



POLITECNICO
MILANO 1863

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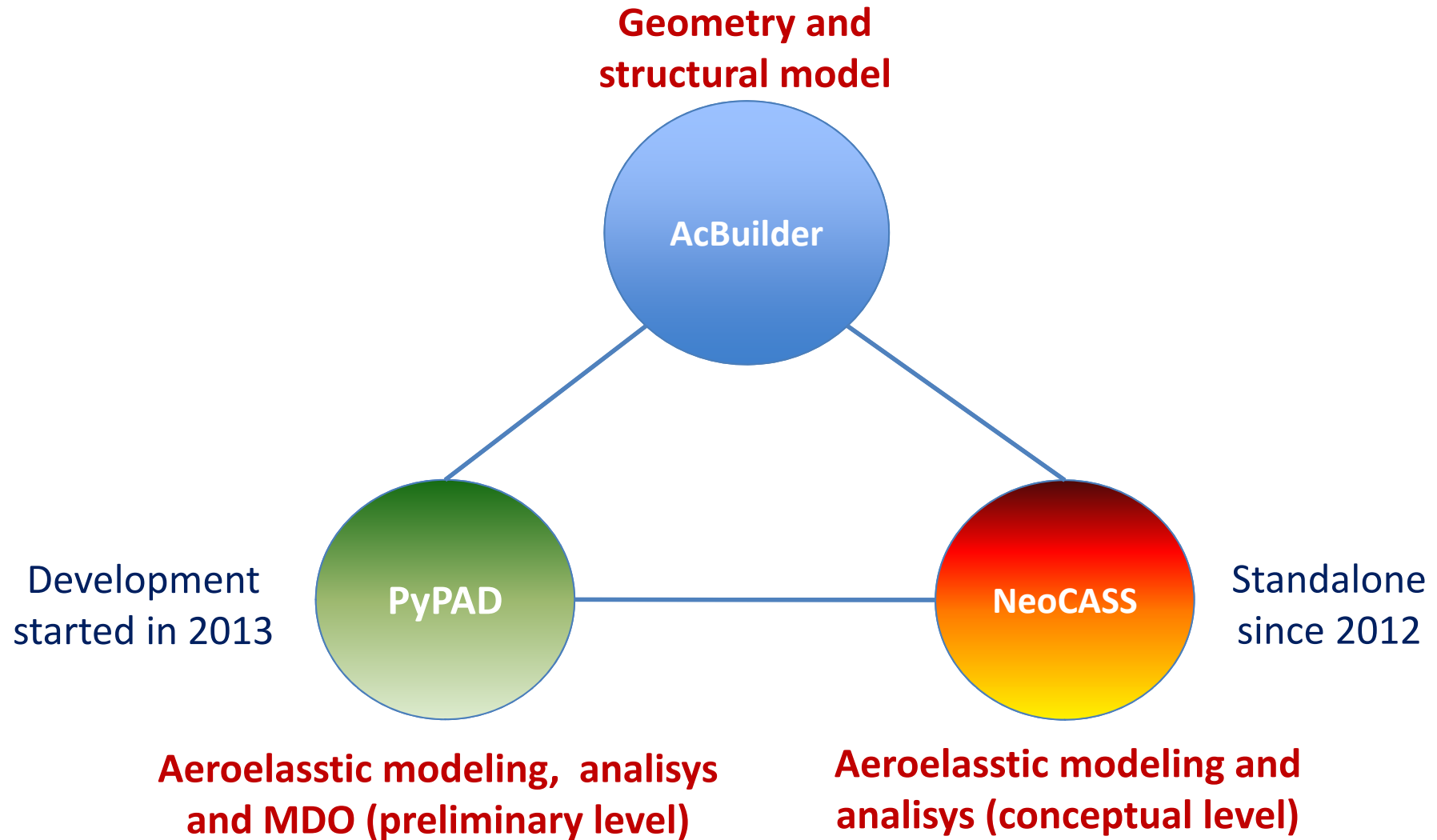
**Recent developments on AcBuilder, NeoCASS and
PyPAD tools: toward a multi-fidelity aeroelastic
framework for conceptual and preliminary
aircraft design**

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



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**

Added components

Main Landing Gear and Aux Landing Gear

The screenshot shows the AcBuilder software interface. On the left, a 3D model of an aircraft is displayed with the main landing gear (MLG) and auxiliary landing gear (ALG) highlighted by green circles. A text box overlaid on the model lists the parameters that can be modified by the user:

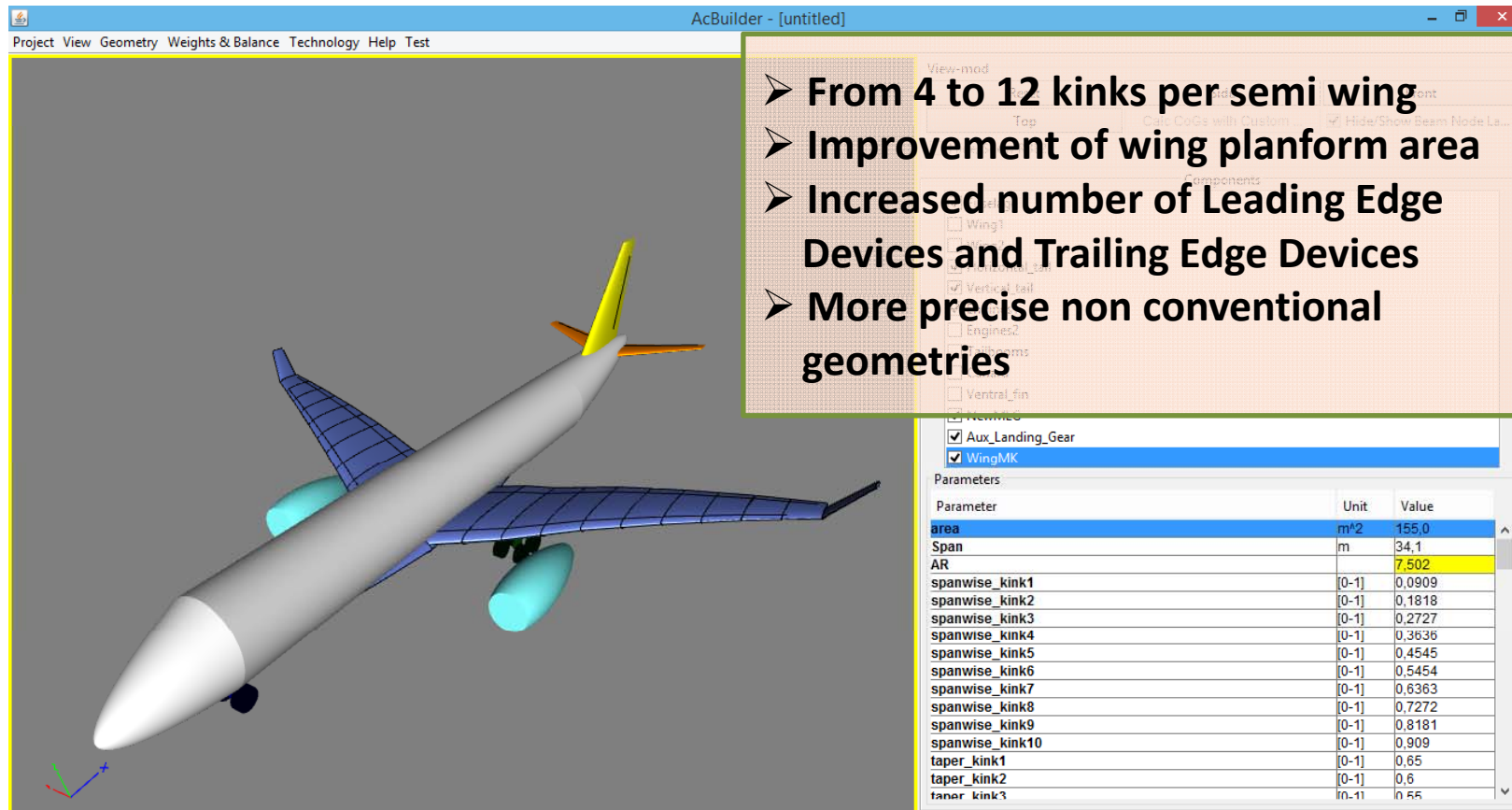
- Location (x,y,z)
- Leg length
- Leg diameter
- Symmetry

On the right, the 'Components' panel shows a list of aircraft parts with checkboxes. The 'Aux_Landing_Gear' component is selected and highlighted in blue. Below this, the 'Parameters' table for the selected component is shown:

Parameter	Unit	Value
x_loc_vs_fus	fusln	0,12
y_loc_vs_span	wspn	0,0001
z_loc_vs_fus_diam	fusva	-0,28
symmetry		<input type="checkbox"/>
total_length	m	2,0
diameter	m	0,5
campo_aggiuntivo	m	55,0
x	m	5,3412
y	m	0,0
z	m	-1,106

Added components

WingMK – Wing Multi Kink



The screenshot displays the AcBuilder software interface. On the left, a 3D model of an aircraft is shown in a perspective view. The aircraft has a white fuselage, blue wings, and a yellow tail. On the right, a parameter table for the WingMK component is visible. The table lists various parameters and their values.

