5th Symposium on Collaboration in Aircraft Design

The stability of join-wing configuration within optimization procedure

MADO - Multidisciplinary Aircraft Design and Optimization software suite (PANUKL, SDSA, OptoM)

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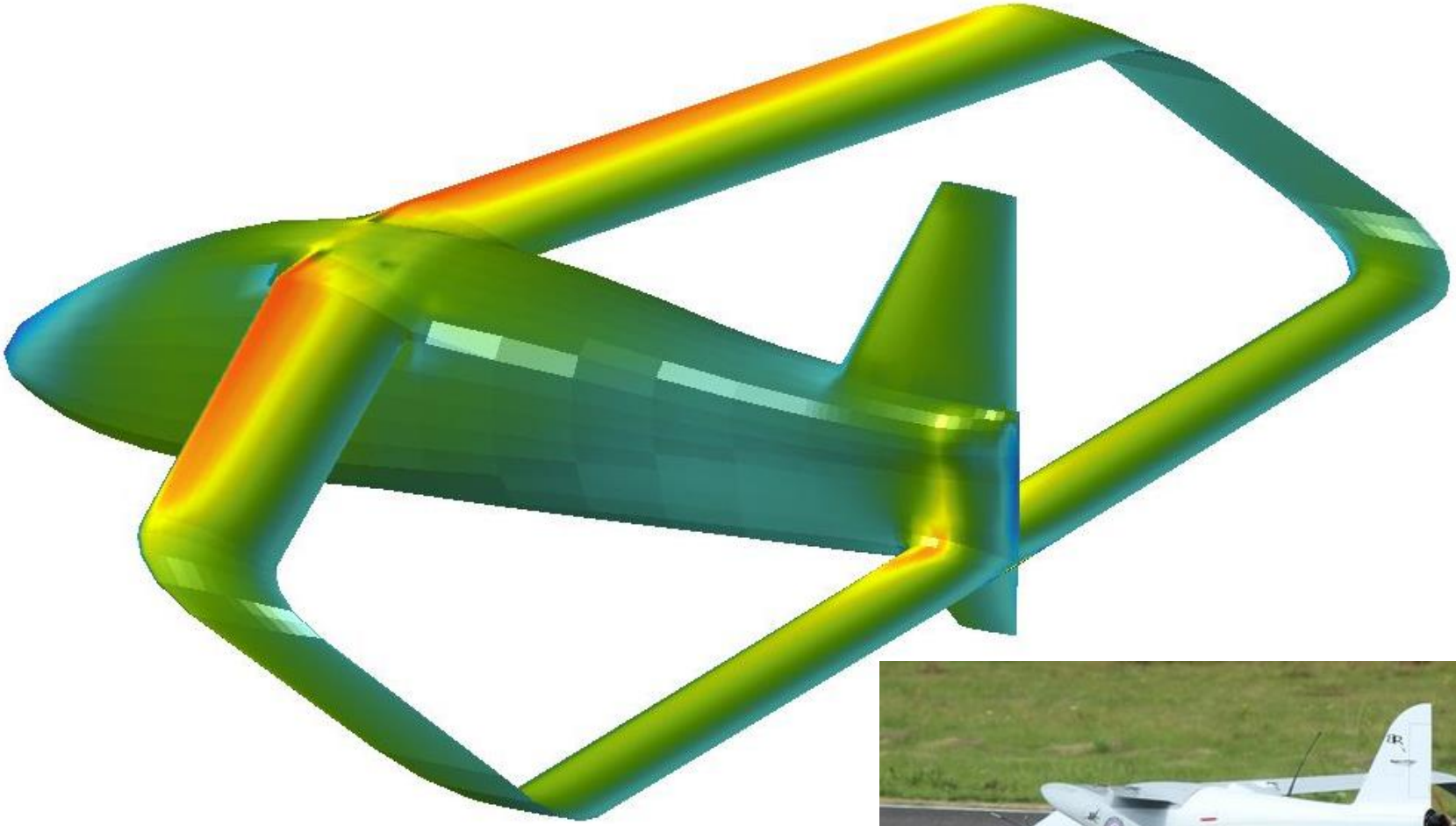
Naples 12-14.10.2015

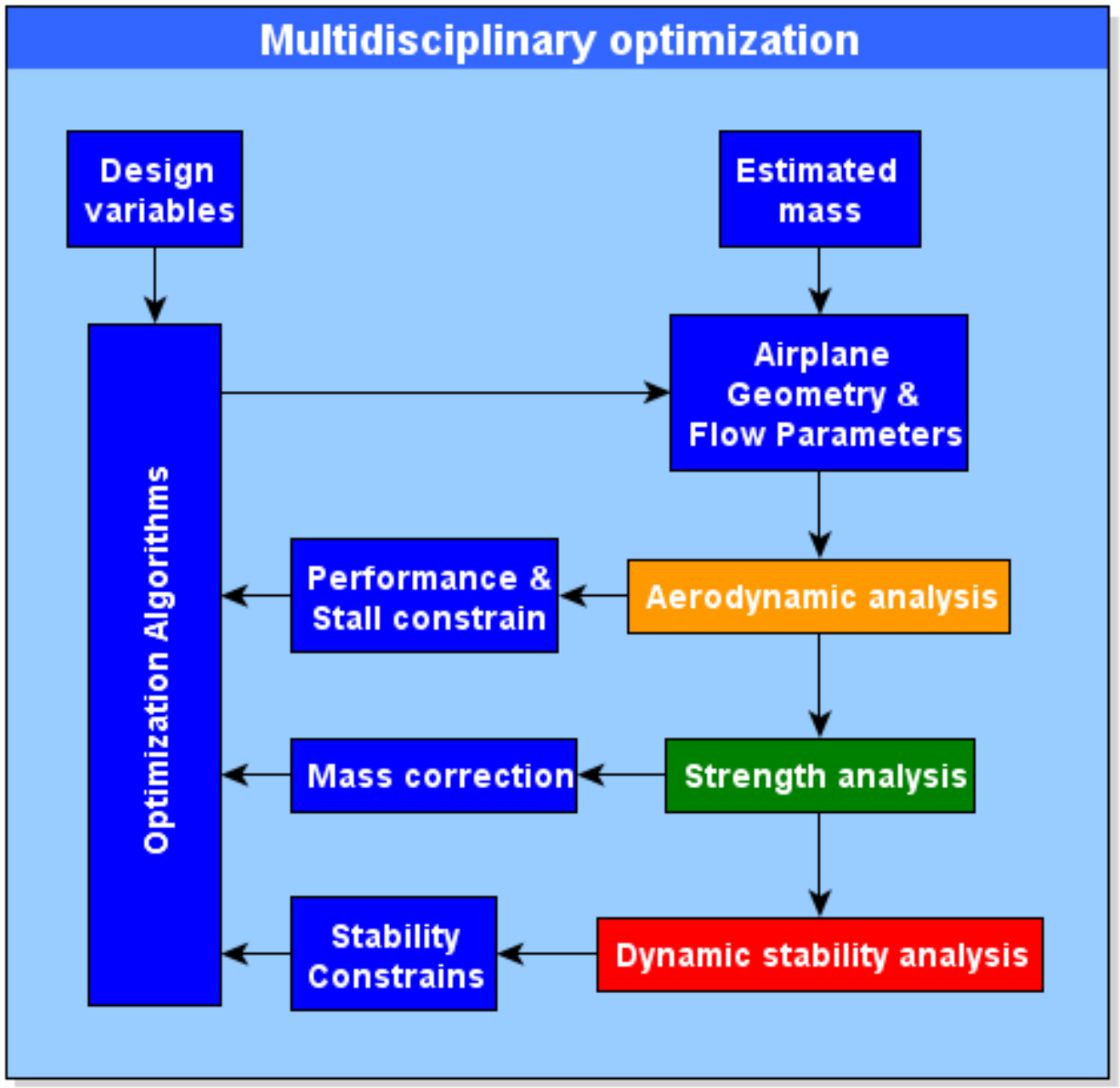
Outline

- Objective
- Analysis tools -MADO
  - Aerodynamics – PANUKL
  - FEM – CalculiX
  - Stability – SDSA
- Tools connection
- Interfaces
- Optimization
- Results – Joined Wing case
- Summary

