Journées Micro-Drones

2ème édition

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Aerodynamic Research on Lifting Surfaces and Performance for Mini & Micro UAVs

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RMA UAV-Center

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Overview

1. Introduction

2. Wind Tunnel Presentation & Validation

3. Laser Doppler Velocimetry Analysis

4. Pressure Measurements

5. Mirador : A Conceptual Design in partnership with ONERA

6. Conclusions

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1. Introduction

- Mini / Micro Aerial Vehicle (MAV)
- Range : 3 - 10 km
- Endurance : 20 – 60 min
- Autonomous Flight
- Quick setting
- Civil & Military Applications

- Challenges :
  - Low Re numbers
  - Stability Control *(gust, windshear, ...)*

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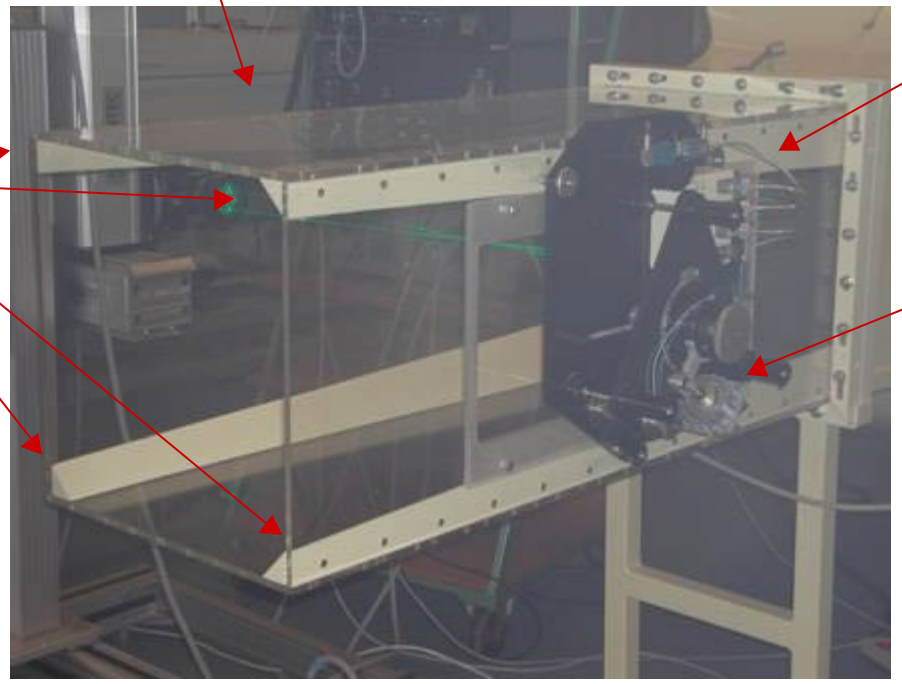
2. Wind Tunnel Facility & Validation

- Low speed wind tunnel < 35 m/s
- Low turbulence level ~ 0.4 % mean speed
- Transparent Test Section 457 x 457 mm



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Wind Tunnel Validation

- Comparison of Force Measurements $(C_L - C_D)$
- Eppler 61 airfoil / Pfenninger 048
- T. Mueller, University of Notre Dame, USA

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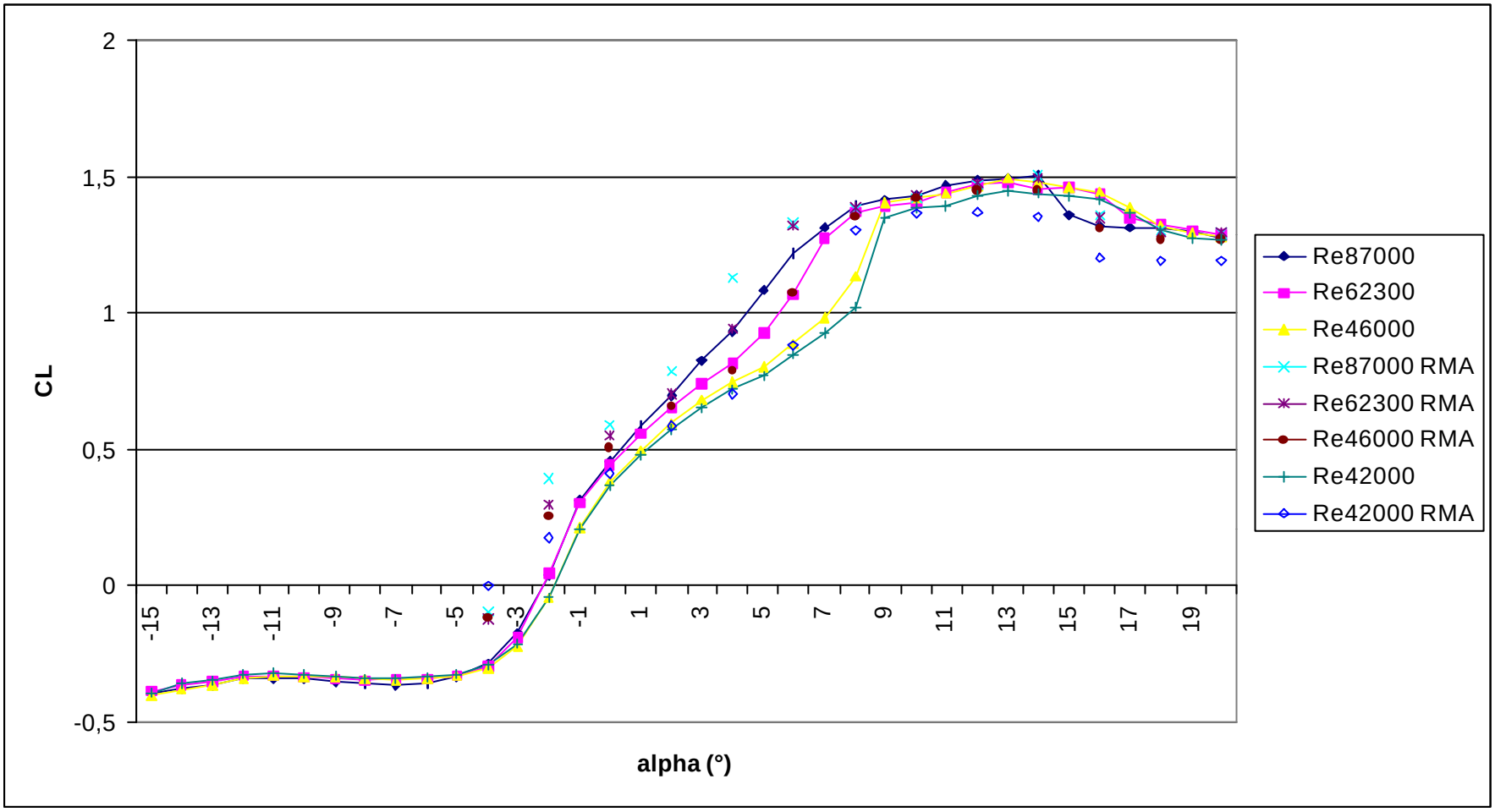
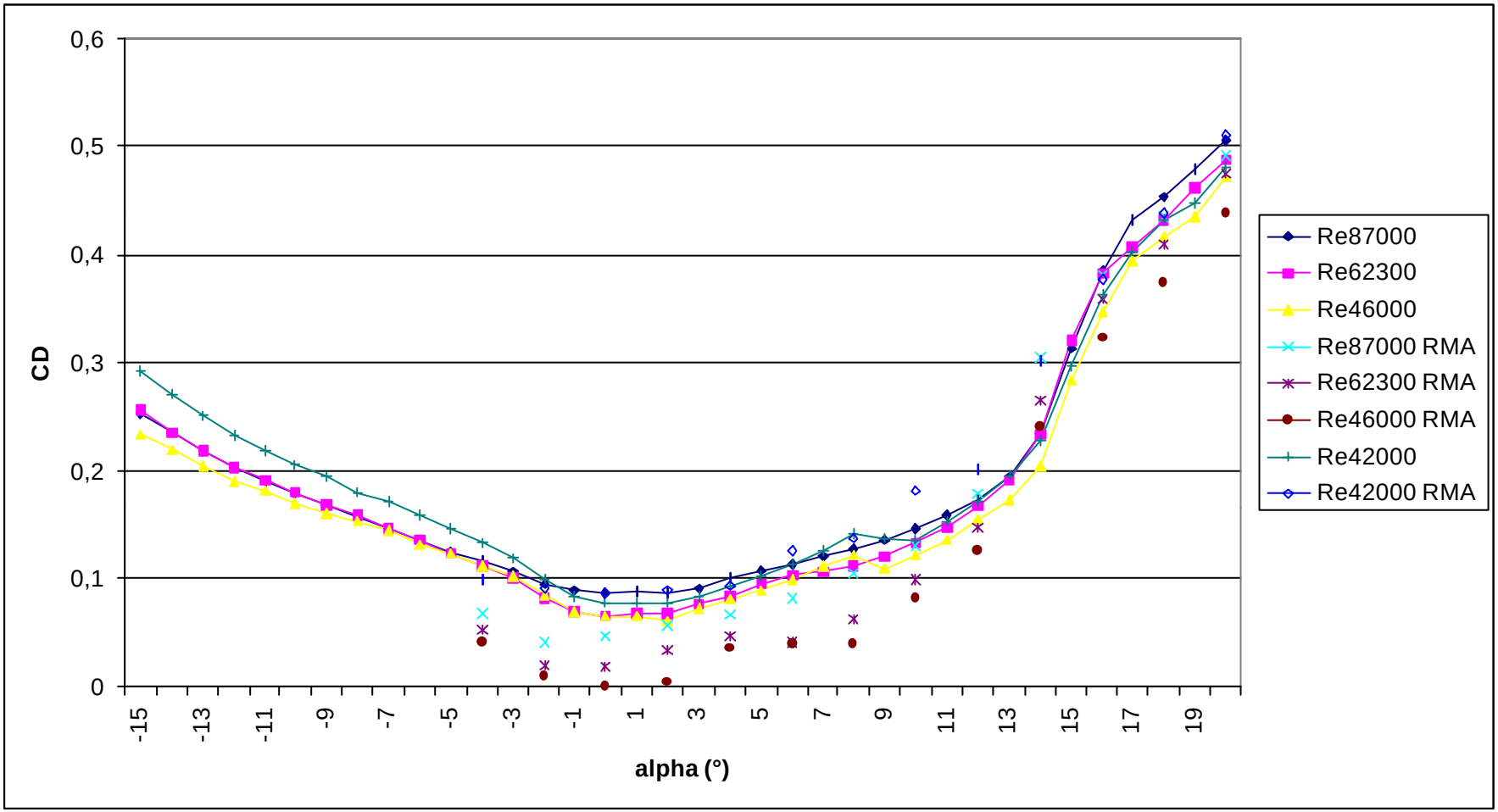
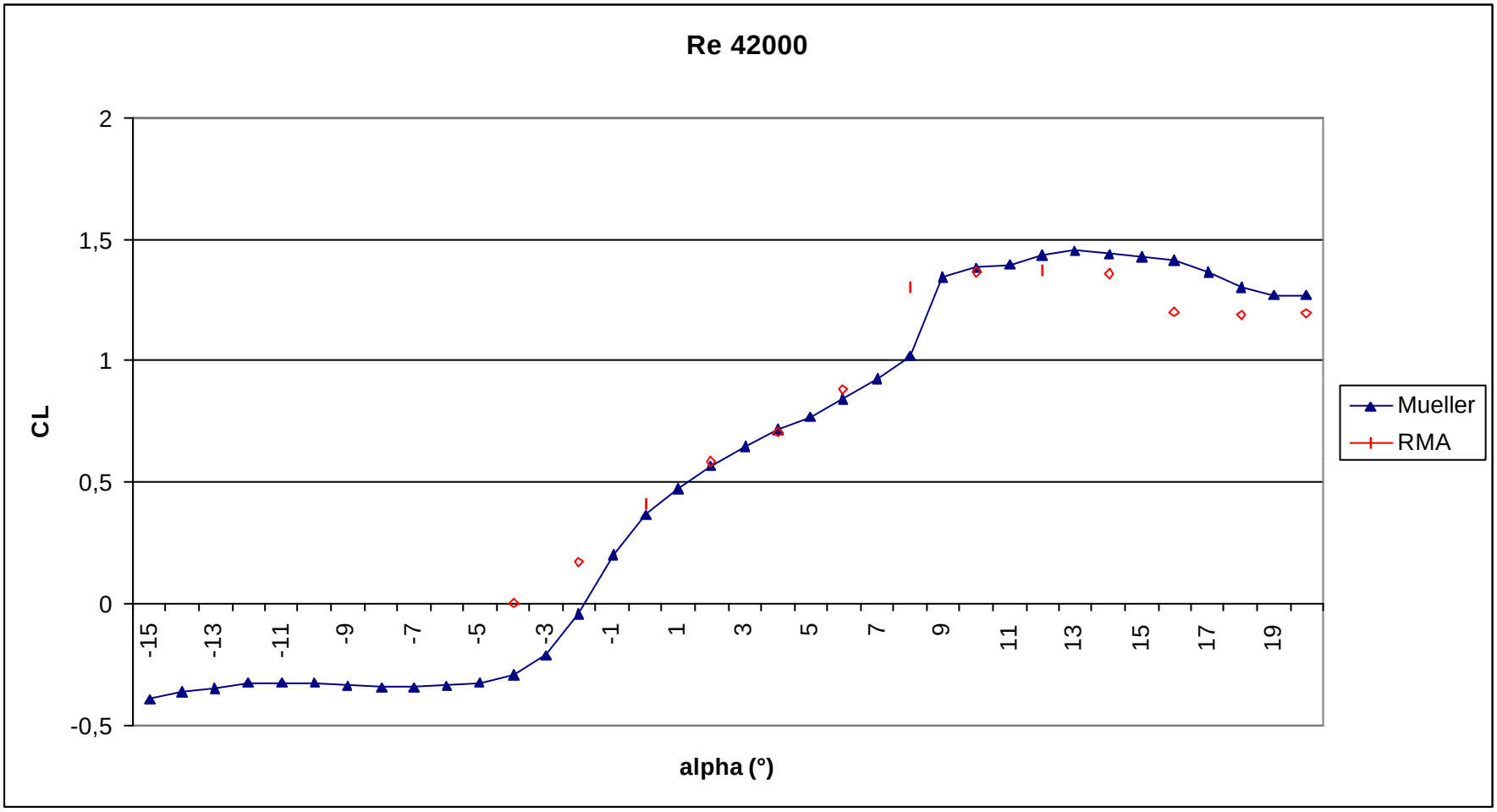
CL Comparison at Different Re