Parameter	Unit	Value
area	m ²	155,0
Span	m	34,1
AR		7,502
spanwise_kink1	[0-1]	0,0909
spanwise_kink2	[0-1]	0,1818
spanwise_kink3	[0-1]	0,2727
spanwise_kink4	[0-1]	0,3636
spanwise_kink5	[0-1]	0,4545
spanwise_kink6	[0-1]	0,5454
spanwise_kink7	[0-1]	0,6363
spanwise_kink8	[0-1]	0,7272
spanwise_kink9	[0-1]	0,8181
spanwise_kink10	[0-1]	0,909
taper_kink1	[0-1]	0,65
taper_kink2	[0-1]	0,6
taper_kink3	[0-1]	0,55

- 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

The screenshot shows the AcBuilder software interface. On the left, a 3D wireframe model of an aircraft is displayed with yellow spheres representing centers of gravity. On the right, the software's control panel is visible, featuring a 'View-mod' section with buttons for 'Reset', 'Side', 'Front', 'Top', and a new button labeled '**Calc CoGs with Custo...'. Below this is a 'List of Components' section with a scrollable list including 'Wing 1', 'Wing 2', 'Horizontal tail', 'Vertical tail', 'Fuselage', 'Powerplant 1 with nacelle & pylon', 'Powerplant 2 with nacelle & pylon', 'Vertical tail 2', 'Canard', 'Tailbooms', 'Landing gear', 'Auxiliary landing gear', and 'Total systems or miscellaneous'. A 'Values' table is also present, showing parameters like x, y, z, and Mass with their respective units and values. At the bottom, there is an 'Information' section with instructions in Italian and a 'View & Save Data' button highlighted with a red box.

- Components centers of gravity coordinates are now editable
- New editable Mass field
- New button **Calc With Custom Masses**
- New View&Save function to save module data in a .txt file

Parameter	Unit	Value
x	m	20.6900284
y	m	0,0
z	m	-0,0411525
Mass	Kg	5600,0

Information

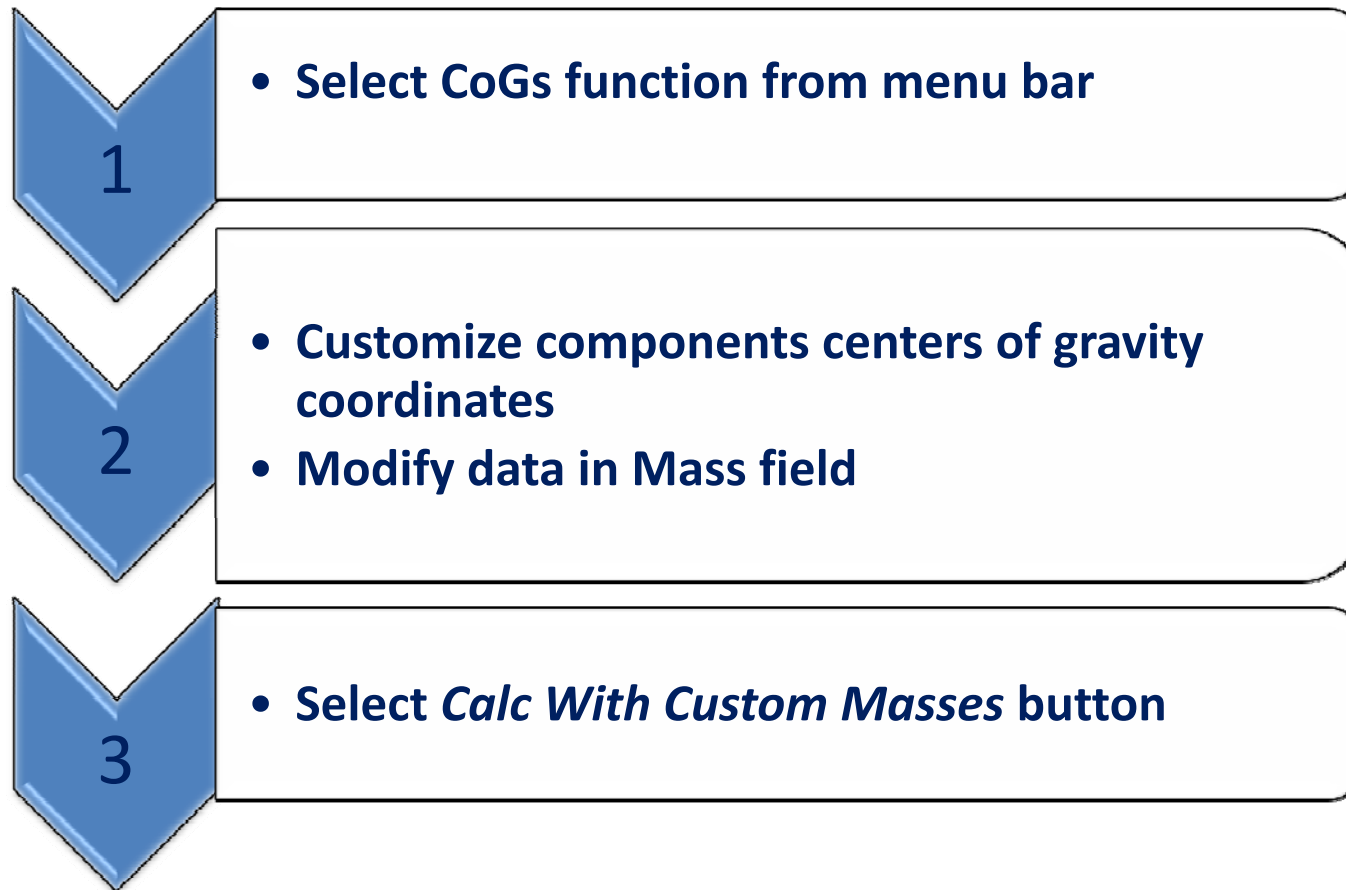
Per modificare le posizioni dei baricentri riferirsi
* all'estremo anteriore della fusoliera per le coordinate X
* al sistema di riferimento del velivolo per le Z.

View & Save Data

Approx Inertia Matrix

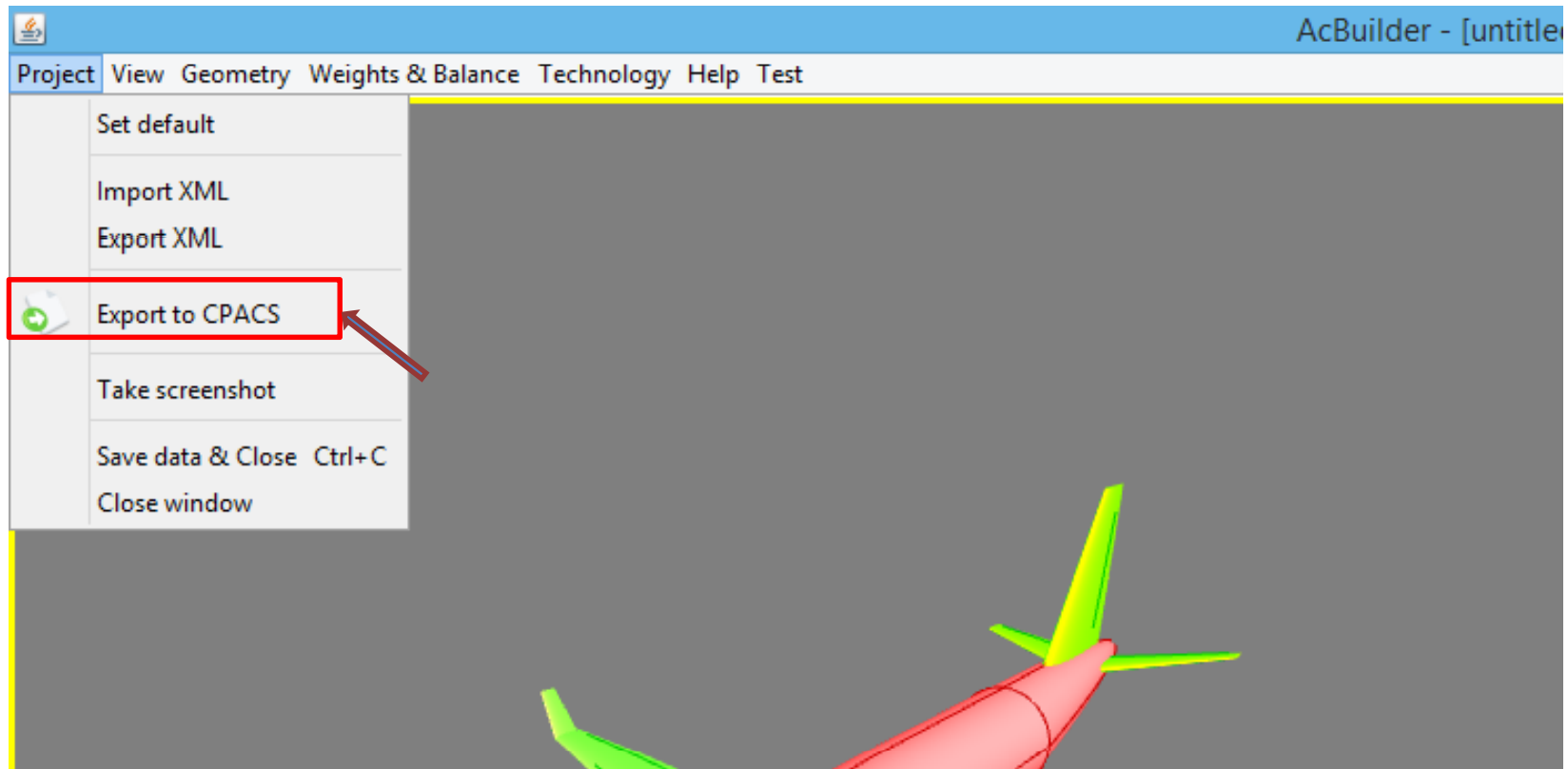
New functionality

How to use it



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)

The screenshot displays the Technology module interface. The main window shows a 3D beam model with nodes labeled 1002 through 1008 and 2501 through 2510. A yellow circle highlights node 1003, labeled 'ID Knot', and another yellow circle highlights node 1005, labeled 'Link'. A red arrow points from the 'Added RBE2 command' text to the RBE2 command panel in the Technology window. Another red arrow points from the 'Added graphic user interface...' text to the RBE2 GUI. The Technology window shows a list of components with 'Geometry (beam_model)' selected. The RBE2 parameters table is as follows:

Parameter	Unit	Value
nwing_inboard		5
nwing_midboard		5
nwing_outboard		5
nwing_carryth		2
nfuse		10

The RBE2 GUI shows the following configuration:

Comp. 1: Fuselage ID Node: 1005 Comp. 2: Wing1 ID Node: 2001

Symmetric

ID RBE2	Component 1	ID Node	Component 2	ID Node	Symmetric
1	Fuselage	1005	Wing1	2001	true

Automatic generation of the stick model

New function

The screenshot shows the AcBuilder software interface. The 'Technology' menu is open, highlighting the 'Stick Model' option. A red arrow points to this option. A text box with a red border and a right-pointing arrow contains the text: 'Added function for creation of the Stick Model using aircraft geometry converted in CPACS'. The main workspace shows a 3D model of an aircraft with a stick model overlaid in blue. The stick model consists of a fuselage and wings, with nodes labeled 1002, 1007, 1008, 2503, 2504, 2505, 2506, 2507, 2508, 2509, and 2510. The right-hand panel shows the 'Technology' settings for the selected 'Geometry (beam_model)'. The 'Parameters' table is as follows:

Parameter	Unit	Value
nwing_inboard		5
nwing_midboard		5
nwing_outboard		5
nwing_carryth		2
nfuse		10

The 'RBE2' section shows the following configuration:

Comp. 1: Fuselage ID Node: 1005 Comp. 2: Wing1 ID Node: 2001

Symmetric Connect! Canc all RBE2 Canc Selected RBE2

ID RBE2	Component 1	ID Node	Component 2	ID Node	Symmetric
1	Fuselage	1005	Wing1	2001	true

NeoCASS background

NeoCASS (Next generation Conceptual Aero-Structural Sizing Suite)

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

NeoCASS background

Step by step NeoCASS sequence of operations:

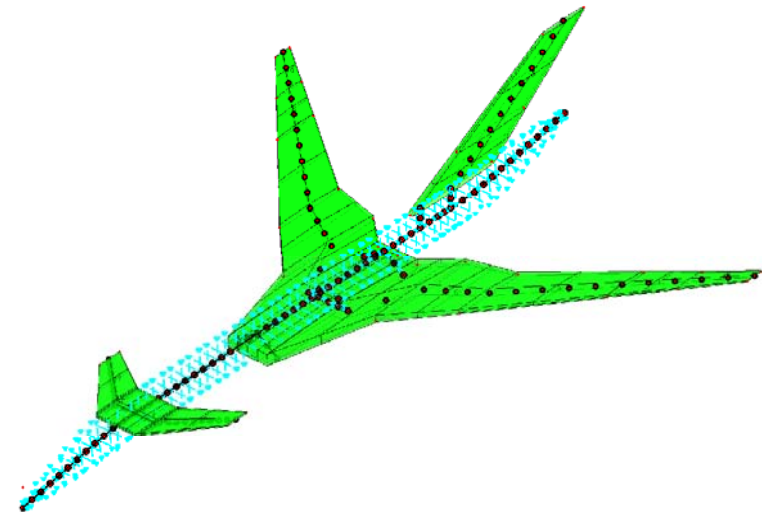
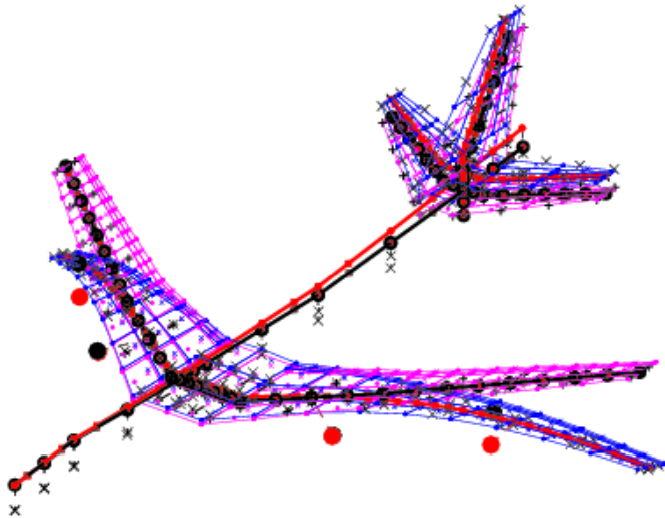
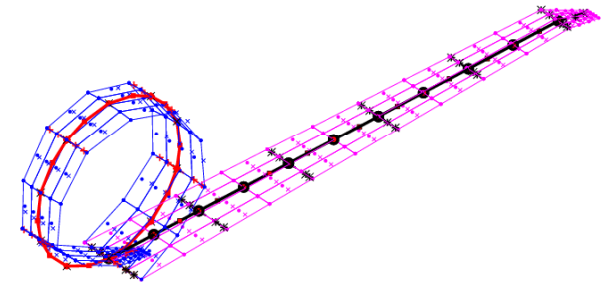
1. Input of **Aircraft Geometric description** and **technological solutions** from AcBuilder module through XML file;
2. Input of **Sizing Mode**;
3. Initial structural sizing; *GUESS*

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

NeoCASS background

Two kind of structural models available:

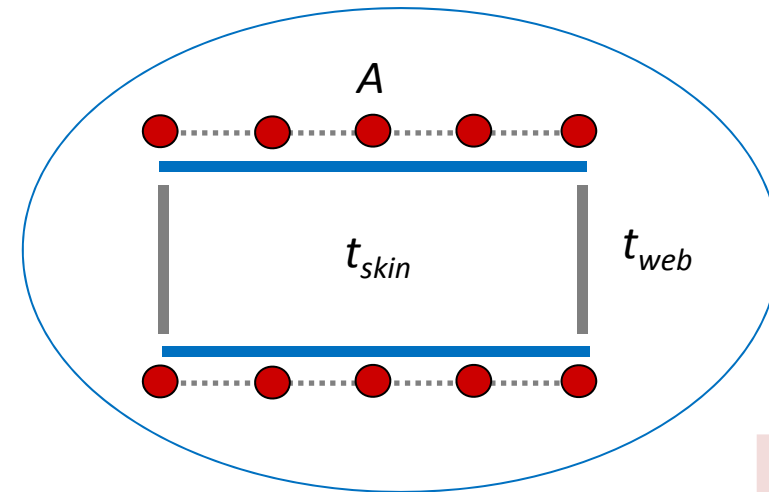
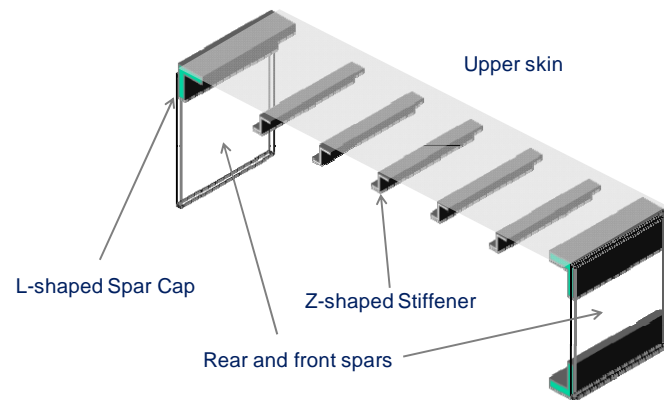
- Three nodes linear-nonlinear beam [2]
- Equivalent plate
- Hybrid models



[2] Ghiringhelli, G. L., Masarati, P., and Mantegazza, P., "Multibody Implementation of Finite Volume CO 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.

