POLITECNICO MILANO 1863

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Recent developments on AcBuilder, NeoCASS and PyPAD tools: toward a multi-fidelity aeroelastic framework for conceptual and preliminary aircraft design

5th SCAD - Symposium on Collaboration in Aircraft Design

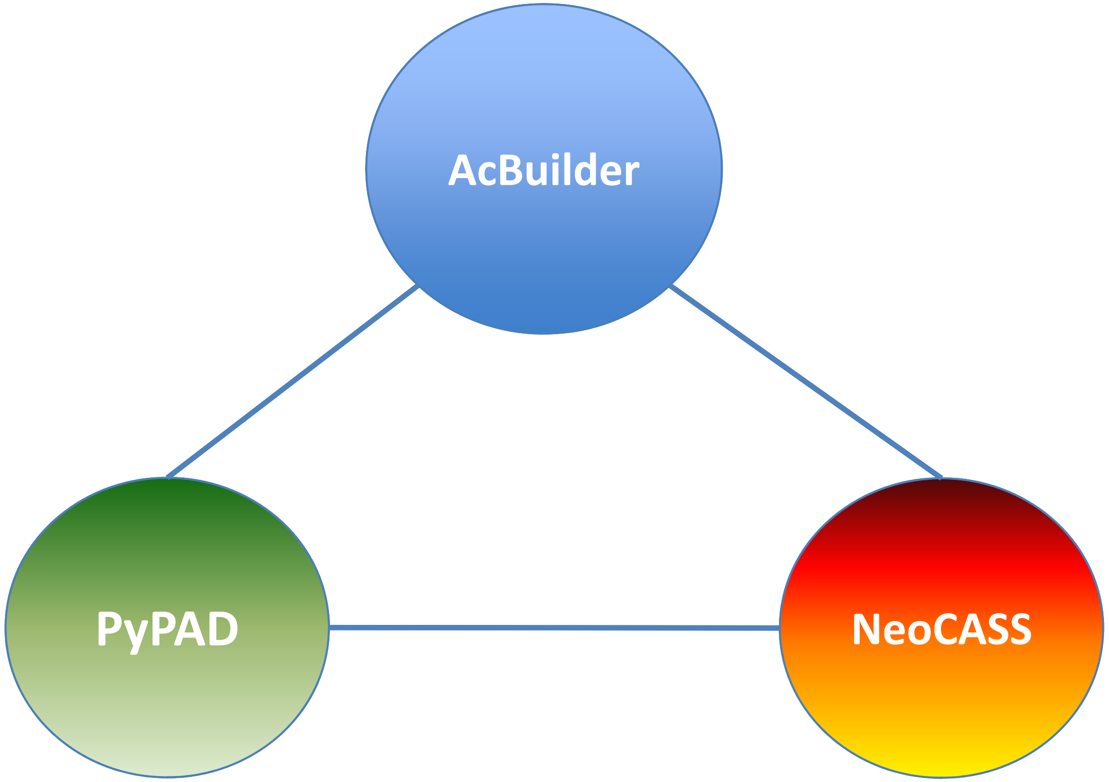
12th -14th October, 2015, Naples

Outline

1. Background
2. Overview of AcBuilder, NeoCASS and PyPAD
3. Recent improvements
4. The multi-fidelity aeroelastic framework
5. Conclusions

Background

Geometry and structural model



Development started in 2013

Standalone since 2012

Aeroelasstic modeling, analisys and MDO (preliminary level)

Aeroelasstic modeling and analisys (conceptual level)

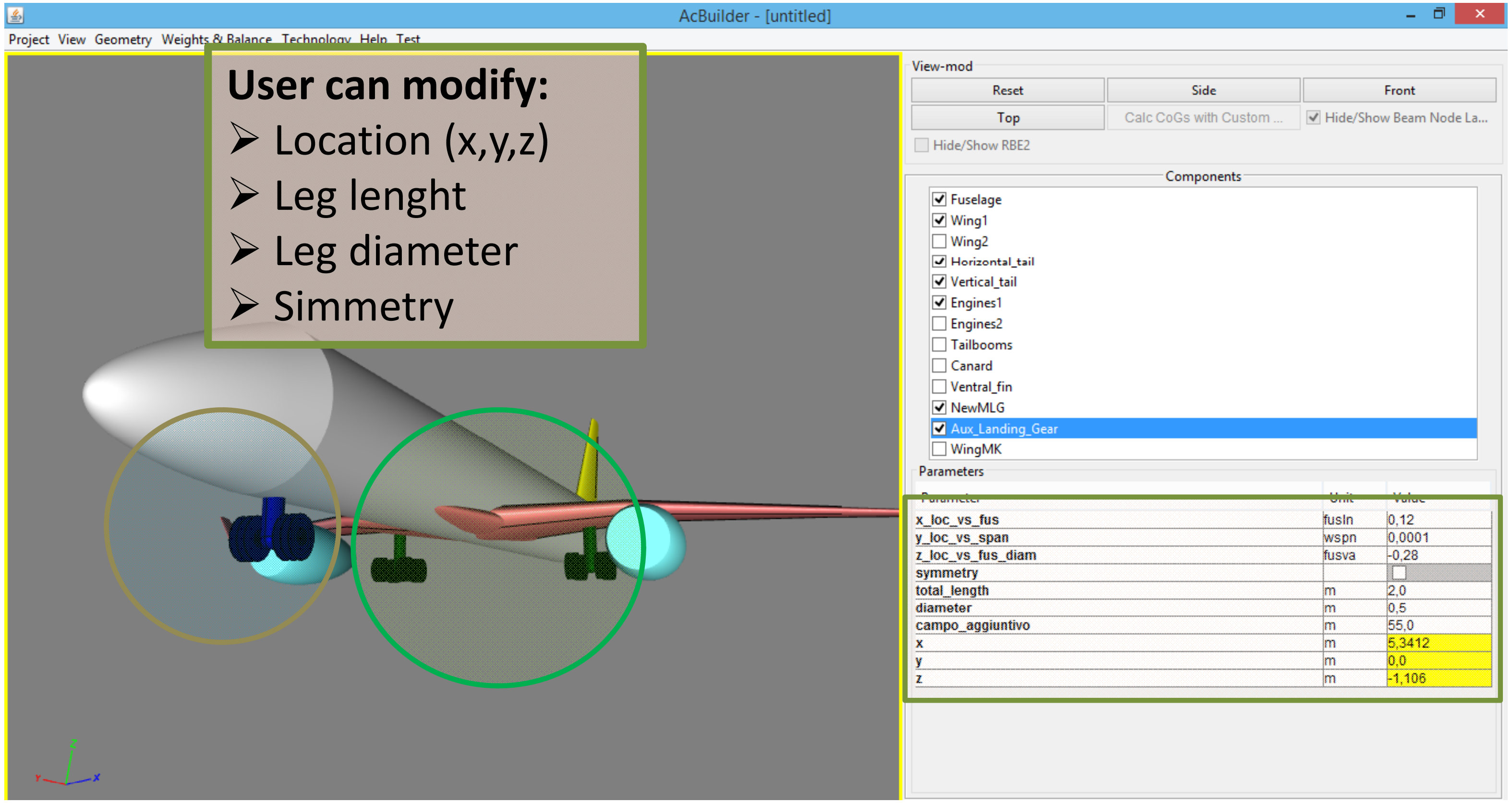
AcBuilder

- **What is:** Graphic editor used to create XML file with complete aircraft geometry description
- **Programming language:** JAVA

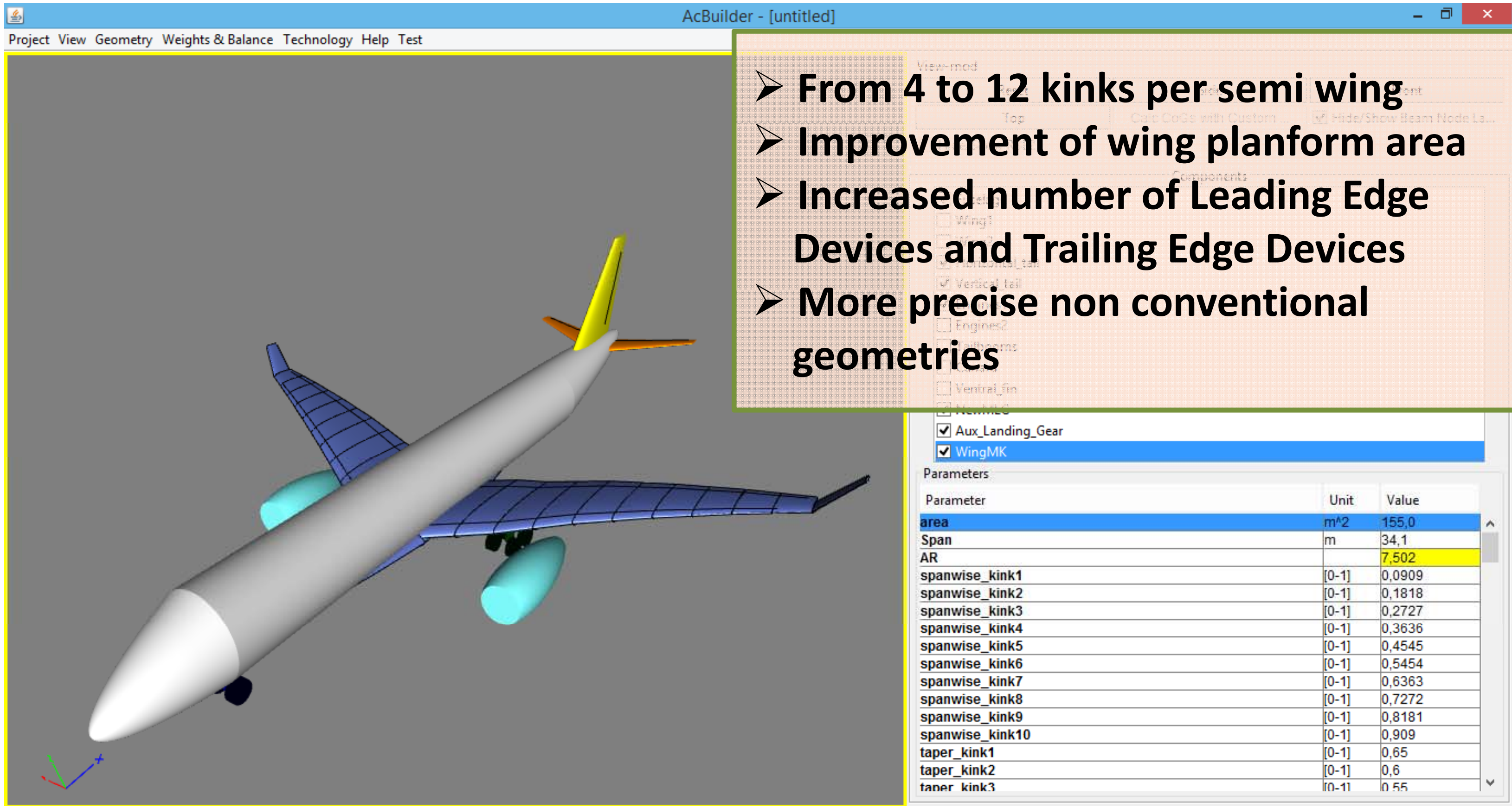
  MATLAB
- **Goals:** to transfer data to other NeoCASS modules

