



5th Symposium on Collaboration in Aircraft Design



# The stability of join-wing configuration within optimization procedure

MADO - **M**ultidisciplinary **A**ircraft **D**esign and **O**ptimization  
software suite  
(PANUKL, SDSA, OptoM)

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Naples 12-14.10.2015

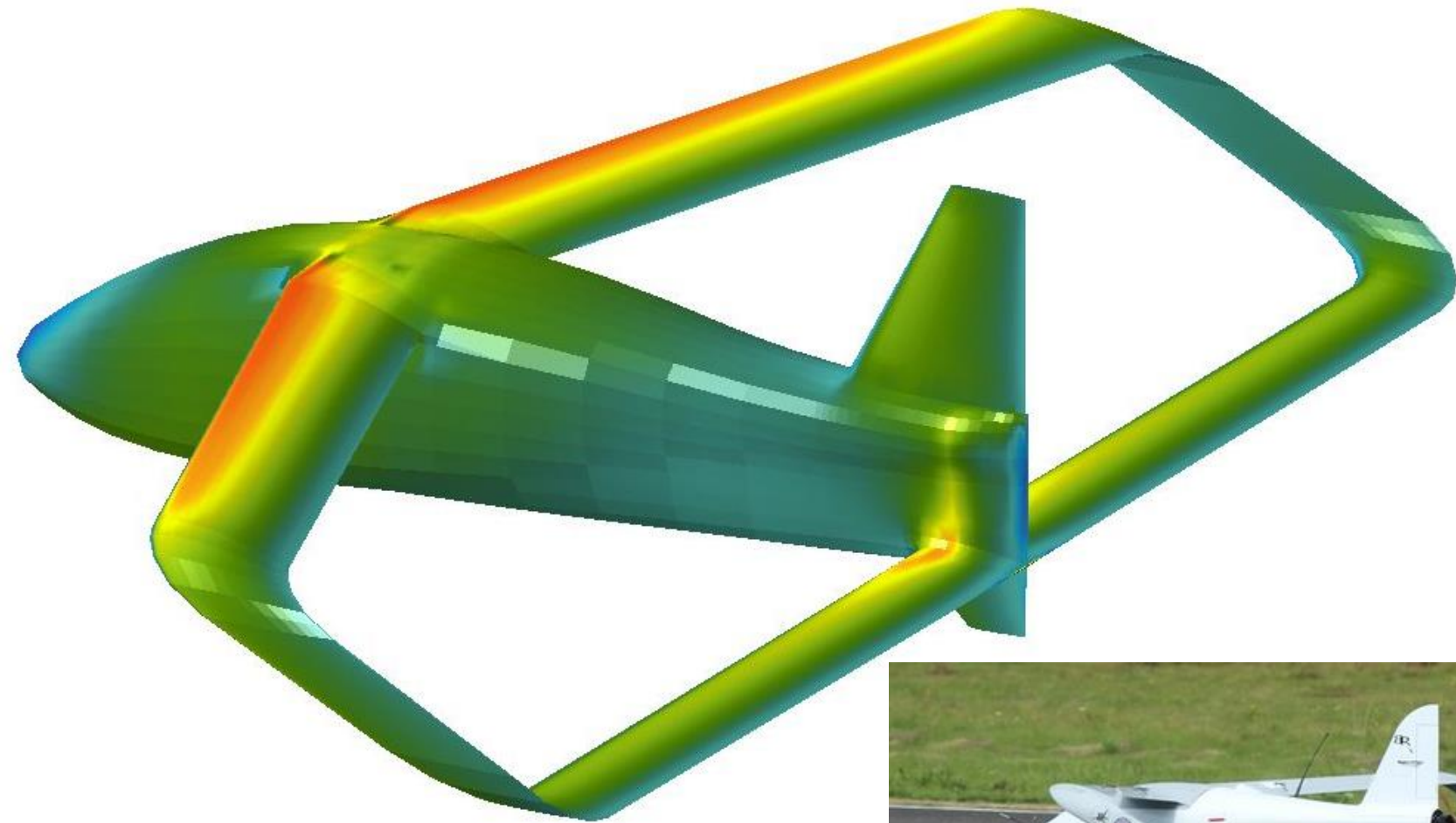


# Outline

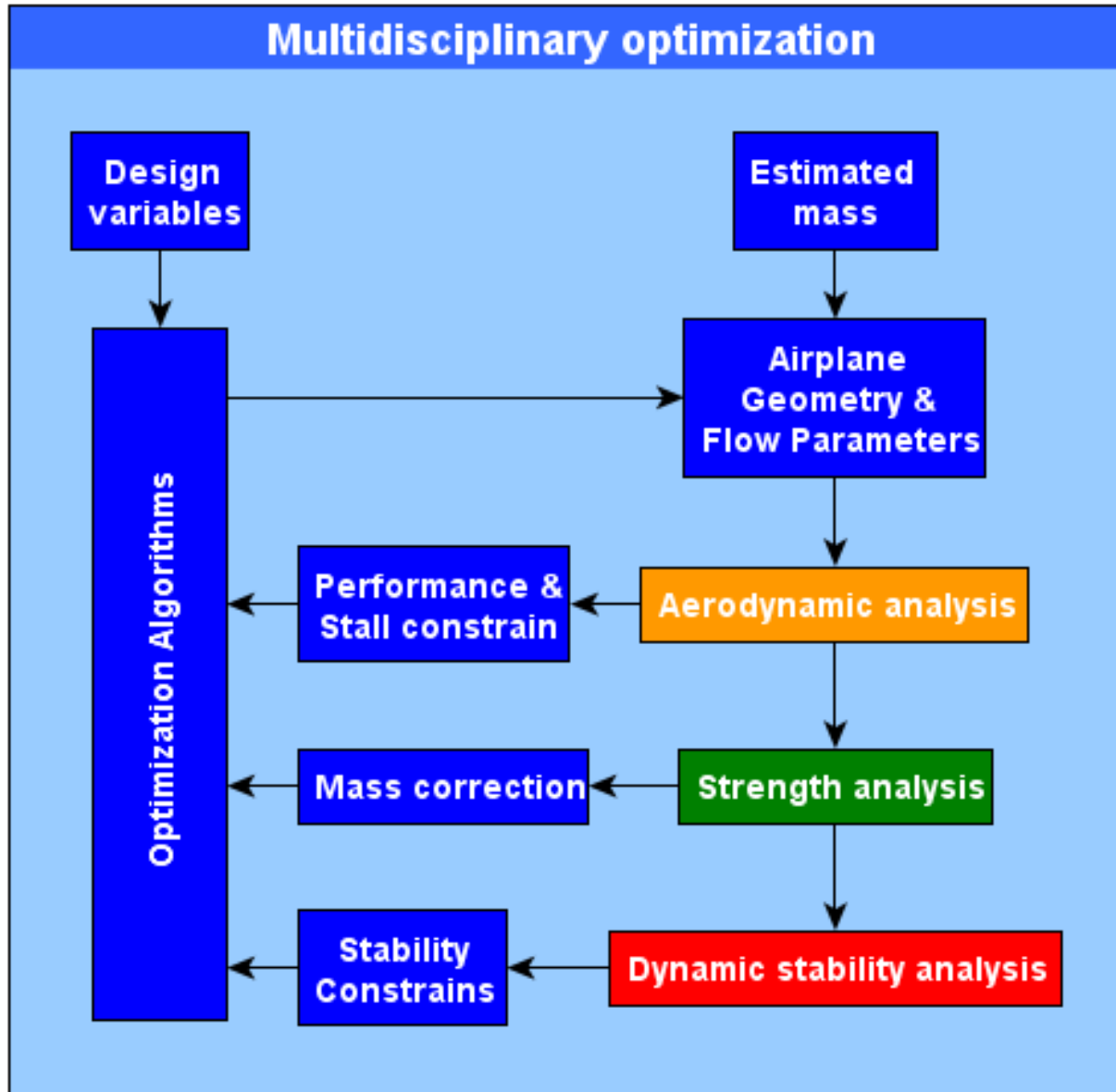
- Objective
- Analysis tools -MADO
  - Aerodynamics – PANUKL
  - FEM – CalculiX
  - Stability – SDSA
- Tools connection
- Interfaces
- Optimization
- Results – Joined Wing case
- Summary



