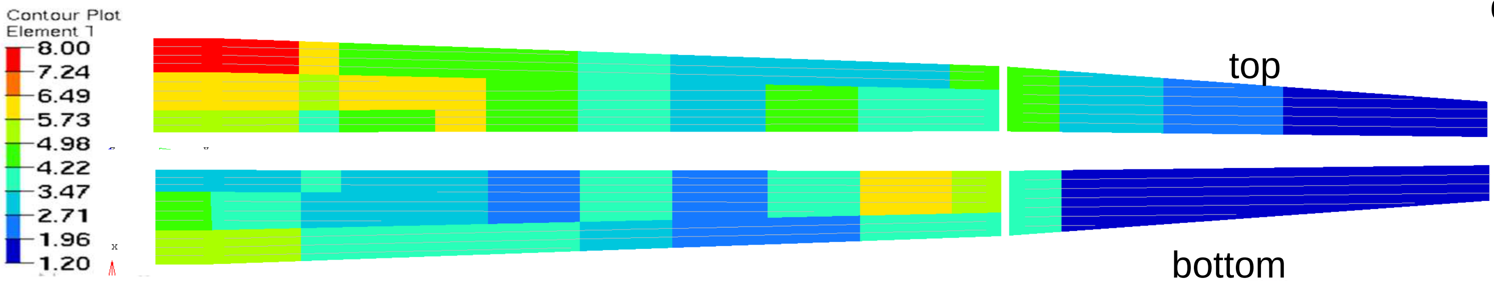
Exemplary Results: Thickness Distribution

- Thickness of Skin





Plots differently scaled

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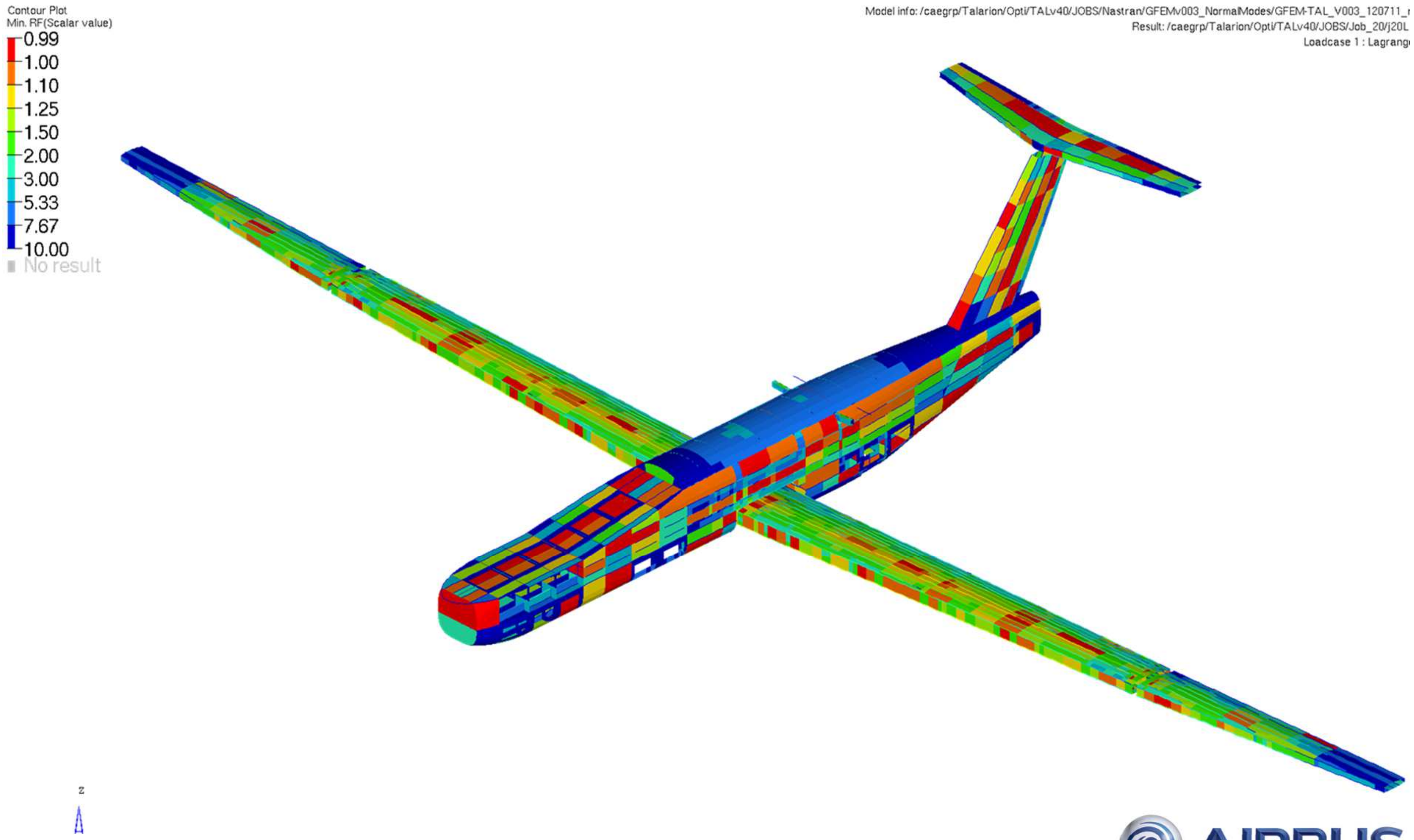
Exemplary Results: Minimum Reserve Factor Map