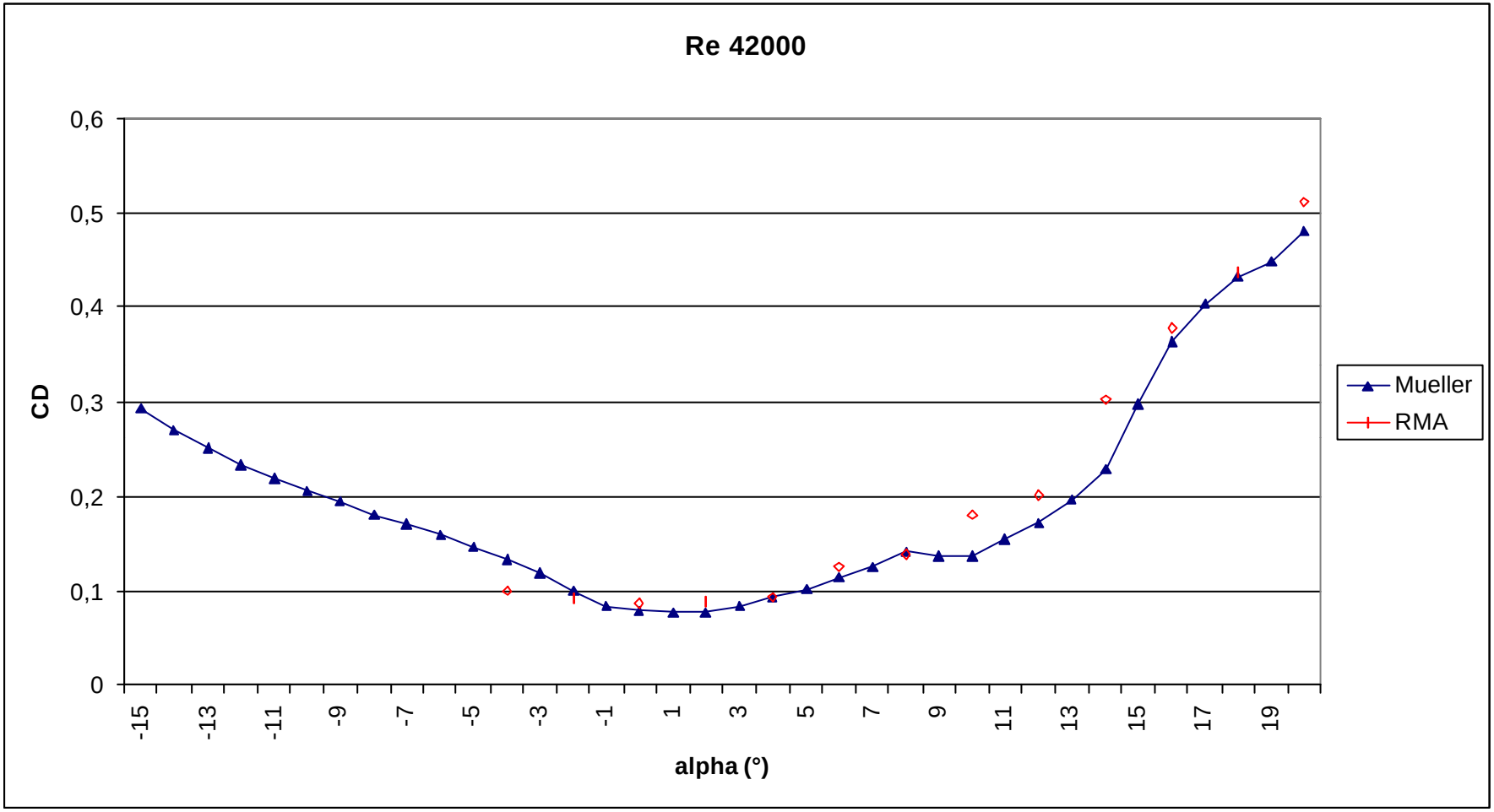
CD Comparison at Different Re



CL at Re = 42000



CD at Re = 42000



We ARE performing RELIABLE measurements

3. Laser Doppler Velocimetry

- Non-Intrusive Measurement Technique
- Low Re : 50,000
- Mesh around the airfoil *(very close ~2 mm)*
- 4,000 particles measured at each point
- Post-processing of data : Matlab 5.3
- Qualitative & Quantitative data

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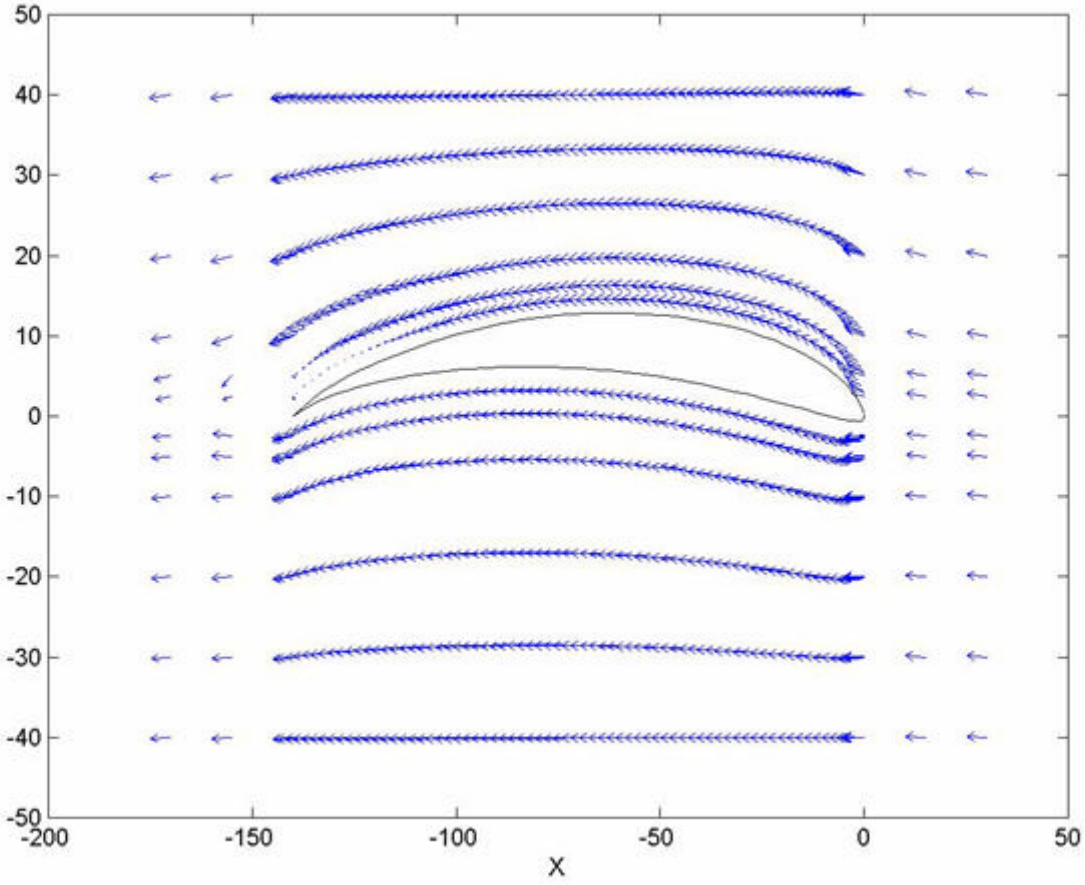
Vector representation
around 2D - Eppler 61 airfoil at Re 42,000