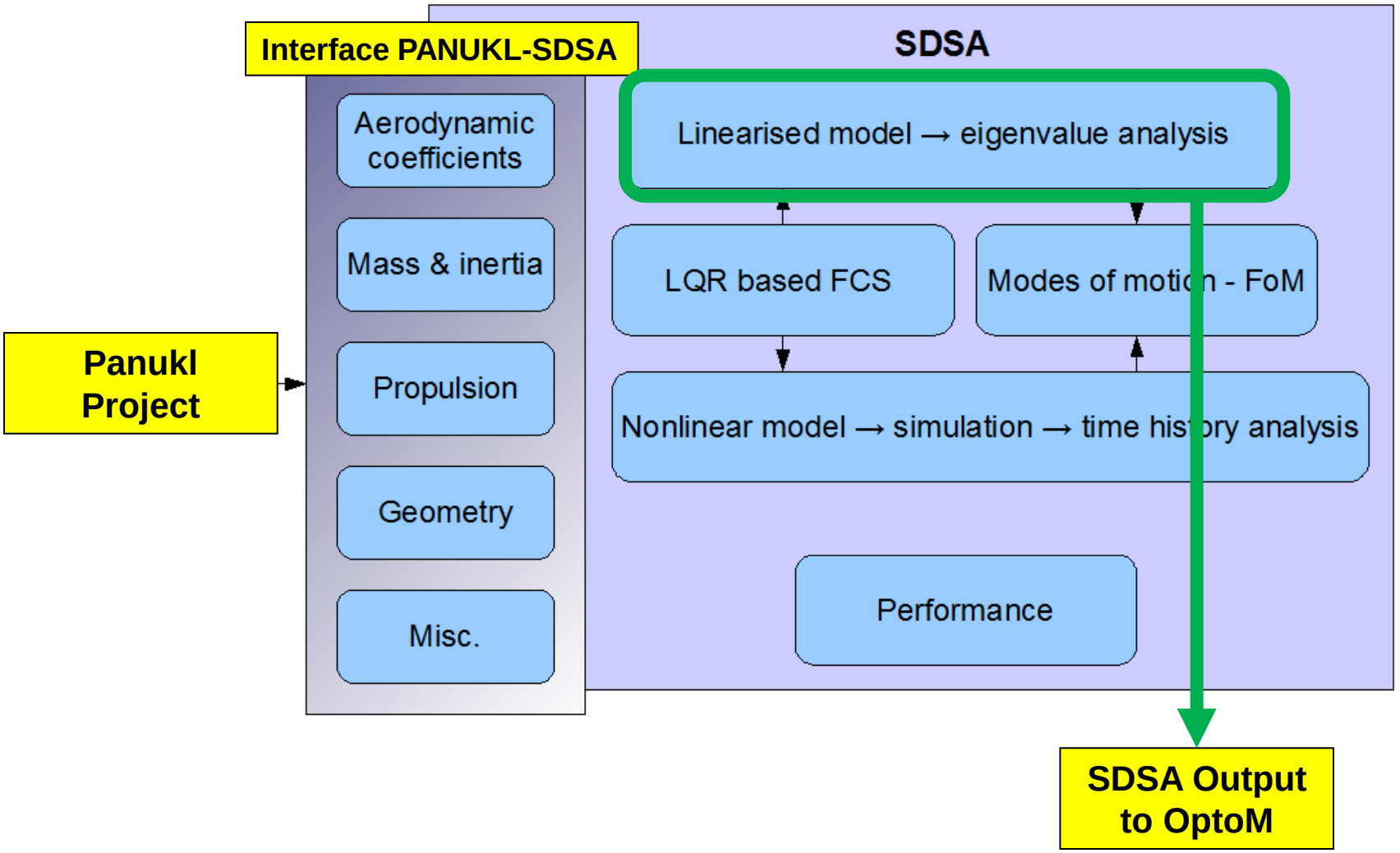
Join-wing as example MADO using (>180 optimization variables)



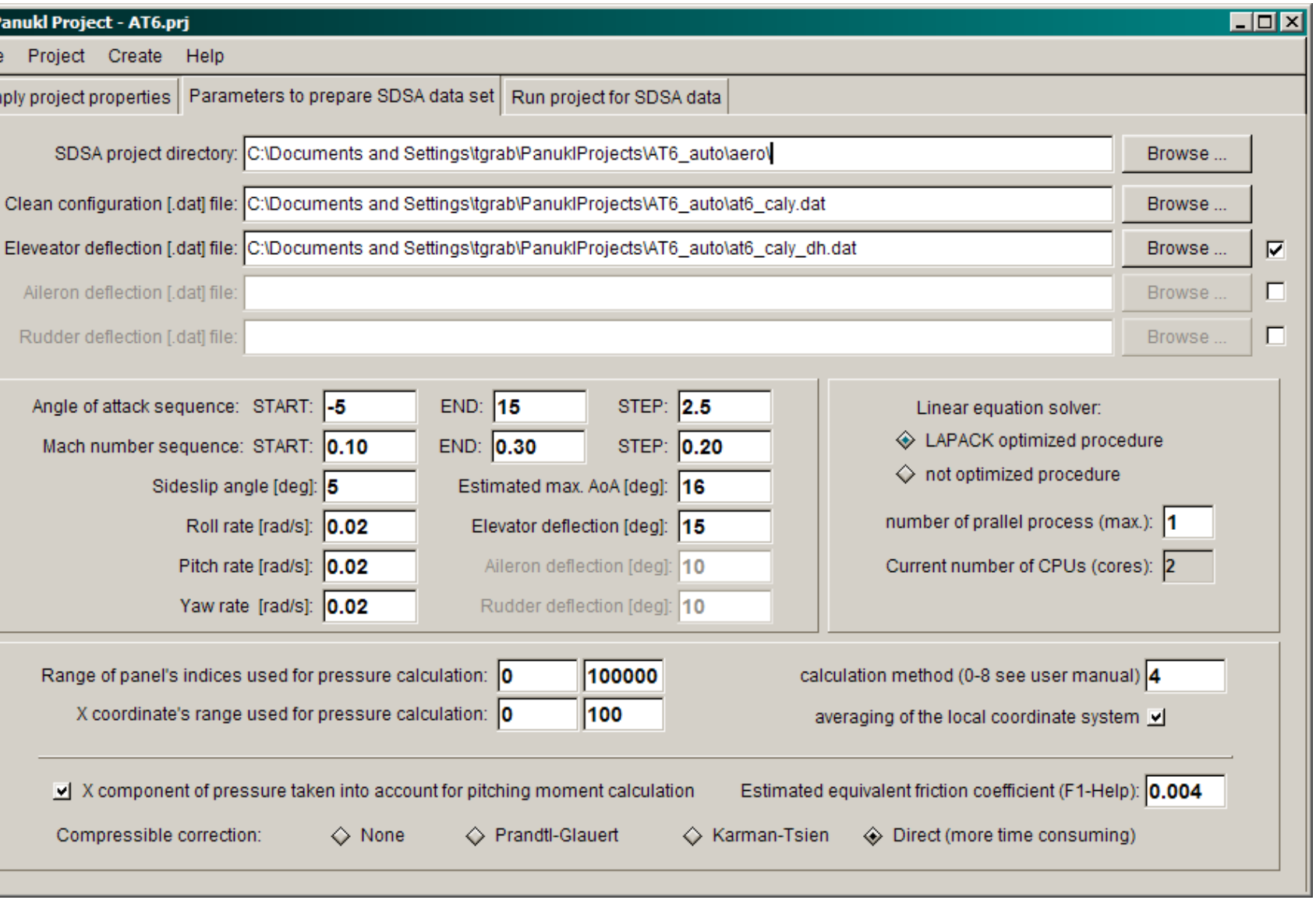
MOSUPS by C.Galiński,
Dynamic analysis: M.Lis


Multidisciplinary optimization
Design variables
Estimated mass
Optimization Algorithms
Airplane Geometry & Flow Parameters
Performance & Stall constrain
Aerodynamic analysis
Mass correction
Strength analysis
Stability Constrains
Dynamic stability analysis