- Overall Map of minimum Reservefactors for strength and stability constraints



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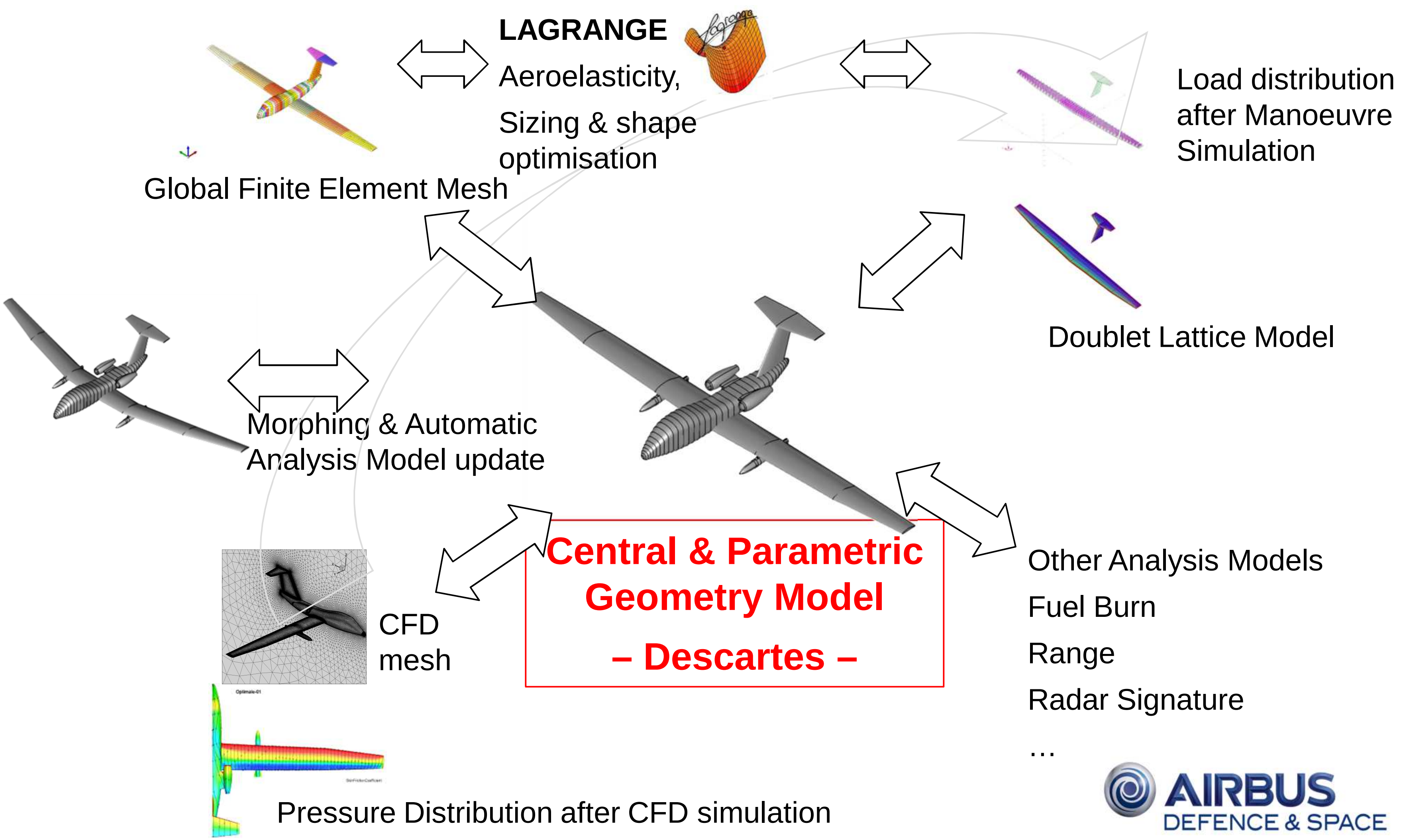
Fast
Model Generation