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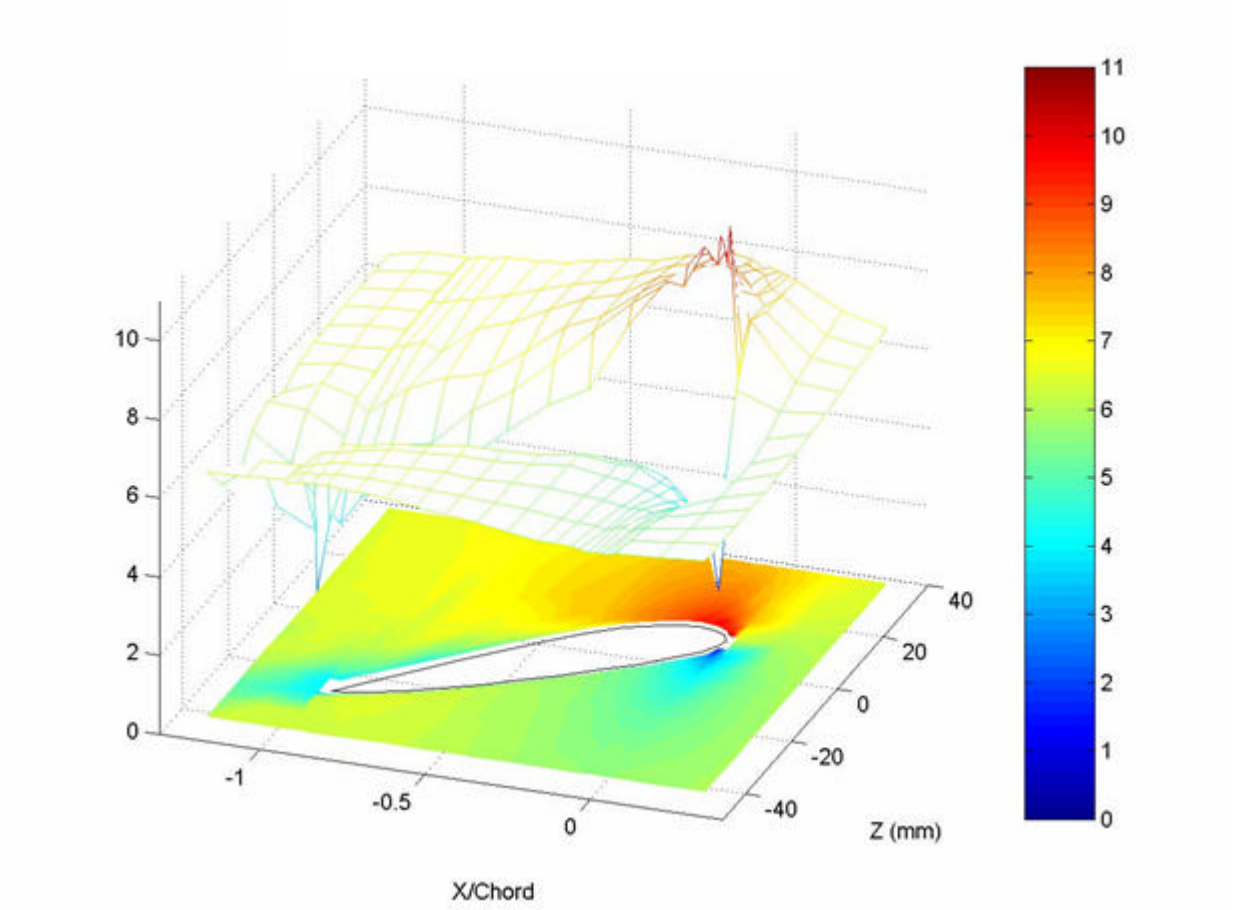
Example of quantitative information around a 2D - Tsagi 12 airfoil



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4. Pressure Measurements

- One single Transducer
- Pressure scanning system *(48 positions)*
  → stationary flow
- Tsagi 12 airfoil already tested
- Eppler 61 already tested
- Pfenninger 048 will be tested

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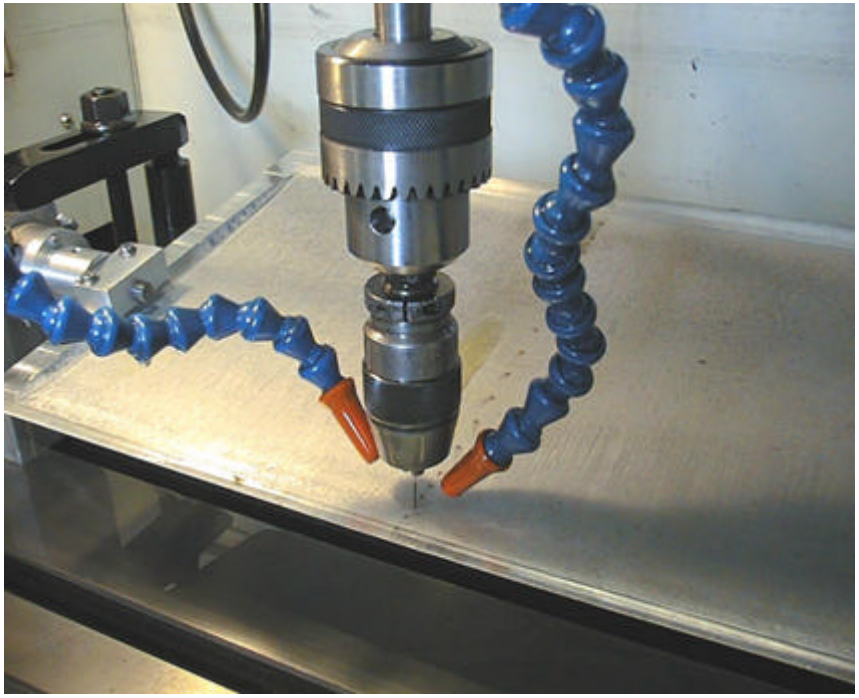
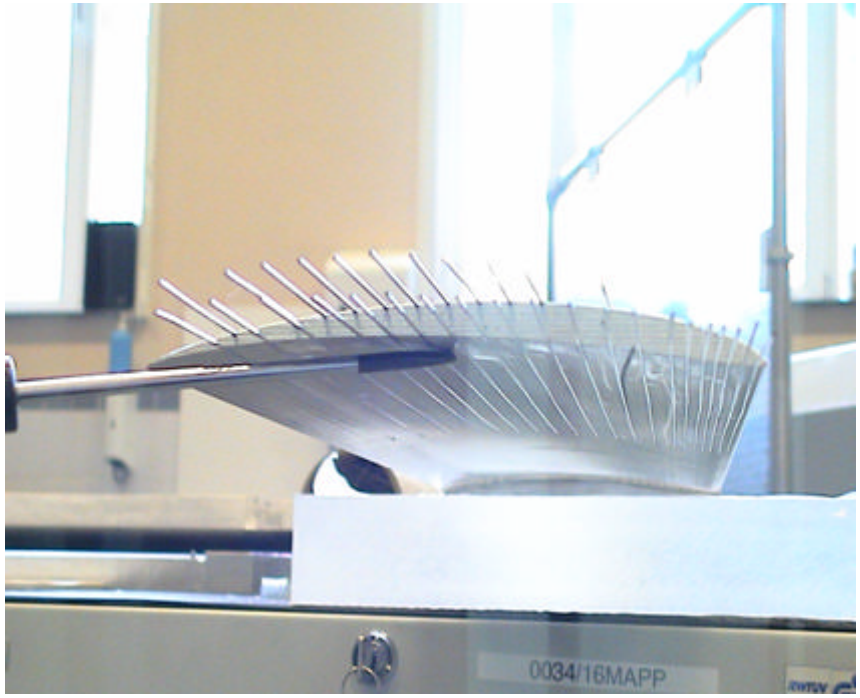
Instrumentation - Pressure Taps Machining

Tsagi 12



Eppler 61



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Holes Drilling

Thin Tubes by Electro Erosion

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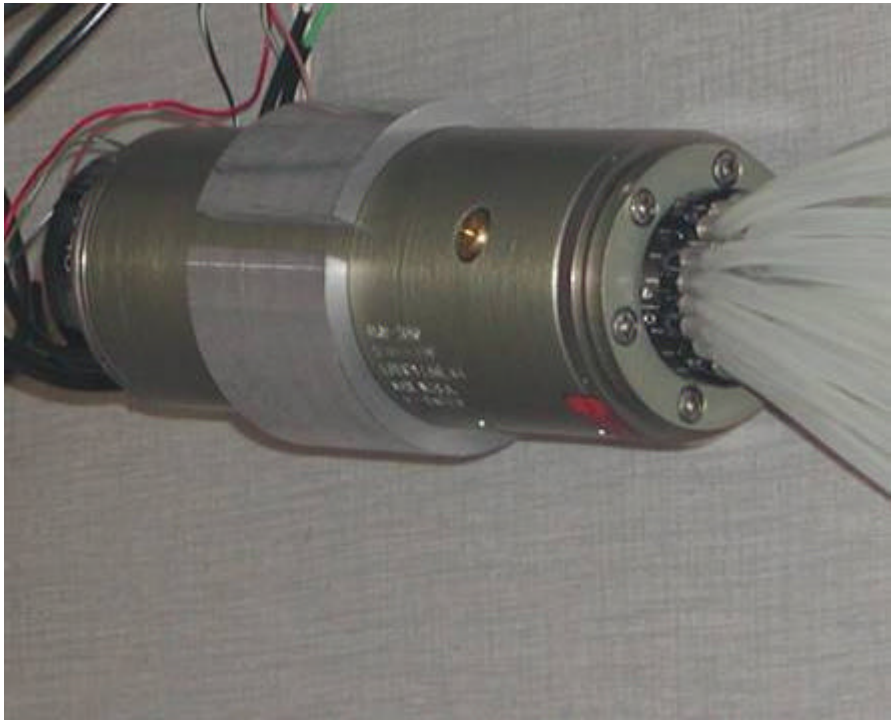
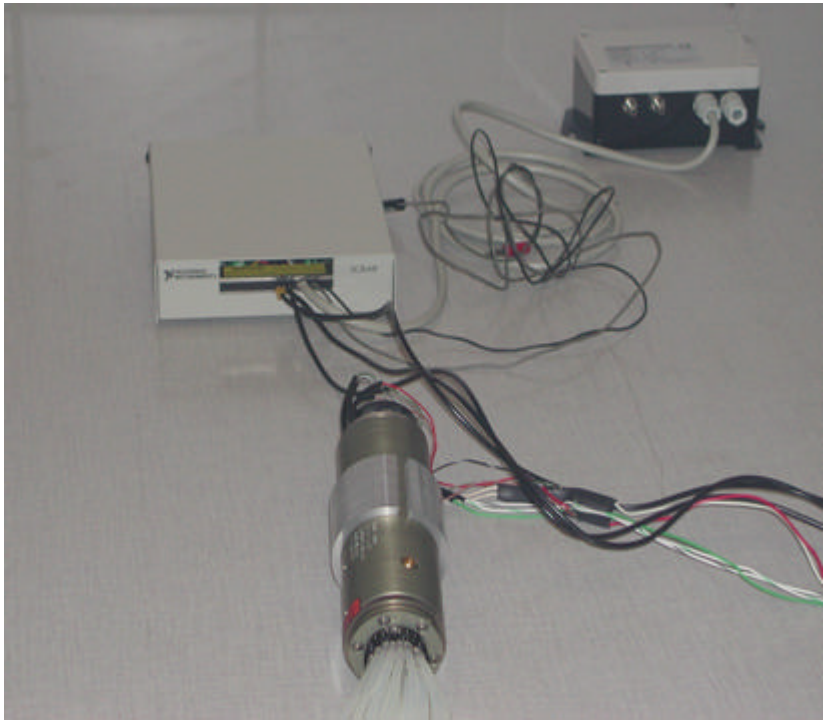
Scanning Valve