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



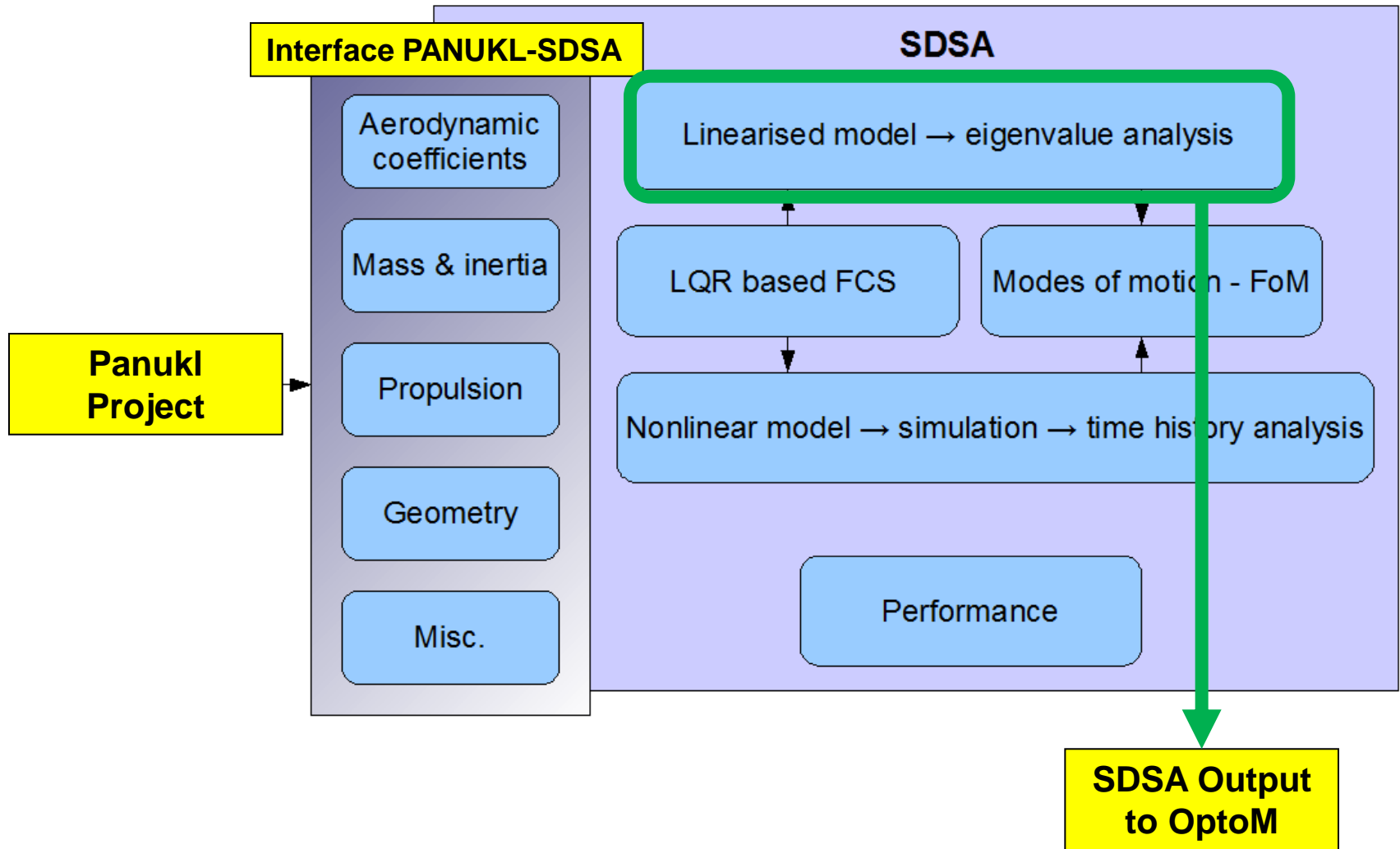
**MOSUPS by C.Galiński,  
Dynamic analysis: M.Lis**



**MADO - Multidisciplinary Aircraft Design and Optimization**



# SDSA architecture





# Export from PANUKL to SDSA



**Panukl Project - AT6.prj** [ \_ ] [ □ ] [ × ]

File Project Create Help

Simply project properties | Parameters to prepare SDSA data set | Run project for SDSA data

SDSA project directory:  Browse ...

Clean configuration [.dat] file:  Browse ...

Eleveator deflection [.dat] file:  Browse ...

Aileron deflection [.dat] file:  Browse ...

Rudder deflection [.dat] file:  Browse ...

Angle of attack sequence: START: <input type="text" value="-5"/>	END: <input type="text" value="15"/>	STEP: <input type="text" value="2.5"/>
Mach number sequence: START: <input type="text" value="0.10"/>	END: <input type="text" value="0.30"/>	STEP: <input type="text" value="0.20"/>
Sideslip angle [deg]: <input type="text" value="5"/>	Estimated max. AoA [deg]: <input type="text" value="16"/>	
Roll rate [rad/s]: <input type="text" value="0.02"/>	Elevator deflection [deg]: <input type="text" value="15"/>	
Pitch rate [rad/s]: <input type="text" value="0.02"/>	Aileron deflection [deg]: <input type="text" value="10"/>	
Yaw rate [rad/s]: <input type="text" value="0.02"/>	Rudder deflection [deg]: <input type="text" value="10"/>	

Linear equation solver:  
 LAPACK optimized procedure  
 not optimized procedure

number of prallel process (max.):

Current number of CPUs (cores):

Range of panel's indices used for pressure calculation:

X coordinate's range used for pressure calculation:

calculation method (0-8 see user manual)

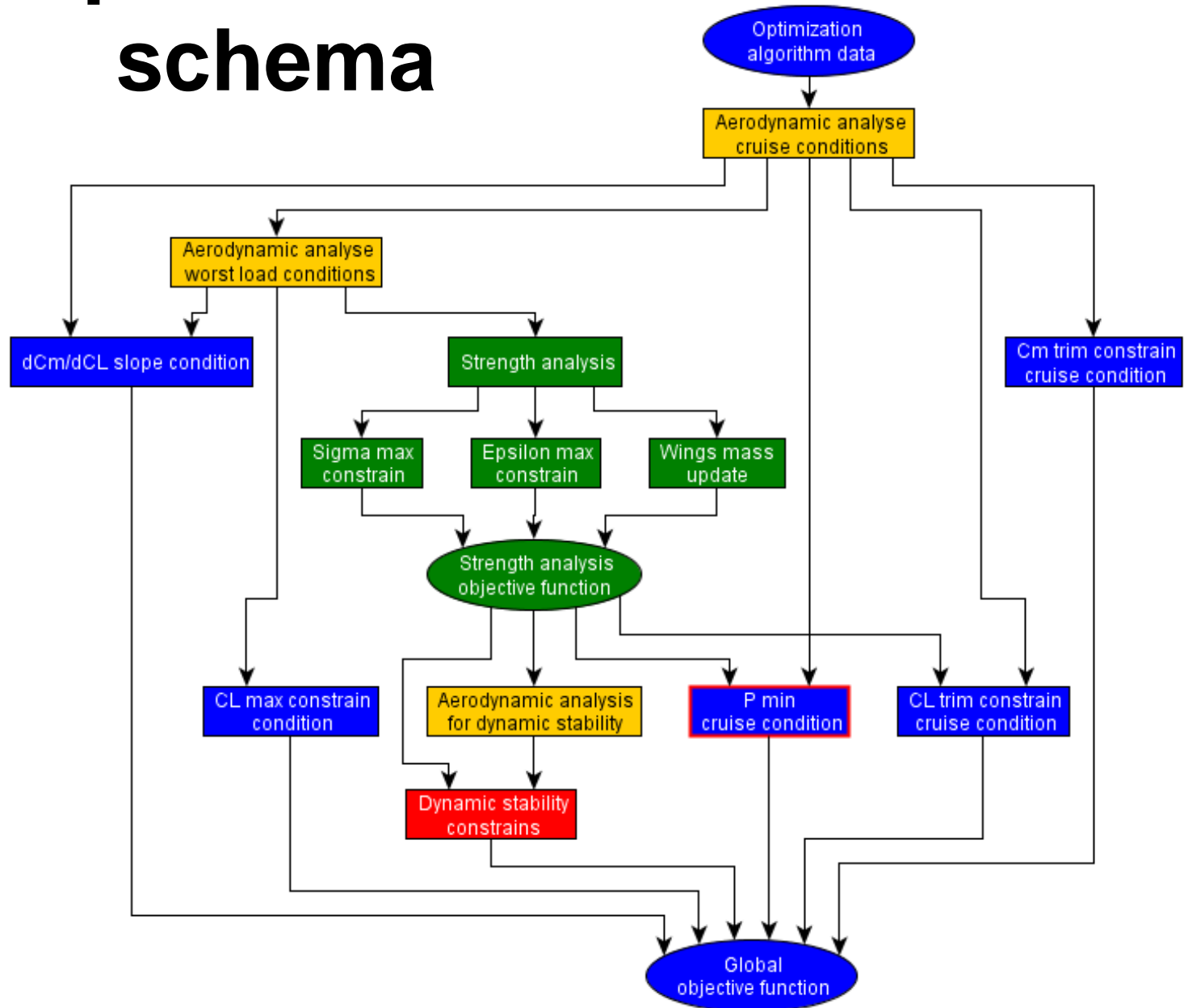
averaging of the local coordinate system