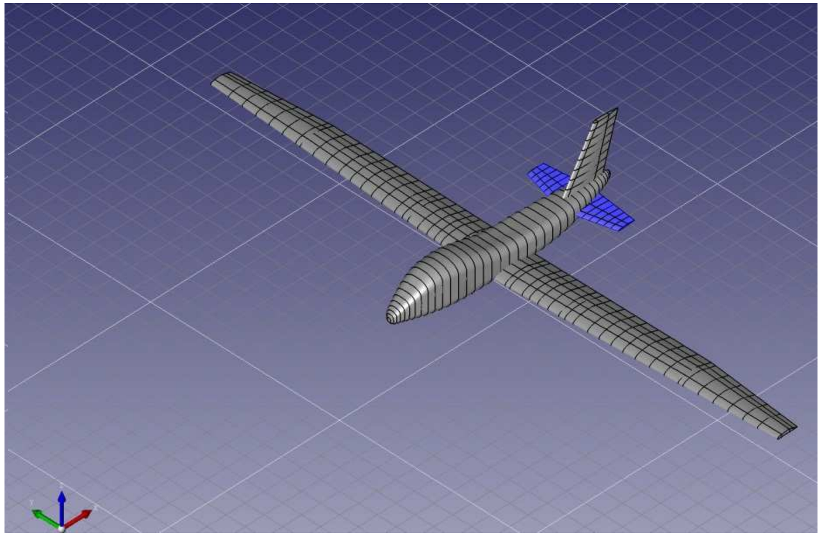
Vision of Integral Multidisciplinary Aircraft Design

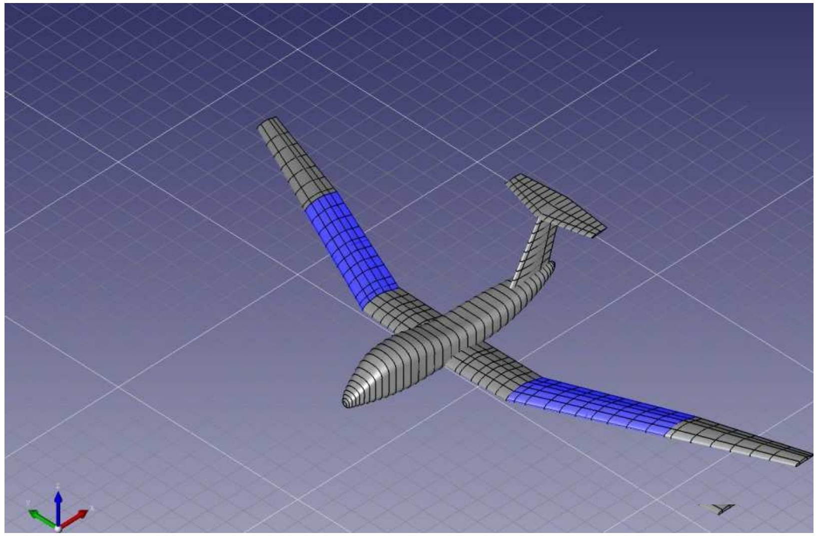
- Tool platform for modular, robust and decentral software coupling



Vision of Descartes

- Tool platform for easy shape modifications including parameterisation on different levels **keeping consistency of geometry model including all intersections!**
  - ❑ Aircraft level (fuselage length, wing span length, position of wing, etc.)
  - ❑ Component level (twist, radius, etc.)
  - ❑ Local level (coordinates of control points)