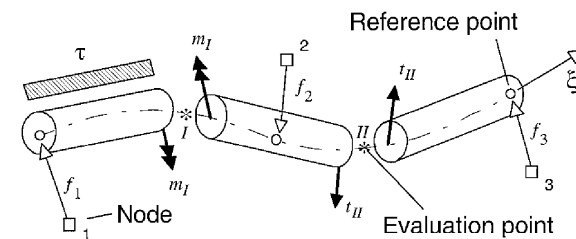


GUESS Design Space

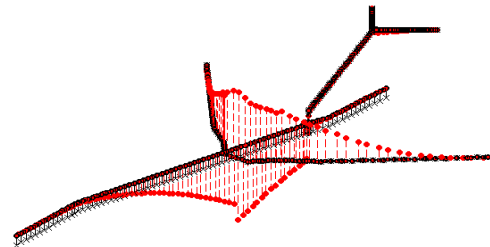
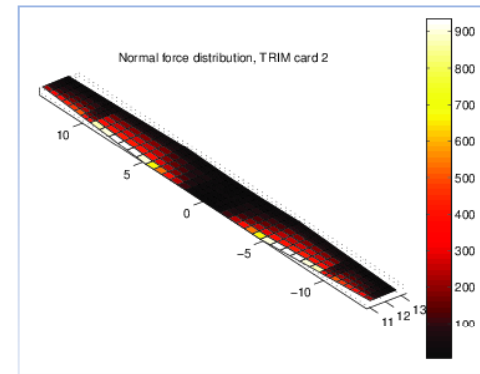
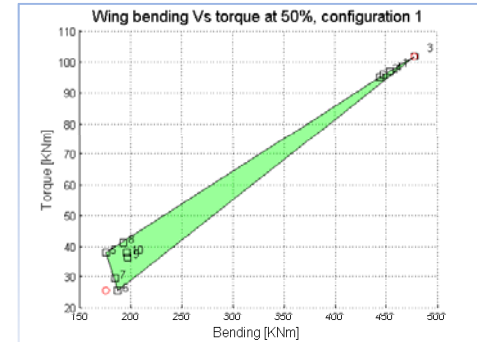
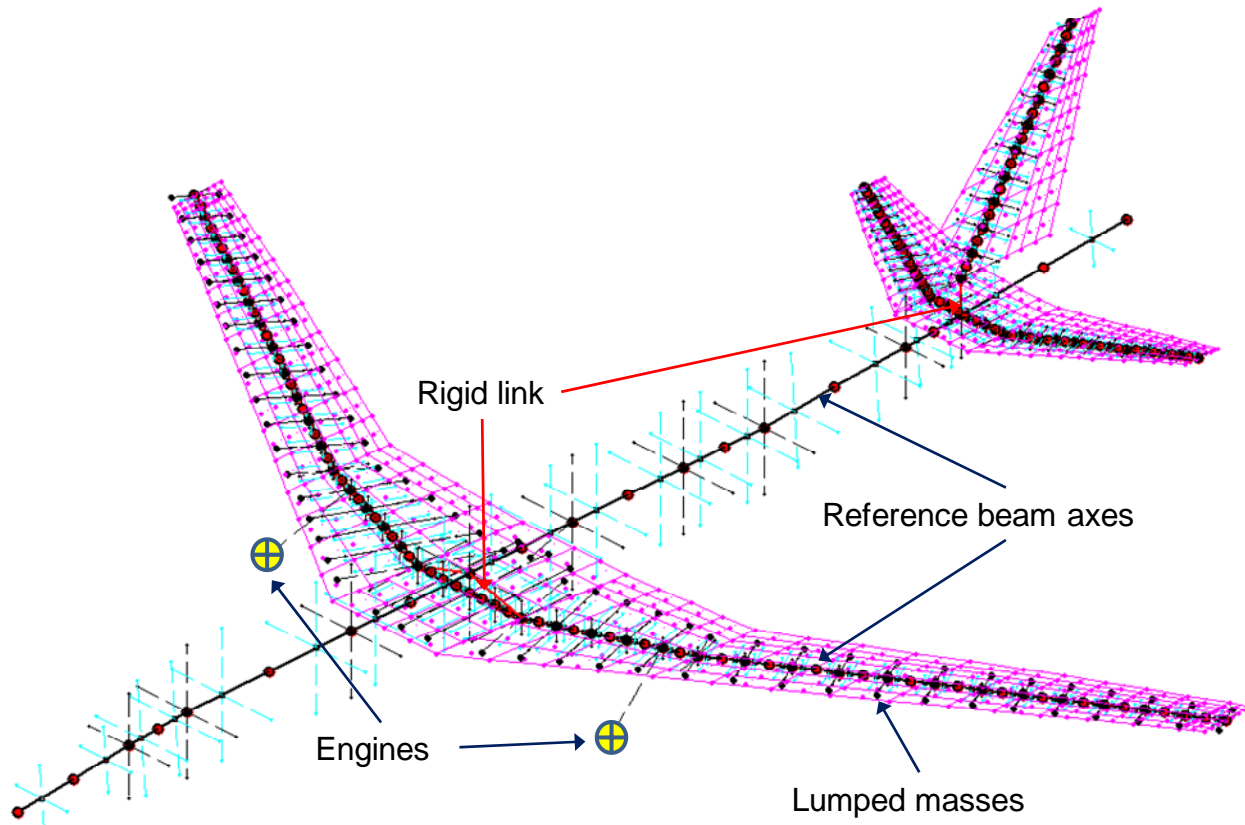
For each station, the following optimization problem is solved:

Min weight, s.t.

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



Typical GUESS outèut



SMARTCAD Overview

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

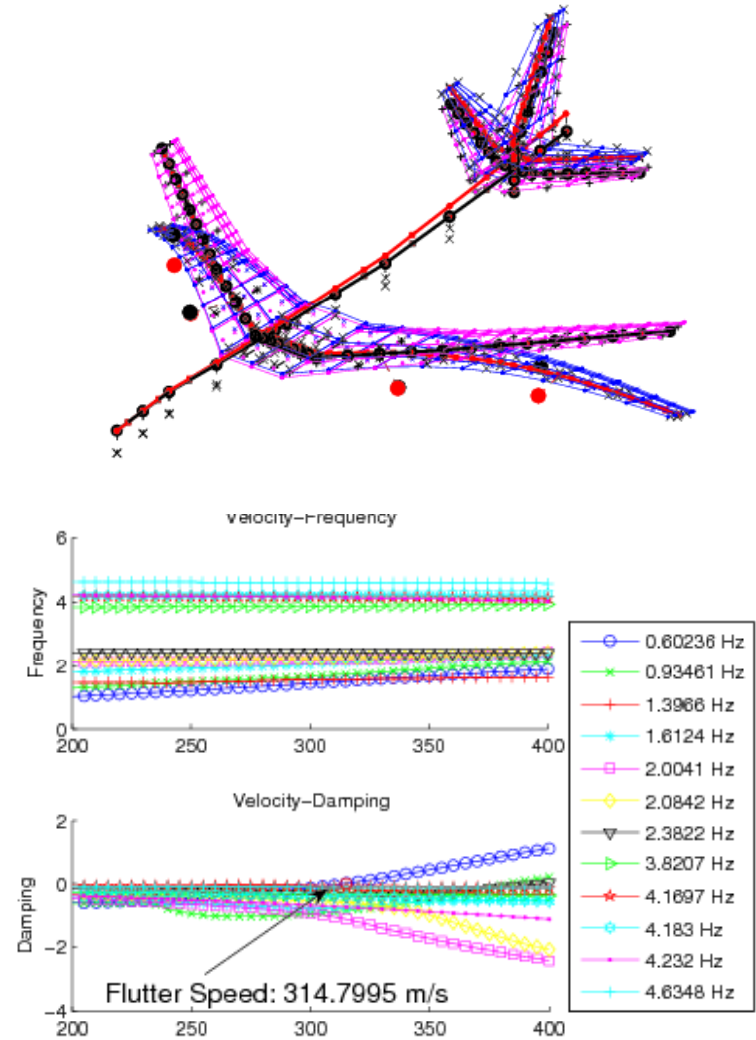
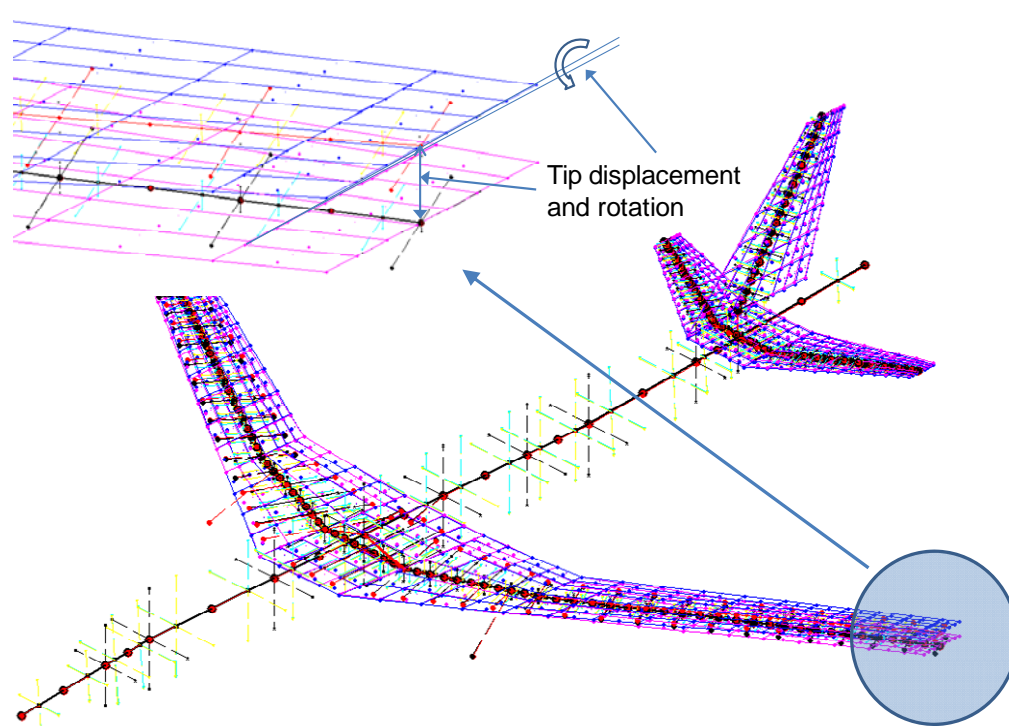
- **Input:** ASCII files derived from NASTRAN[®] formats. Why?
 - ✓ Platform independent;
 - ✓ To avoid wasting time to define and learn a new format;
 - ✓ Commercial pre/post-processors can be used to visualize the model and results;
 - ✓ **SMARTCAD** can be almost easily bypassed in favor of NASTRAN[®] 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:

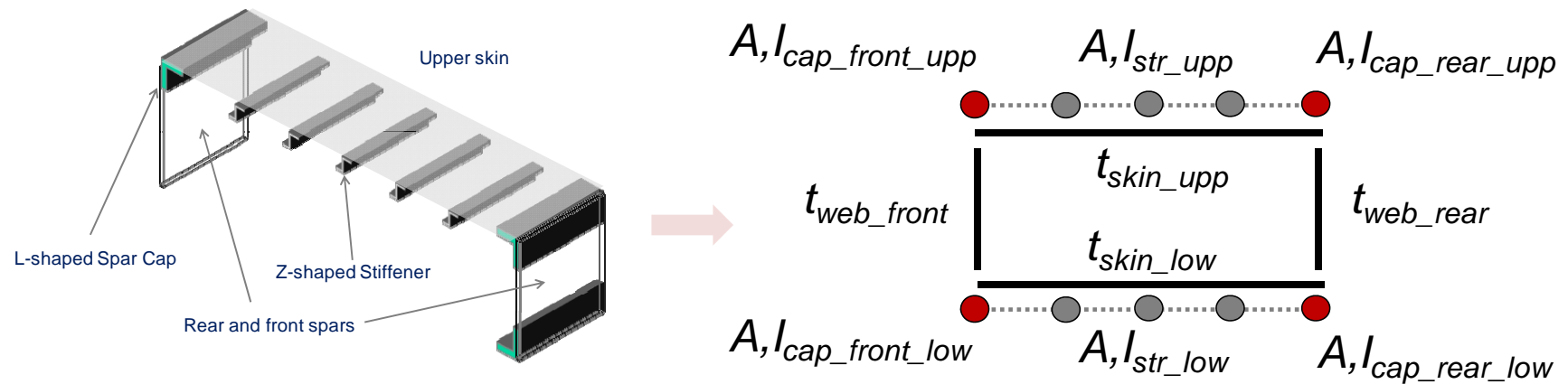
- Static aeroelasticity;
 - ✓ Divergence speed;
 - ✓ Deformable trimmed configuration;
 - ✓ Flexible stability derivatives.
- Dynamic aeroelasticity;
 - ✓ Flutter diagram (V-g plot);
 - ✓ Flutter envelope.
- MDO, to improve any of the aeroelastic responses by changing the structural properties initially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

SMARTCAD typical output

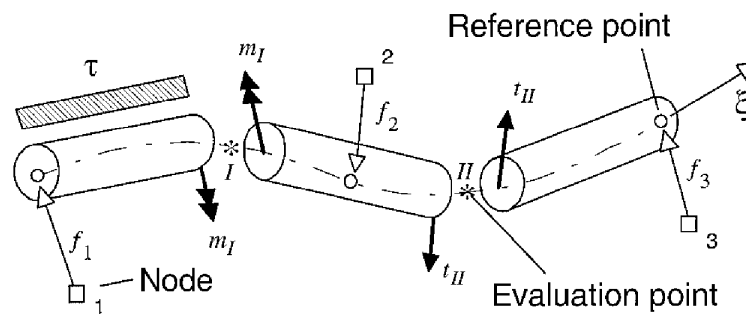


NeoCASS: GUESS new features

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



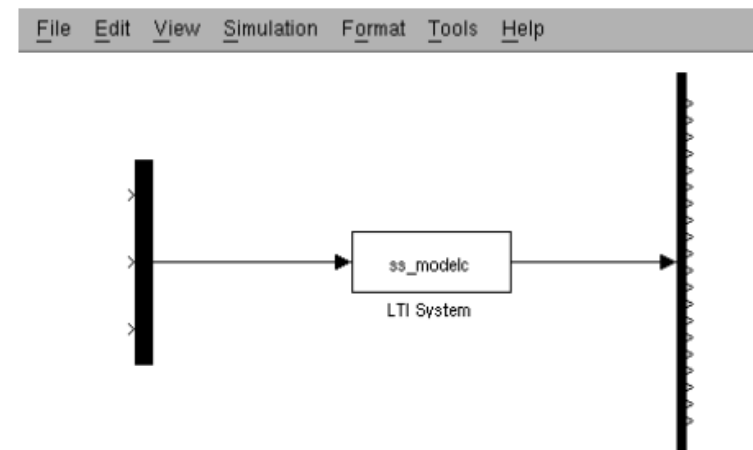
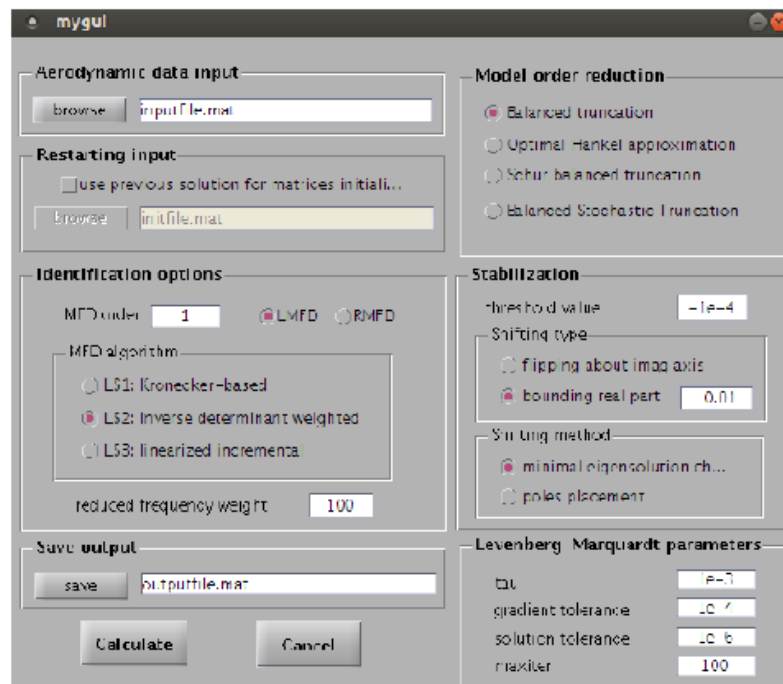
GUESS Design Space



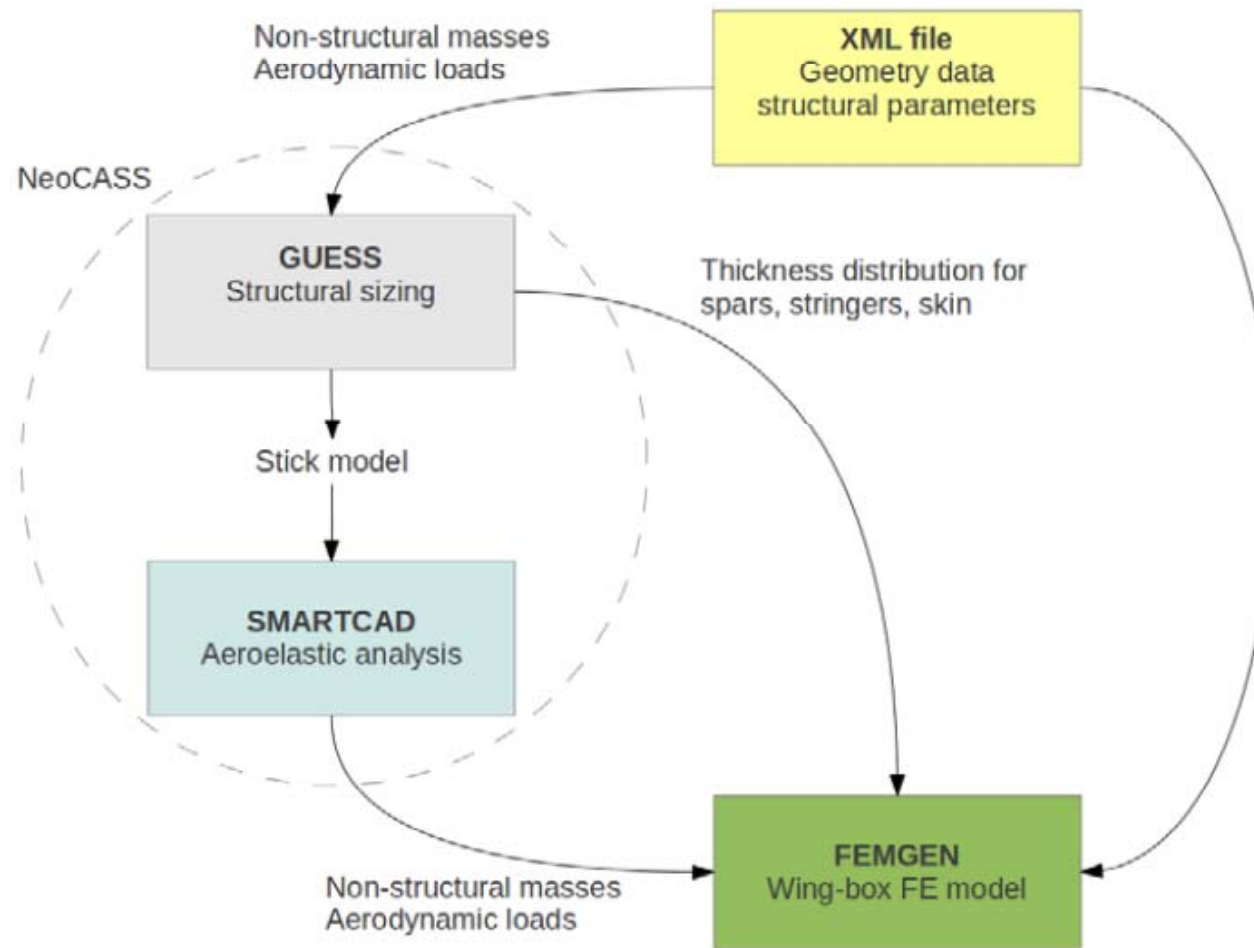
NeoCASS: SMARTCAD new features

Dynamic response module (NeoRESP) to calculate:

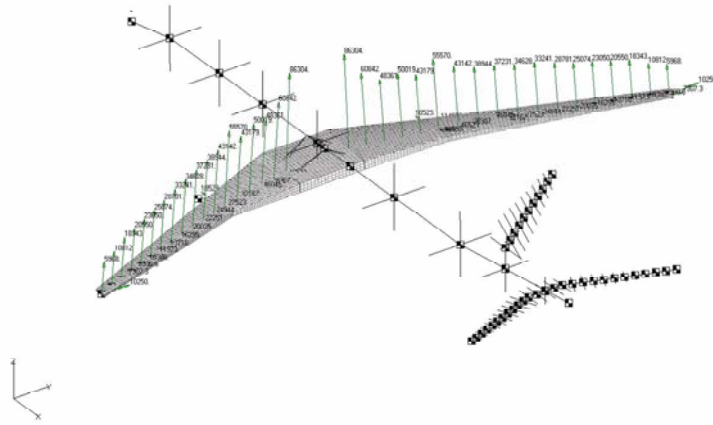
- ❑ Discrete gust response (including mode acceleration)
- ❑ Response to control surface motion or concentrated forces
- ❑ State-space aeroelastic models, to be used for time simulation inside Simulink