X component of pressure taken into account for pitching moment calculation Estimated equivalent friction coefficient (F1-Help):

Compressible correction:  None  Prandtl-Glauert  Karman-Tsien  Direct (more time consuming)



# Optimization schema





# Objective function & constraints

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

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

$$C_m = 0$$

$$\frac{dC_m}{dC_z} = -0.15$$

$$C_z < C_{z_{\max}}$$





# Objective function & constraints



- 183 variables – shell thickness
- material - aluminum alloy

$$m_{\min}$$

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

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



# Dynamic constraints



$$\zeta_{phugoid} > 0.04$$

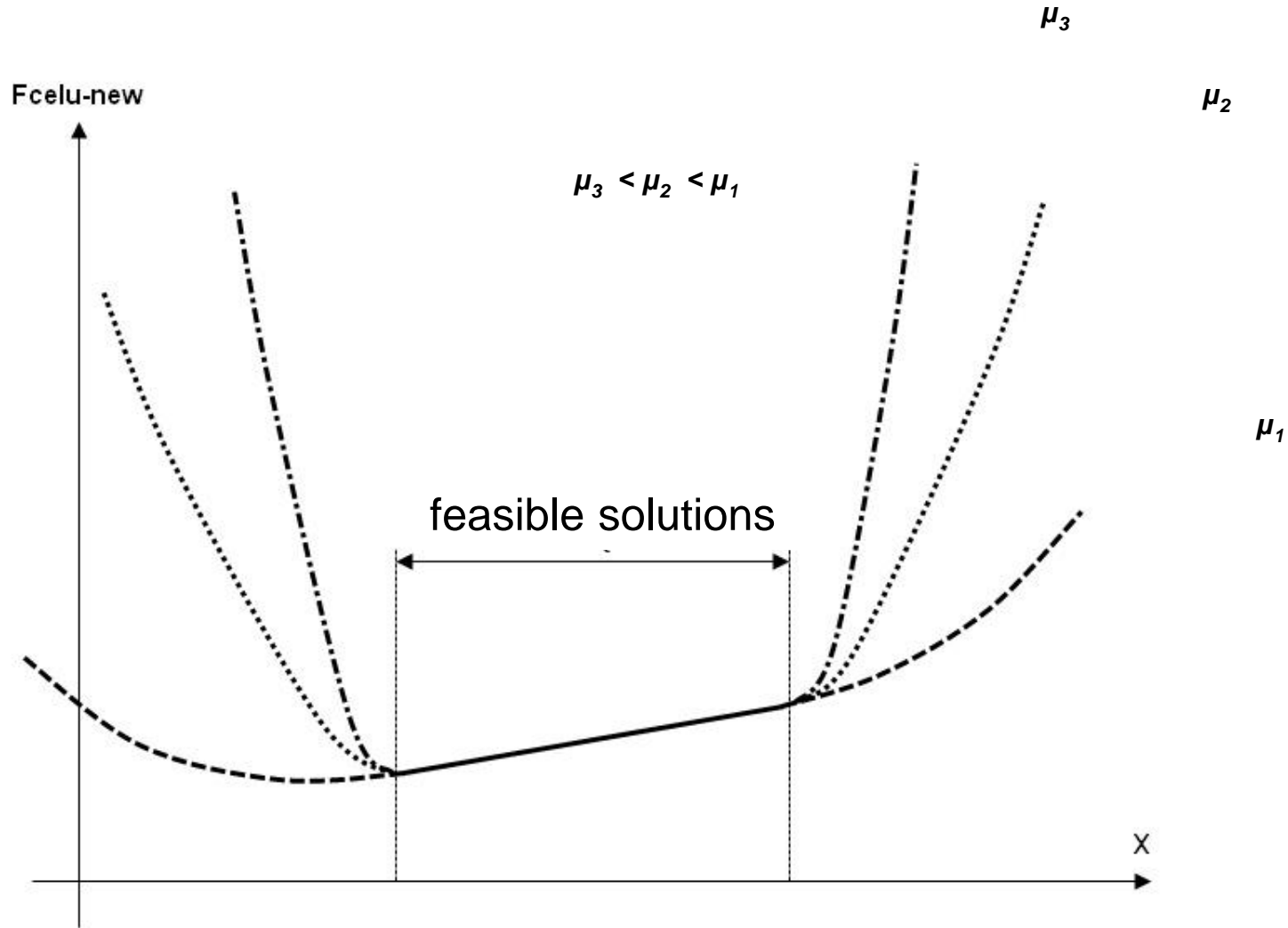
$$0.35 < \zeta_{short\_period} < 1.3$$

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

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

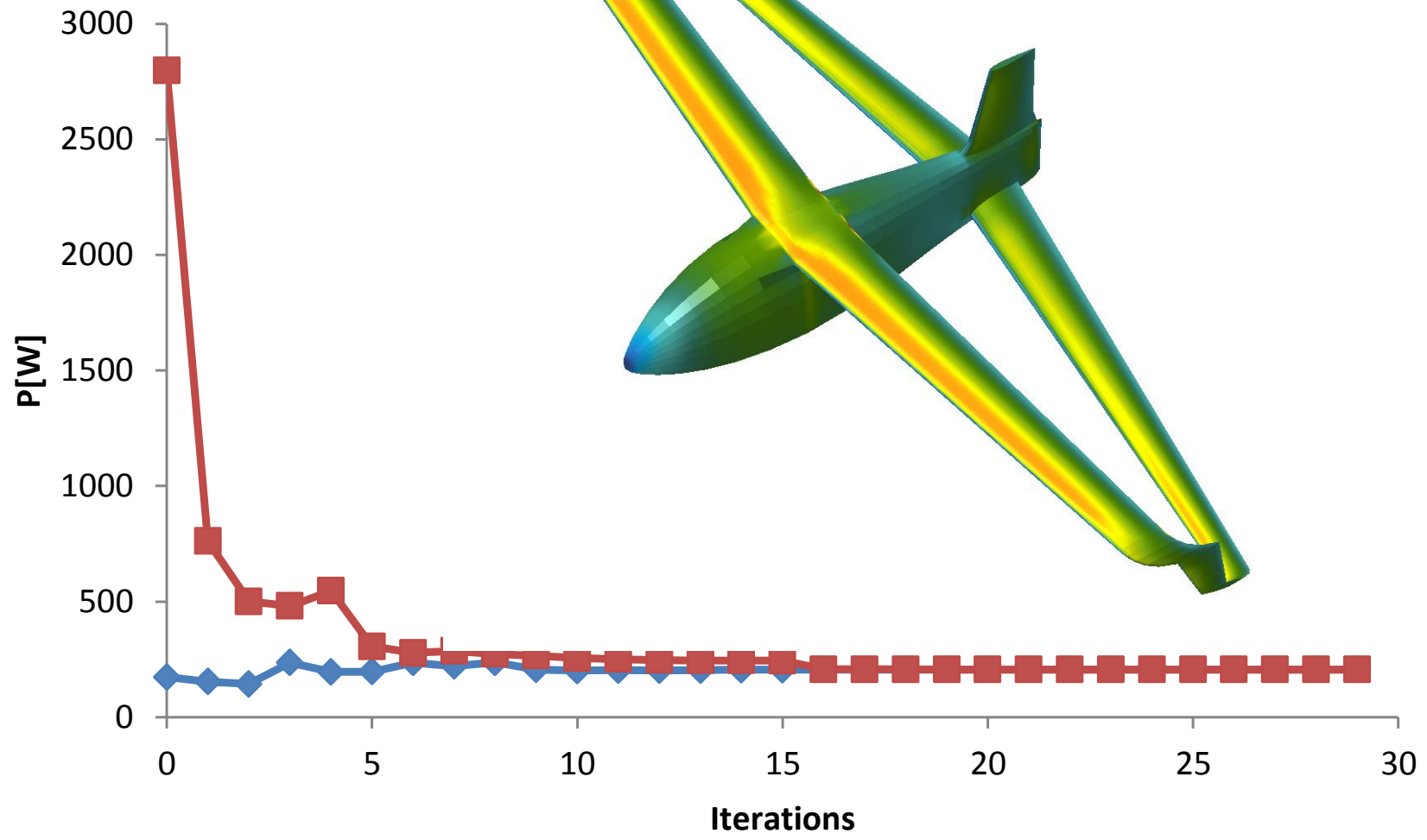


# Penalty function constrains

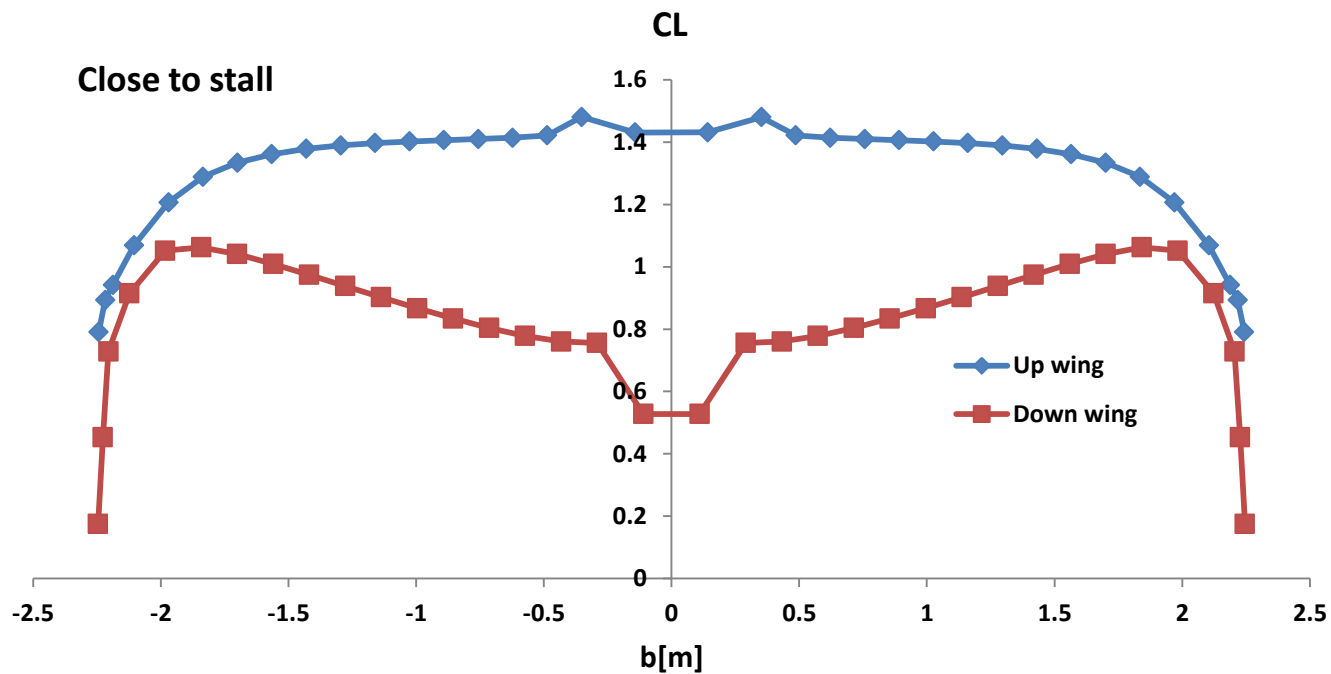
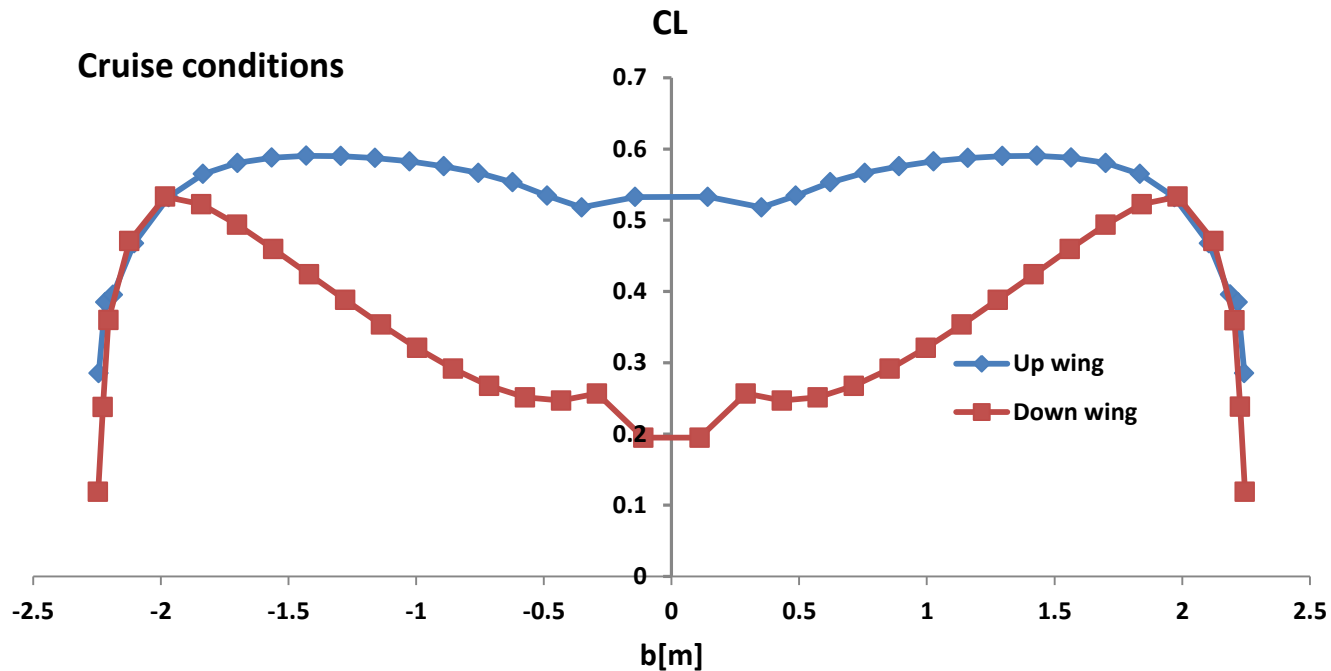


$$F_{CELU-NEW} = F_{CELU} + \frac{1}{2 \cdot \mu} \sum c^2(x) \quad \text{where} \quad c = \max[g - x, 0]$$

