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Performance Calculation for UAVs

10th European Workshop on Aircraft Design Education

Naples, 24-27 May 2011

Introduction

Team Project:

- 3-5 Students
- Cooperation

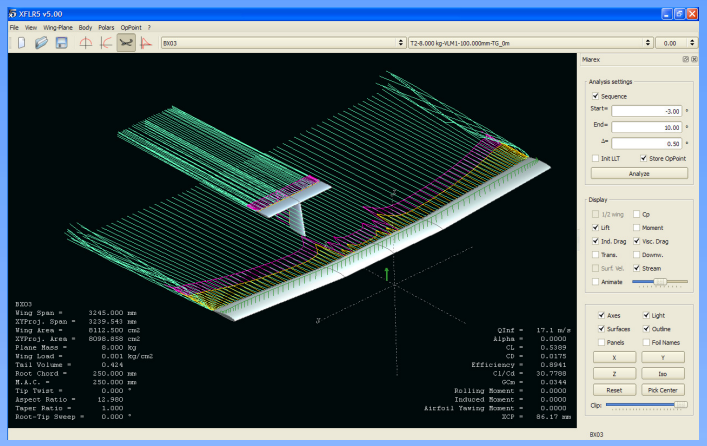
To develop a tool:

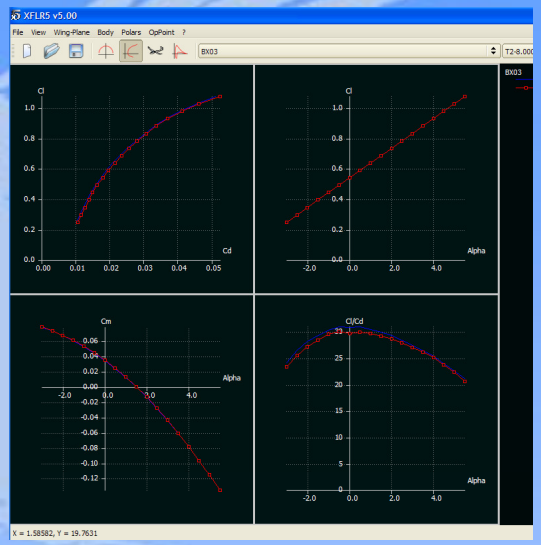
- To analyze the performance of a given configuration
- Compare the performance of configuration candidates

Method:

- Power required (Lifting surfaces + fuselage)
- Power available (Engine + Propeller)
- Analysis of Penauld-diagram

XFLR5





- High-order panel method (XFoil)
- Lifting Line Theory,
- Vortex Lattice Method
- 3D Panel Method
- Textfile Output

Lister - [c:\Users\balazs\2009 bonn\BX03\BX03_T1-30.0 m s-VLM1-100.000mm-TG_0m_8.5kg.txt]

File Edit Options Encoding Help 99 %

XFLR5 v5.00

Wing name : BX03
Wing polar name : BX03_T1-30.0 m/s-VLM1-100.000mm-TG_0m_8.5kg
Freestream speed : 30.000 m/s