- **Features**
  - **Aircraft components geometric description**
  - **Weights Evaluation**
  - **Technological description**

Main Landing Gear and Aux Landing Gear



WingMK – Wing Multi Kink



- From 4 to 12 kinks per semi wing
- Improvement of wing planform area
- Increased number of Leading Edge Devices and Trailing Edge Devices
- More precise non conventional geometries

Weight and Balance module

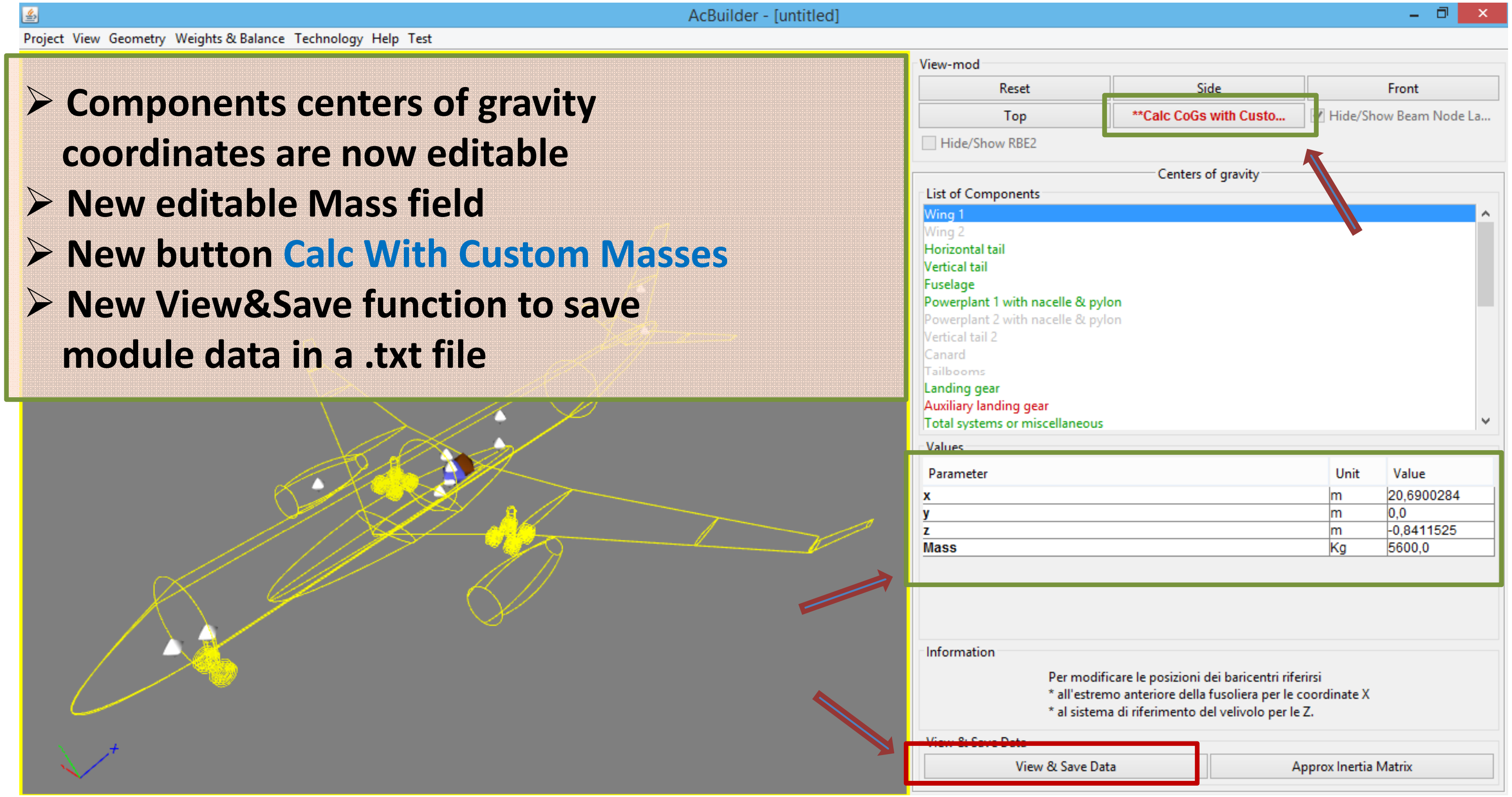
Centers of Gravity *[CoGs]* Function (Before update)

- **For each component evaluates mass and center of gravity location using empirical and statistical formulas**

Centers of Gravity *[CoGs]* Function (After update)

- **For each component user can customize mass and center of gravity location**

New CoG function



How to use it

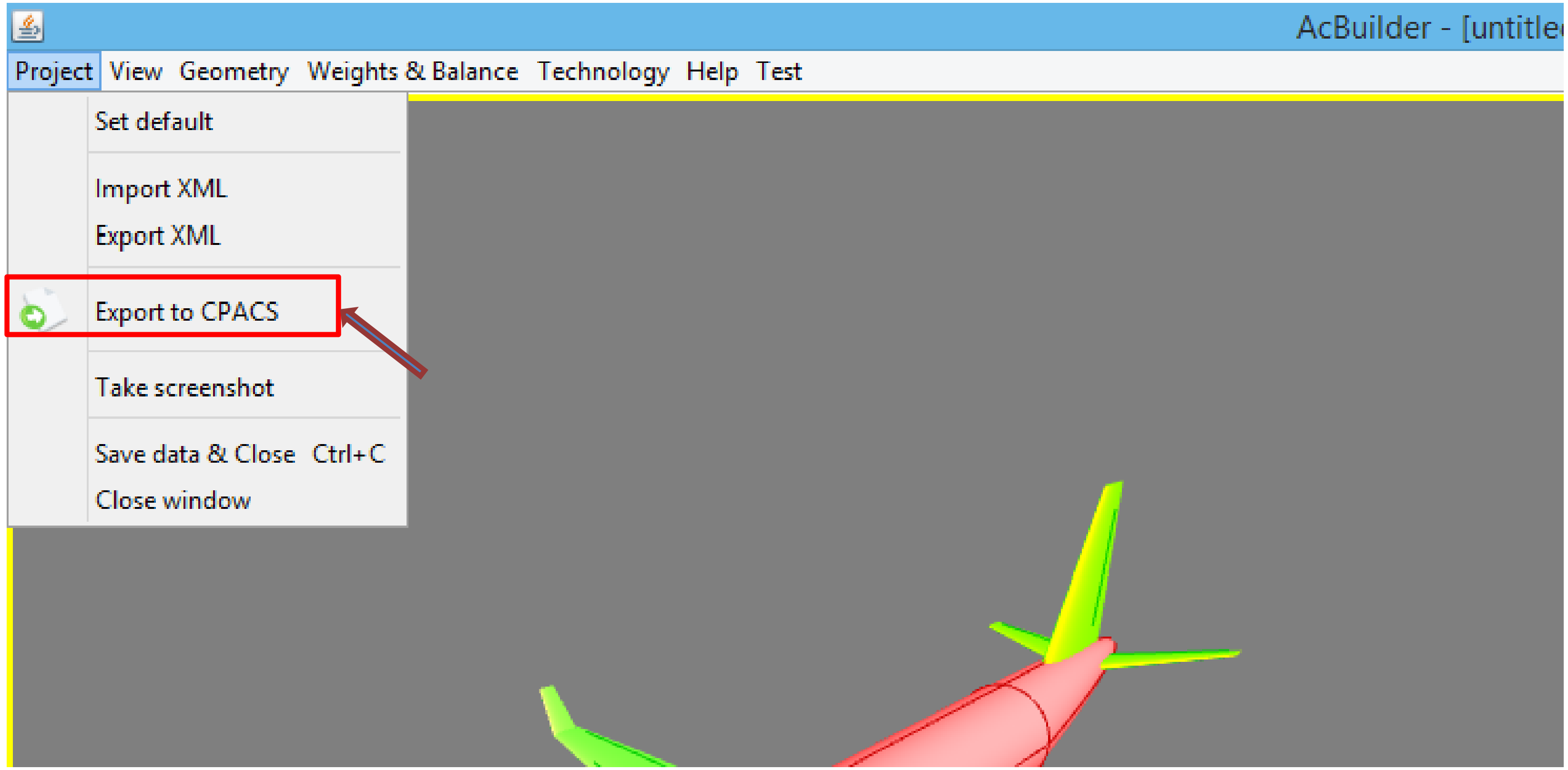
1
- **Select CoGs function from menu bar**

2
- **Customize components centers of gravity coordinates**
- **Modify data in Mass field**