$g$  – constraint value



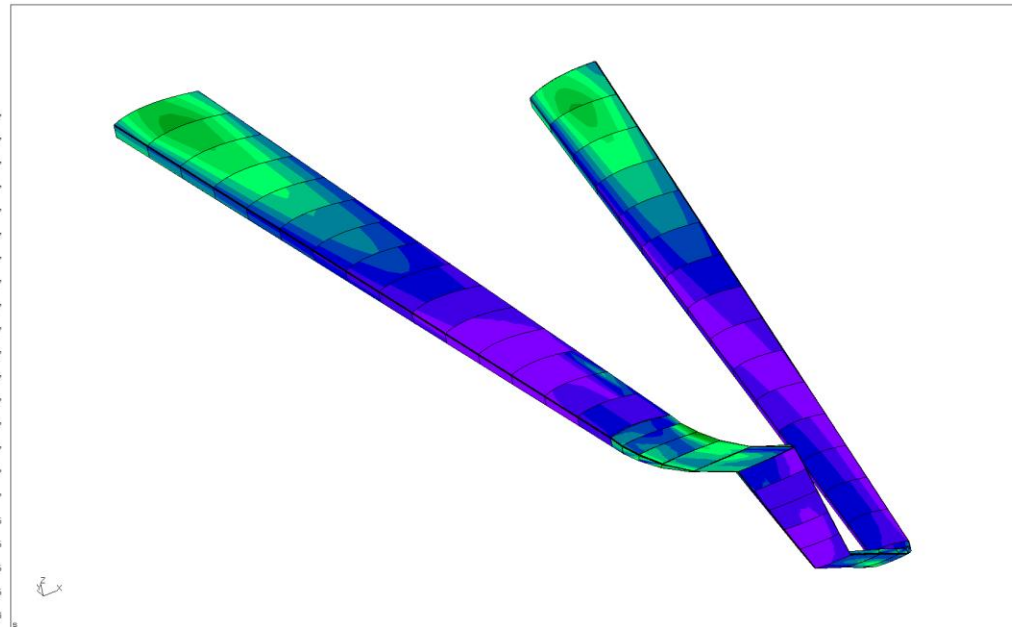
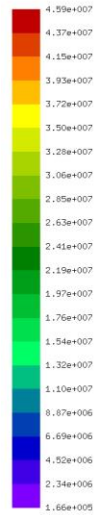
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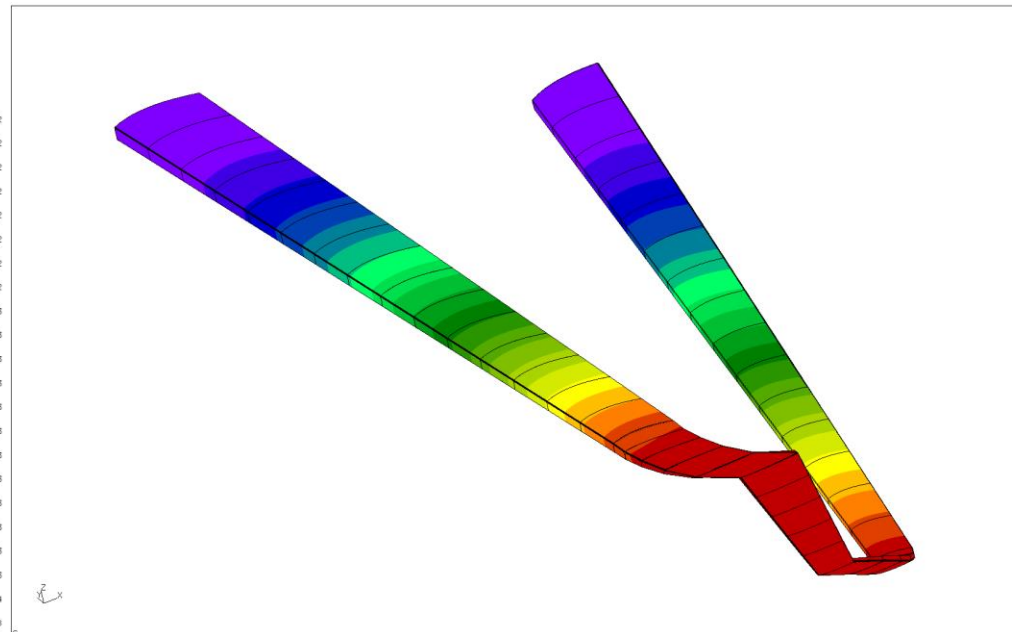
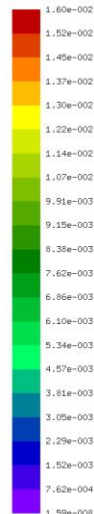
DtT2:STRESSR  
Time:1.000000  
Entity:MISES