alpha	CL	ICd	PCd	TCd	CY	Cm	Rm	Ym	IYm	QInf
-5.000	0.056067	0.001148	0.008972	0.010120	-0.000000	0.089239	-0.000000	0.000000	0.000000	30.00
-4.500	0.104333	0.001239	0.007961	0.009200	0.000000	0.087388	0.000000	-0.000000	-0.000000	30.00
-4.000	0.152620	0.001459	0.007658	0.009117	0.000000	0.084937	0.000000	-0.000000	-0.000000	30.00
-3.500	0.200926	0.001807	0.007578	0.009384	-0.000000	0.081666	-0.000000	0.000000	0.000000	30.00
-3.000	0.249247	0.002282	0.007551	0.009832	0.000000	0.077499	0.000000	0.000000	0.000000	30.00
-2.500	0.297456	0.002880	0.007551	0.010431	-0.000000	0.072463	-0.000000	0.000000	0.000000	30.00
-2.000	0.345665	0.003603	0.007562	0.011165	-0.000000	0.066522	-0.000000	0.000000	0.000000	30.00
-1.500	0.393886	0.004451	0.007580	0.012031	0.000000	0.059671	0.000000	0.000000	0.000000	30.00
-1.000	0.442163	0.005417	0.007602	0.013019	-0.000000	0.051910	-0.000000	-0.000000	-0.000000	30.00
-0.500	0.490501	0.006463	0.007631	0.014094	0.000000	0.043237	0.000000	0.000000	0.000000	30.00
0.000	0.538875	0.007965	0.007662	0.015627	0.000000	0.033560	0.000000	0.000000	0.000000	30.00
0.500	0.587286	0.009089	0.007700	0.016789	0.000000	0.023139	0.000000	0.000000	0.000000	30.00
1.000	0.635779	0.010612	0.007798	0.018411	0.000000	0.011631	-0.000000	0.000000	0.000000	30.00
1.500	0.684376	0.012247	0.008004	0.020251	-0.000000	-0.000910	0.000000	0.000000	-0.000000	30.00
2.000	0.733070	0.013994	0.008445	0.022439	0.000000	-0.014426	0.000000	0.000000	0.000000	30.00
2.500	0.781860	0.015866	0.009085	0.024951	0.000000	-0.028927	0.000000	0.000000	0.000000	30.00
3.000	0.830744	0.017868	0.009697	0.027565	-0.000000	-0.044518	-0.000000	-0.000000	-0.000000	30.00
3.500	0.879720	0.019999	0.010305	0.030304	-0.000000	-0.061193	0.000000	-0.000000	-0.000000	30.00
4.000	0.928789	0.022260	0.011086	0.033266	-0.000000	-0.078907	-0.000000	-0.000000	-0.000000	30.00
4.500	0.977946	0.024652	0.012085	0.036737	-0.000000	-0.097525	-0.000000	-0.000000	-0.000000	30.00
5.000	1.027188	0.027175	0.013506	0.040681	-0.000000	-0.117043	-0.000000	-0.000000	-0.000000	30.00
5.500	1.076511	0.029829	0.014829	0.044658	-0.000000	-0.137647	0.000000	0.000000	-0.000000	30.00
6.000	1.125909	0.032615	0.016068	0.048684	0.000000	-0.159339	0.000000	0.000000	0.000000	30.00
6.500	1.175381	0.035533	0.017400	0.052933	-0.000000	-0.182039	0.000000	-0.000000	-0.000000	30.00
7.000	1.224921	0.038583	0.019047	0.057630	-0.000000	-0.205636	0.000000	-0.000000	-0.000000	30.00

Corrections

Correction of drag:

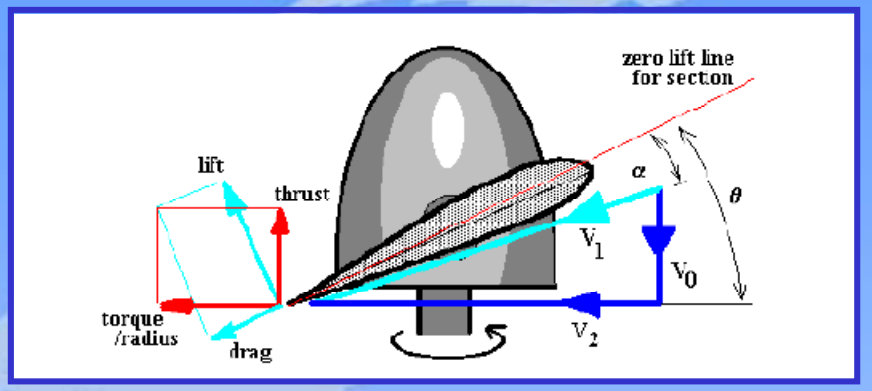
- k_d, Drag Factor

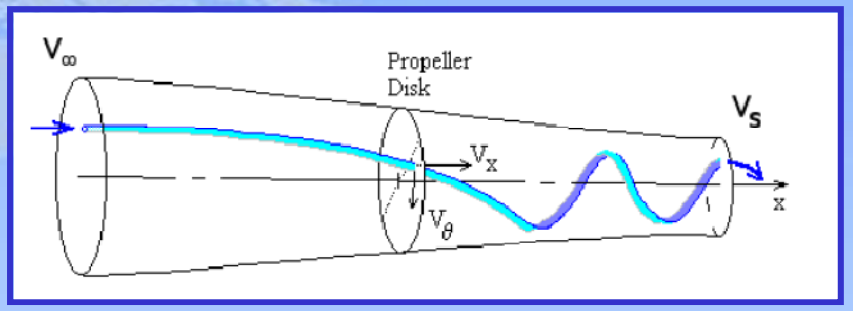
Fuselage effect:

- C_{d0_fus}, Fuselage Form Drag Factor
- C_{dS_fus}, Fuselage Surface Drag Factor
- Δz, Thrust Line Offset (trim)

Propeller Analysis

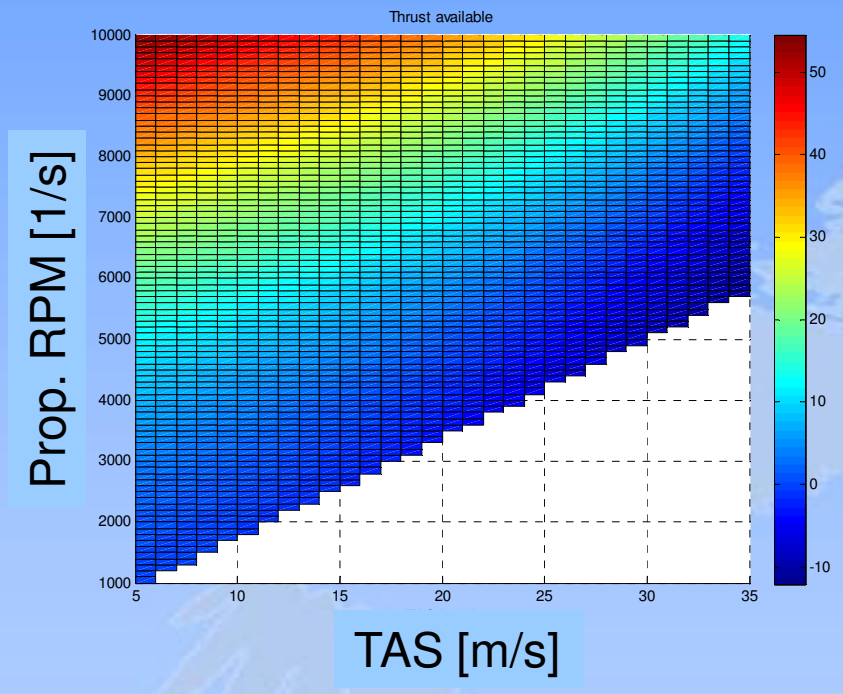
- Glauert blade element theory
- Axial and angular conservation of flow momentum
- *D.J. Auld & K.Srinivas* (University of Sidney)



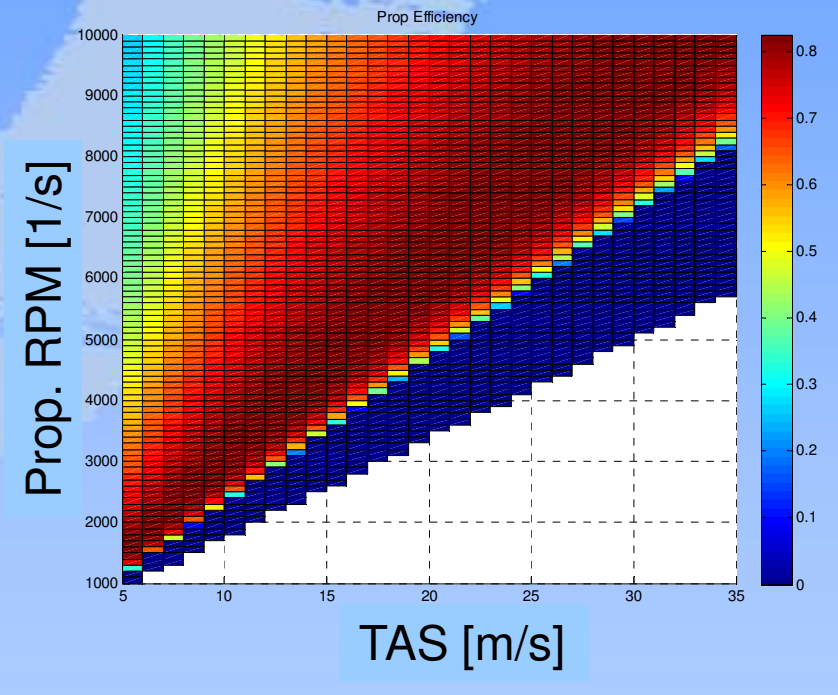


Propeller Characteristics

Thrust



Efficiency



Propeller Operating Points

Operating RPM is a trade off between propeller and engine

Engine model:

$$P_{eng} = \eta_{eng+contr} \cdot P_{\max}\left(1 - e^{-\frac{RPM_{\max} - RPM}{k}}\right)$$