Scanning Valve

Acquisition Systems :

- Terminal Screw
- Pressure Transducer

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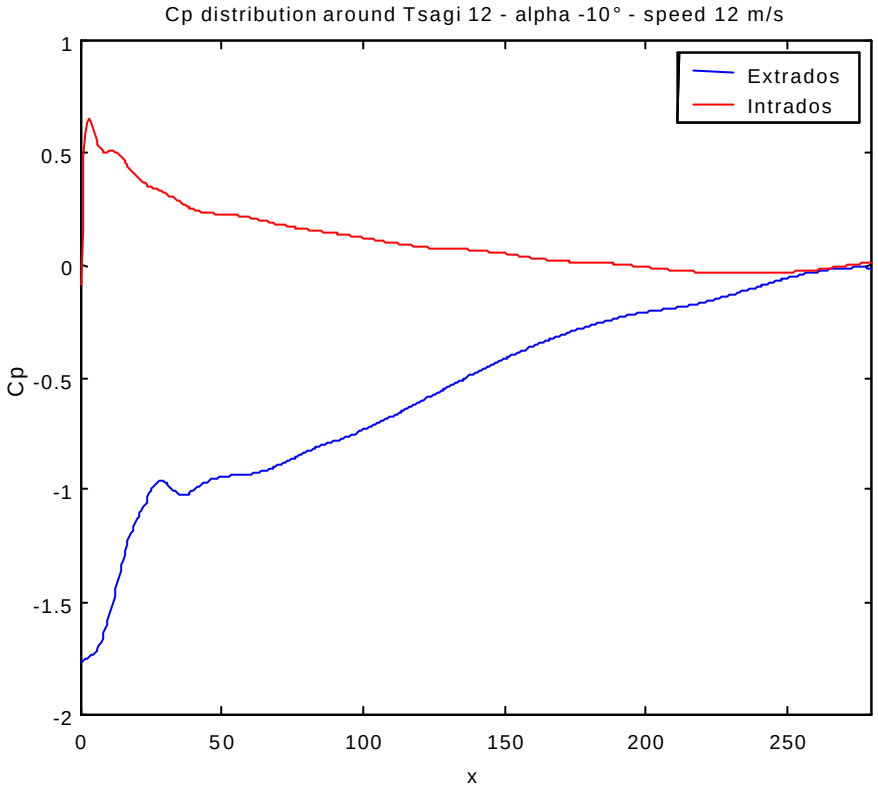
Cp Measurements Tsagi 12 – alpha 10° - V = 12 m/s



$$Cp = \frac{p - p_\infty}{\frac{1}{2} r_\infty V_\infty^2}$$

Suction Peak on the upper side

Lift due to lower pressure on the upper side

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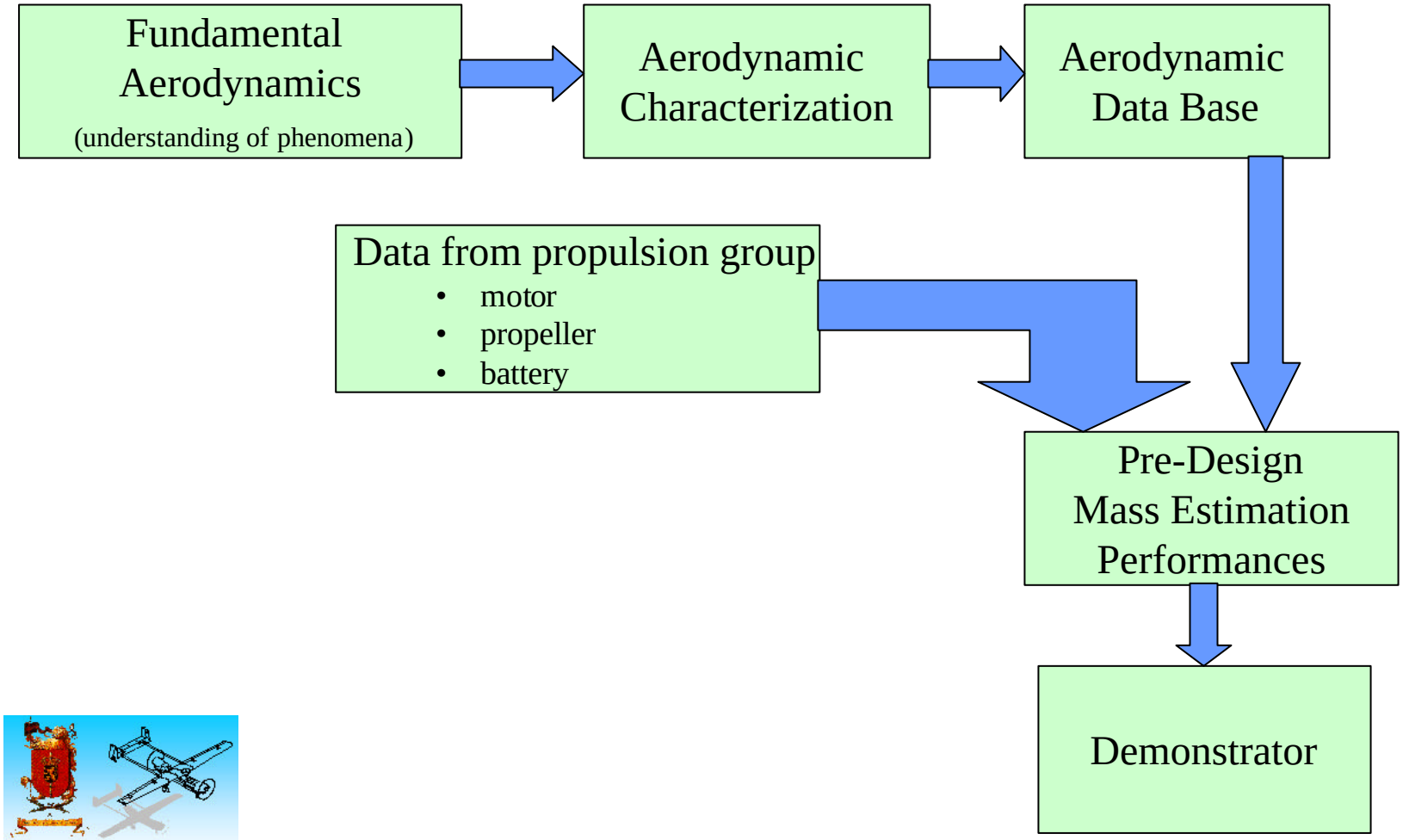
5. *MIRADOR* : A Conceptual Design

MIcRo Aerial-vehicle Demonstrator Onera-Rma

- Bi-plane concept → *better L/D, vortex induced D reduction*
- Low Aspect Ratio *(< 1)* → *fly safely*
- Shape between circular and elliptical → C_l *max along span*
- Progressive dihedral → *stabilizing effect, min vortex induced drag*
- Airfoils : - MH60 for the wings
  - NACA 009 for the vertical posts
- First Version : 150 mm Wingspan
- Off-the-Shelf components integration
  → New Evolution : 250 mm

Development Methodology



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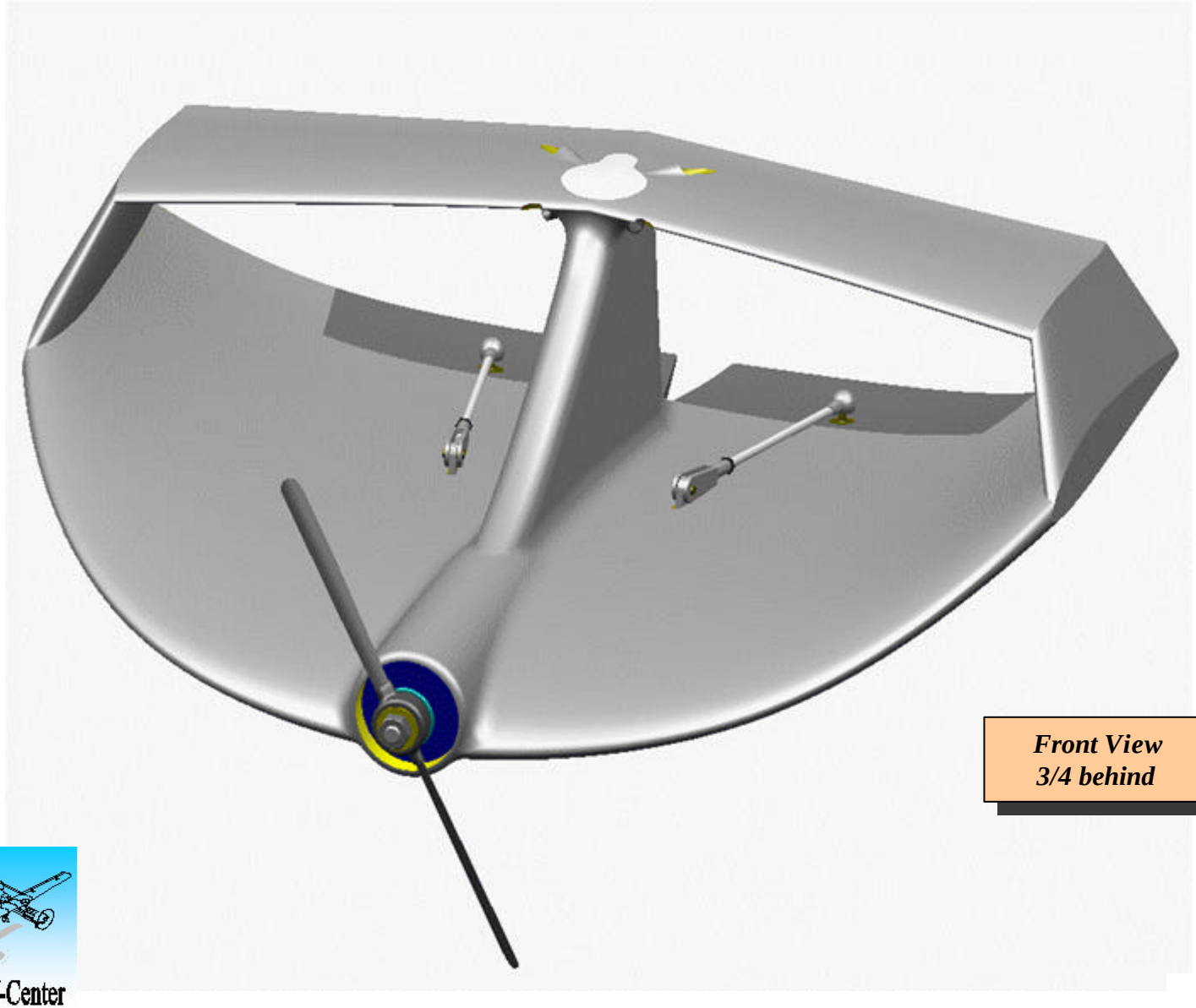