max: 4.59e+007  
min: 1.66e+005



DtT1:DISPR  
Time:1.000000  
Entity:ALL

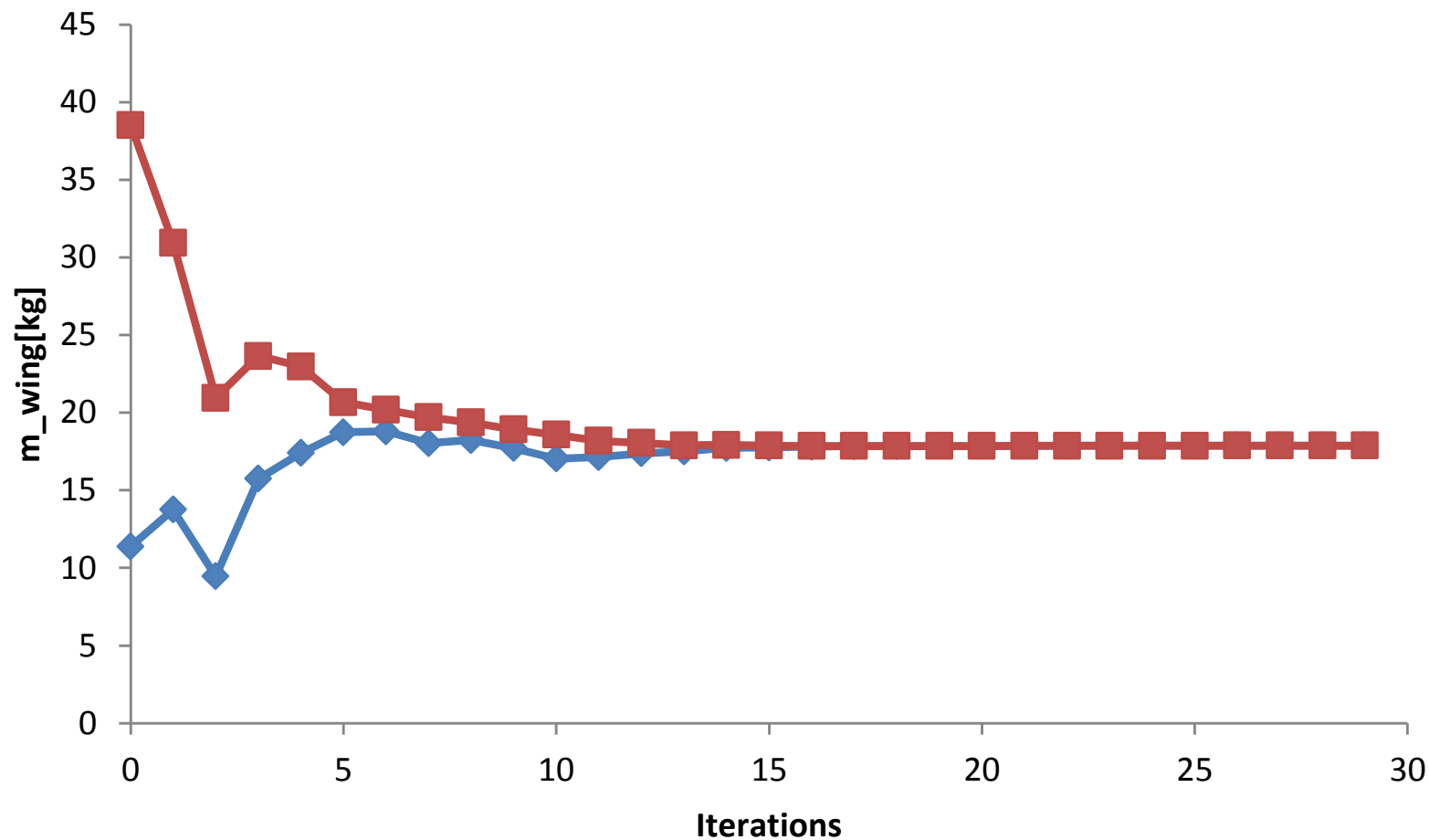
max: 1.60e-002  
min: 1.59e-008



# CalculiX results

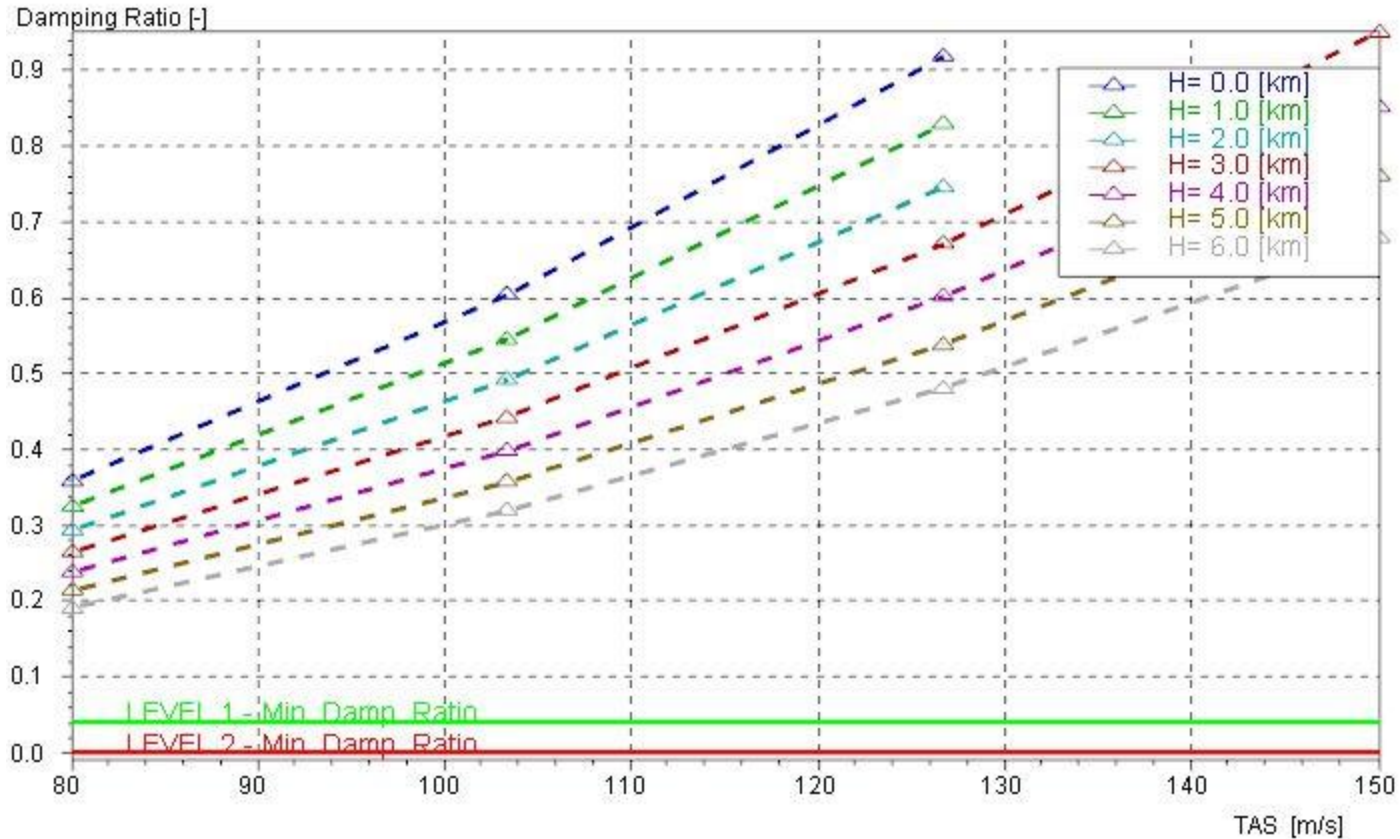


## Weight of wing





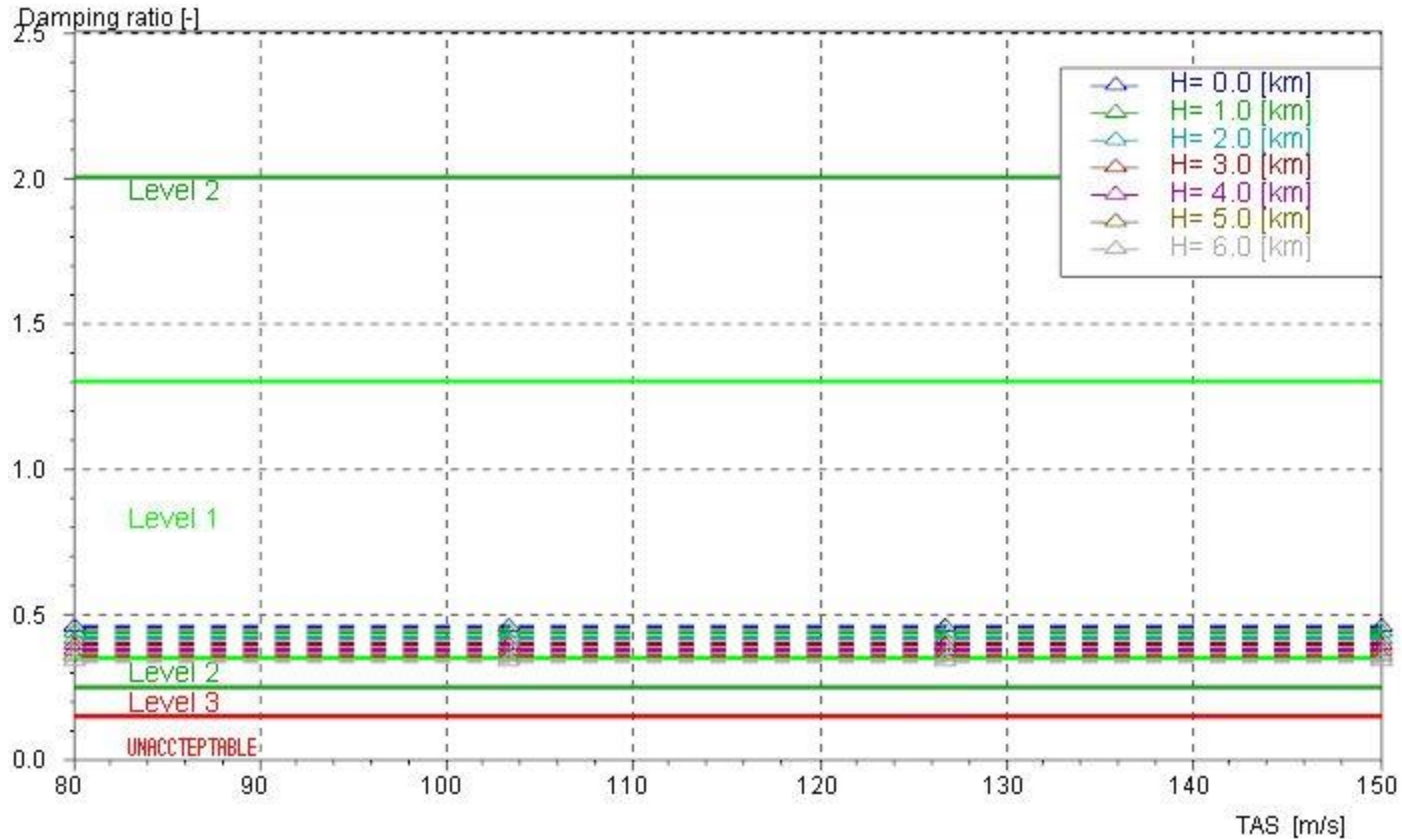
# Phugoid mode - damping ratio





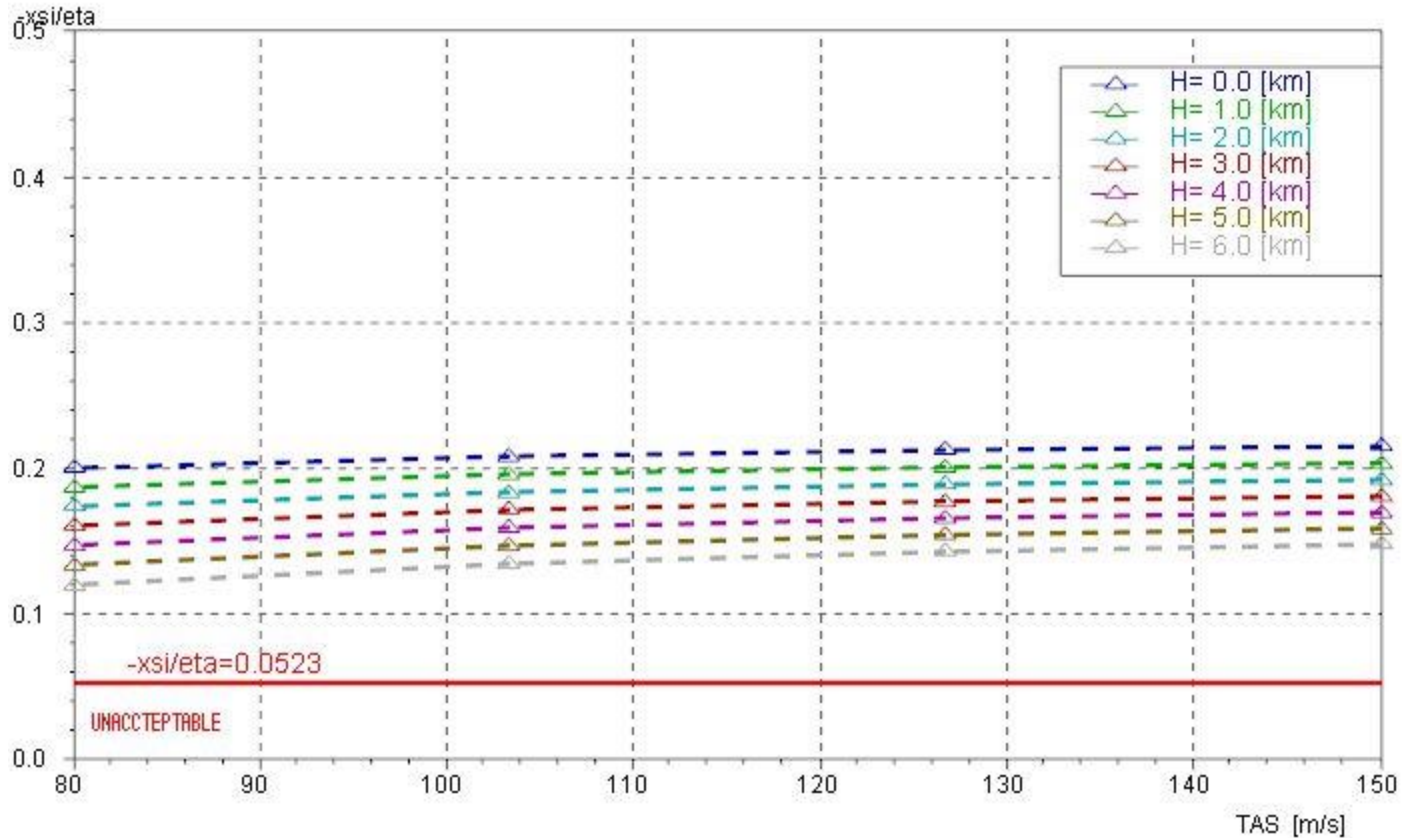


# Short Period mode - damping ratio



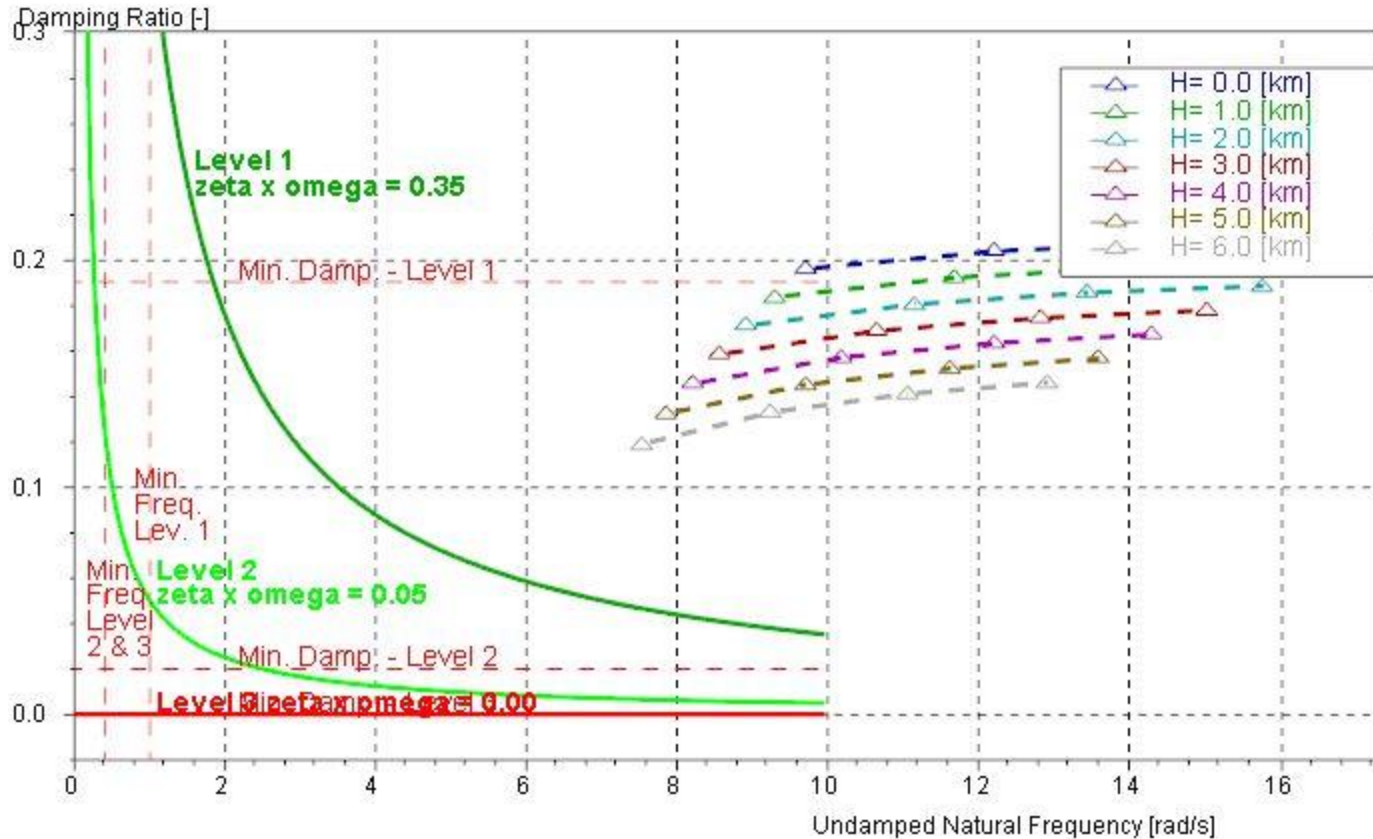


# Dutch roll mode – CS-23 criterion



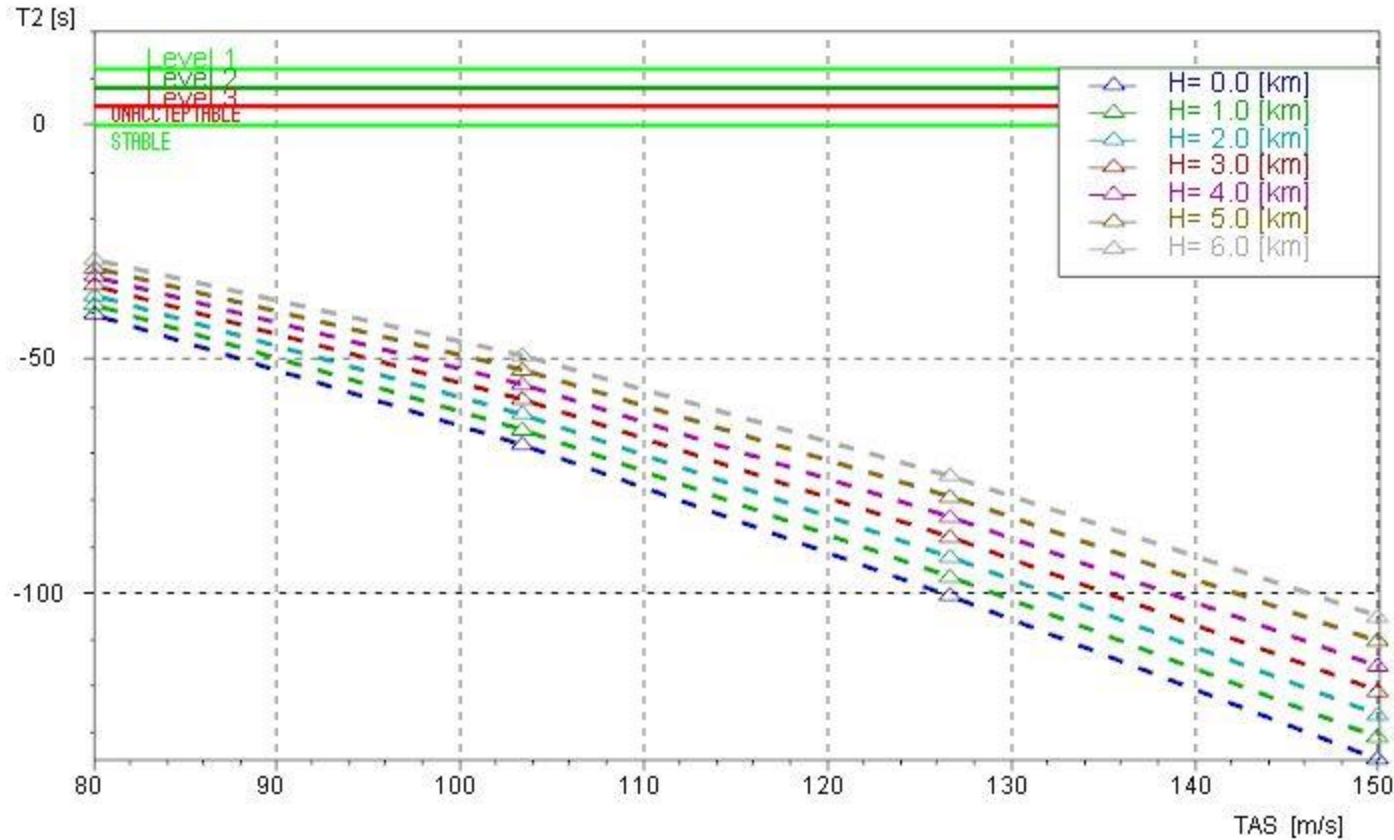