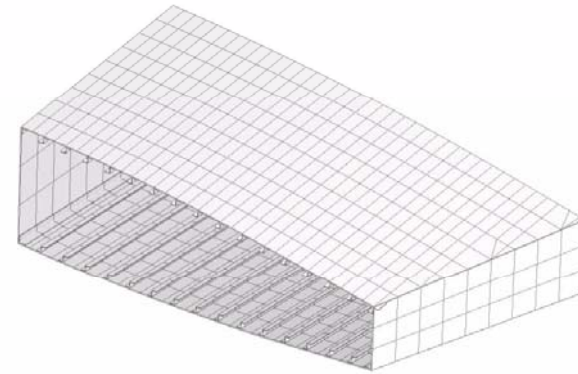
FEMGEN: 3D wingbox generation



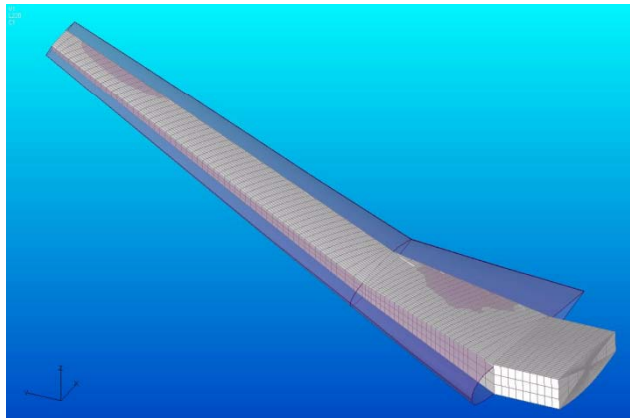
FEMGEN and hybrid models



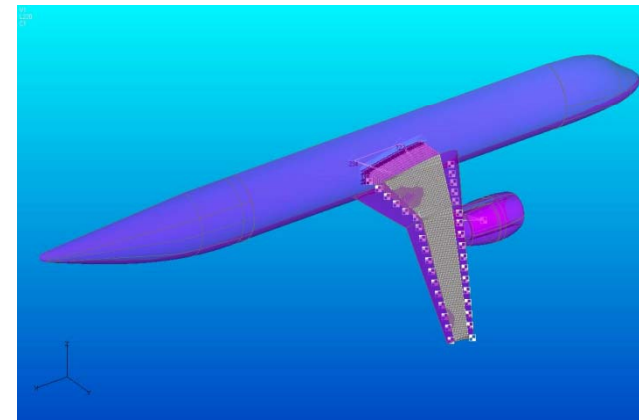
Hybrid model



3D model of the wingbox



Details of the wing



Half body with embedded wbox

NeoCASS: SMARTCAD new features

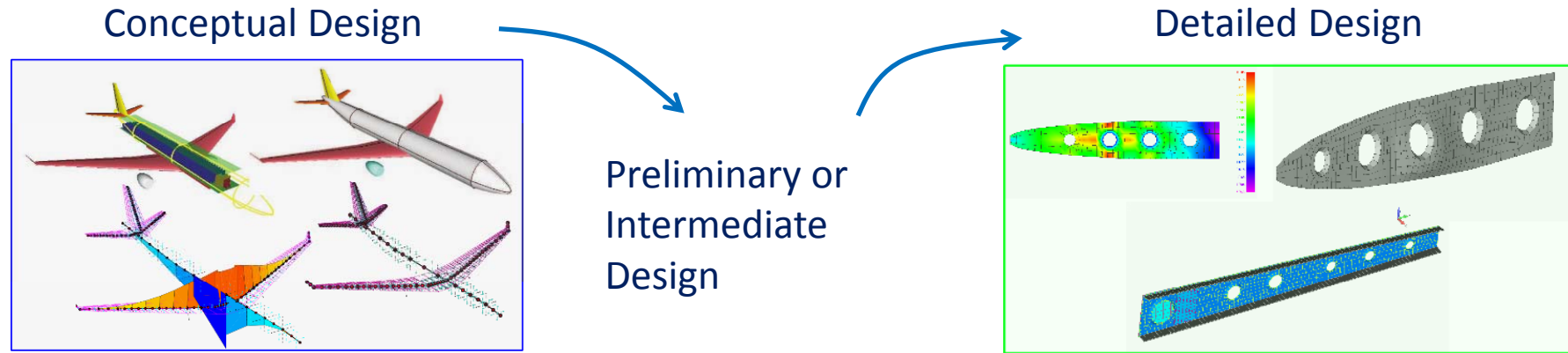
Optimization problem generated by FEMGEN:

- 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

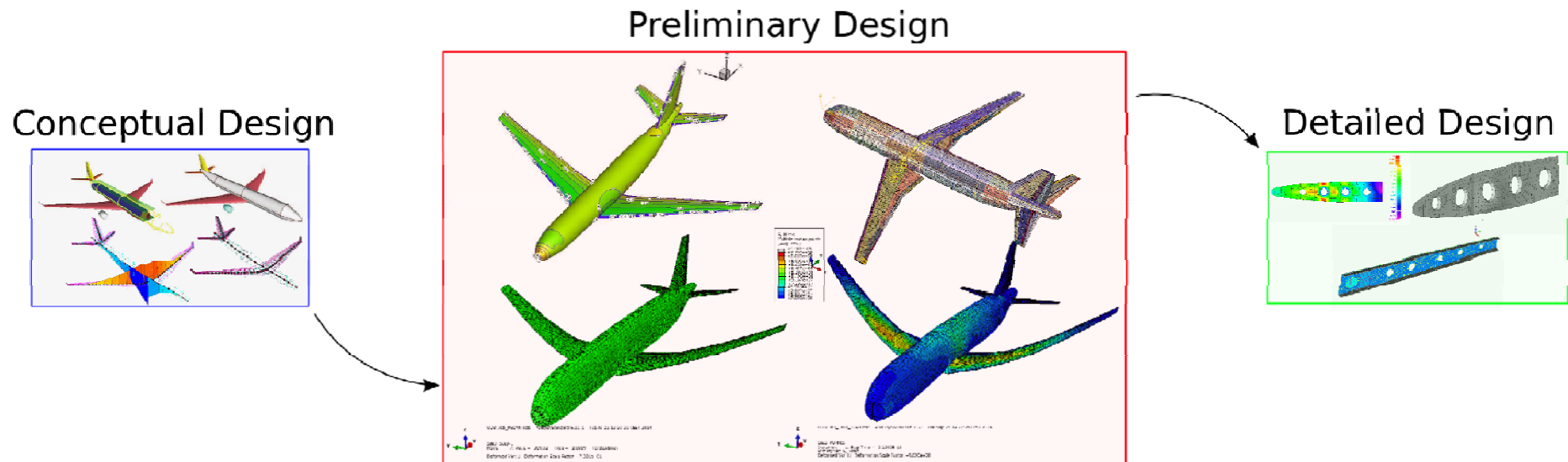
Some implementation details:

- 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



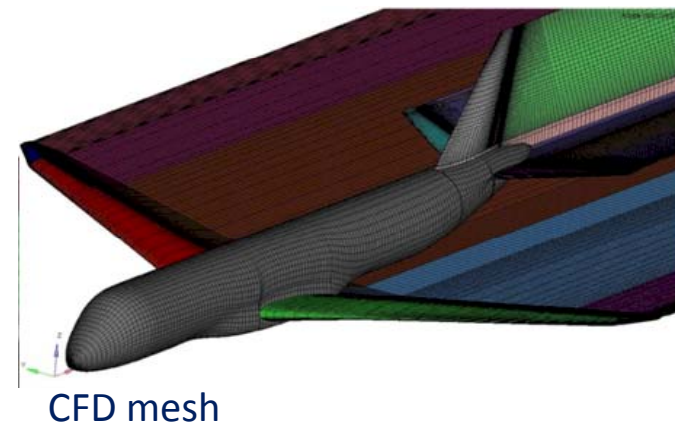
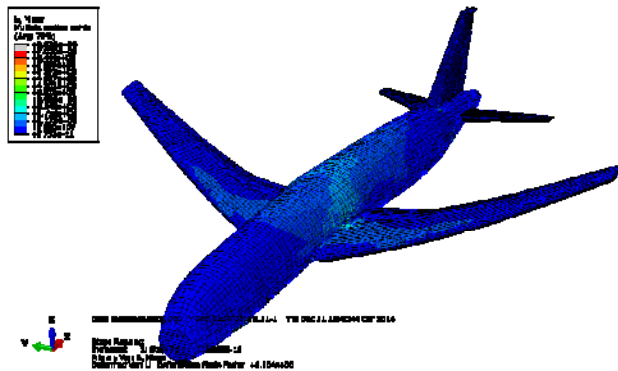
PyPAD background