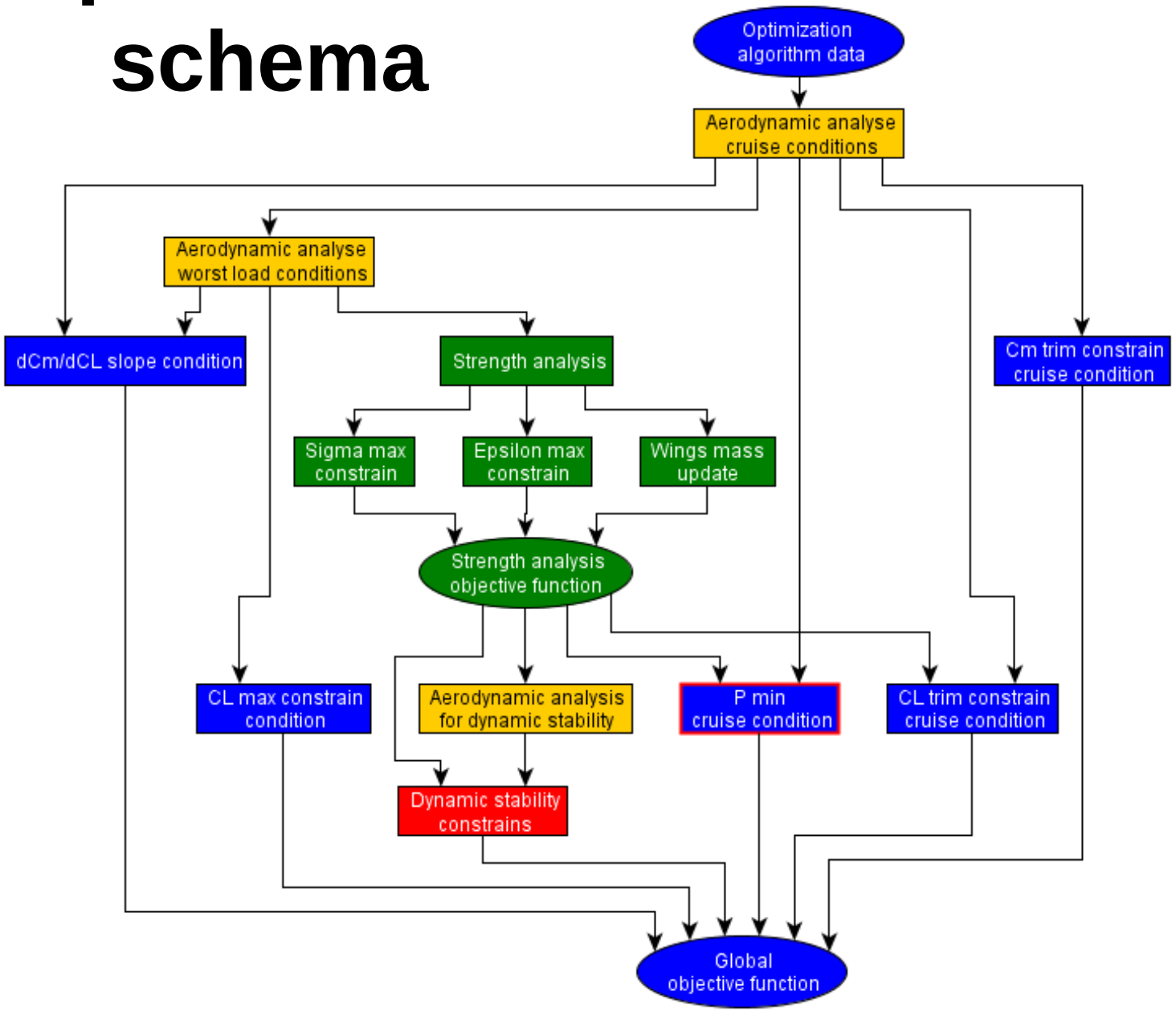
SDSA architecture



Export from PANUKL to SDSA



Optimization schema



Objective function & constrains

$$P_{\min} = \frac{1}{2} \cdot \rho \cdot V^3 \cdot S \cdot Cx$$

$$m \cdot g = \frac{1}{2} \cdot \rho \cdot V^2 \cdot S \cdot Cz$$

$$Cm = 0$$

$$\frac{dCm}{dCz} = -0.15$$

$$Cz < Cz_{\max}$$

Objective function & constrains

$$m_{\min}$$

- 183 variables – shell thickness
- material - aluminum alloy

$$\varepsilon < \varepsilon_{\max}$$

$$\sigma < \nu \cdot \sigma_{dop}$$

Dynamic constrains

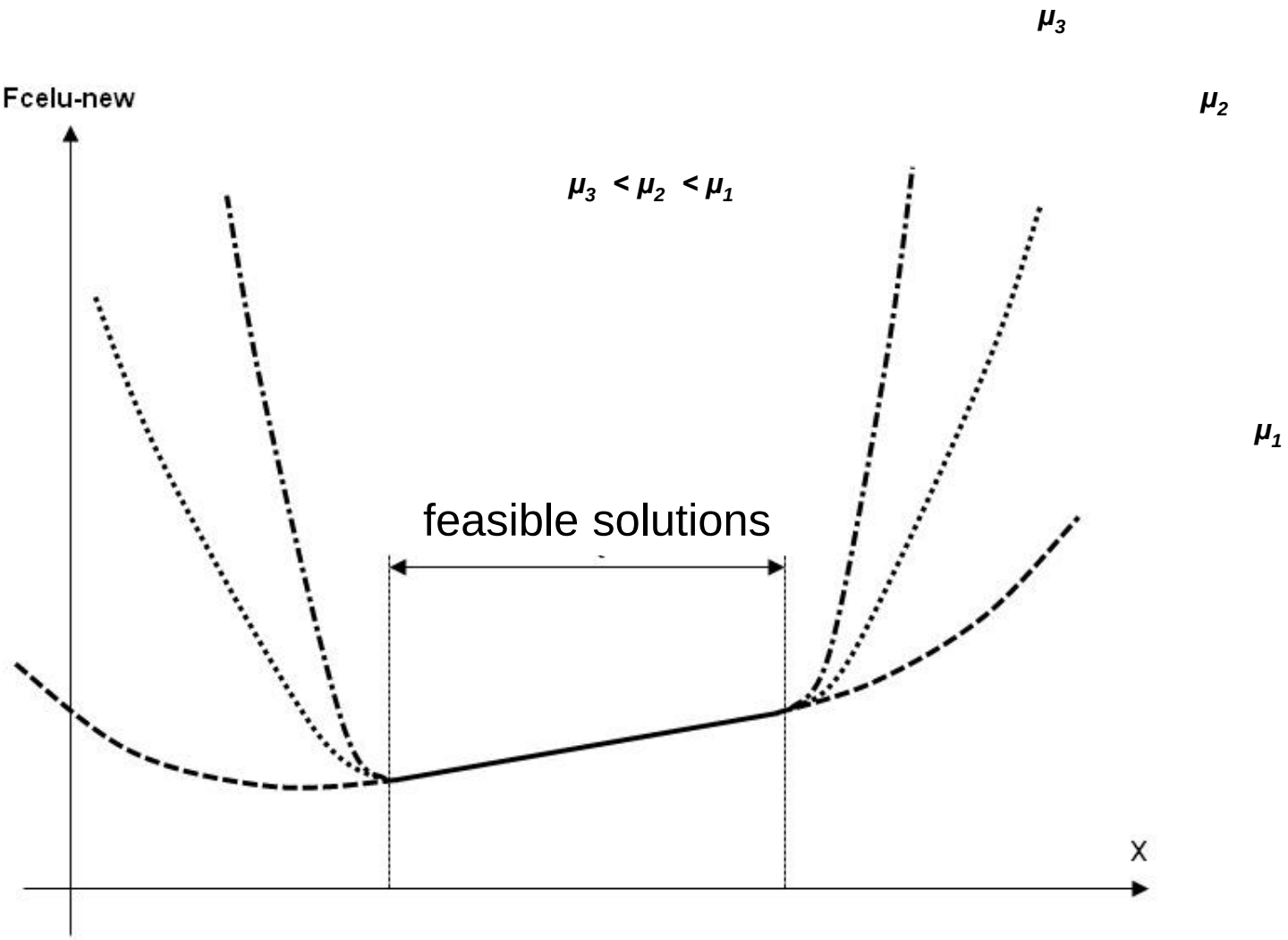