# Dutch roll mode – MIL criterion





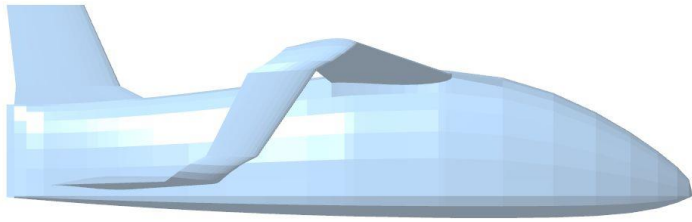
# Spiral mode – MIL criterion



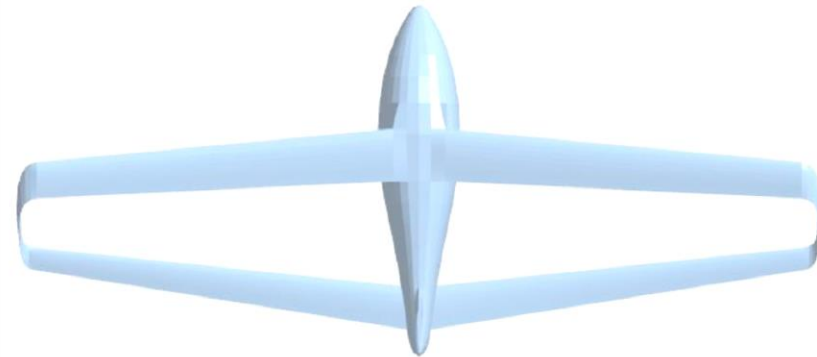
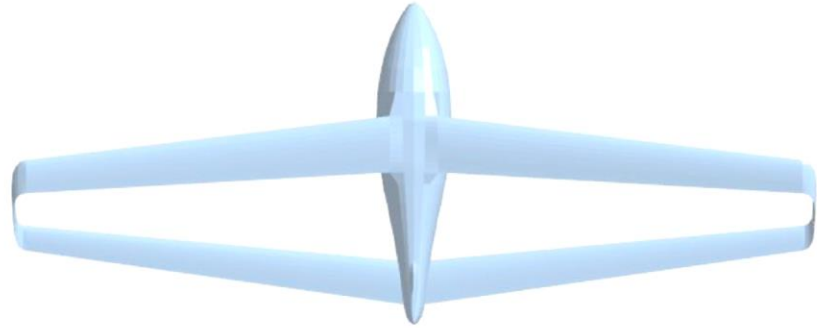
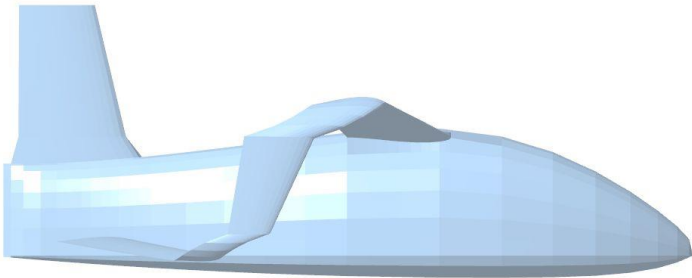


# Final solution

baseline



25th iteration





# Future work

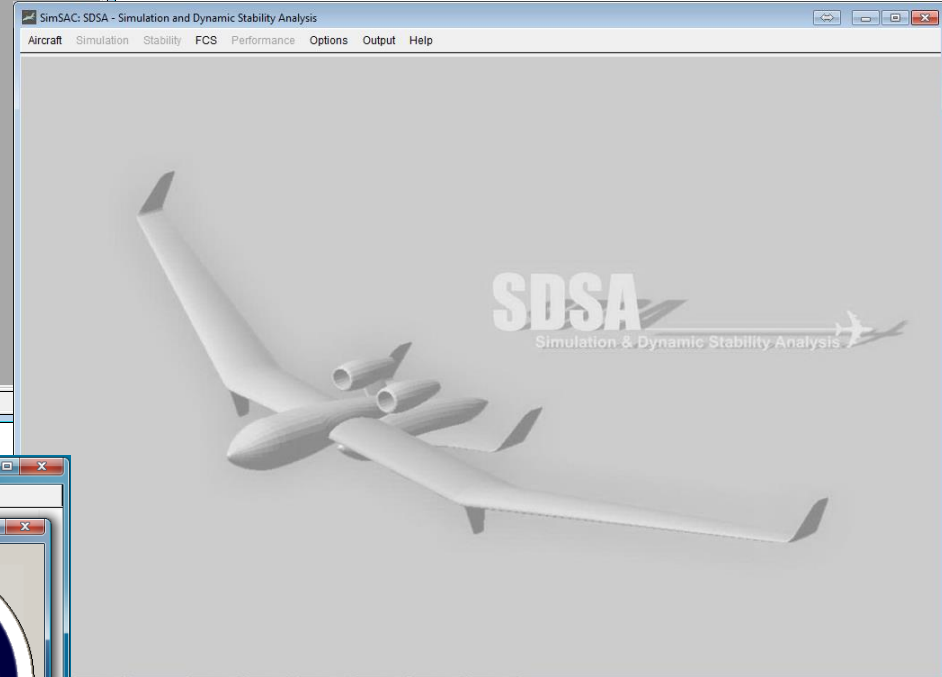
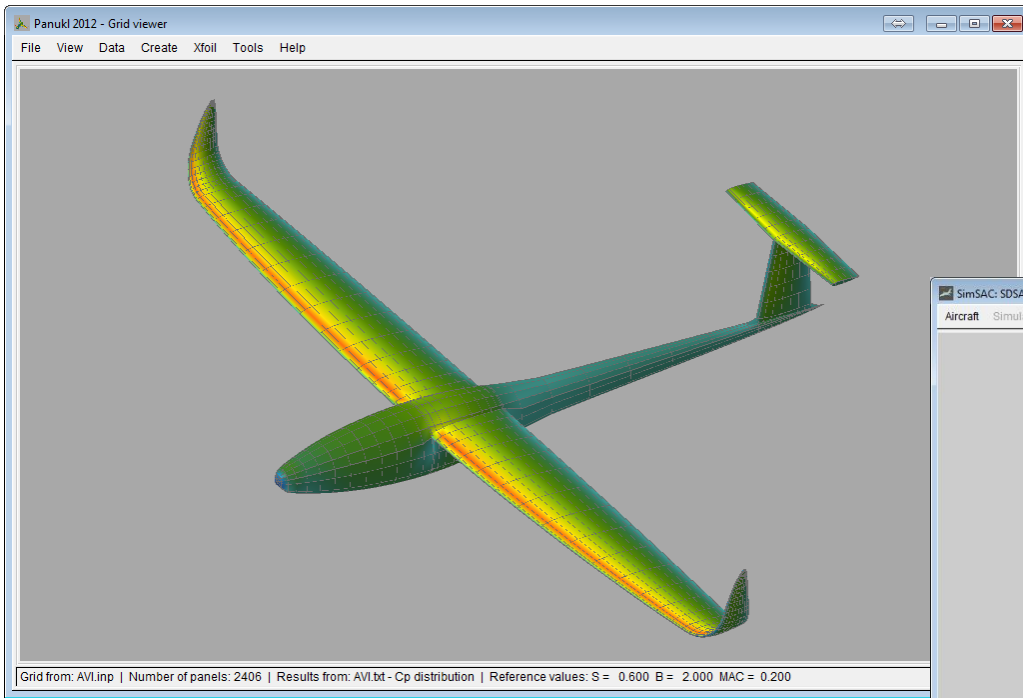


## Coming soon:

- **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**



OptoM - Gradient Based