3
- **Select *Calc With Custom Masses* button**

New exporting function

New **Export to CPACS** function



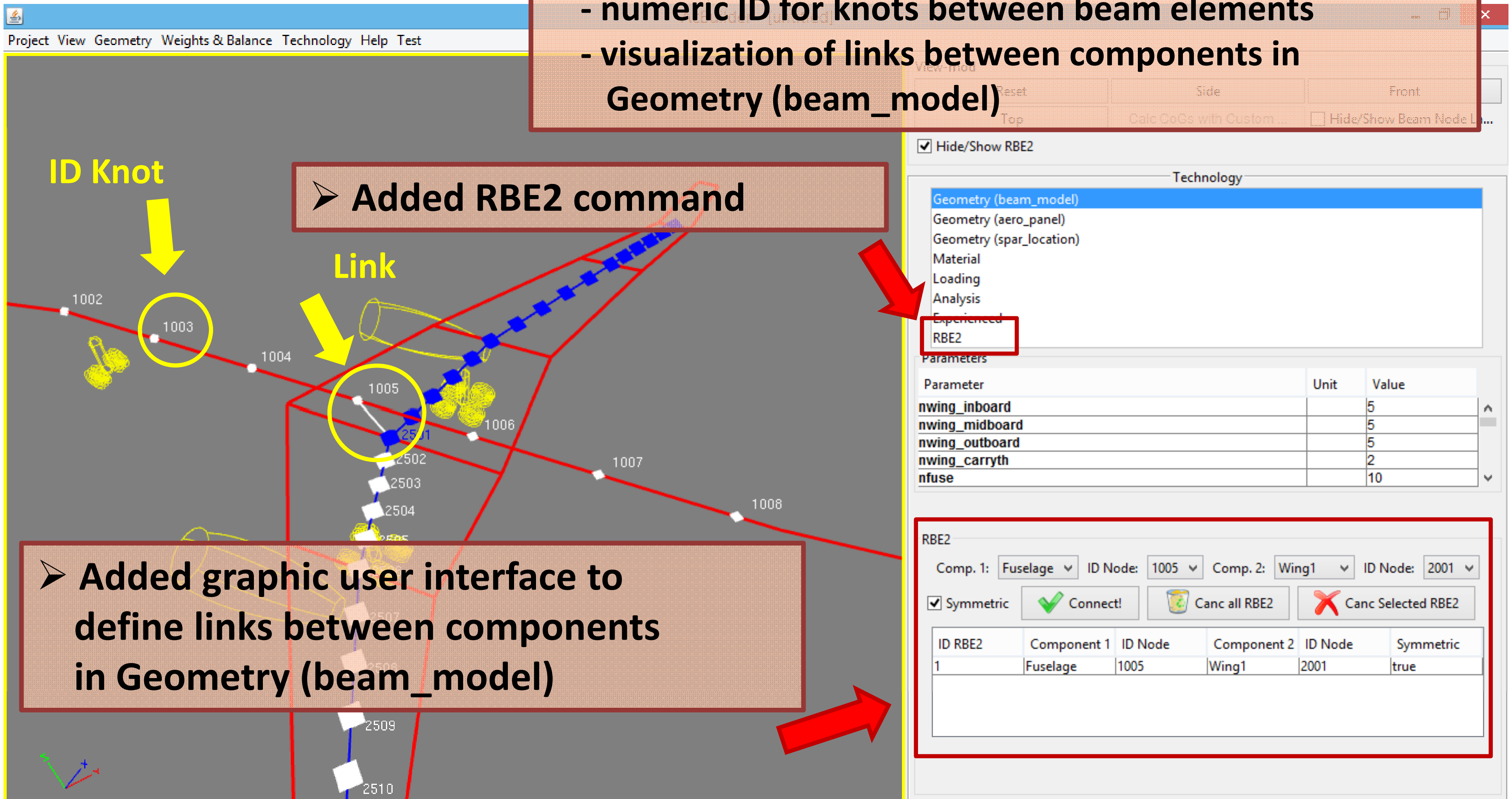
New features of Technology module

New features

- **Added:**
  - **numeric ID for knots between beam elements**
  - **visualization of links between components in Geometry (beam_model)**

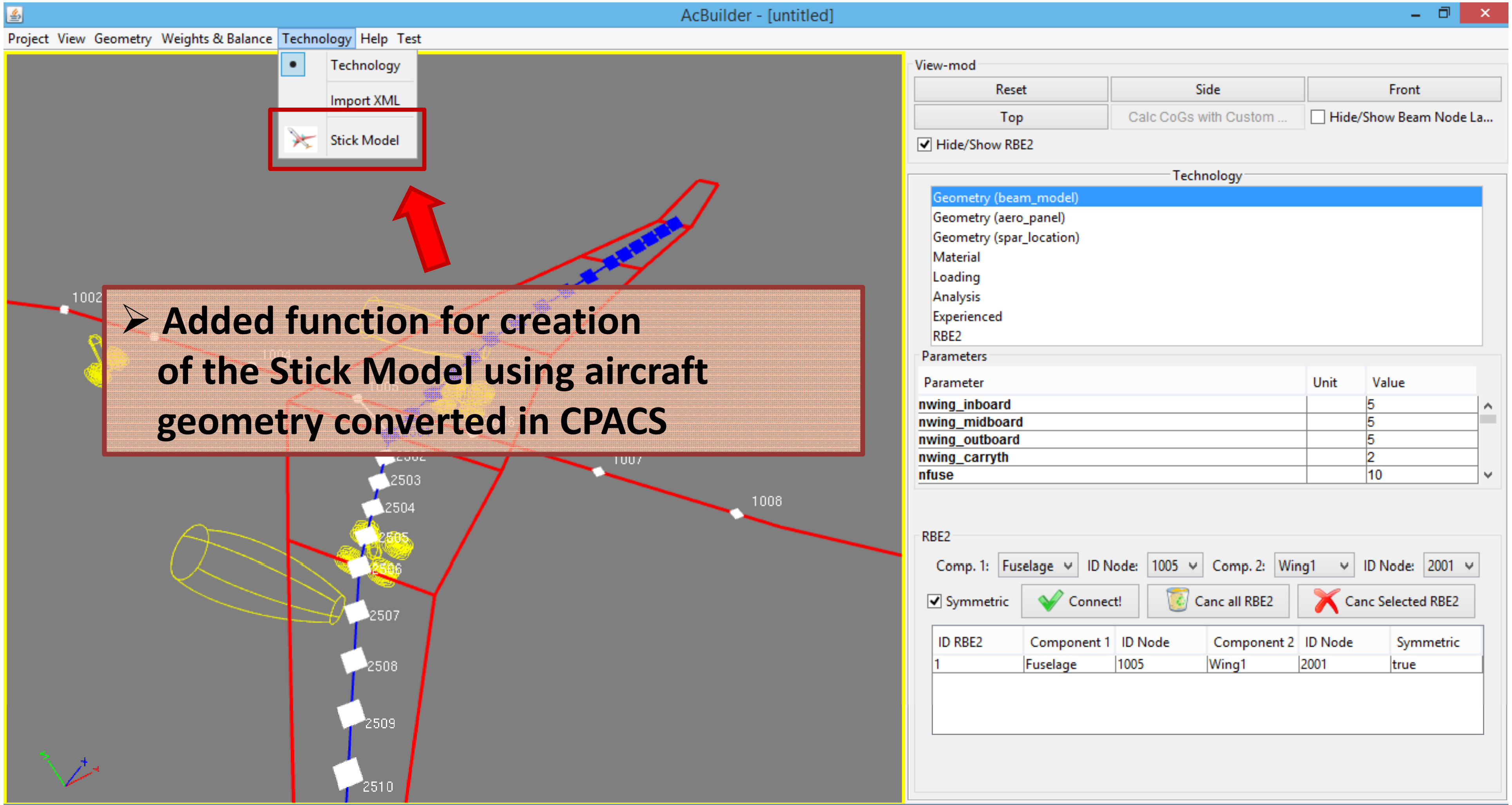
- **Added RBE2 command**

- **Added graphic user interface to define links between components in Geometry (beam_model)**



Automatic generation of the stick model

New function



NeoCASS background

NeoCASS (**Ne**xt generation **C**onceptual **A**ero-Structural **S**izing **S**uite) is a collection of Matlab® analysis modules for:

- Initial aircraft structural sizing;
- Modal analysis;
- Linear/non-linear static analysis;
- Aeroelastic analysis (static aeroelasticity, flutter);
- 'Flexible' Aerodynamic stability derivatives.

connected with tools for:

- Spatial coupling (MLS and RBF);
- Aerodynamic analysis (internal VLM/DLM);
- MDO.

interfaced to:

- External codes (Edge-FOI, MSC/NASTRAN, others)
- other modules of CEASIOM

Step by step NeoCASS sequence of operations:

1. Input of **Aircraft Geometric description** and **technological** solutions from AcBuilder module through XML file;
2. Input of **Sizing Mode**;
3. Initial structural sizing;

GUESS

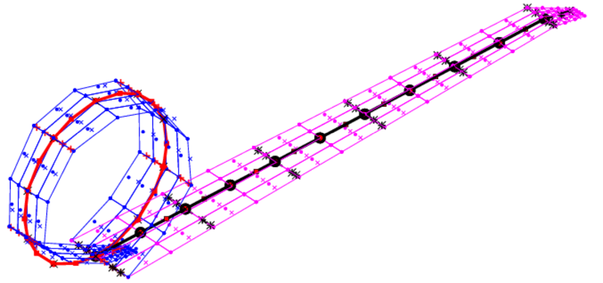
4. Structural Analysis;
5. Aeroelastic analysis, including MDO;
6. Output: **vibration modes**, **trimmed elastic aircraft**, **aeroelastic derivatives, flutter boundaries, divergence speed, aileron reversal, corrected inertia properties**

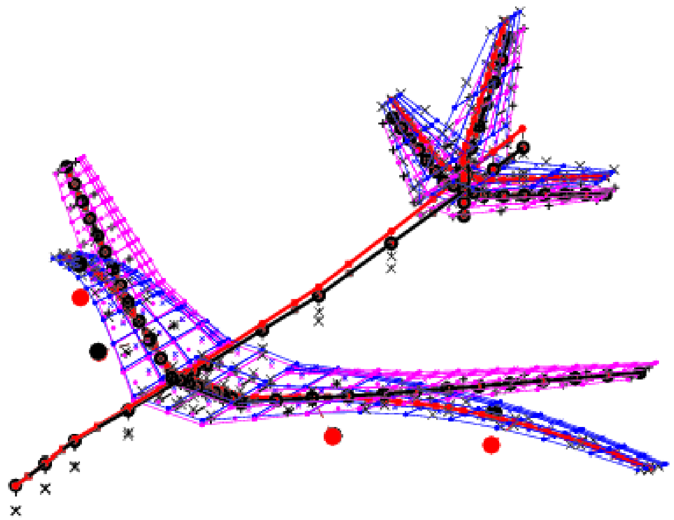
SMARTCAD

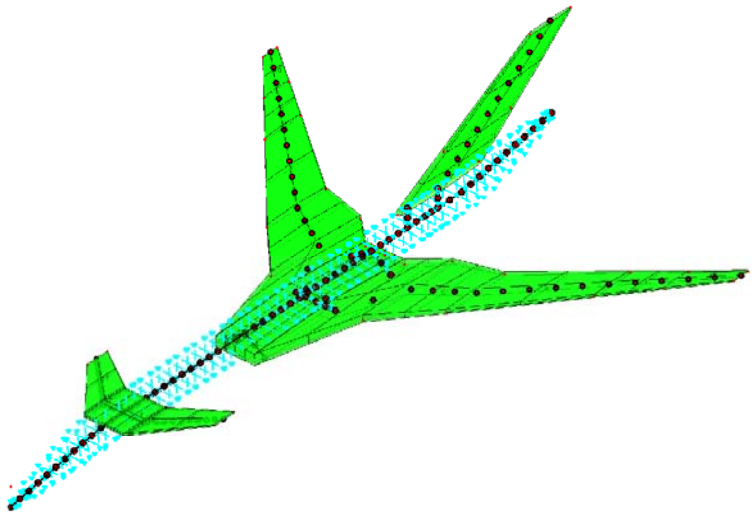
NeoCASS background

Two kind of structural models available:

- Three nodes linear-nonlinear beam [2]
- Equivalent plate
- Hybrid models



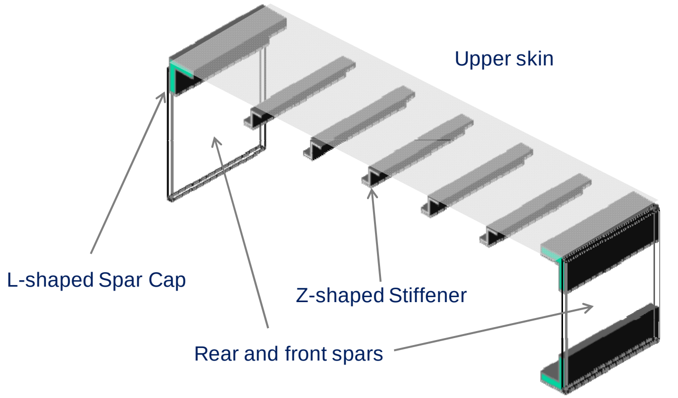


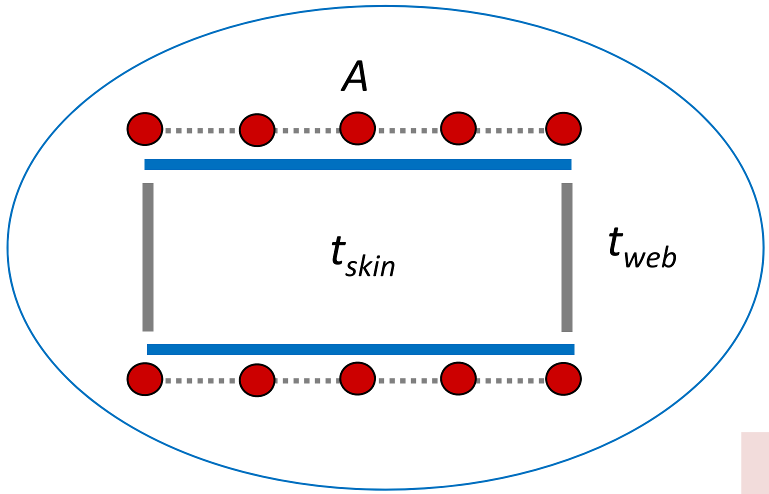


[2] Ghiringhelli, G. L., Masarati, P., and Mantegazza, P., "*Multibody Implementation of Finite Volume C0 Beams*" **AIAA Journal**, Vol. 38, No. 1, January 2000.