Operating Point Calculation:

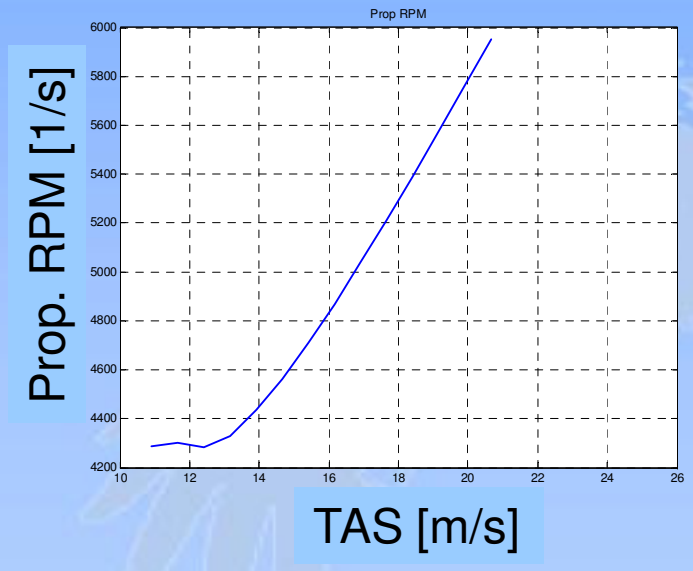
combination of bisection, secant and inverse quadratic interpolation methods

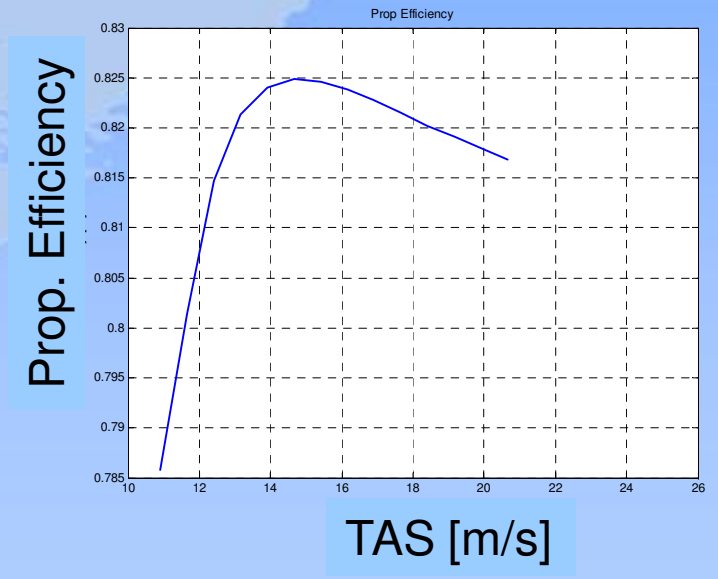
Forsythe, G. E., M. A. Malcolm, and C. B. Moler,

Propeller Operating Points

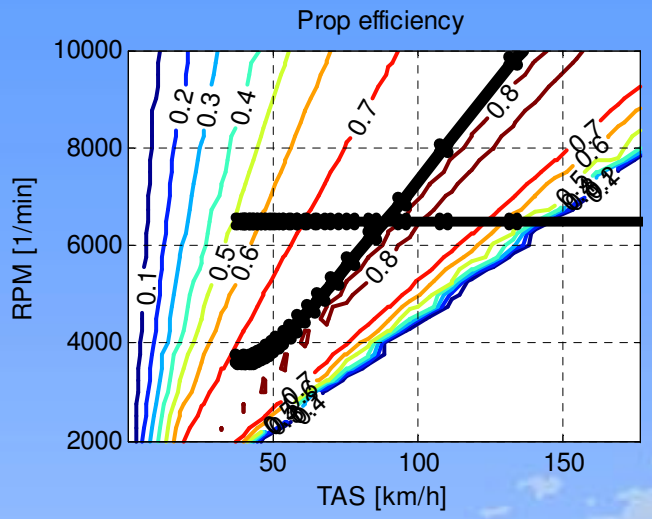
Operating Points for:

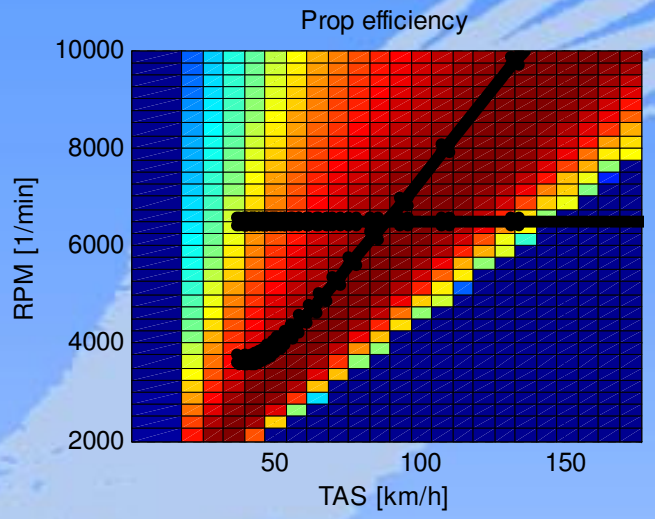
- Power Required
- Power Available

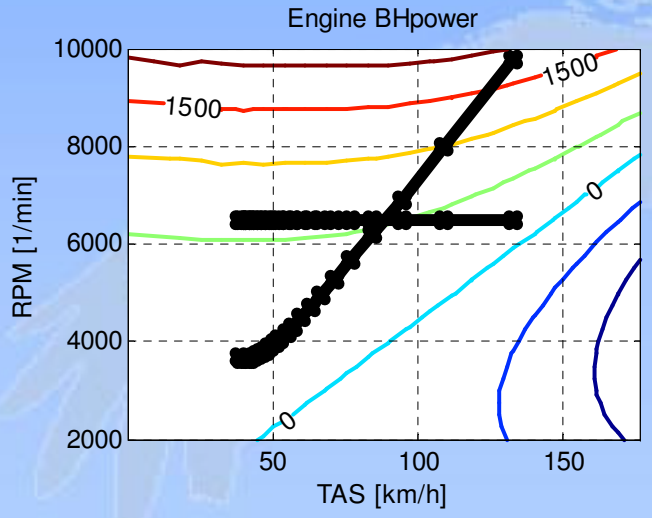


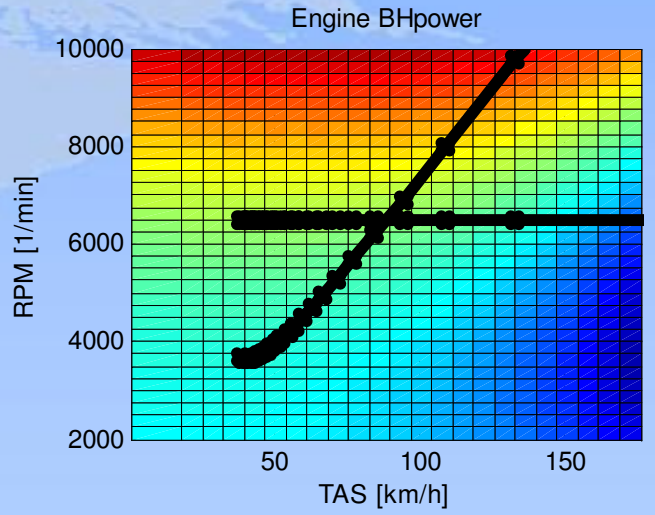


Propeller Operating Points









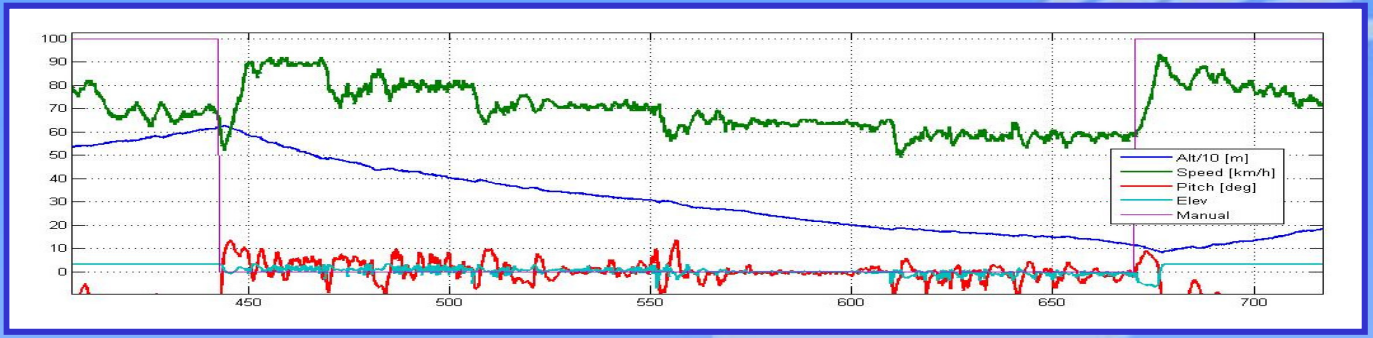
Penauld - diagram

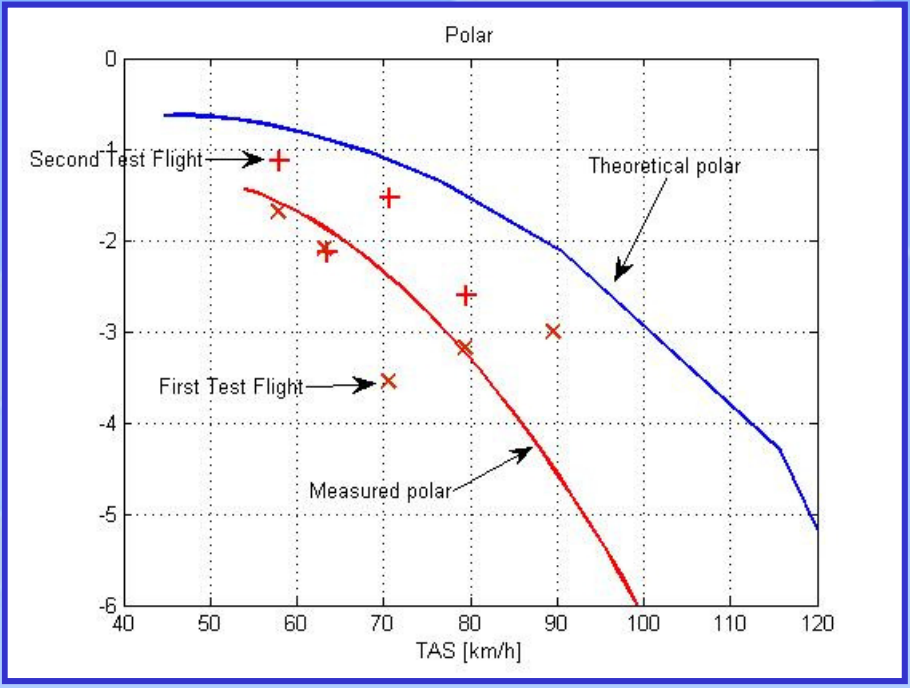
Test Flight

Test Flight

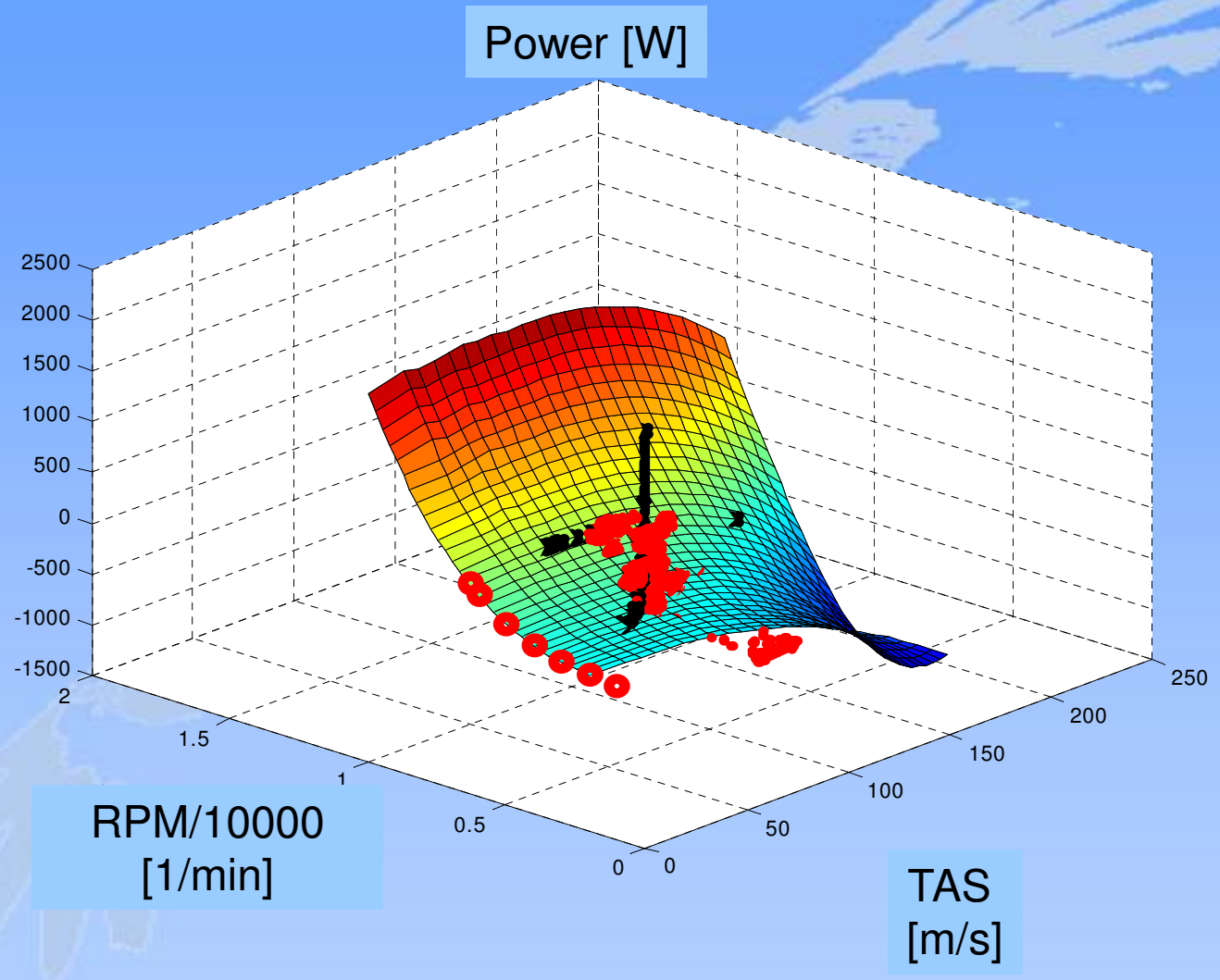