Front View
3/4 behind

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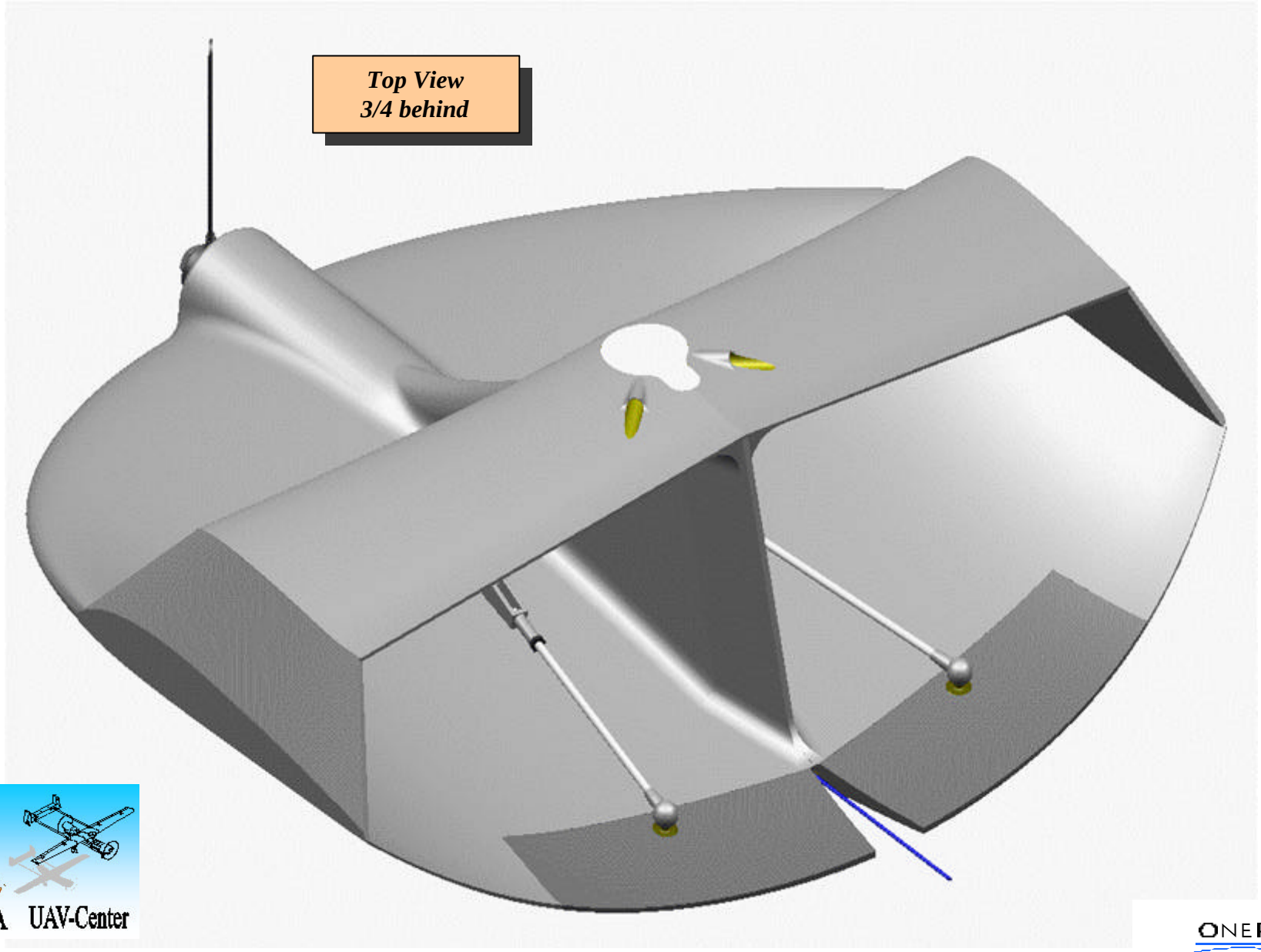

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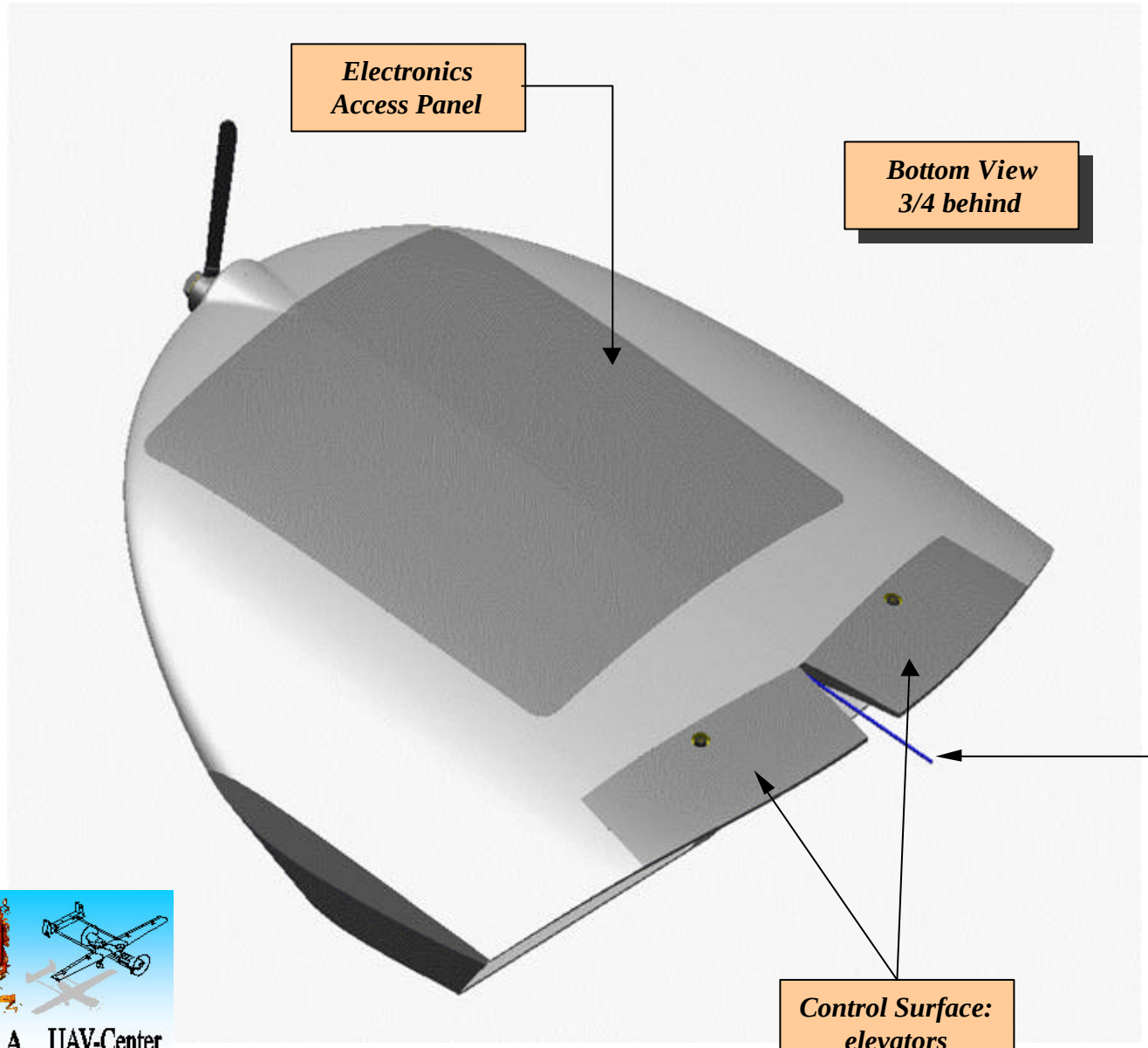
VERSION 250

Presentation Slide of the Vehicle



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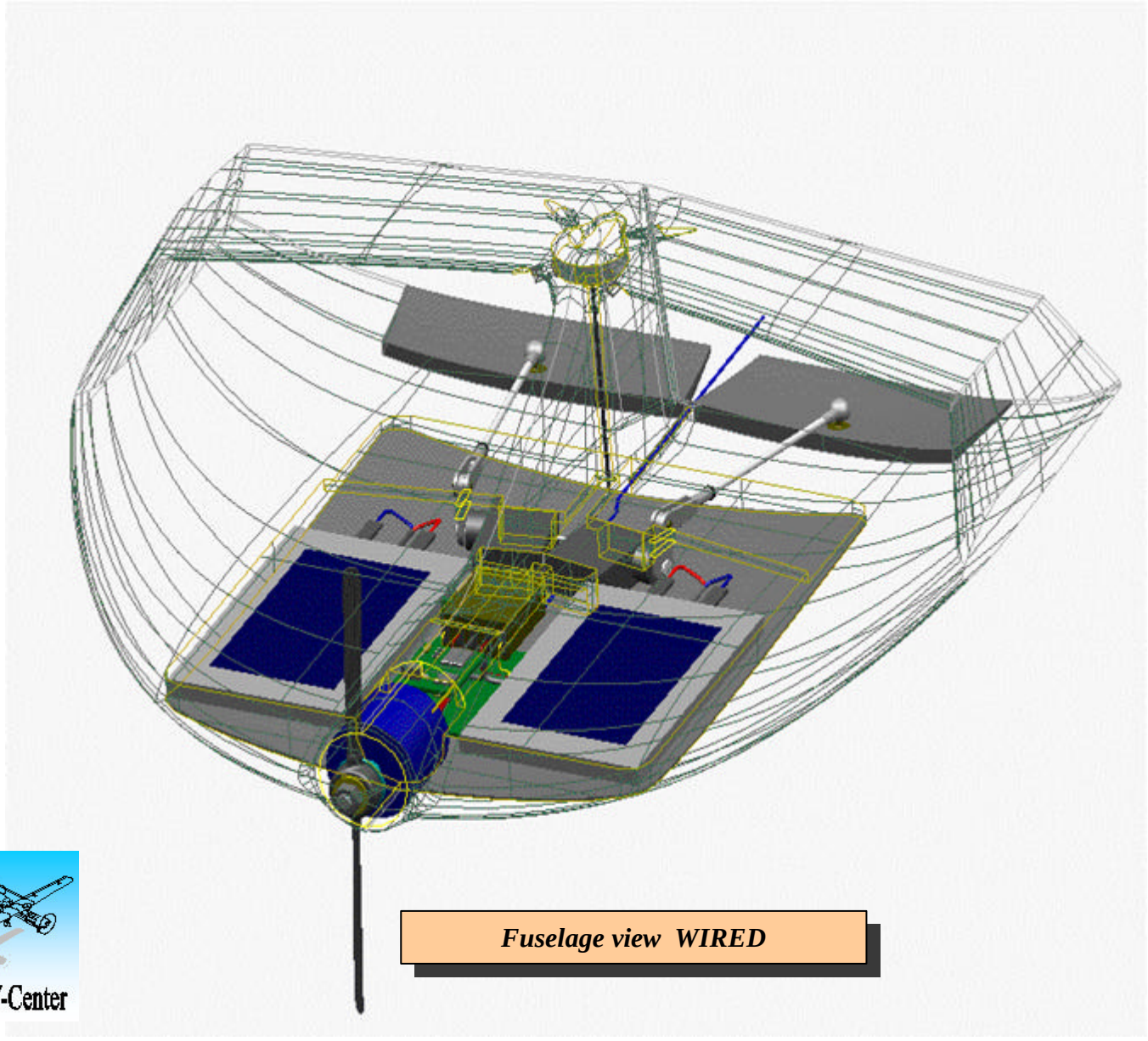