File Optimization Help

Iter	F_exe	Th	ct	F
0	1	-1.900	2.000	267.620
1	9	-1.068	1.403	11.175
2	16	-1.146	1.338	4.666
3	23	-1.098	1.212	4.406
4	30	-0.938	0.868	3.767
5	37	-0.767	0.563	3.189
6	44	-0.662	0.429	2.771
7	53	-0.495	0.212	2.651
8	60	-0.495	0.212	2.344
9	67	-0.296	0.049	1.833
10	74	-0.142	-0.003	1.357
11	81	0.062	-0.039	1.062
12	88	0.166	0.016	0.708
13	96	0.220	0.036	0.623
14	105	0.361	0.106	0.537
15	112	0.361	0.106	0.468
16	119	0.474	0.212	0.292
17	127	0.585	0.325	0.203
18	136	0.701	0.472	0.154
19	143	0.701	0.472	0.127
20	150	0.830	0.672	0.057
21	157	0.847	0.717	0.023
22	164	0.943	0.879	0.012
23	171	0.951	0.904	0.002
24	176	0.993	0.984	0.000
25	185	0.997	0.993	0.000
26	192	1.000	1.000	0.000

Start of optimization: Sun May 27 11:25:19 2012  
End of optimization: Sun May 27 11:25:20 2012  
Total time of optimization: 0.0166667min

Alfa Search: 0

Iteration: 10/30

About

OptoM Version: 4.1  
Compiled: Apr 1 2012  
Copyright (C) Jacek Mieloszyk

OK

# Thank you for attention