NeoCASS stick model

The stick model is obtained by condensing a physical-based model of the wingbox, sized through a local optimization run section by section.



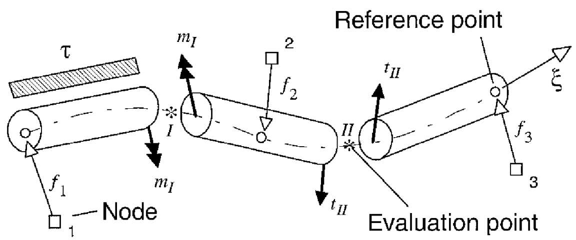


GUESS Design Space

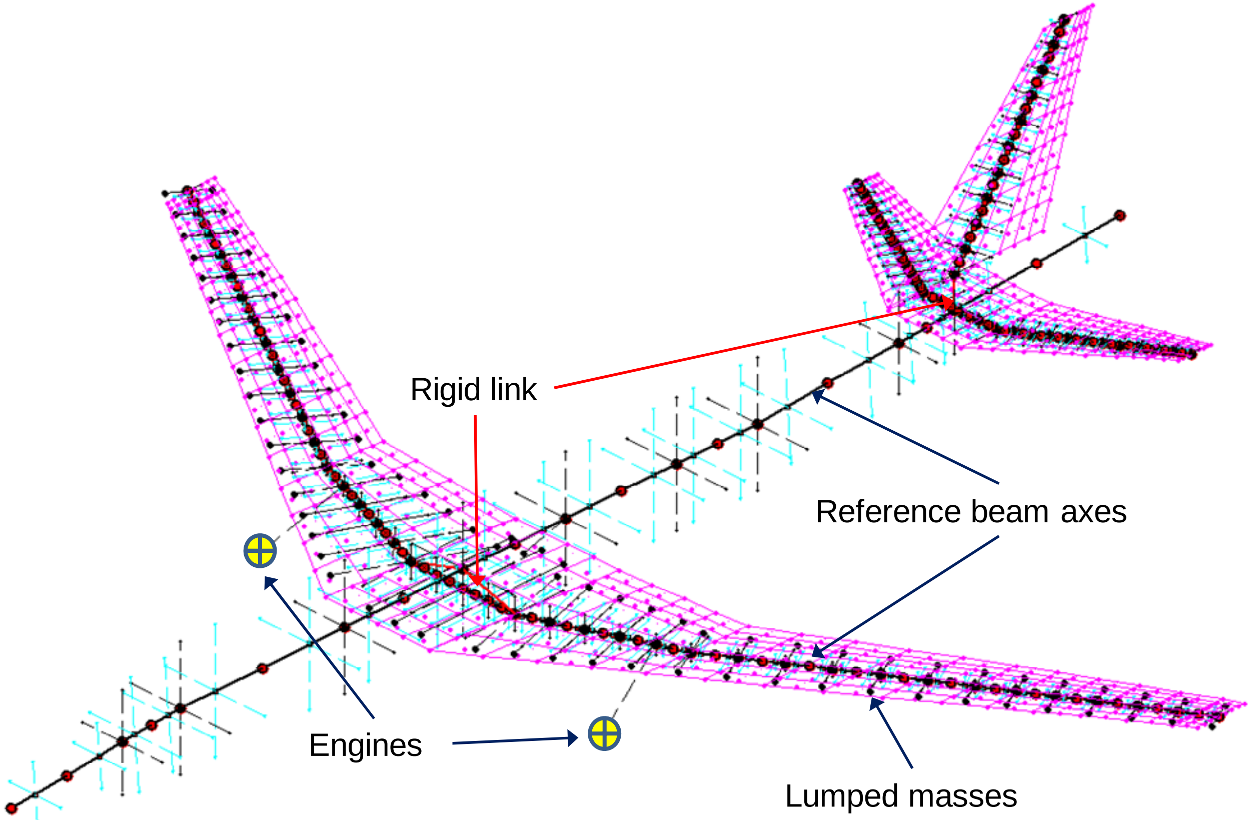
For each station, the following optimization problem is solved:

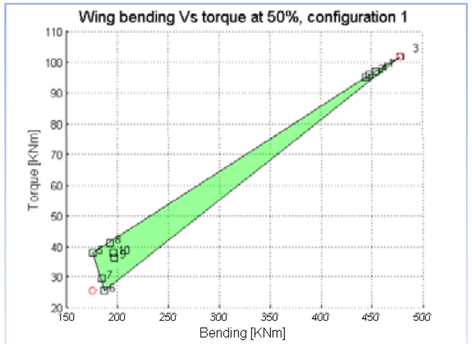
Min weight, s.t.

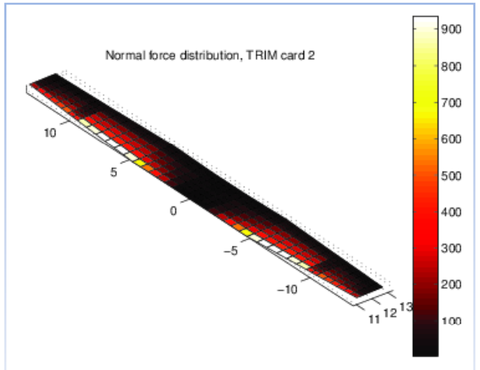
- Max stress
- Buckling of panels under compression, bending and Eulero-Johnson for stringers

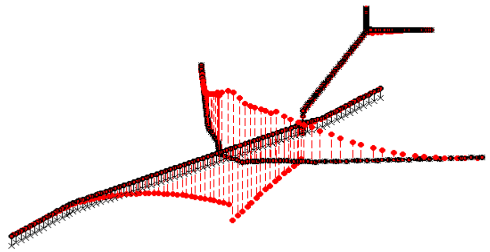


Typical GUESS outèut









SMARTCAD Overview

SMARTCAD (***S***implified ***M***odels for ***A***eroelasticity in ***C***onceptual ***A***ircraft ***D***esign)

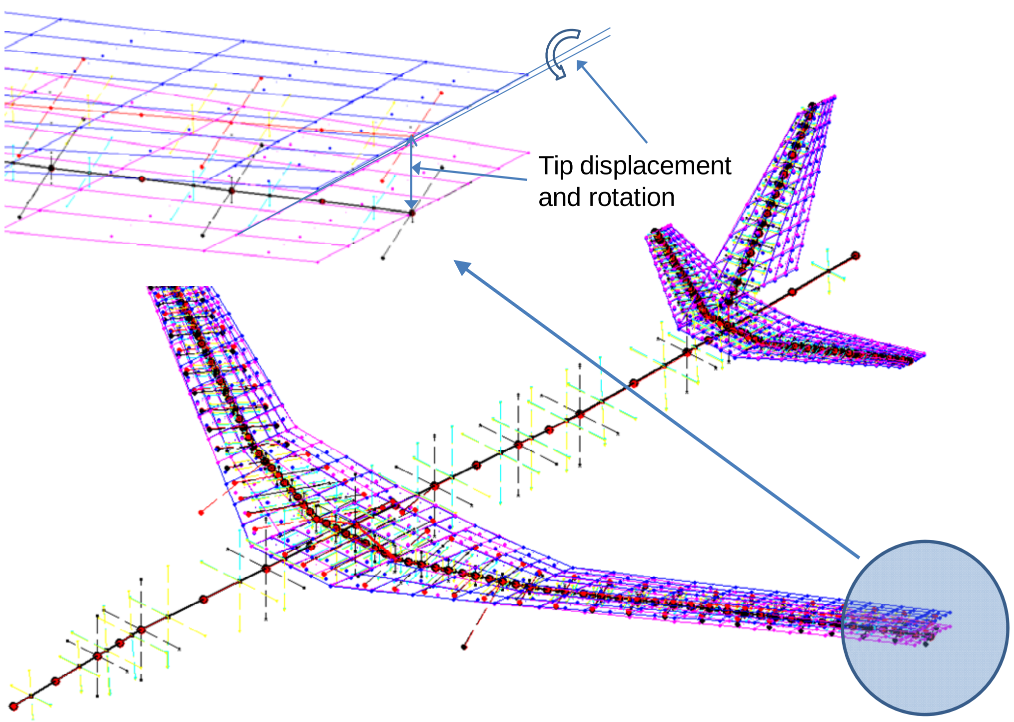
- **Input**: ASCII files derived from NASTRAN® formats. Why?
  - ✓ Platform independent;
  - ✓ To avoid wasting time to define and learn a new format;
  - ✓ Commercial pre/post-processors can be used to visualize the model and results;
  - ✓ **SMARTCAD** can be almost easily bypassed in favor of NASTRAN® without precluding the overall functionality of CEASIOM design tool;
  - ✓ The comparison with the validated commercial code is then straightforward.