Fuselage view WIRED

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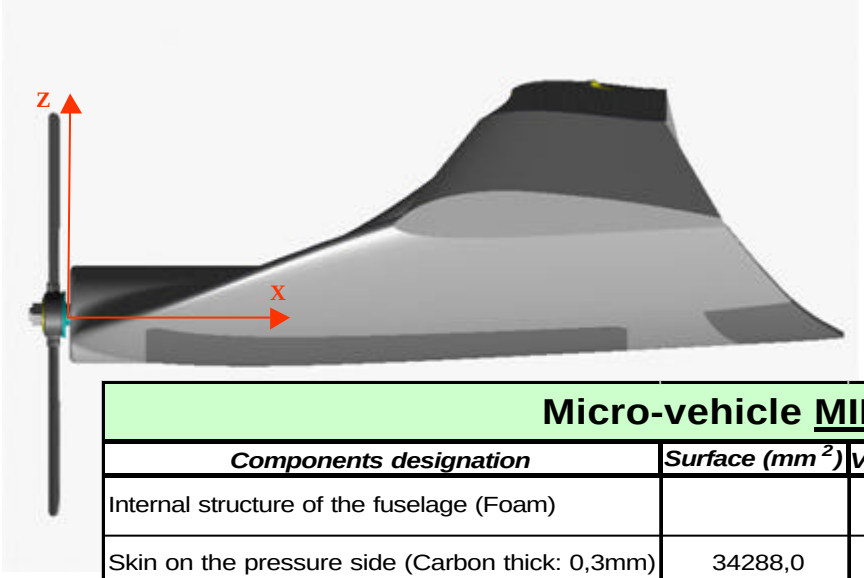
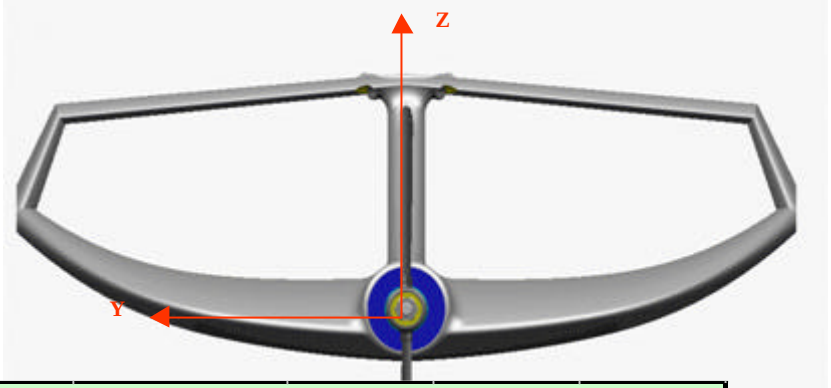
Mass and center of gravity





Micro-vehicle MIRADOR Version 250

Components designation	*Surface (mm^2)*	*Volume (mm^3)*	*Density (kg/dm^3)*	*Mass (g)*	*Xg (mm)*	*Zg (mm)*
Internal structure of the fuselage (Foam)		477664	0,050	23,9	128,20	22,25
Skin on the pressure side (Carbon thick: 0,3mm)	34288,0	10286,40	0,300	3,1	130,65	3,75
Catching hood (Carbon thick: 0,6mm)	21338	13867,2	0,300	4,2	102,14	3,40
Electric motor P/N 801V BRUSHLESS				30,0	16,50	7,00
"ULTRALIFE" Battery UBC				86,0	69,00	7,00
Ultra micro receiver NPM05FM				8,0	84,50	9,50
Electronic speed variator Série NES				15,0	51,00	12,00
Circuit "FLIGHT CONTROLLER"				15,0	62,50	-2,00
Sensor "FLIGHT CONTROLLER"				3,0	155,70	72,65
Servo-mechanism				11,0	130,00	3,40
Propeller				1,5	-5,14	7,00
Total				**201**	**72,7**	**9,3**

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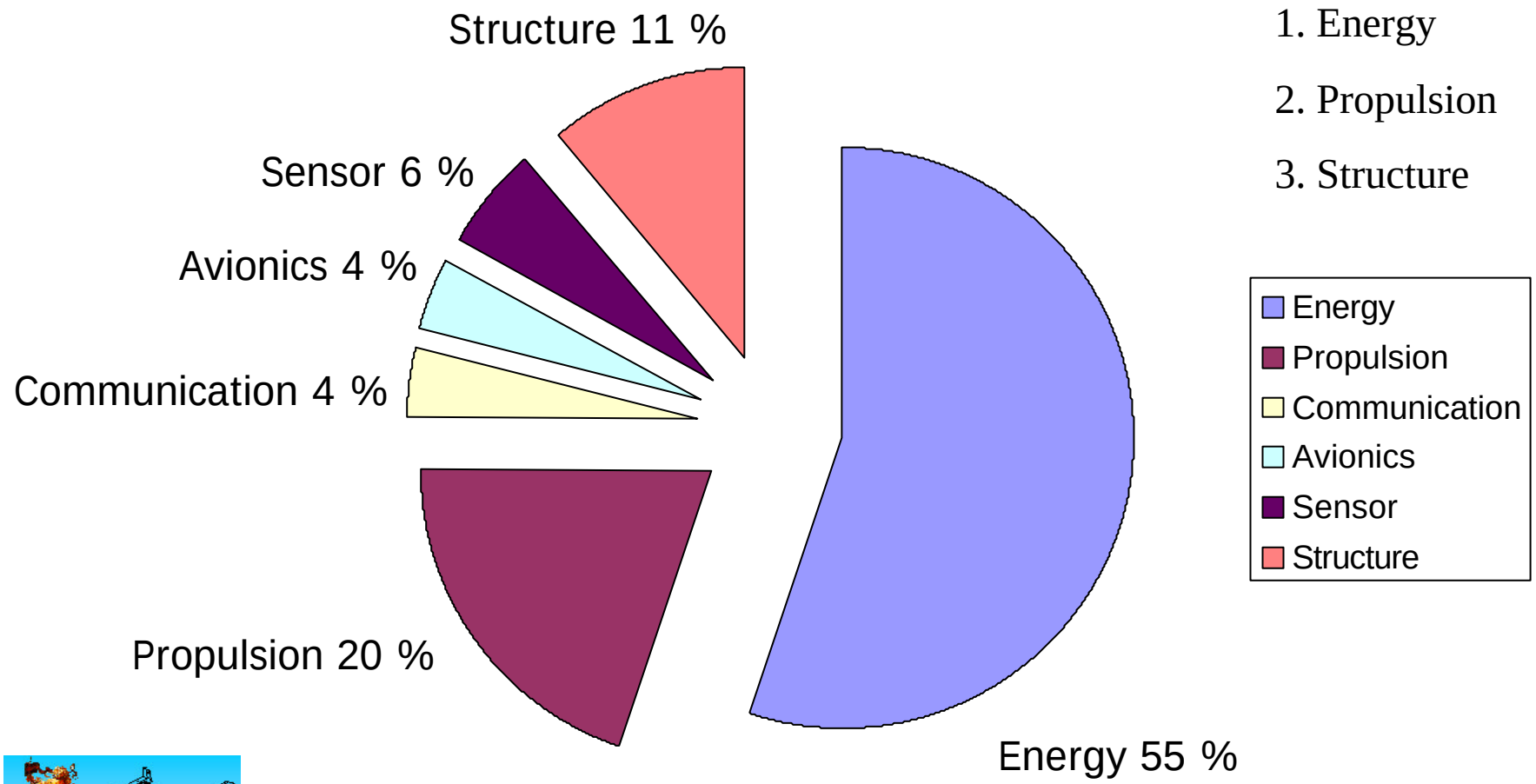
VERSION 250
Weight Breakdown

Critical points :

1. Energy
2. Propulsion
3. Structure



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ULTRALIFE Polymer Battery UBC

- **Thin : < 1 mm → 6 mm**
- **Lightweight : 1,5 g → …**
- **No memory effect**
- **Voltage range : 3 → 4,2 V**
- **Capacity range :**
  30 mAh → 3,800 mAh

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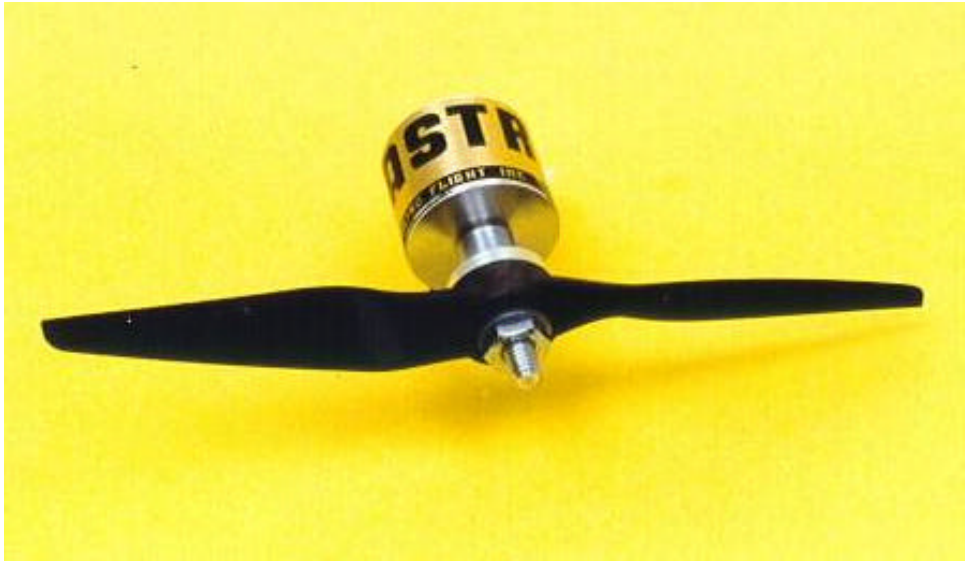
ASTROFLIGHT P/N 801 Mighty Micro



- **Brushless motor**
- **Load : 150 mA**
- **Length : 23 mm**
- **Diameter : 25 mm**
- **Propeller : APC 5.5 x 2.5**
- **Speed : 13,500 rpm**