Test Flight

Measured data and validation

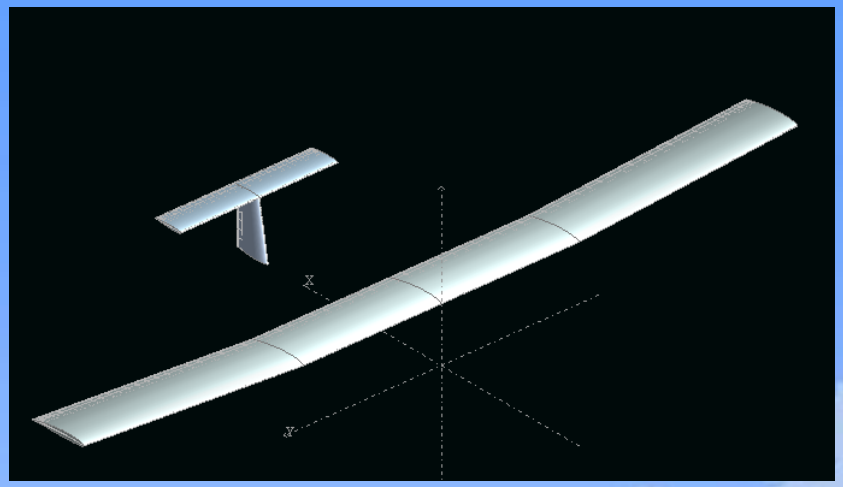




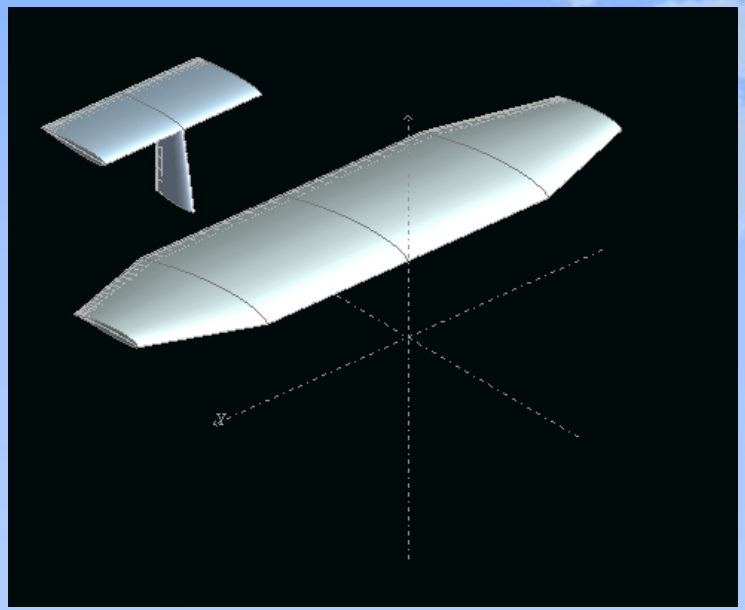
Measured data and validation



Application



- b = 3.6 m
- S = 1.0 m^2
- AR = 12.1
- MTOW = 9.0 kg



- b = 2.0 m
- S = 1.0 m^2
- AR = 3.7
- MTOW = 6.0 kg

Application

******** SUMMARY **********

TAKE OFF
Zero Speed Thrust:
1.config: 32 N