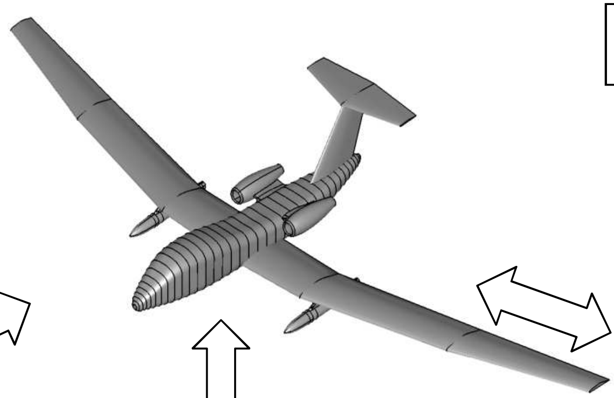




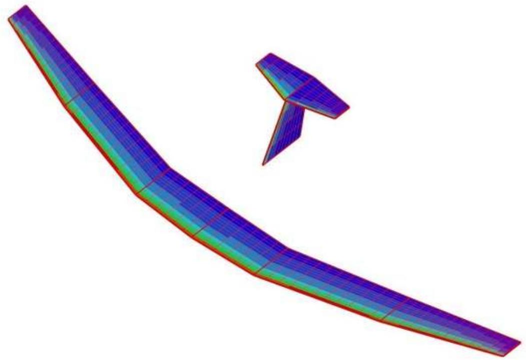
Vision of Descartes

- Tool platform for easy generation of numerical analysis models **including the link between geometry and analysis mesh**
  - Change Geometry
  - Update Analysis Models

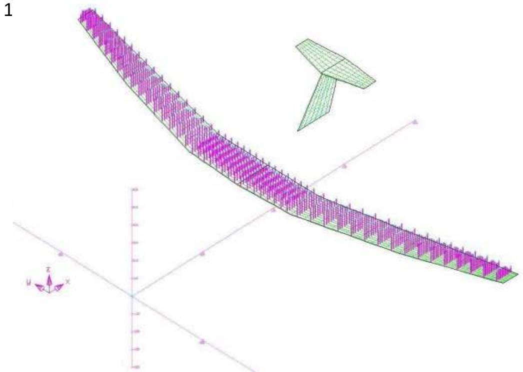
Watch in presentation mode for animation



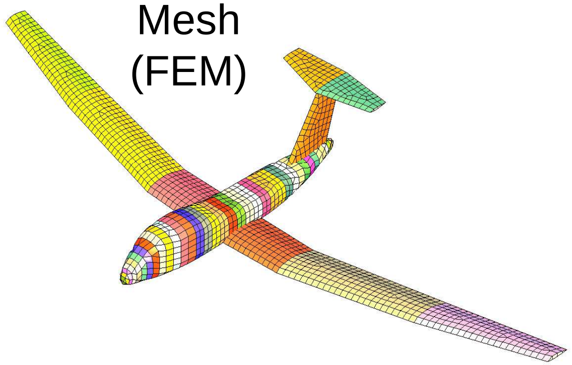
DLM Model



Vortex Lattice Model



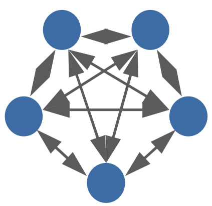
Structure Analysis Mesh (FEM)