$$\zeta_{phugoid} > 0.04$$

$$0.35 < \zeta_{short\_period} < 1.3$$

$$\zeta_{dutch\_roll} > 0.19 \quad \wedge \quad \omega_{dutch\_roll} > 1$$

$$T_{2\_spiral} > 20 \quad \vee \quad T_{2\_spiral} < 0.0$$

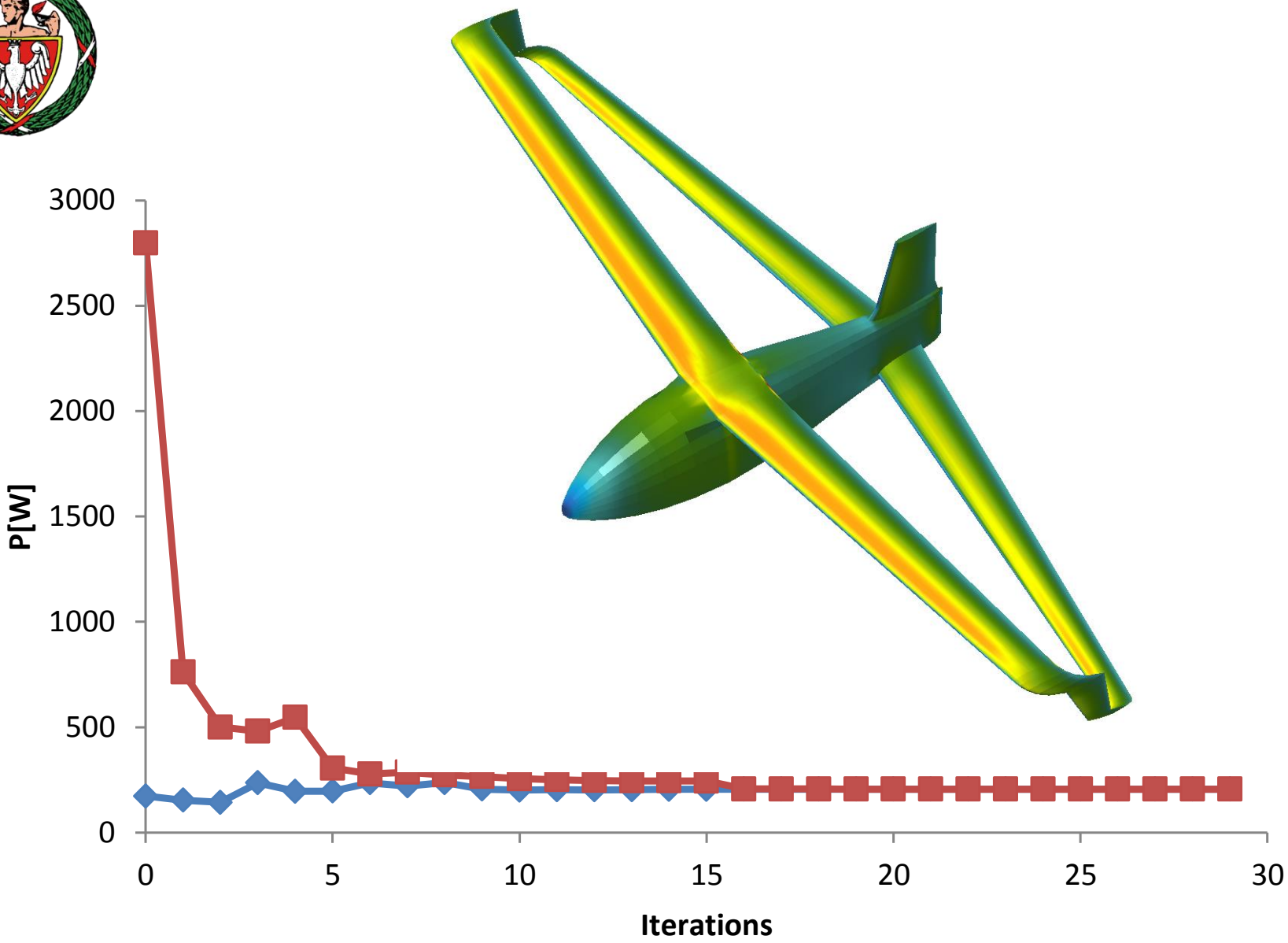
Penalty function constrains



$$F_{CELU-NEW} = F_{CELU} + \frac{1}{2 \cdot \mu} \sum c^2(x)$$

where $c = \max[\, g - x, 0]$

g – constraint value



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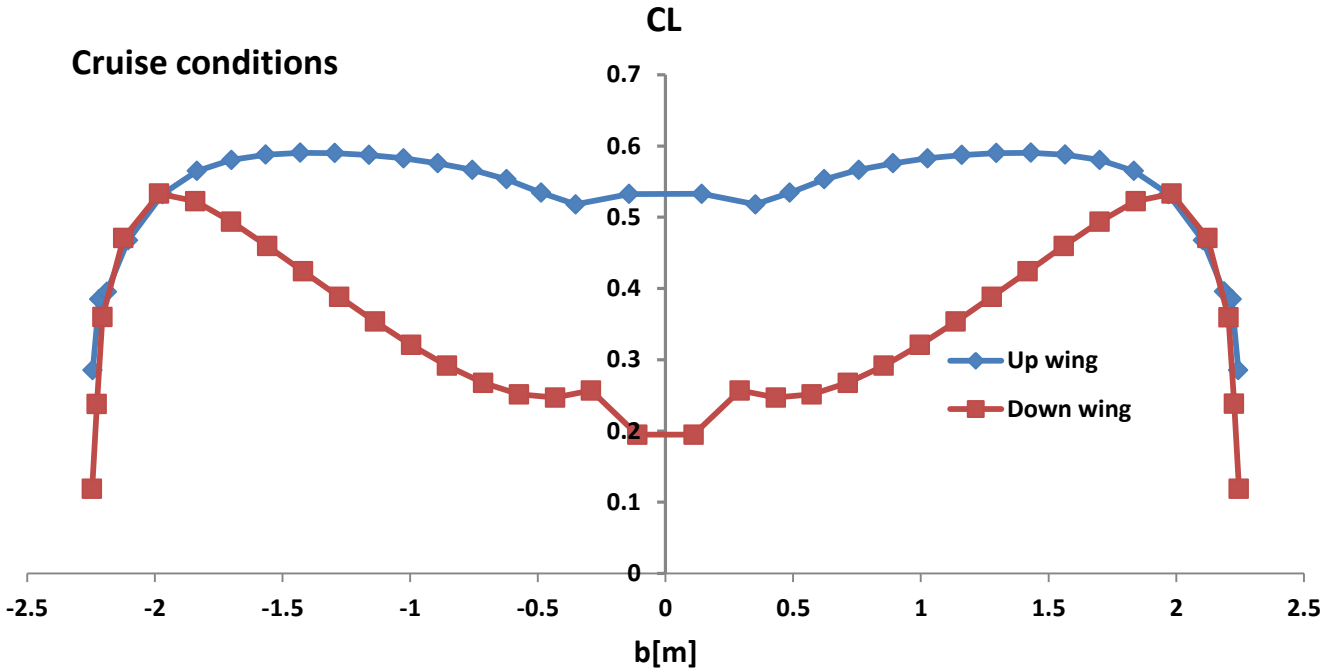
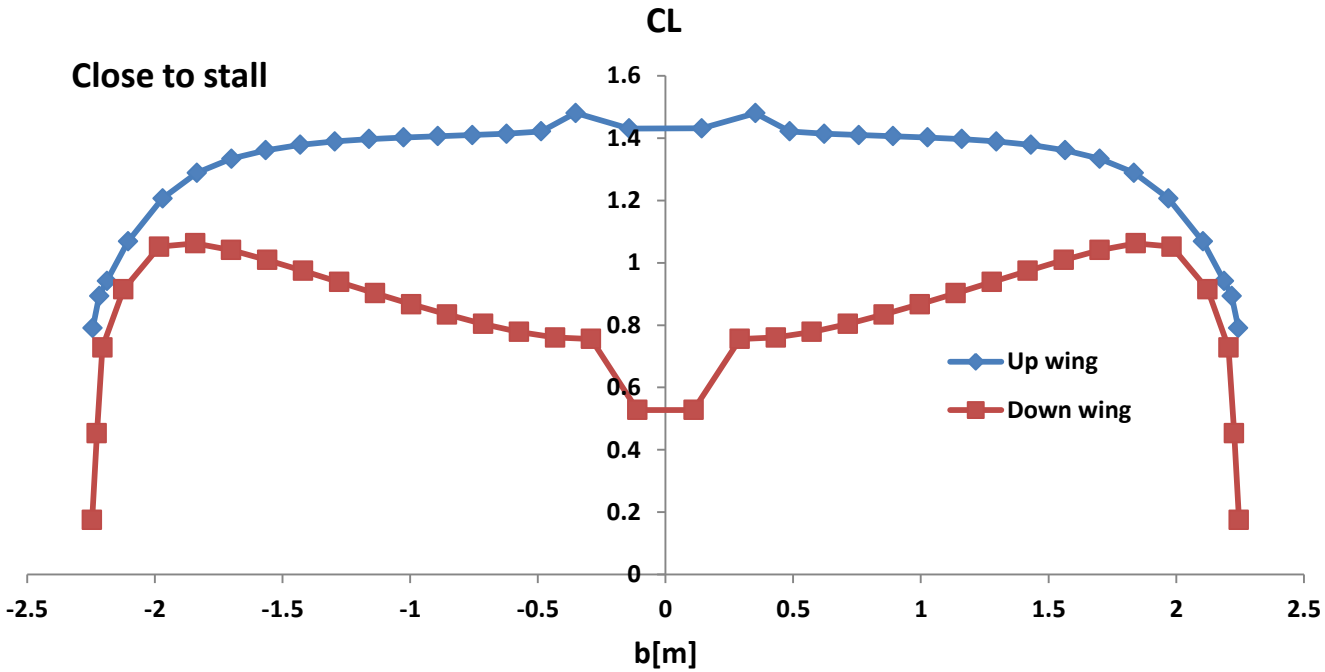
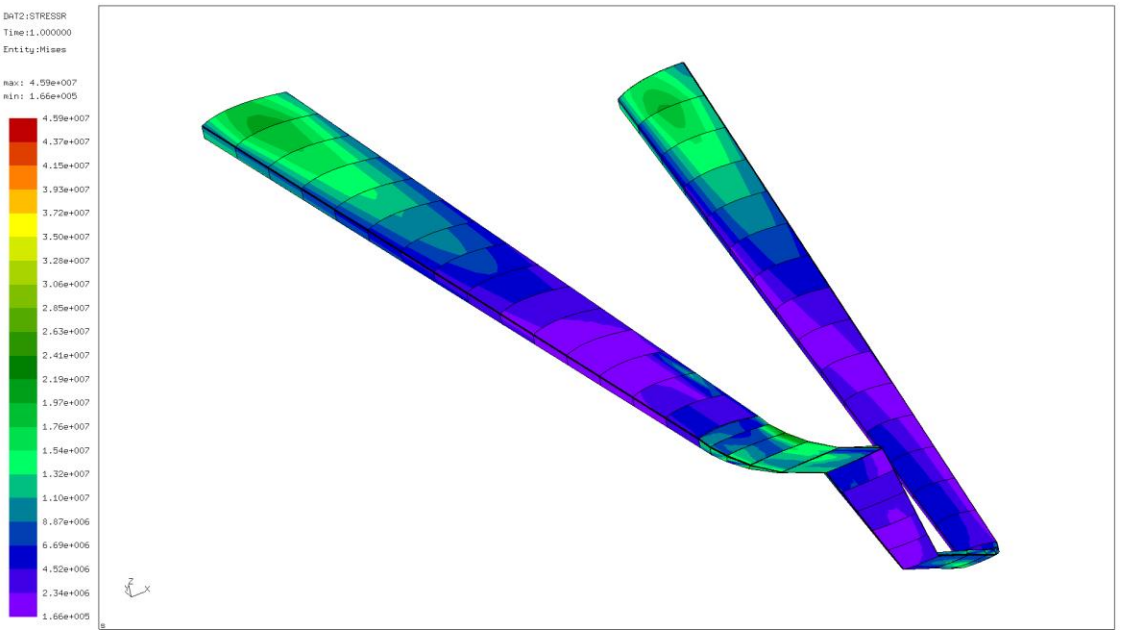
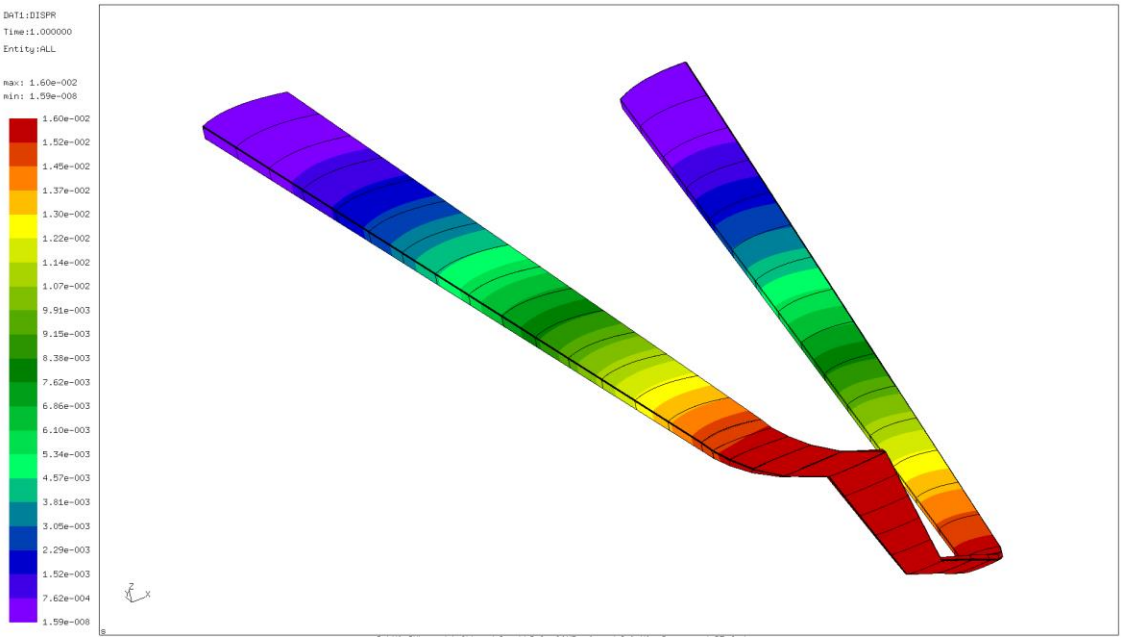