2.config: 32 N
TAS min:
1.config: 38 km/h
2.config: 35 km/h

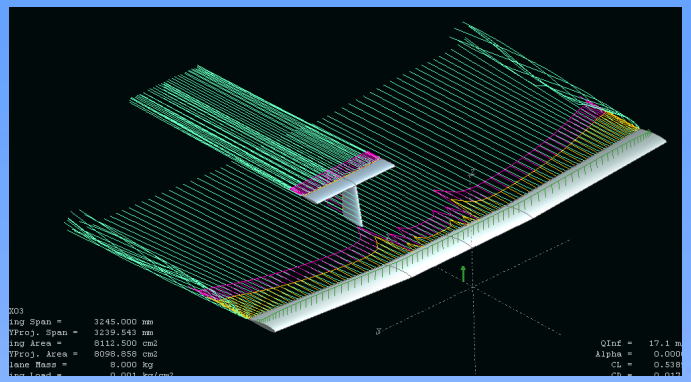
CLIMB
TAS:
1.config: 52 km/h
2.config: 53 km/h
Maximum Climb:
1.config: 3.3 m/s
2.config: 4.8 m/s

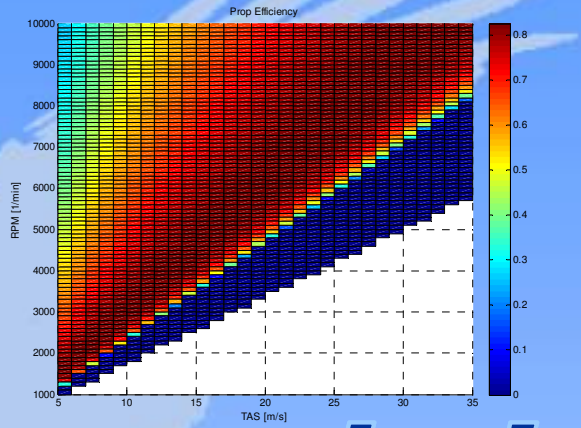
LOITER
TAS:
1.config: 42 km/h
2.config: 36 km/h
Maximum Endurance :
1.config: 64 min
2.config: 66 min

CRUISE
TAS:
1.config: 45 km/h
2.config: 43 km/h
Maximum Range
1.config: 46 km
2.config: 43 km

FAST CRUISE
TAS:
1.config: 70 km/h
2.config: 70 km/h
Endurance
1.config: 24 min
2.config: 24 min
Range
1.config: 28 km
2.config: 28 km

TOP CRUISE
TAS:
1.config: 88 km/h
2.config: 88 km/h
Endurance
1.config: 13 min
2.config: 13 min
Range
1.config: 18 km
2.config: 18 km





Thank you for the attention!