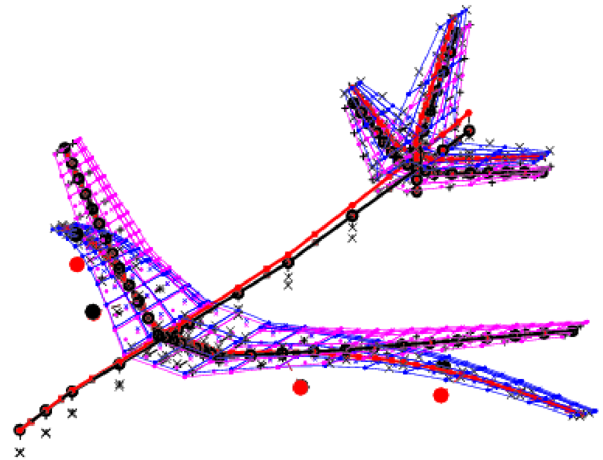
SMARTCAD Background

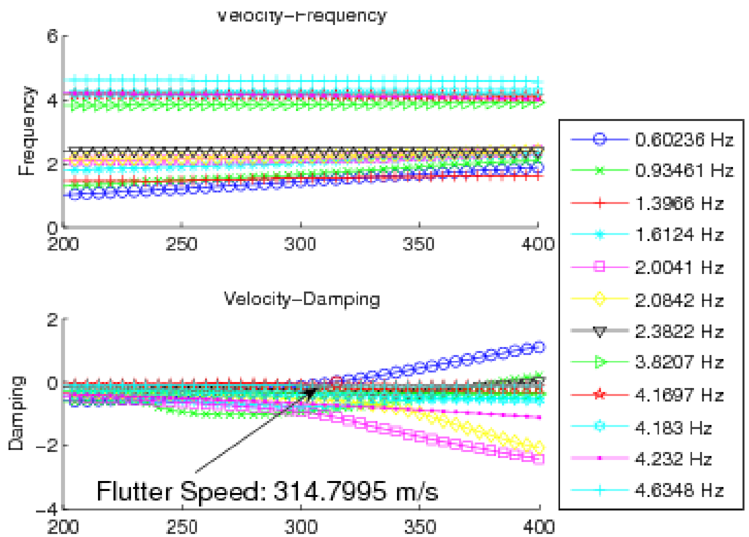
Once available, the aeroelastic model can be processed by **SMARTCAD** to compute:

- Static aeroelasticity;
  - ✓ Divergence speed;
  - ✓ Deformable trimmed configuration;
  - ✓ Flexible stability derivatives.
- Dynamic aeroelasticity;
  - ✓ Flutter diagram (*V*-g plot);
  - ✓ Flutter envelope.
- MDO, to improve any of the aeroelastic responses by changing the structural properties initially estimated by **GUESS**.

SMARTCAD typical output

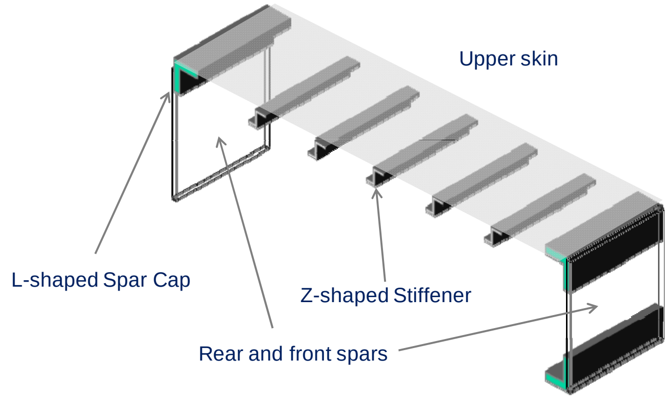


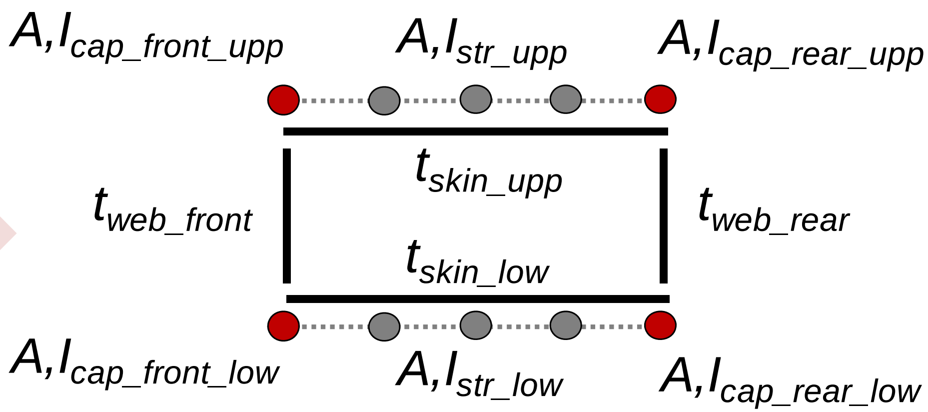




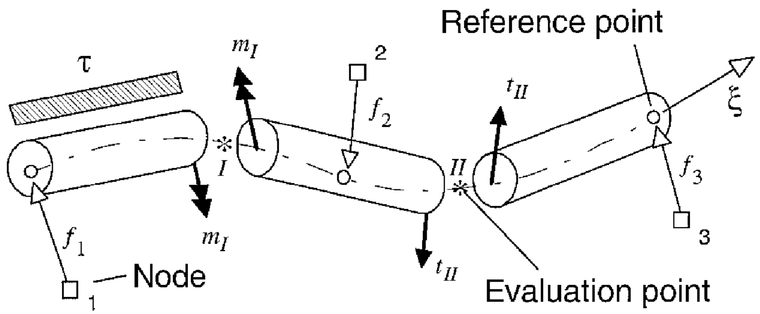
NeoCASS: GUESS new features

The stick model is obtained by condensing a physical-based model of the wingbox, sized through a local optimization run section by section.





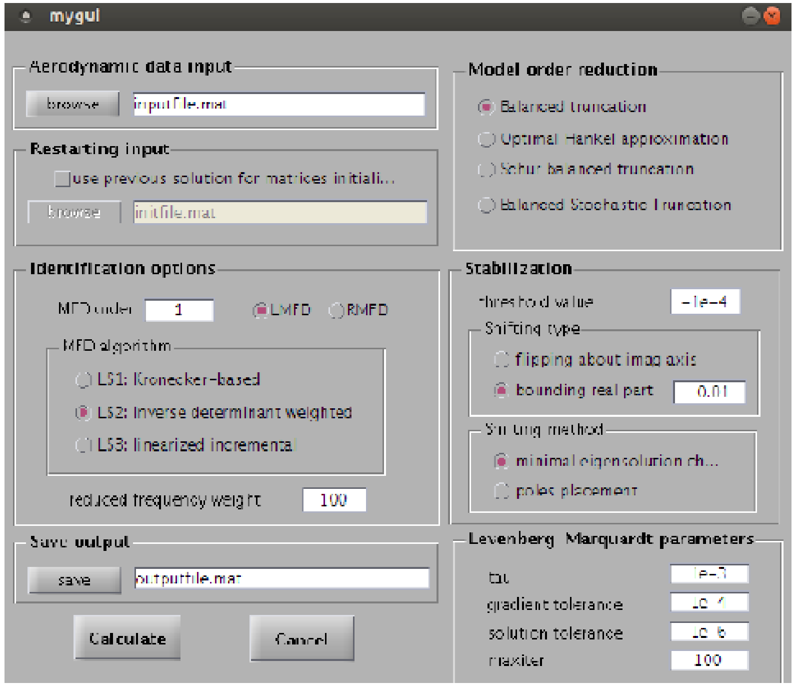
GUESS Design Space

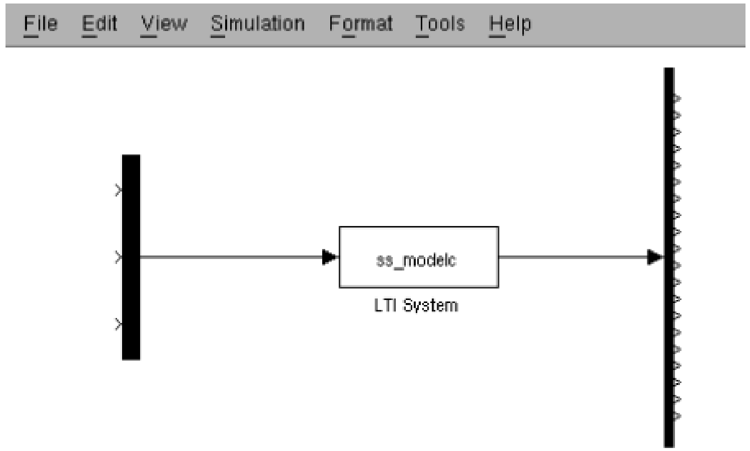


NeoCASS: SMARTCAD new features

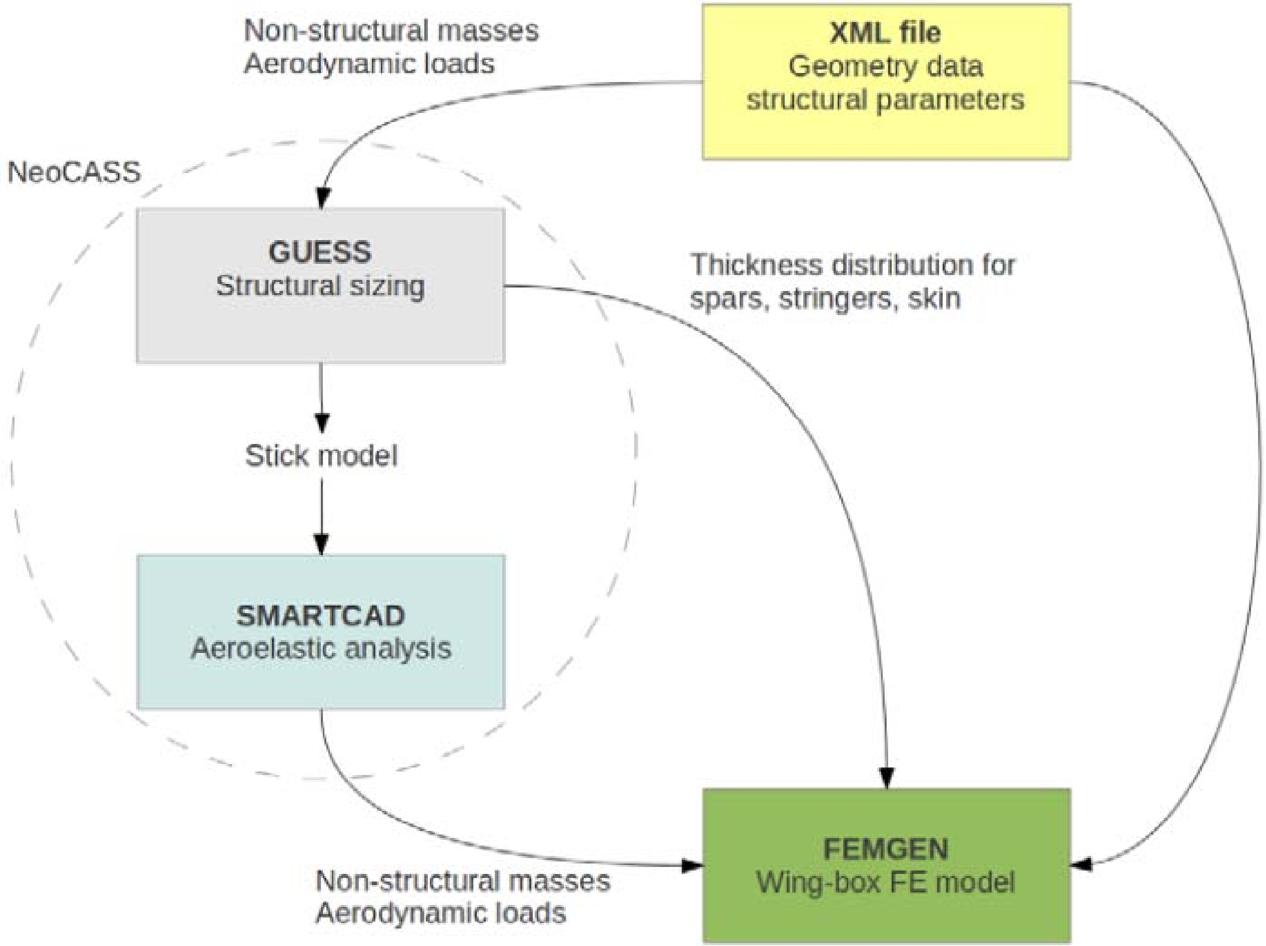
Dynamic response module (NeoRESP) to calculate:

- Discrete gust response (including mode acceleration)
- Response to control surface motion or concentrated forces
- State-space aeroelastic models, to be used for time simulation inside Simulink

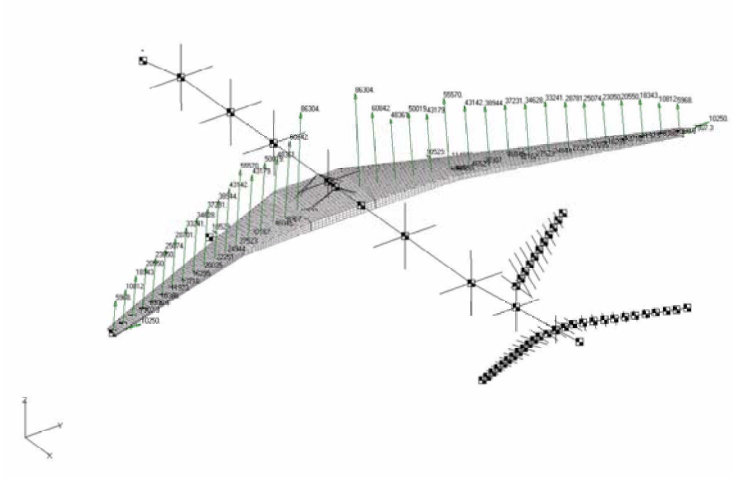




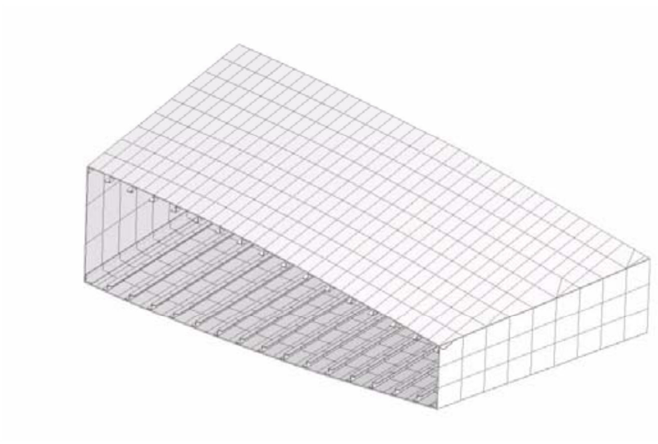
FEMGEN: 3D wingbox generation



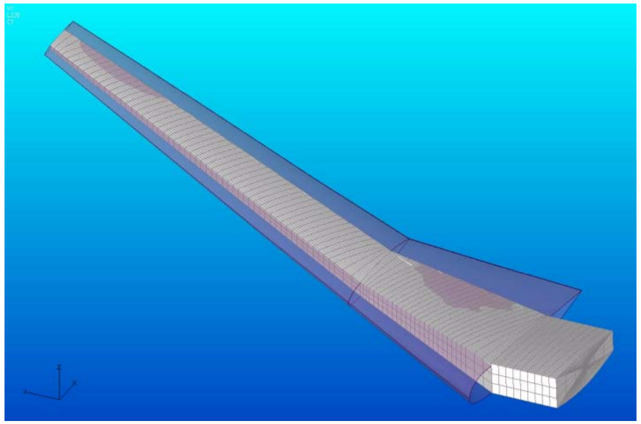
FEMGEN and hybrid models



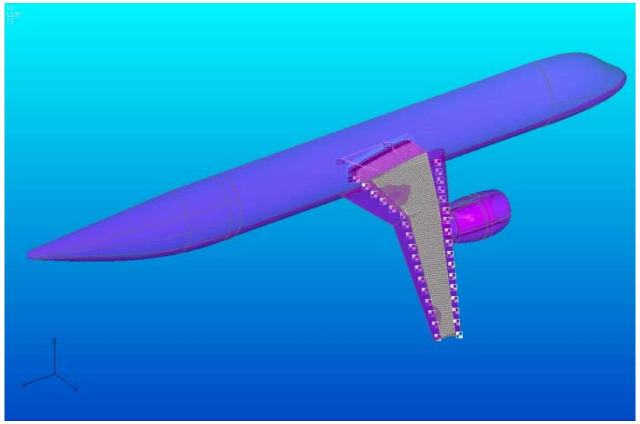
Hybrid model



3D model of the wingbox



Details of the wing



Half body with embedded wbox

NeoCASS: SMARTCAD new features

Optimization problem generated by FEMGEN:

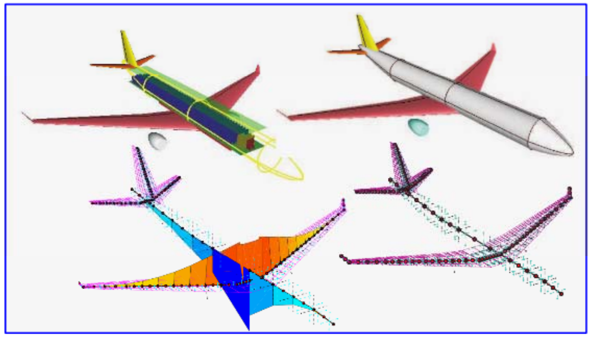
- OBJ: Minimum weight
- Load conditions: no limitations
- Constraint: failure criteria, stability margin of safety for panels and beams
- Aerodynamic loads: from VLM or CFD, reduced to CONM2 nodes using RBF FSI interface based on RBF

Some implementation details:

- Automatic generation of DESVAR cards
- Automatic generation of DEQUATN cards to implement analytical calculation of stability margins
- Stability margins based on Bruhn and Boeing design manual
- Buckling of panels under compression, bending and Eulero-Johnson for stringers are considered

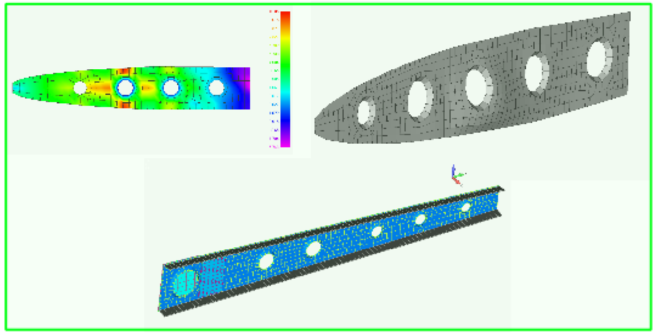
PyPAD background

Conceptual Design

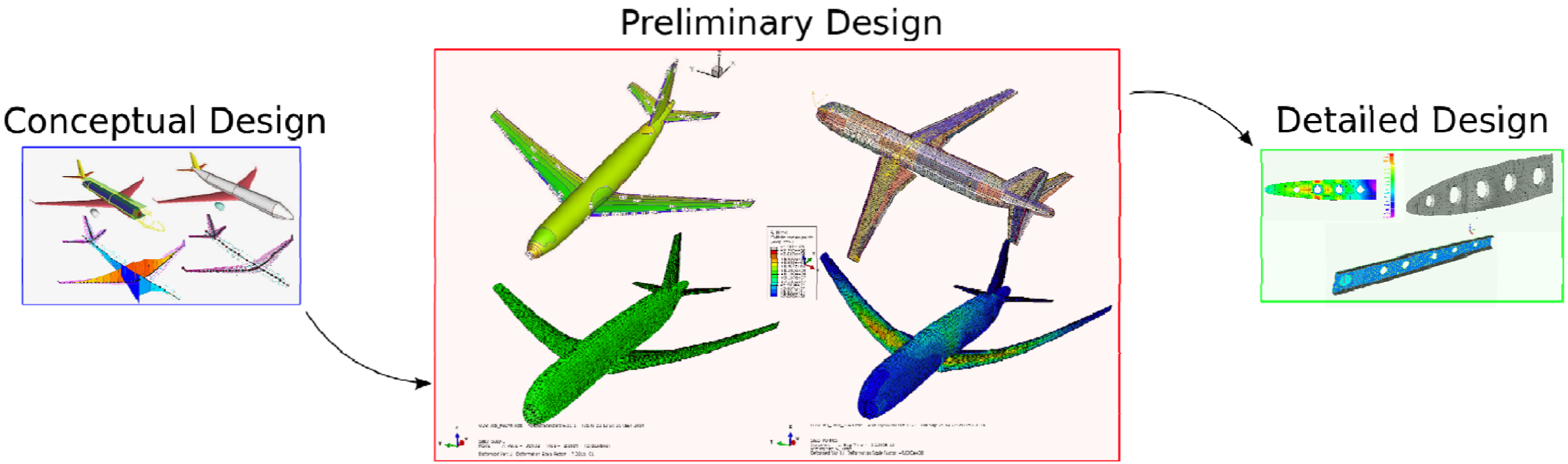


Preliminary or Intermediate Design

Detailed Design



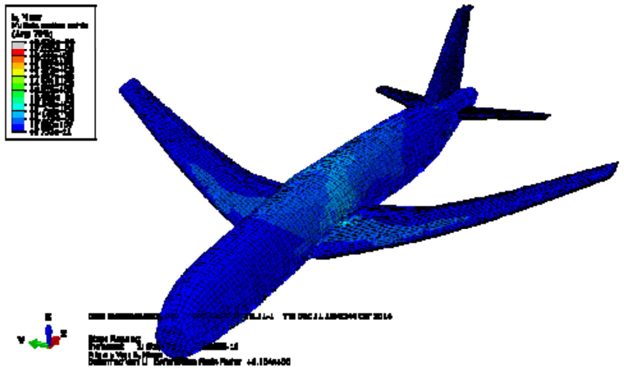
PyPAD background

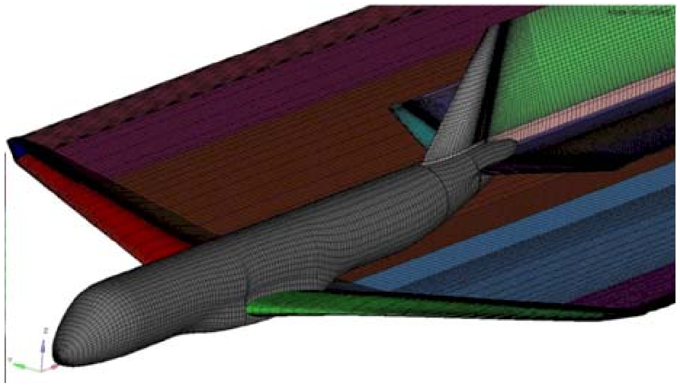


GOAL: To develop a dedicated framework for preliminary design, focused on dynamic loads and airframe sizing, keeping some of the capabilities typical of conceptual design tools, like automatic model generation.