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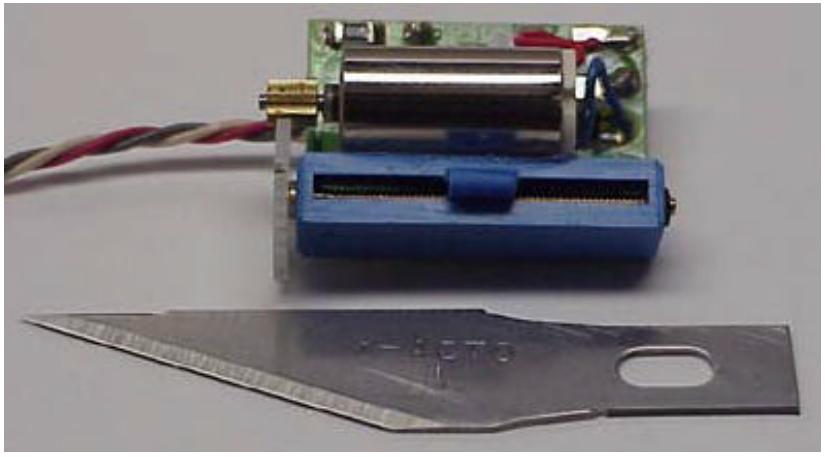
WES-Technik LS-2.4



- **Max deflexion : 14 mm**
- **Time to full deflexion : 0,2 s**
- **Max output force : 175 g**
- **Operating voltage : 3-5 V**
- **Load Current : < 100 mA**

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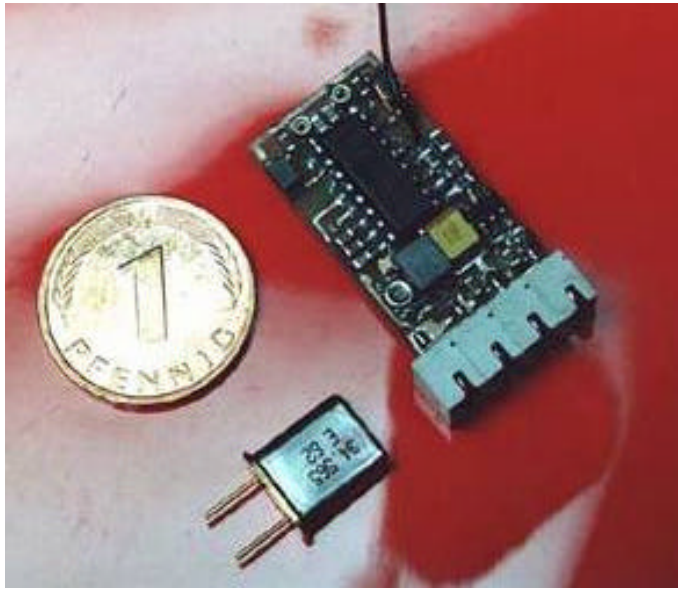
WES-Technik JMP RX5-2.3



- **Frequency bandth : 35 MHz**
- **Power supply : 3.1 – 15 V**
- **Dimensions : 23 x 16 x 6 mm**
- **Mass : 1.35 g**

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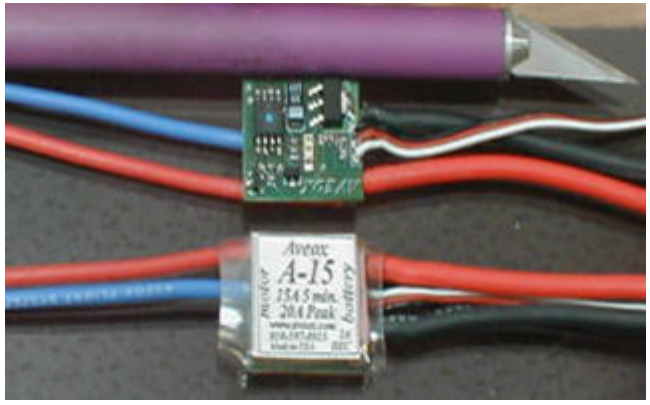
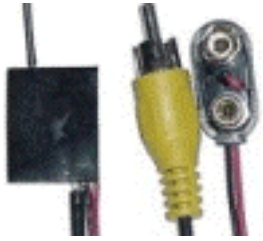
Aveox A-15



Speed Variator



Transmitter

Camera

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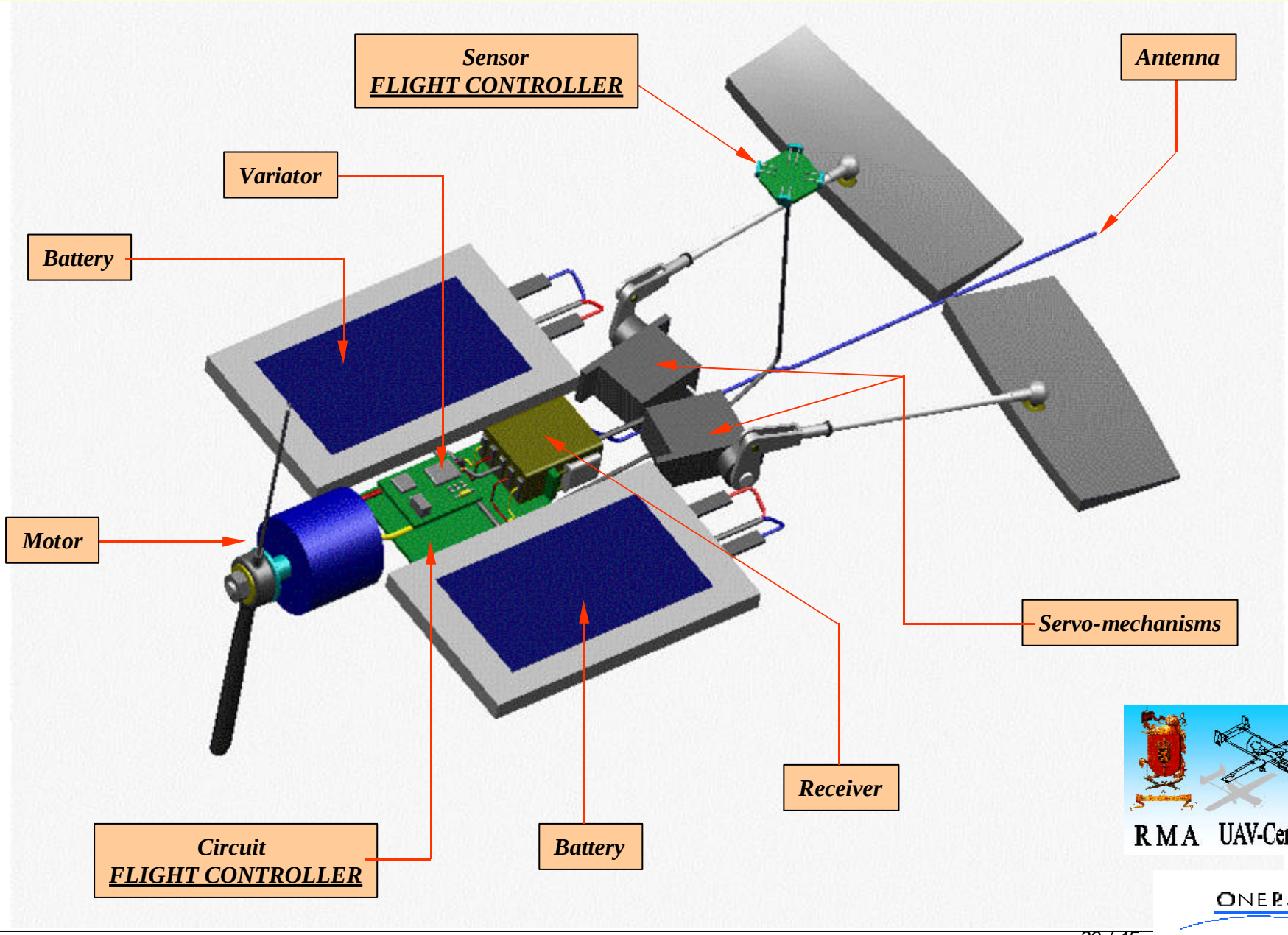
VERSION 250
Components Assembly



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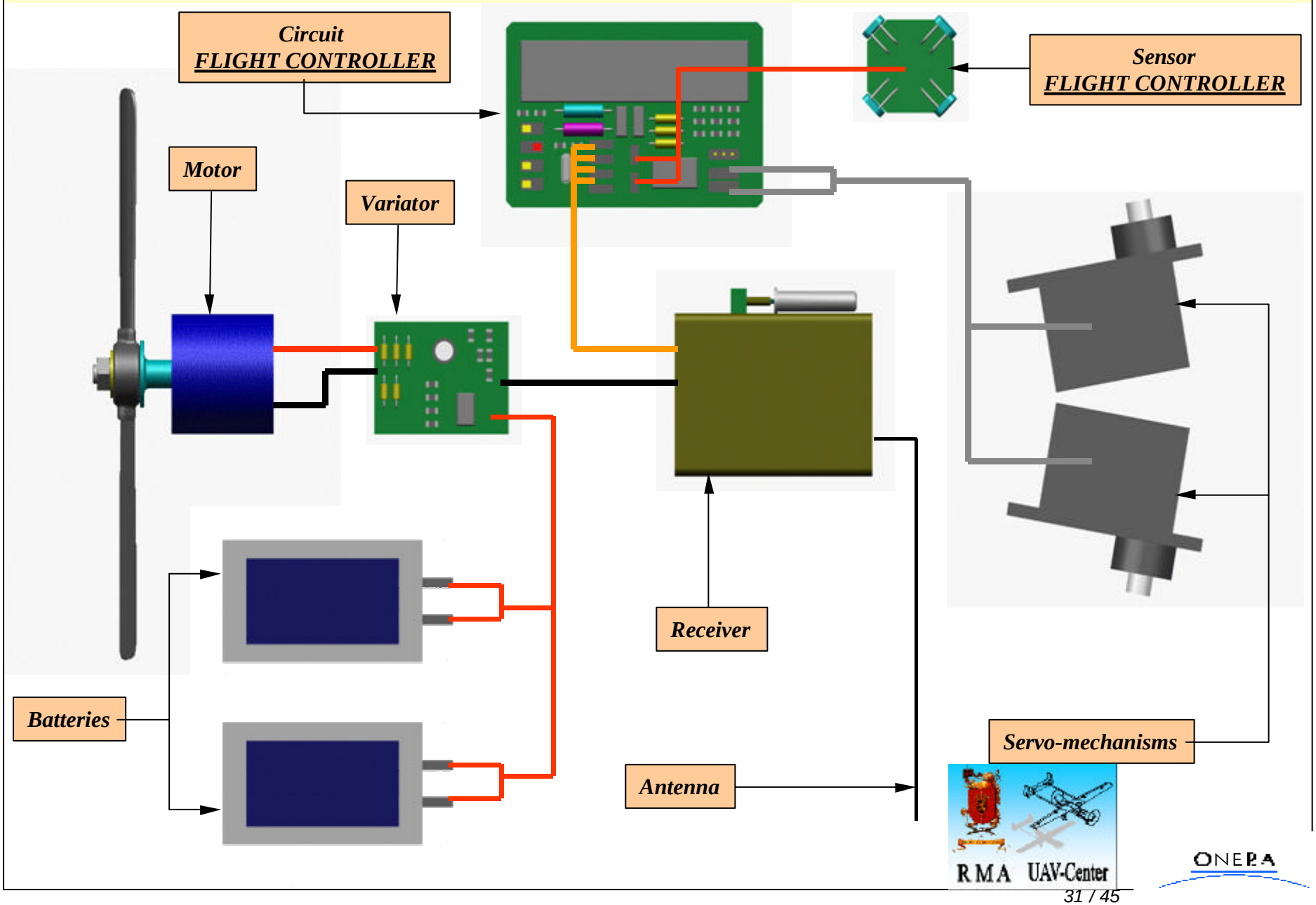
MIRADOR