CL
Cruise conditions
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
b[m]
Up wing
Down wing

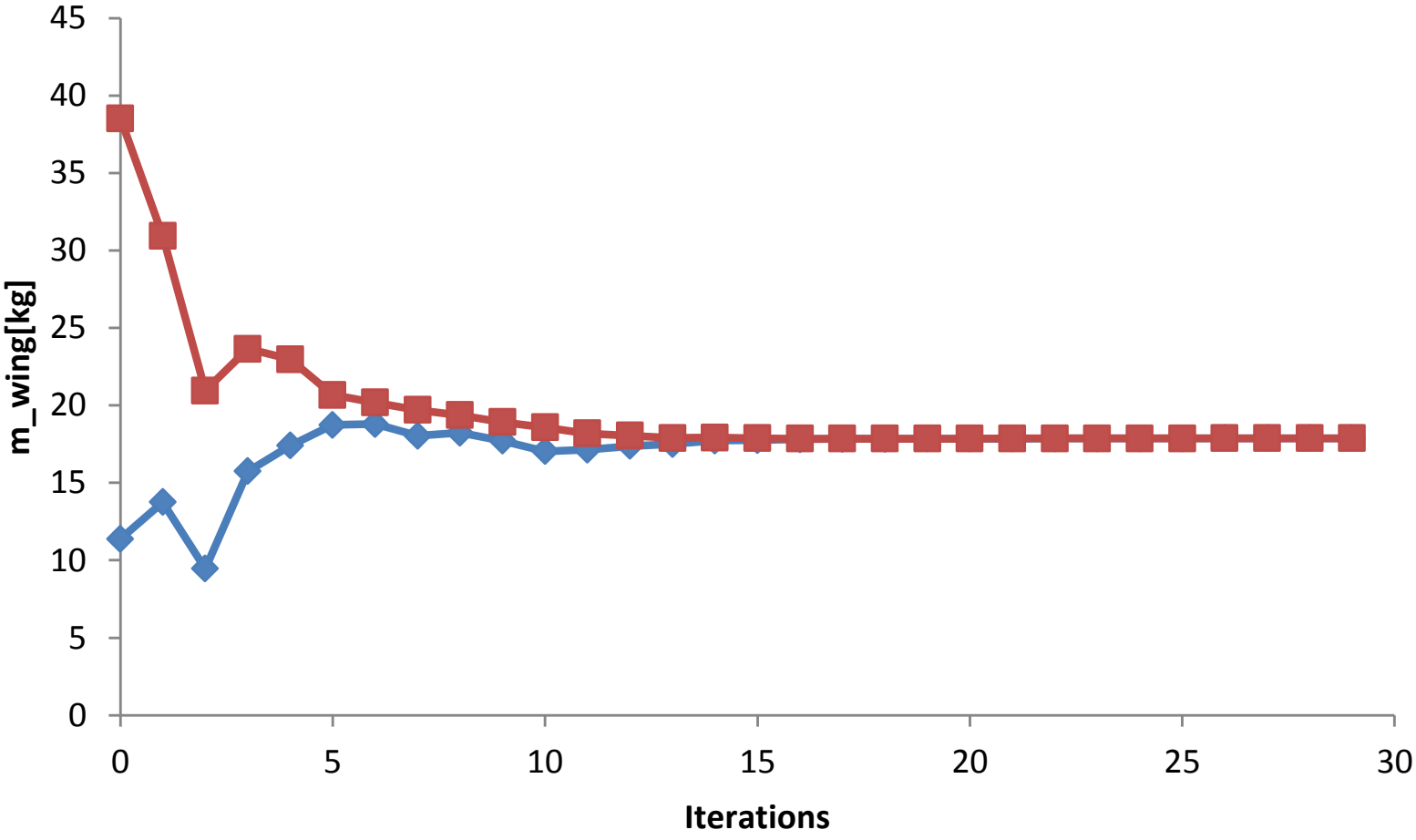

CL
Close to stall
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
b[m]
Up wing
Down wing