PyPAD background

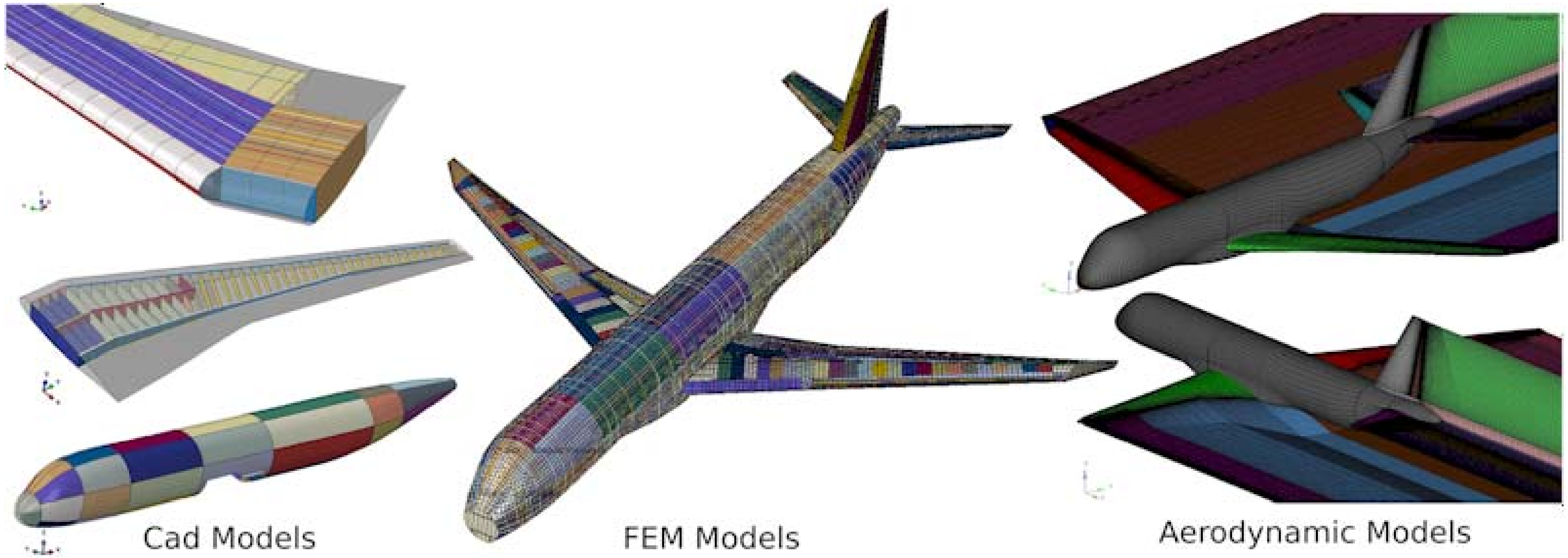
- PyGFEM: a model generator (in Abaqus-CAE environment), able to define FE and aerodynamic models starting from a fully parametric aircraft description based on CPACS
- PyAERO: a package for dynamic loads computation and aeroelastic analysis
- PySIZE: a package for the structural sizing, able to deal with different sizing criteria



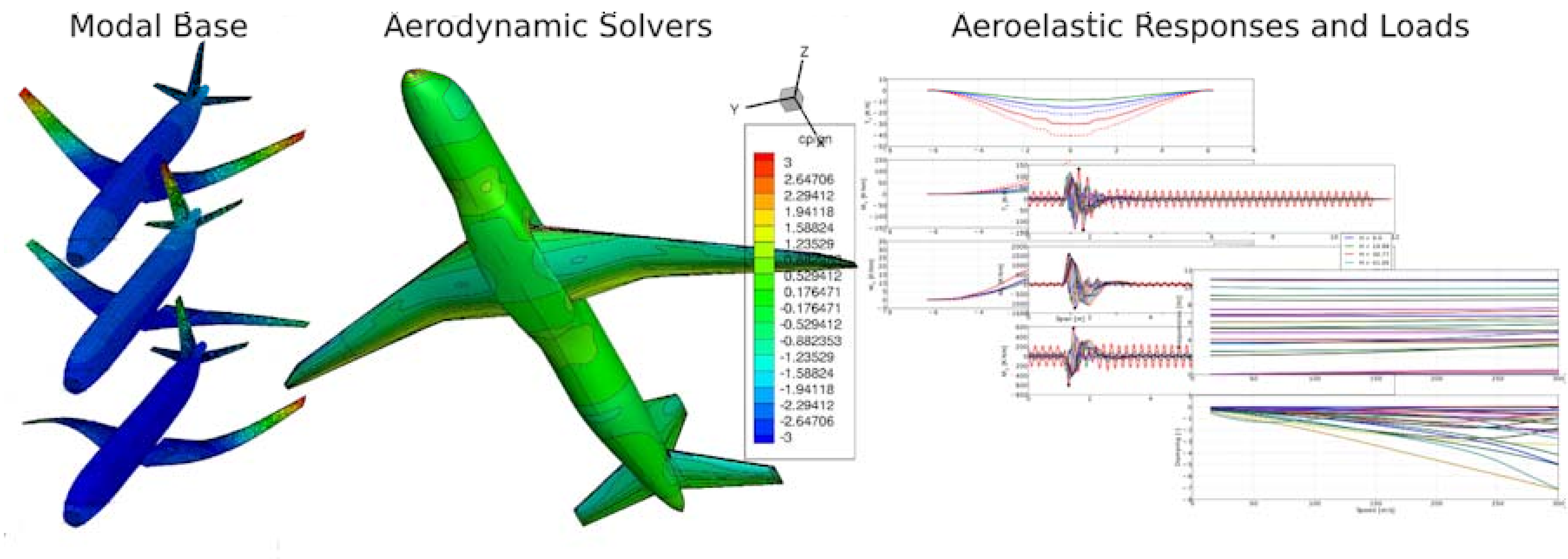


CFD mesh

PyGFEM overview

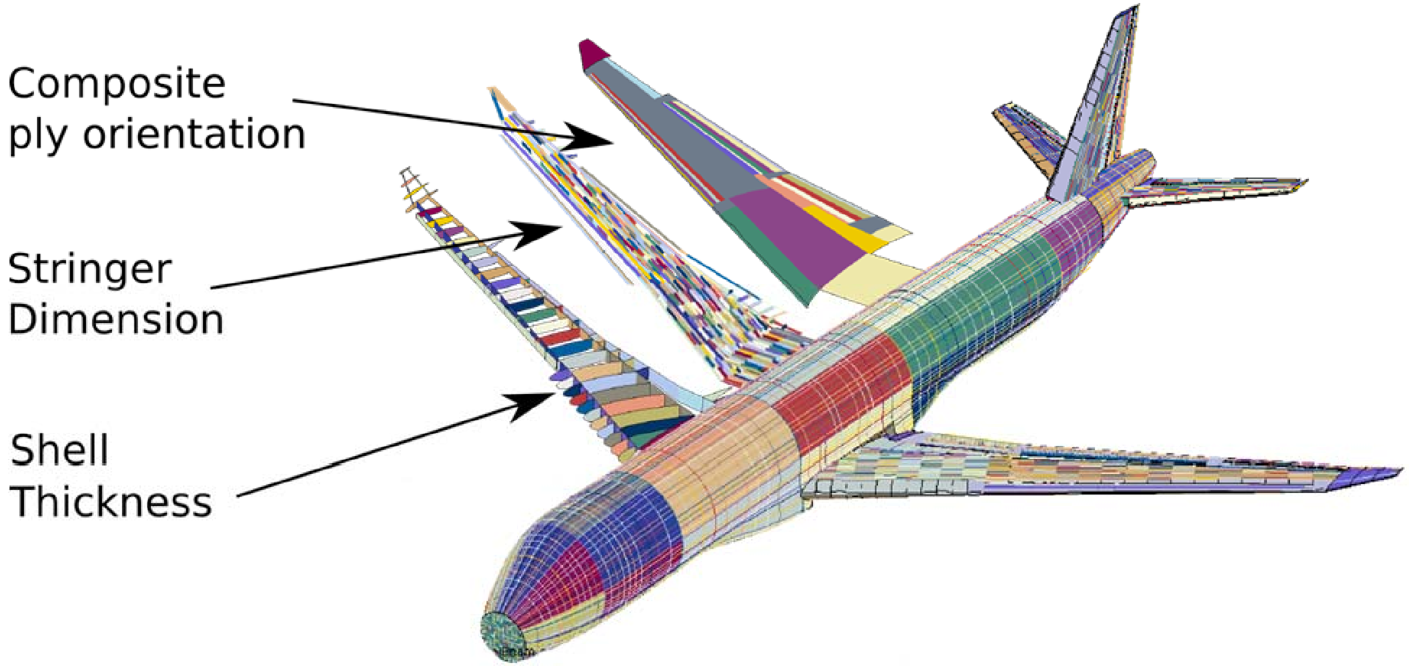


It is an object-oriented tool, developed in Python under Abaqus-CAE, able to define structural and aerodynamic models fully automatically, as the one reported in the figure above. It is also able to handle the different structural propriety definitions of the and export a parametric structural model.