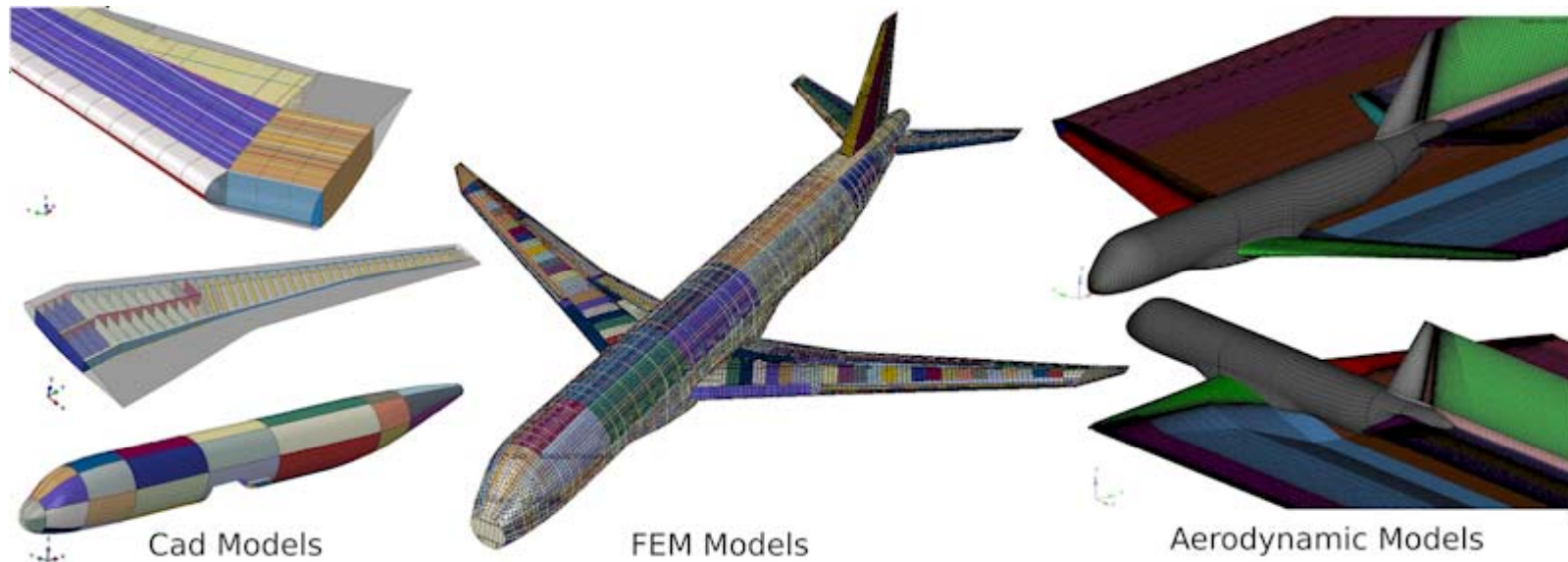
GOAL: To develop a dedicated framework for preliminary design, focused on dynamic loads and airframe sizing, keeping some of the capabilities typical of conceptual design tools, like automatic model generation.

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

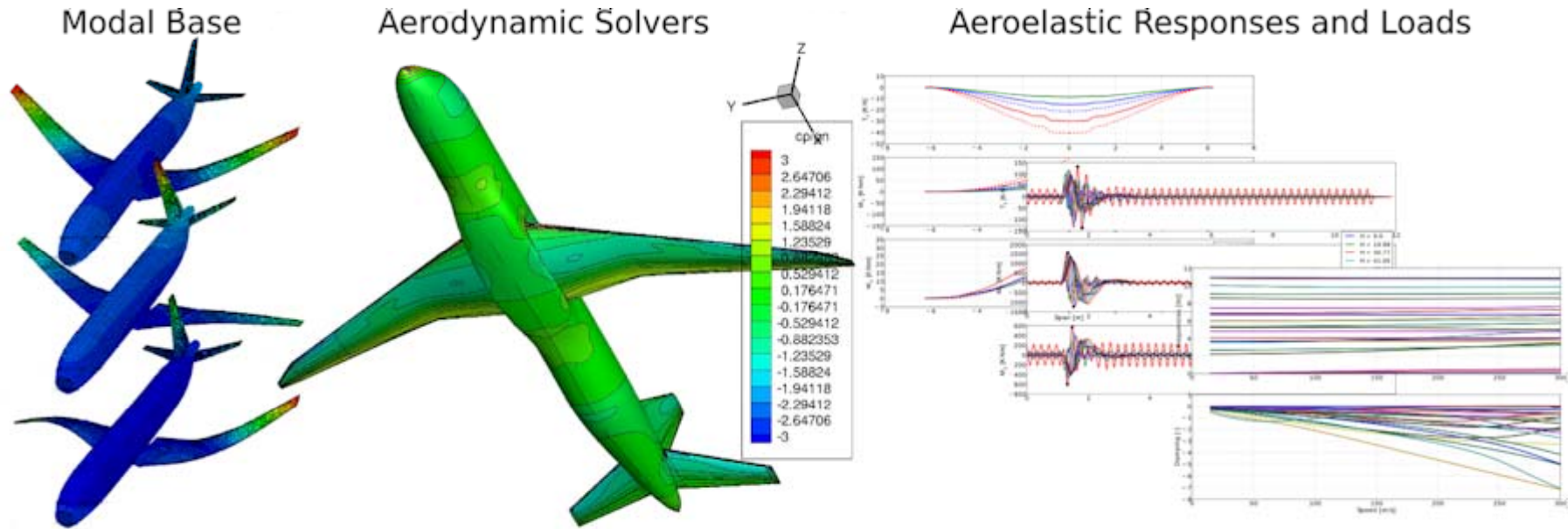


PyGFEM overview



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.

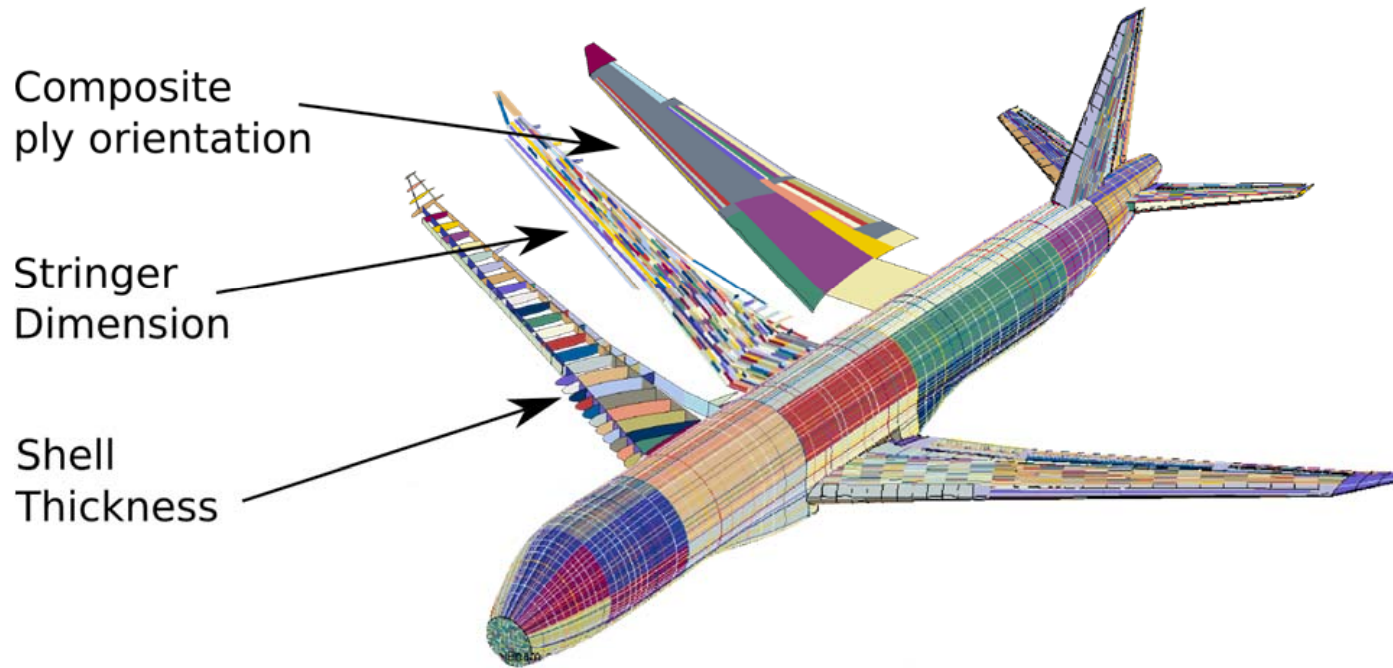
PyAERO overview



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.