CalculiX results

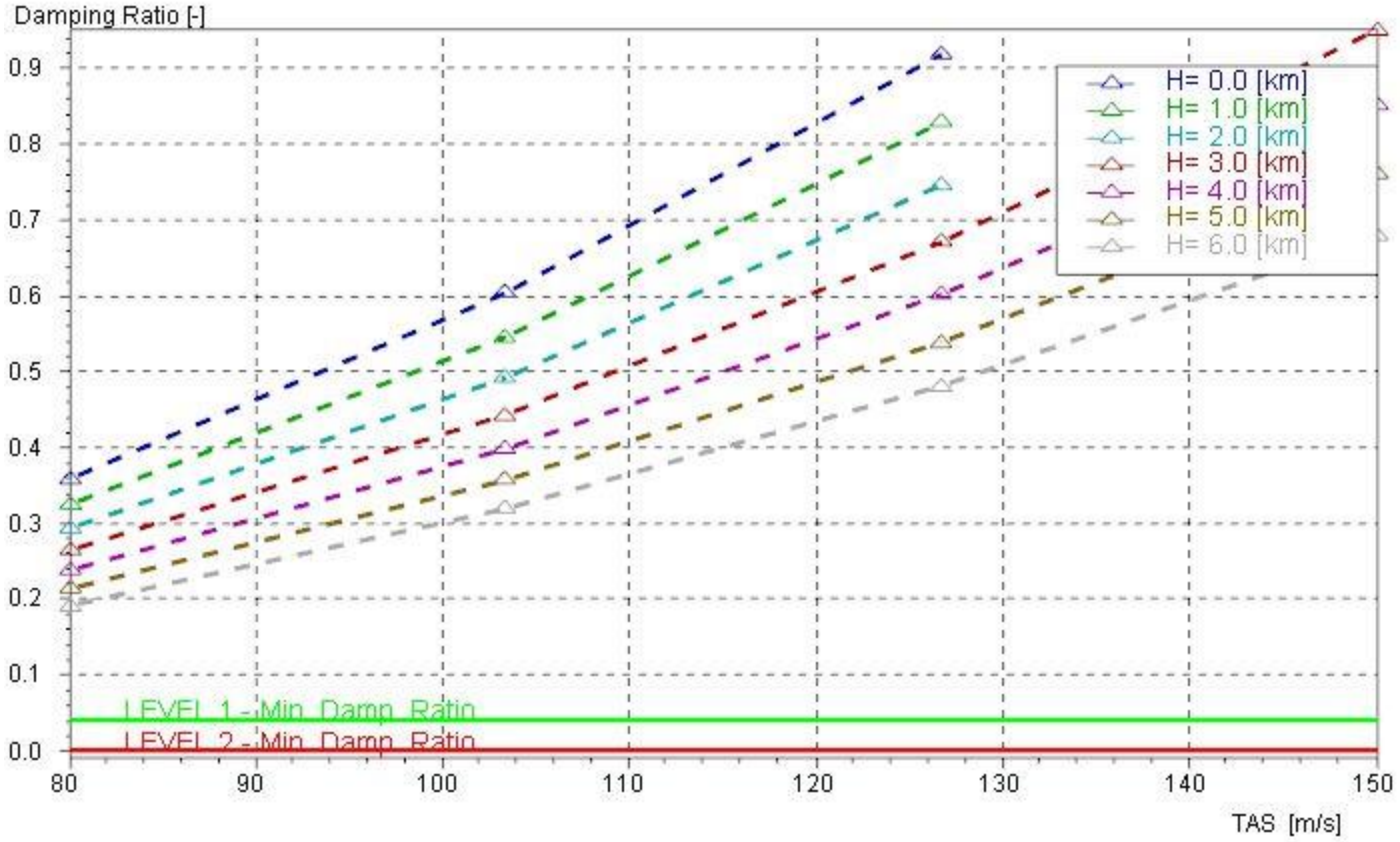




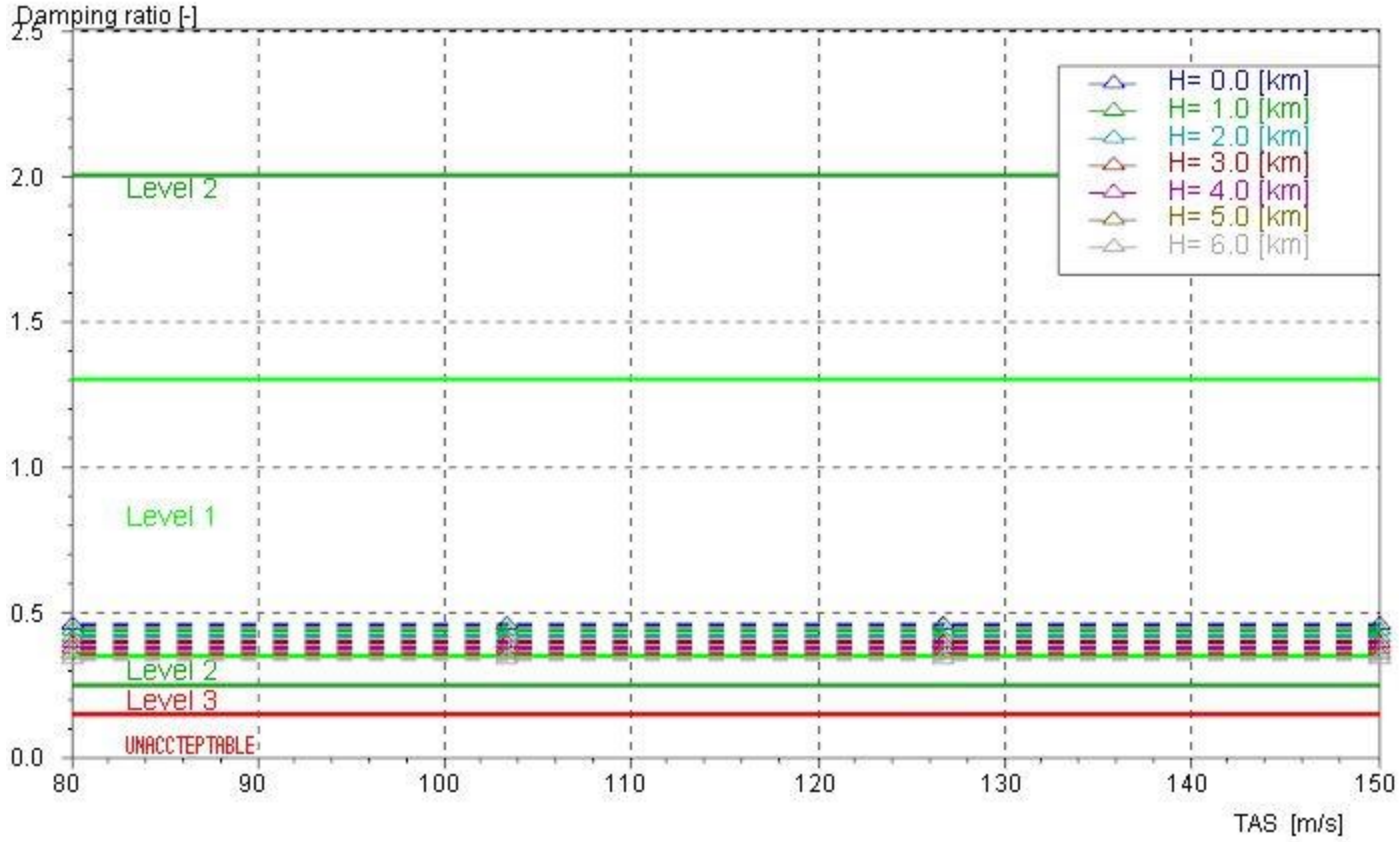
Weight of wing



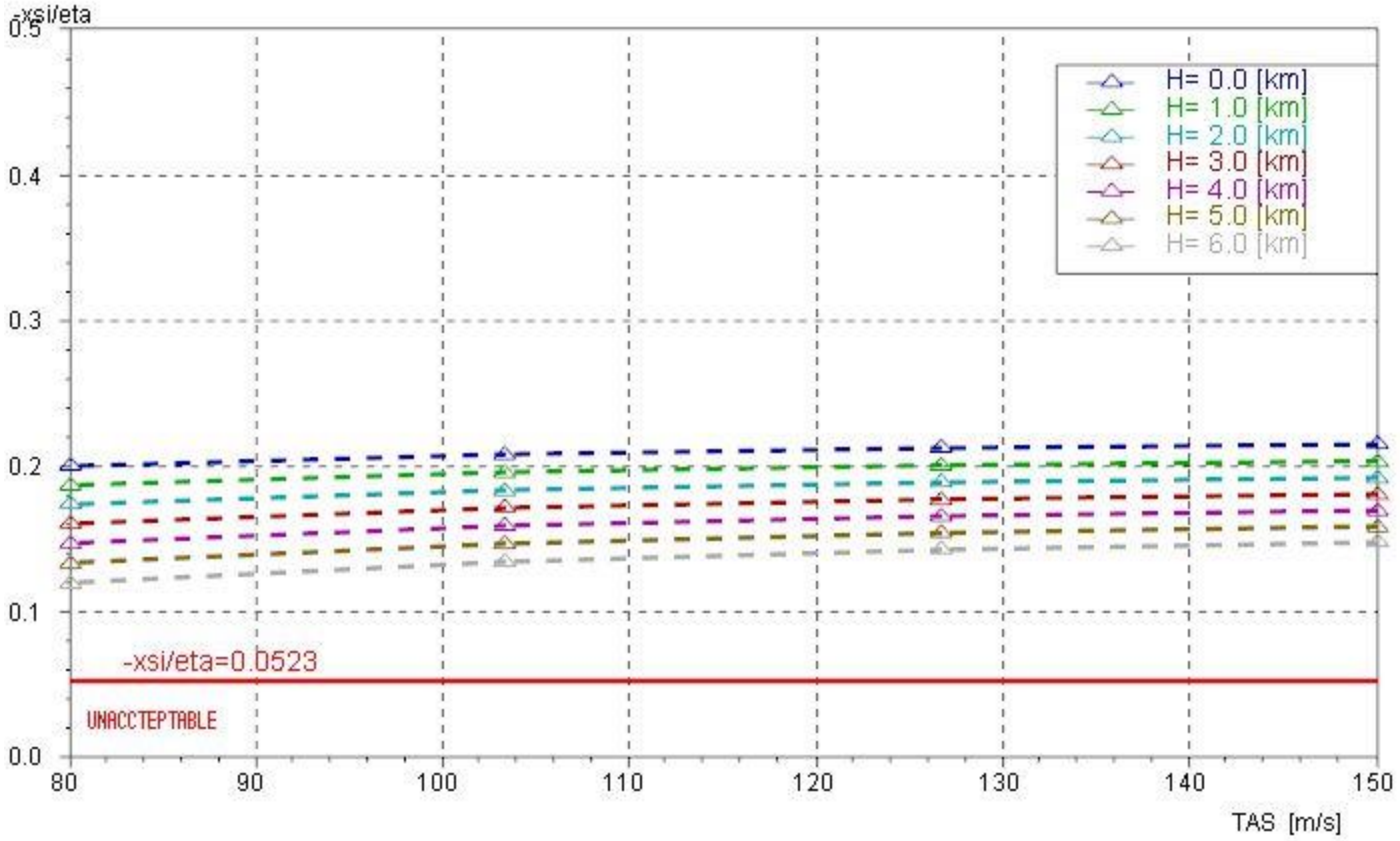
Phugoid mode - damping ratio



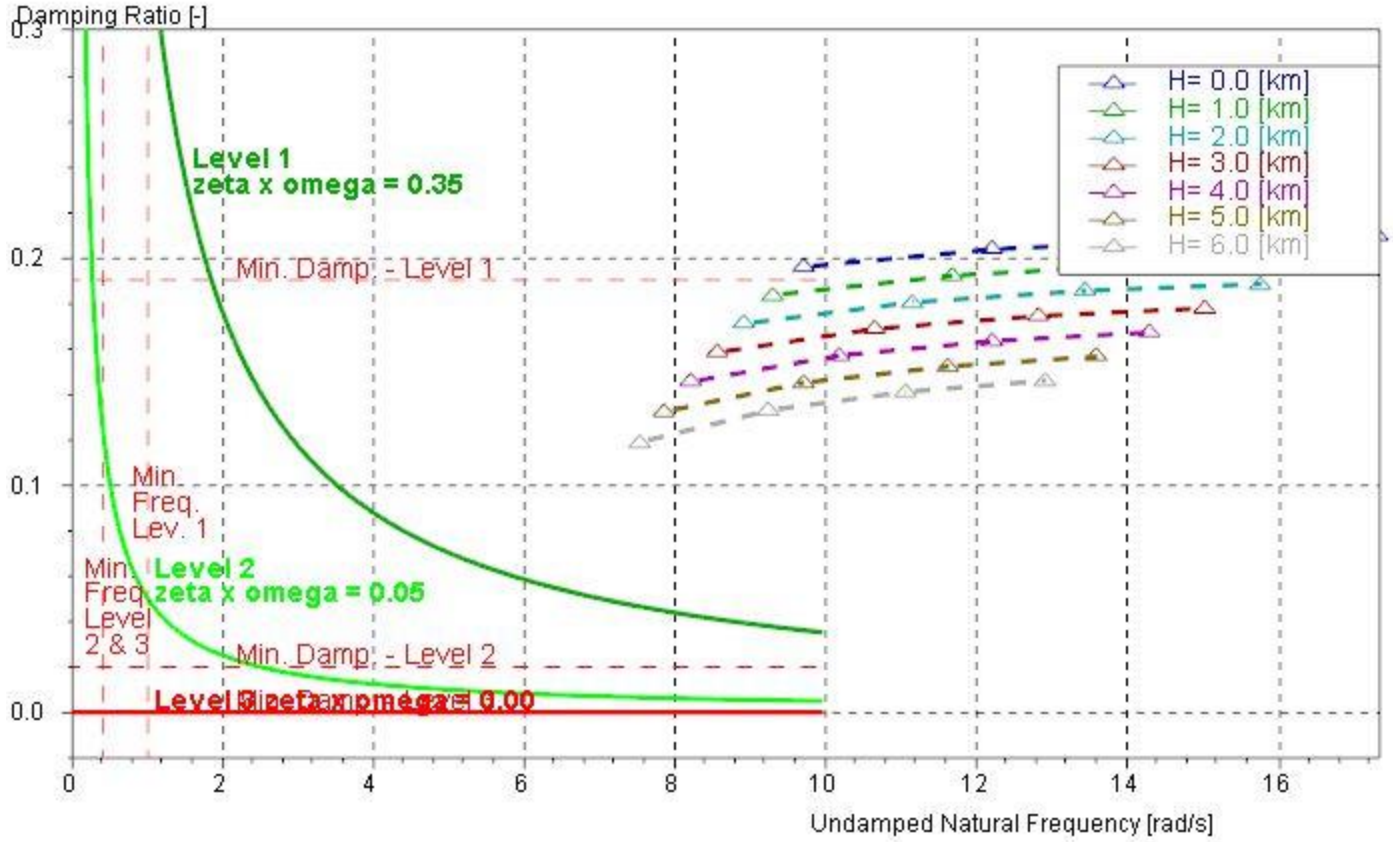
Short Period mode - damping ratio



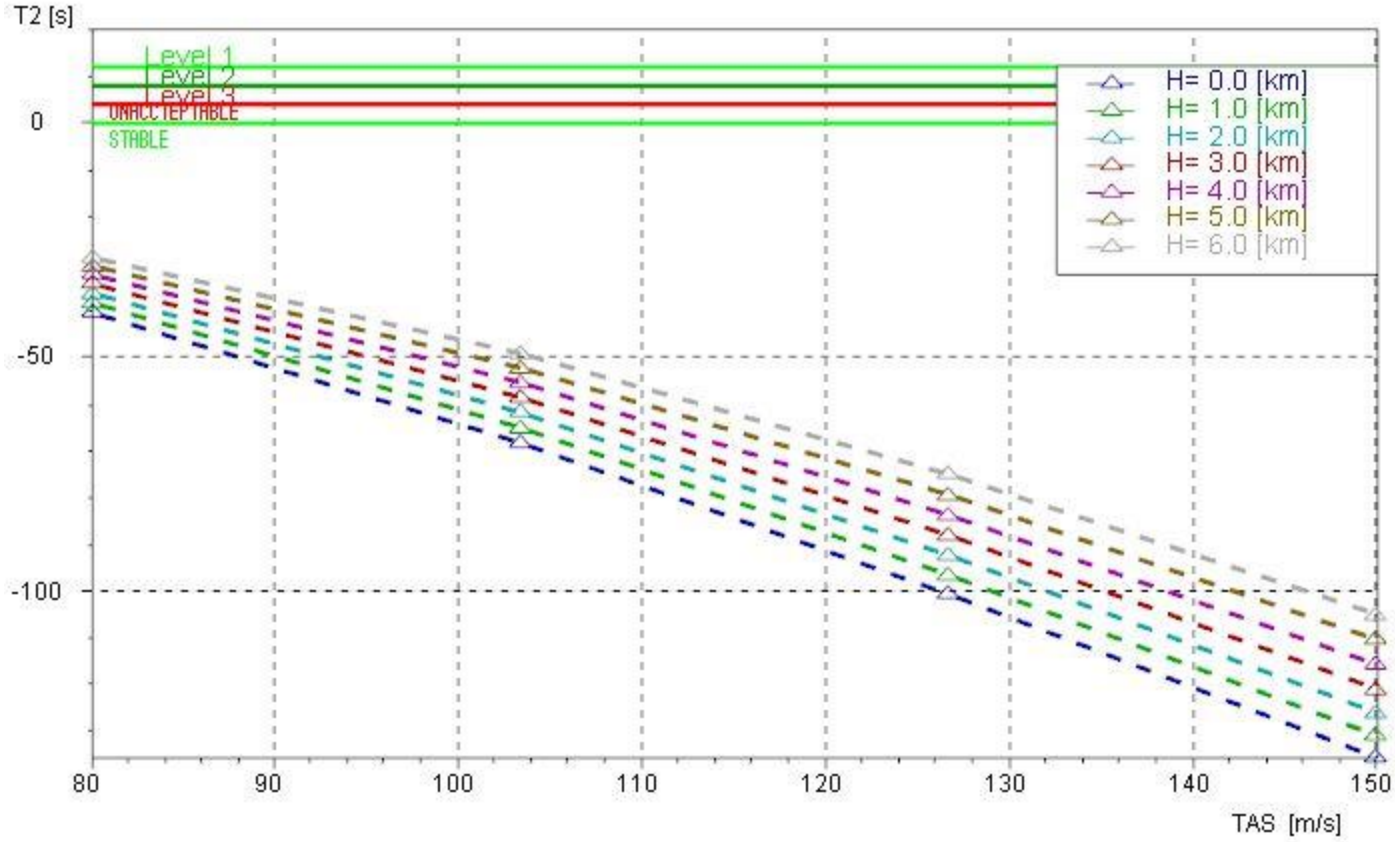
Dutch roll mode – CS-23 criterion



Dutch roll mode – MIL criterion