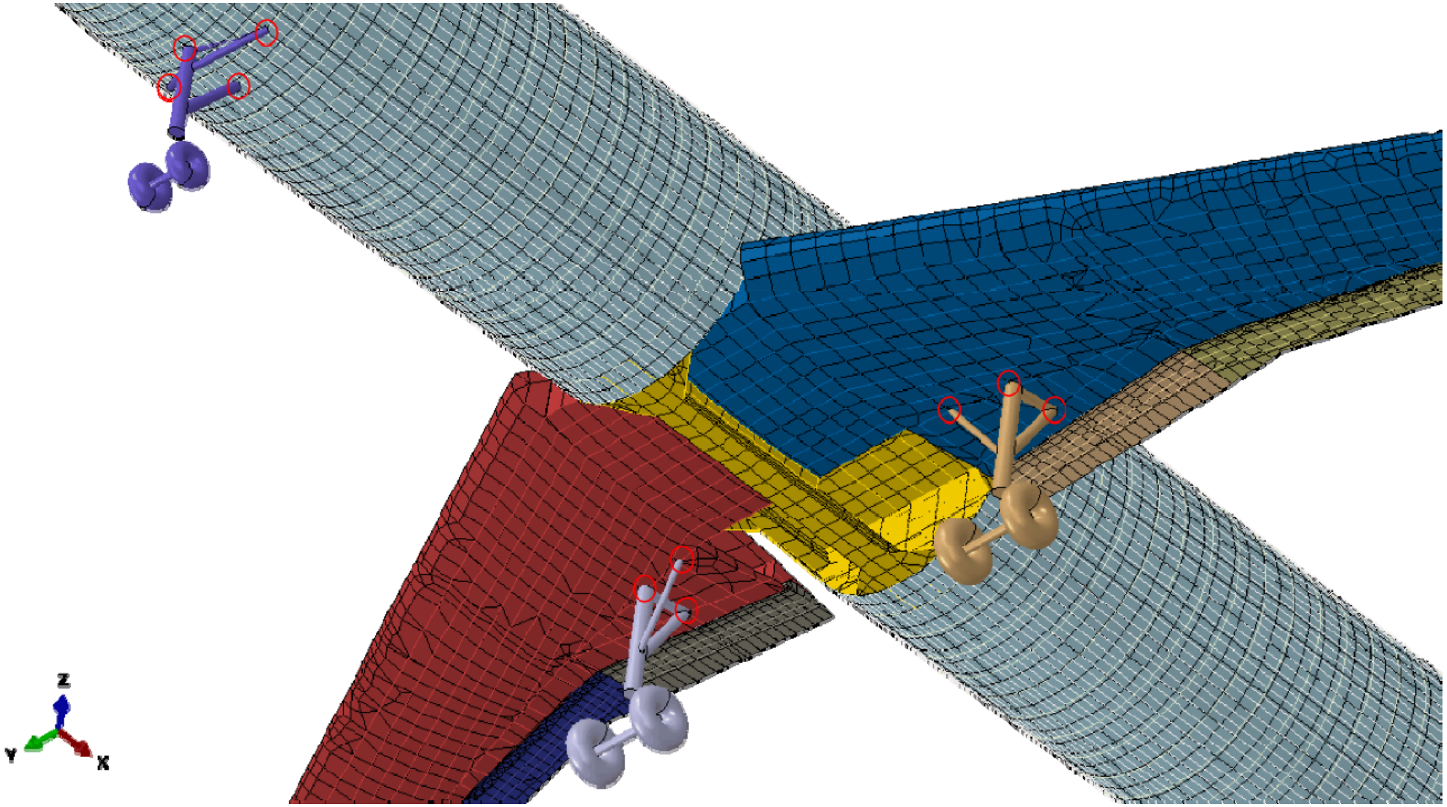
PyAERO (Python module for the AEROelastic analysis):
developed to compute all the aeroelastic responses such as Trim, Flutter, Dynamic Analysis, and the sizing loads of the structures, coupling the structural model defined by PyGFEM and an aerodynamic solver based on the Morino method. It is written using Python and FORTRAN, exploiting the power of parallel computing using OpenMP.

PySIZE Overview



PySIZE (Python module for MDO SIZing):
developed using the PyOpt library, can handle different kind of structural parameters. It can compute both the value and the sensitivity of several kind of structural and aeroelastic respones, using Abaqus for the computation of global matrices and stress derivatives.

FEM-mbody hybrid models

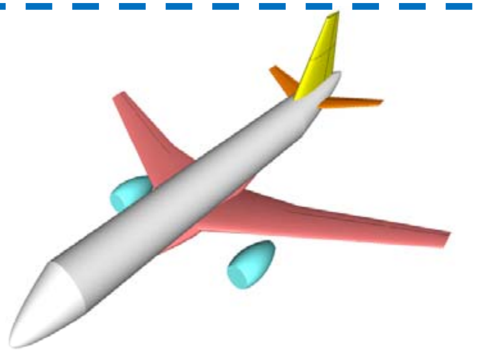


- Airframe structures: modal body (Craig-Bampton)
- Connection between modal body and MBDyn model through Lagrange multipliers

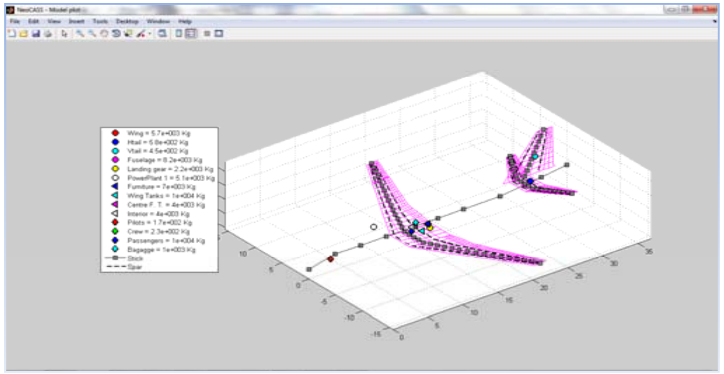
Multi-fidelity aeroelastic framework

CS requirements

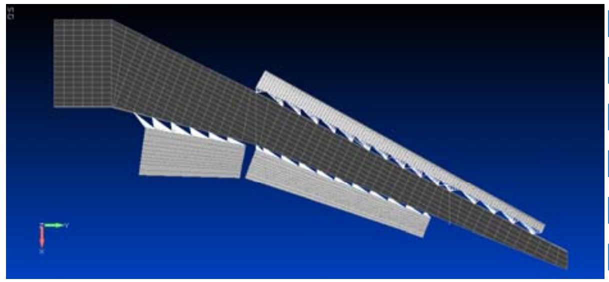
NeoCASS domain

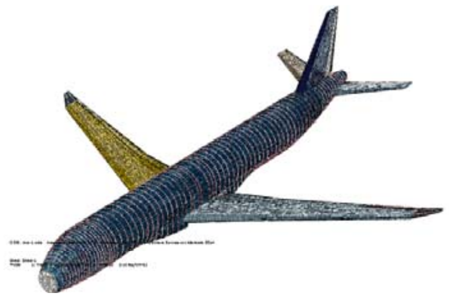


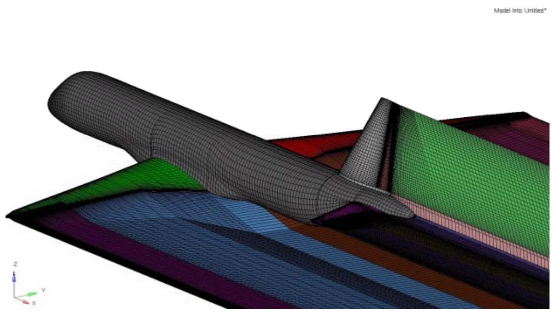
Stick model



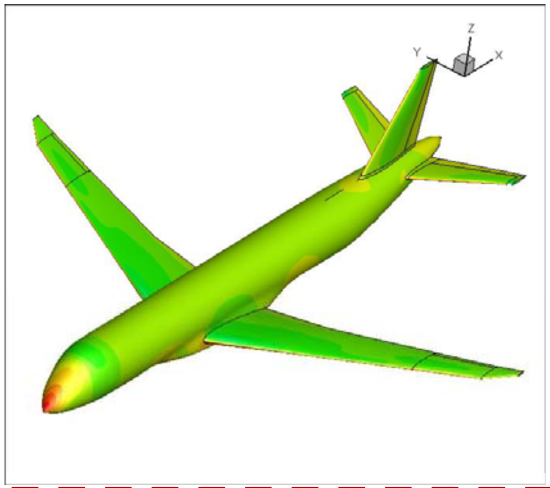
FEMGEN model





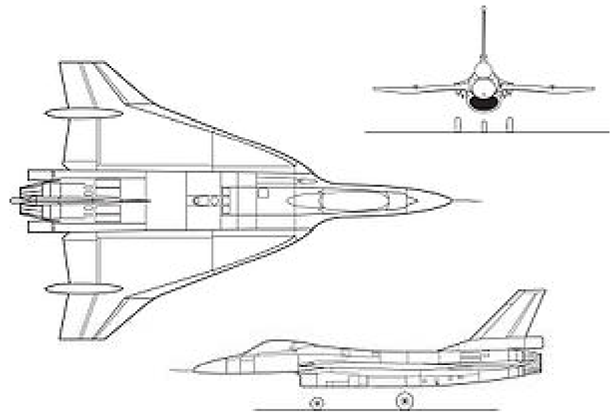


PyPAD domain



Fast generation of an aeroelastic mode without data…

Inputs used: data available on public literature

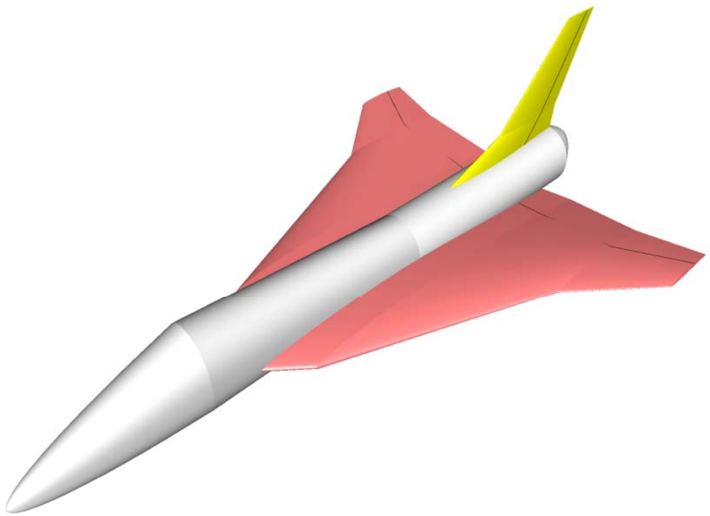


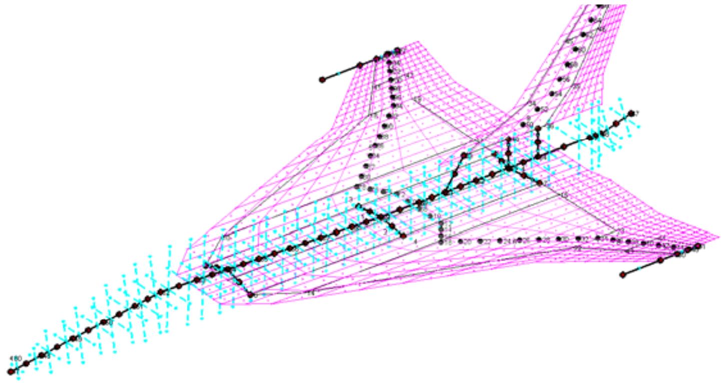
General characteristics
Crew: One or Two
Length: 54 ft 2 in (16. 51 m)
Wingspan: 34 ft 3 in (10. 44 m)
Height: 17 ft 7 in (5. 36 m)
Wing area: 633 ft² (58. 8 m²)
Empty weight: 22,000 lb (9,980 kg)
Loaded weight: 48,000 lb (21 800 kg)
Max takeoff weight: 48,000 lb (22,000 kg)
Powerplant: 1× General Electric F110-GE-100
Dry thrust: 17,155 lbf (76. 3 kN)

NASA-TM 104264 *Ground Vibrations and Flight Flutter Tests of the Single-Seat F16XL with a Modified Wing*, D.F.Voracek, June 1993

Fast generation of an aeroelastic mode without data…

- VLM aerodynamic model for loads
- Aeroelastic Trim, free-free condition
- Stiffnesses ad masses distribution from NeoCASS suite (www.neocass.org)
- Hybrid model: lifting surfaces with linear equivalent plate, fuselage with linear beam model
- No aerodynamic model for fuselage
- Inboard flaperon used as trim surface (pitch)
- MASS configuration = 12196 kg
- Updating after initial sizing to improve numerical vs. experimental frequency matching





The end