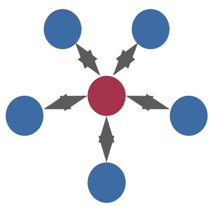
1

OpenCasCade, Tigl, CPACS and Descartes

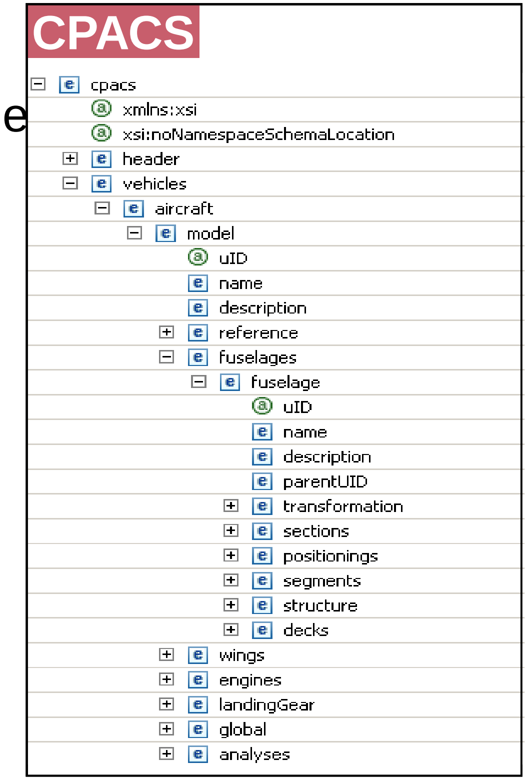
- Descartes is based on the TIXI / TIGL, a framework developed by DLR. The core geometry capabilities are based on openCascade.
- Descartes uses a central CPACS database and provides functionalities for **automatic** model **generation** and **modification**.
- CPACS: Common Parametric Aircraft Configuration Sche
  - Common Language within DLR
  - Development from 2005 TIVA, VAMP, FrEACs
  - Public Release March 2012
  - Open Source Version 2.1



▸ n (n – 1)