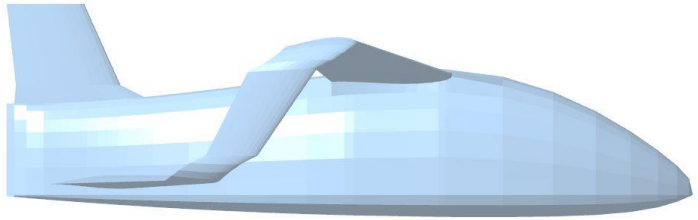


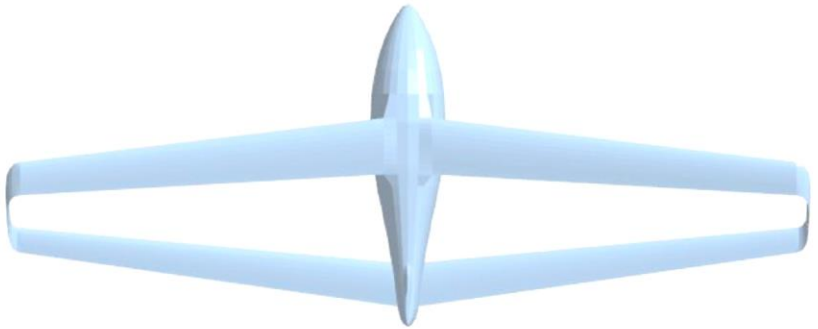
Spiral mode – MIL criterion



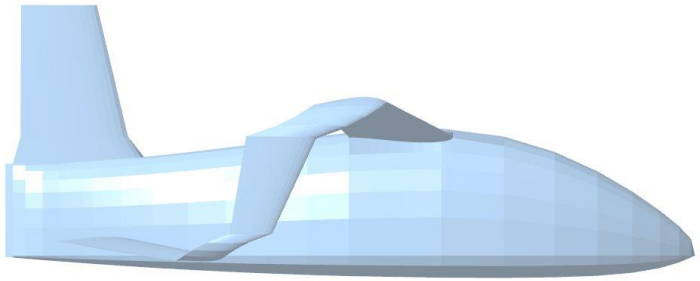
Final solution

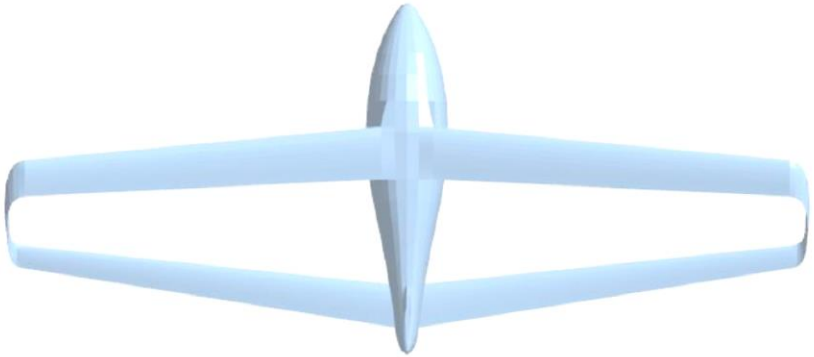
baseline





25th iteration





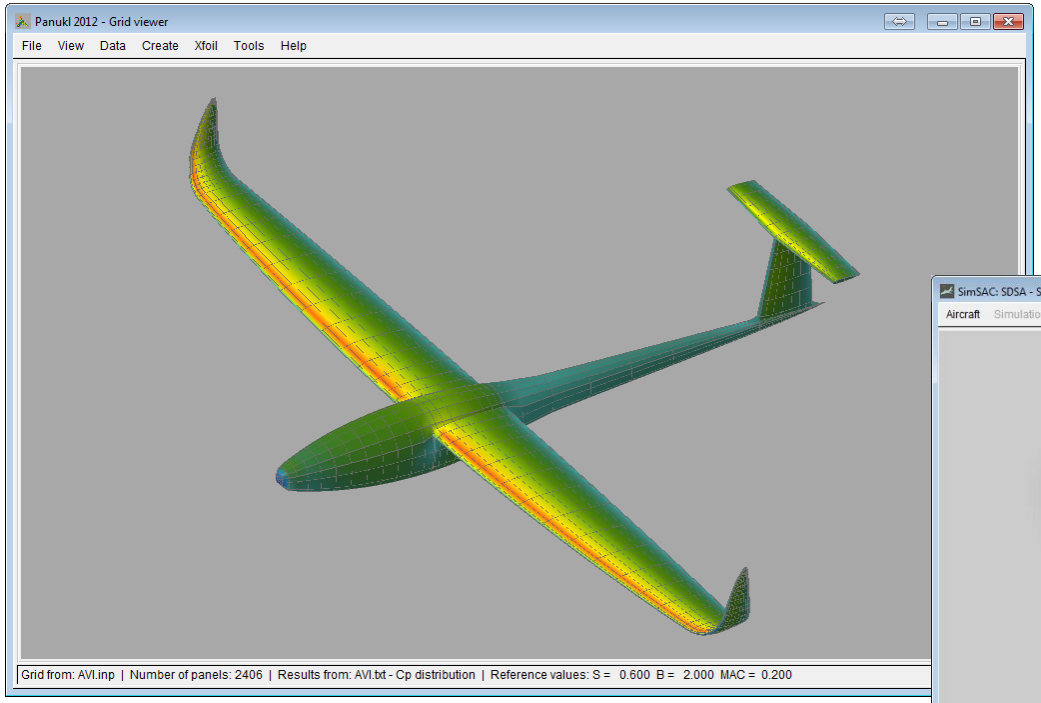
Future work

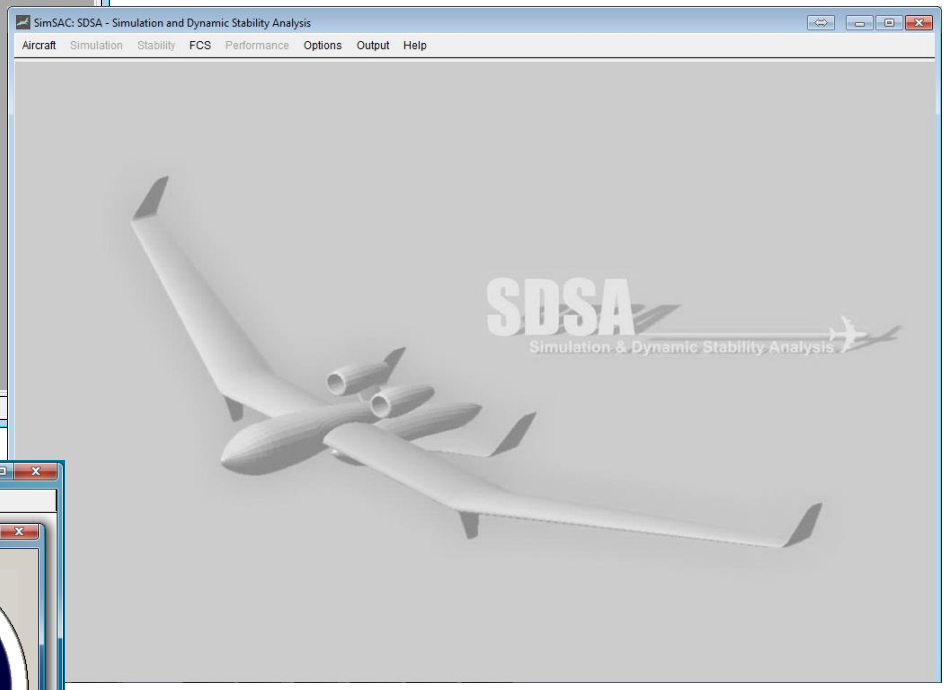
Coming soon:

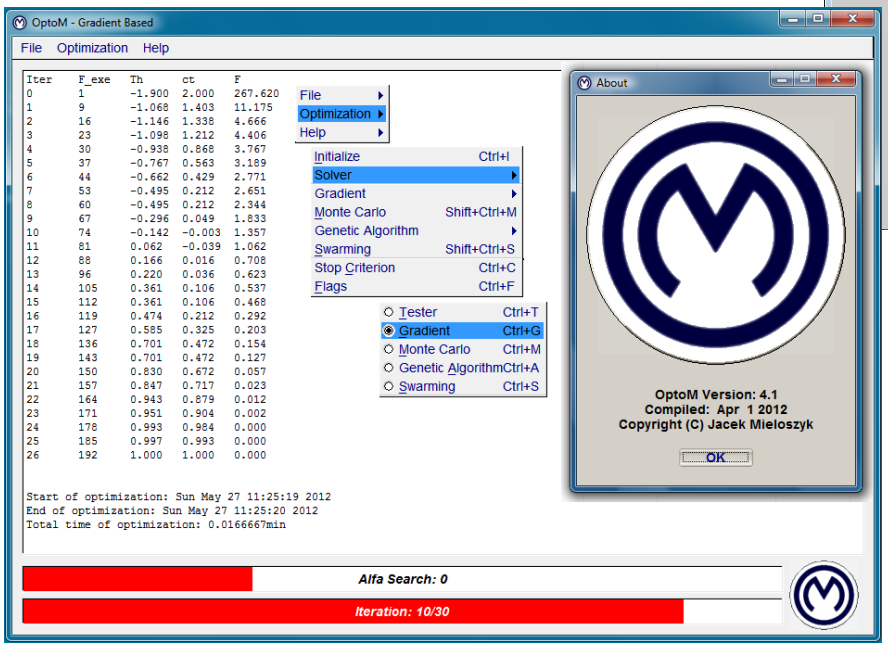
- C++ API functions for Panukl and SDSA batch operations (almost done)
- Structure moments of inertia
- FEM export
  - 8 node shell panels
  - composite definition as orthotropic material
  - internal FEM analysis execution

Long term:

- Propeller influence as actuator disc
- Export to other FEM solvers (?)
- GUI for aircraft mass properties
- Parallelization of computation







Thank you for attention