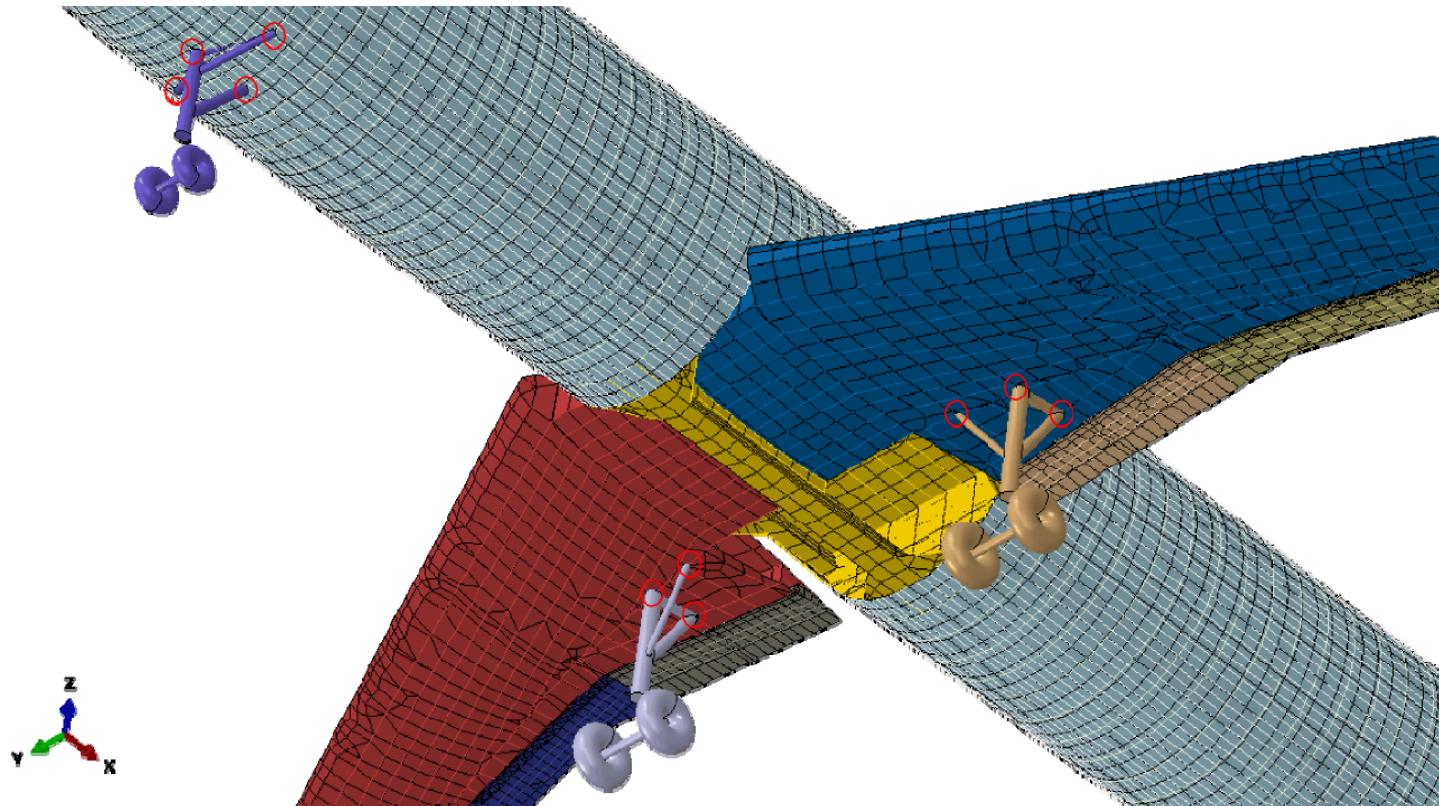
PySIZE Overview



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 responses, using Abaqus for the computation of global matrices and stress derivatives.

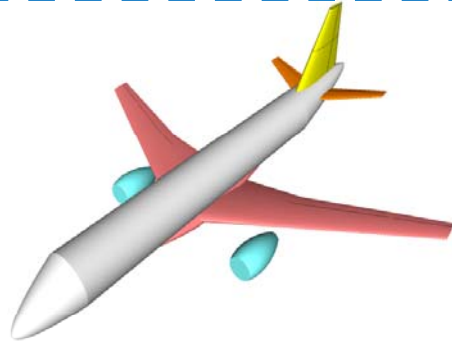
FEM-mbody hybrid models



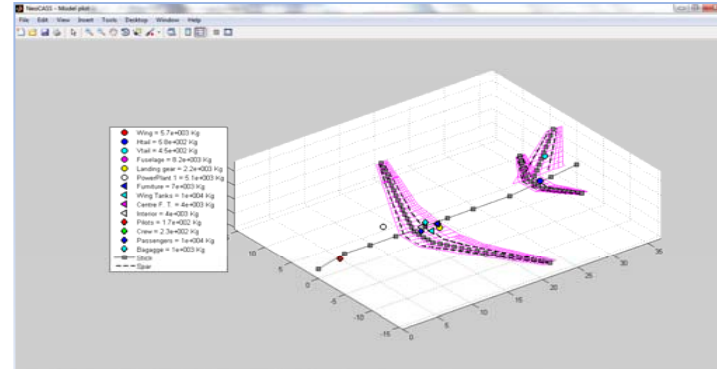
- Airframe structures: modal body (Craig-Bampton)
- Connection between modal body and MBDyn model through Lagrange multipliers

Multi-fidelity aeroelastic framework

CS requirements

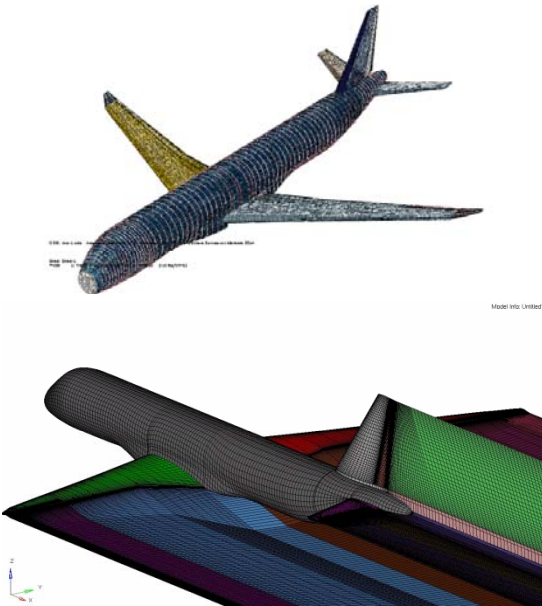


Stick model

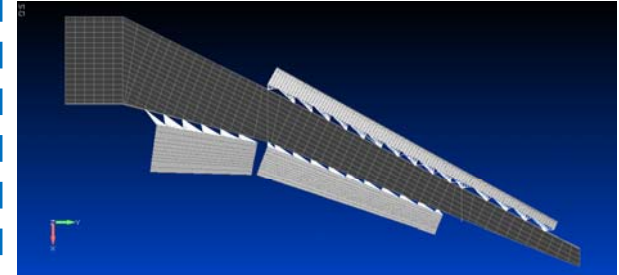
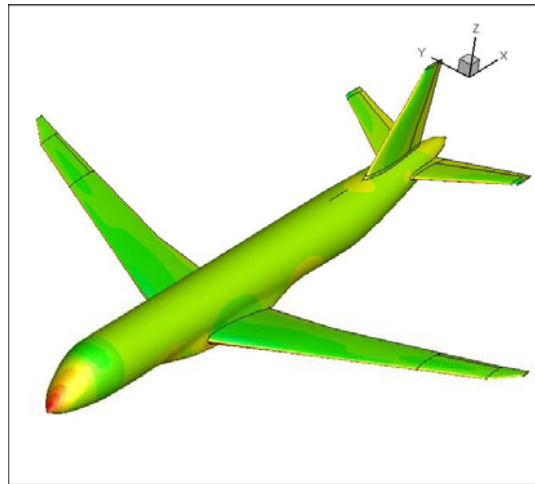


NeoCASS domain

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)

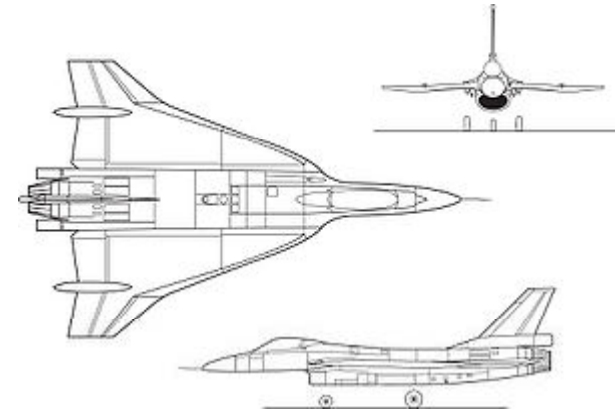
Loaded weight: 48,000 lb (21 800 kg)

Max takeoff weight: 48,000 lb (22,000 kg)

Powerplant: 1× General Electric F110-GE-100

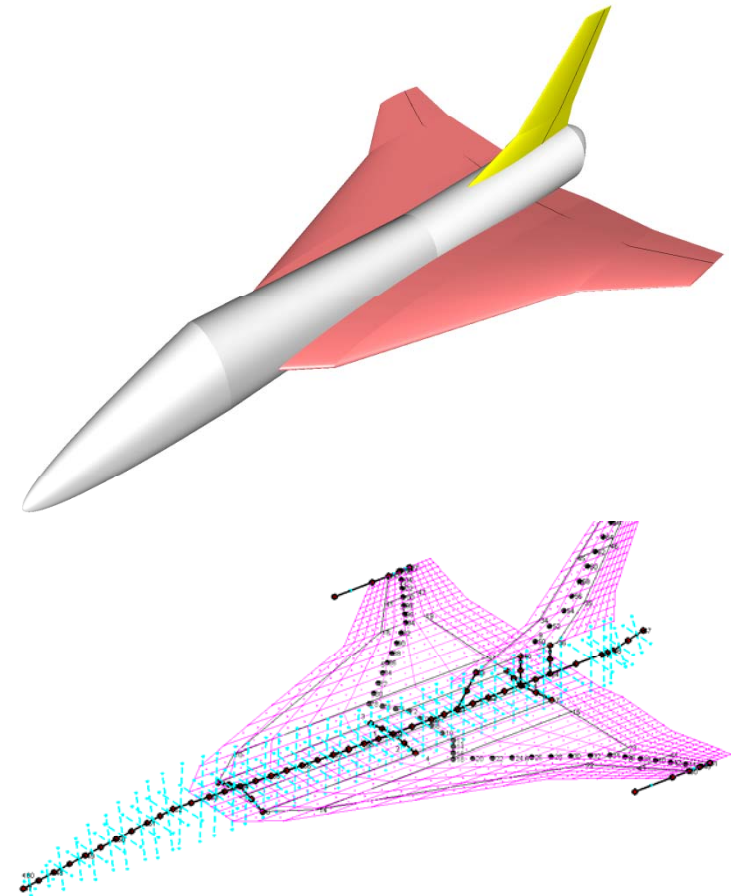
Dry thrust: 17,155 lbf (76. 3 kN)

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 and 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

THE END