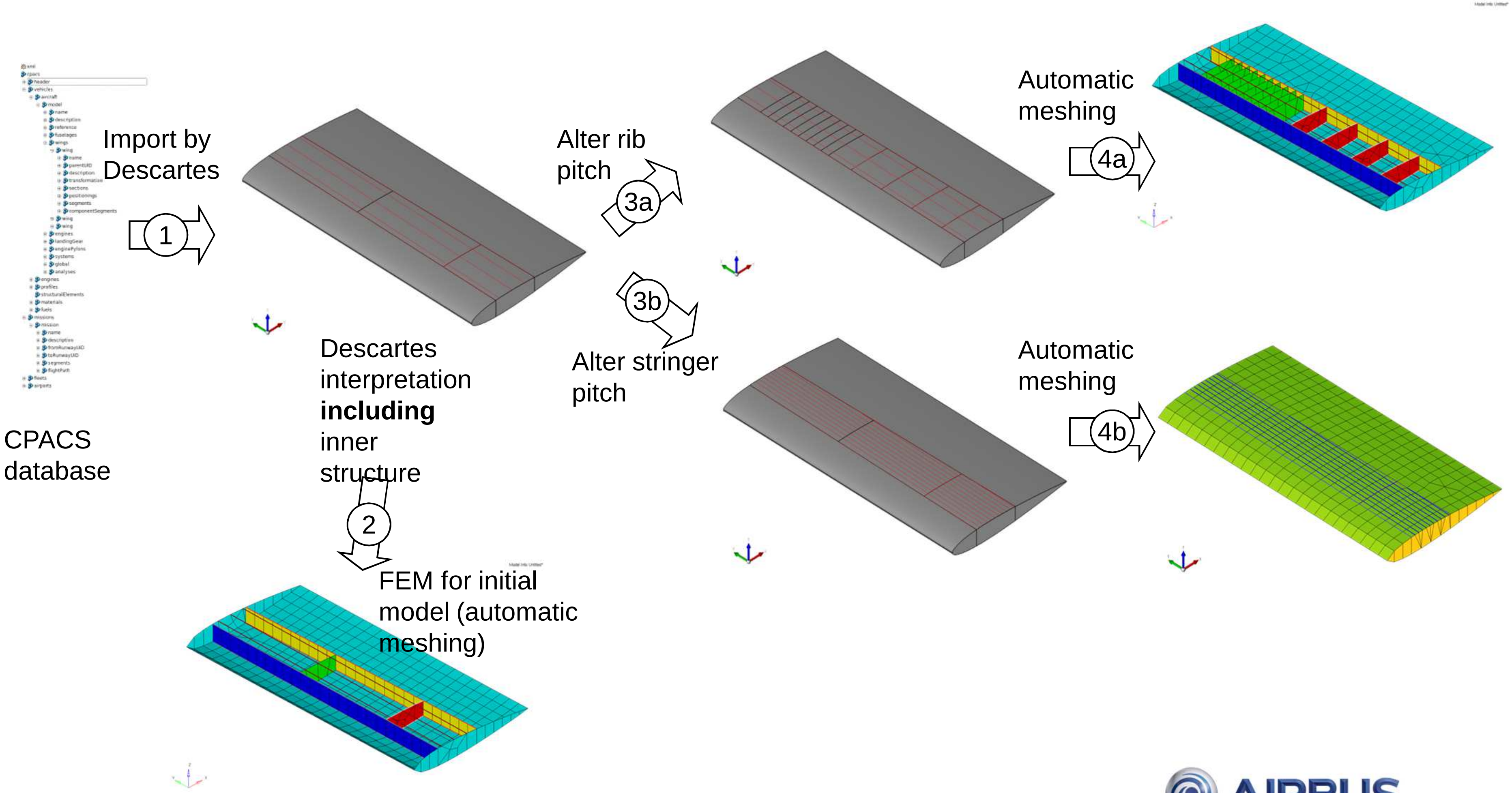
▸ 2 * n



C. M. Liersch and M. Hepperle, A distributed toolbox for multidisciplinary preliminary aircraft design, CEAS Aeronaut J (2011)}

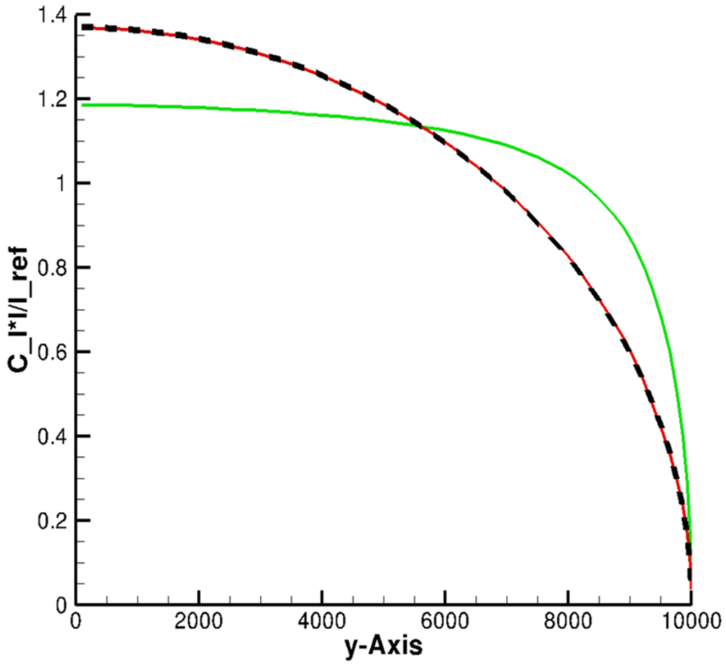
Descartes: Use Cases

- Tool platform for easy pitch studies (e.g. rib, stringer or frame pitches)

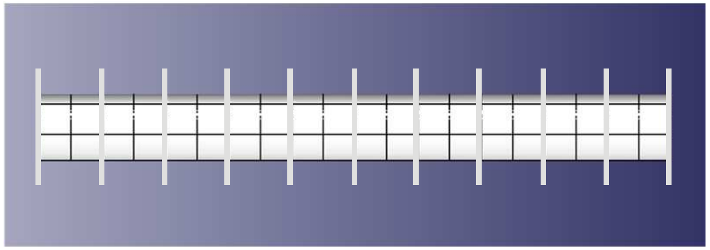


Descartes: Use Cases

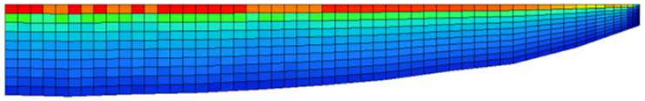
- Tool platform for shape optimisation
  - Wing / fuselage span length
  - Chord length, twist
  - Profile shape
  - Etc.



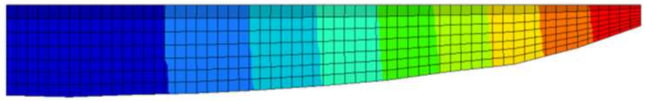
Initial wing geometry (top view)
with parameterised sections (chord length)



C_p distribution



Displacements



MDO
Integrated Framework

Vision of Integral Multidisciplinary Aircraft Design