VERSION 250
Wiring Scheme



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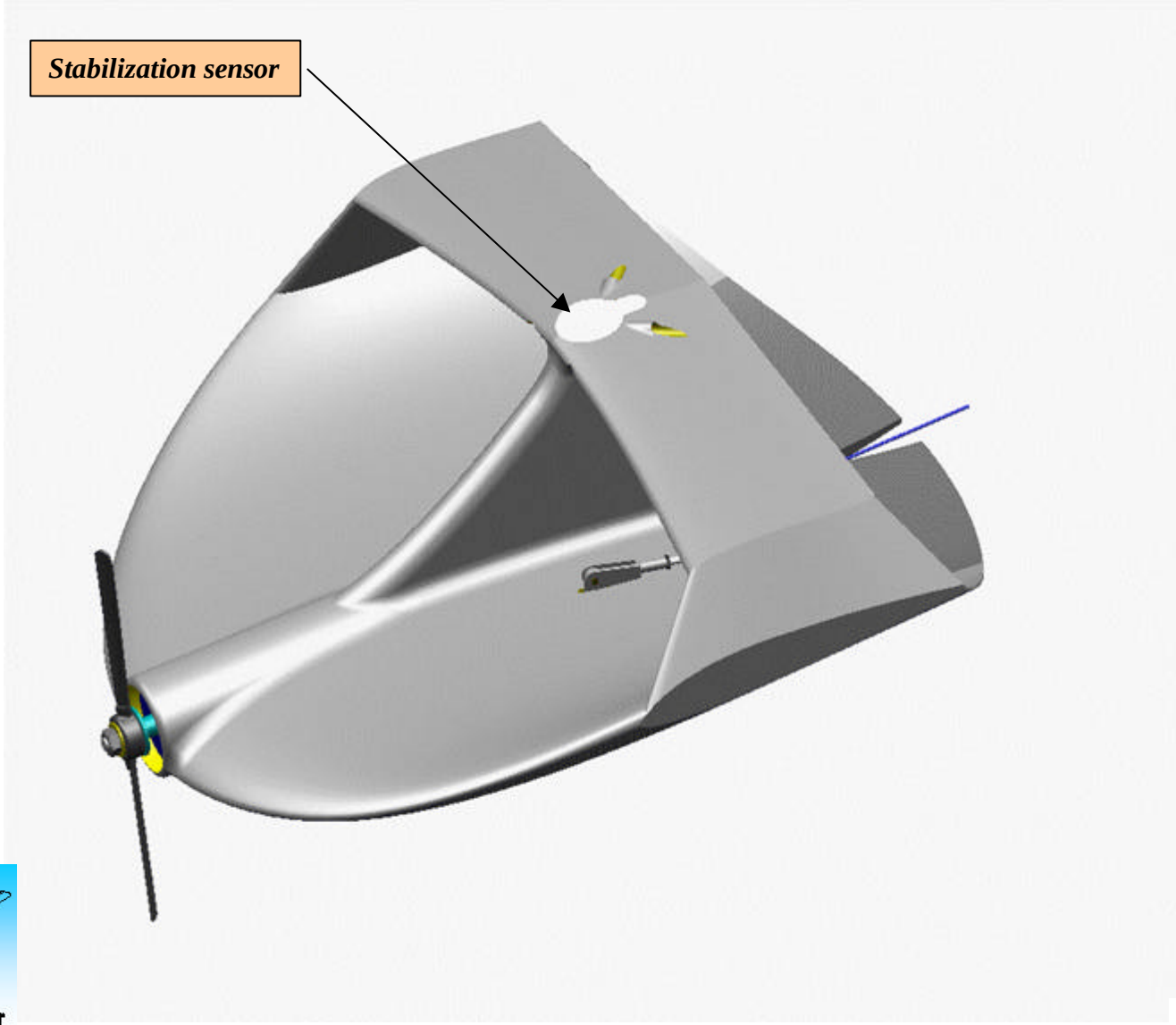

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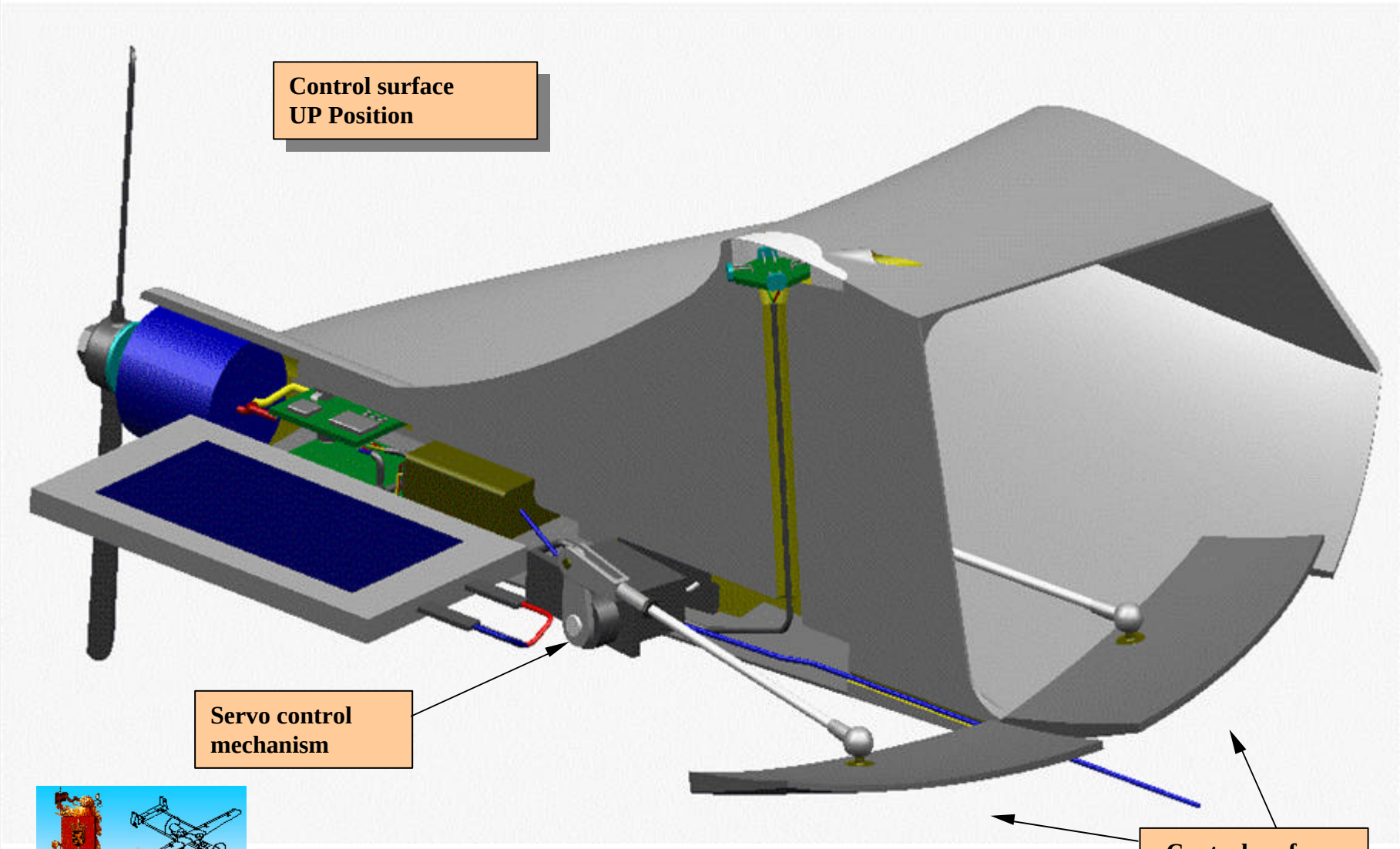
View of the Control Surfaces Mechanisms α ± 15°



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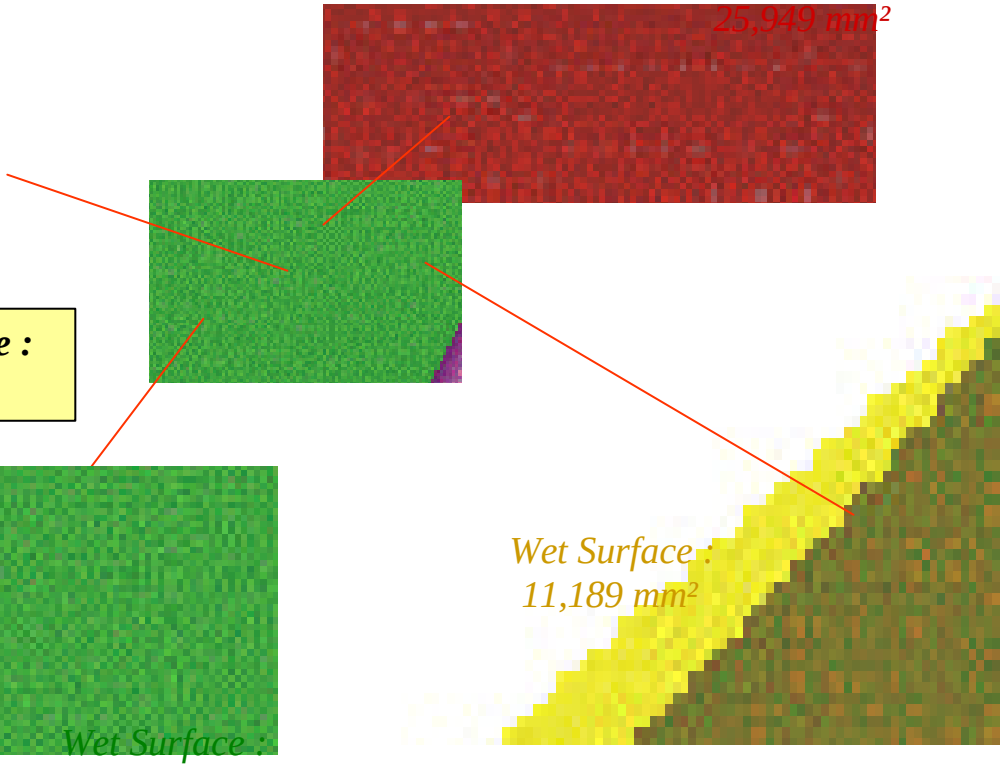
Demonstrator Assembly

- Decomposition of the Surfaces shaped in Carbon / Kevlar Fiber

Wet Surface :
14,282 mm²

Wet Surface :
25,949 mm²



Density : 188 g/m²

→ ***m = 31 g***

Total Wet Surface :
164,871 mm²

Wet Surface :
113,451 mm²

Wet Surface :
11,189 mm²

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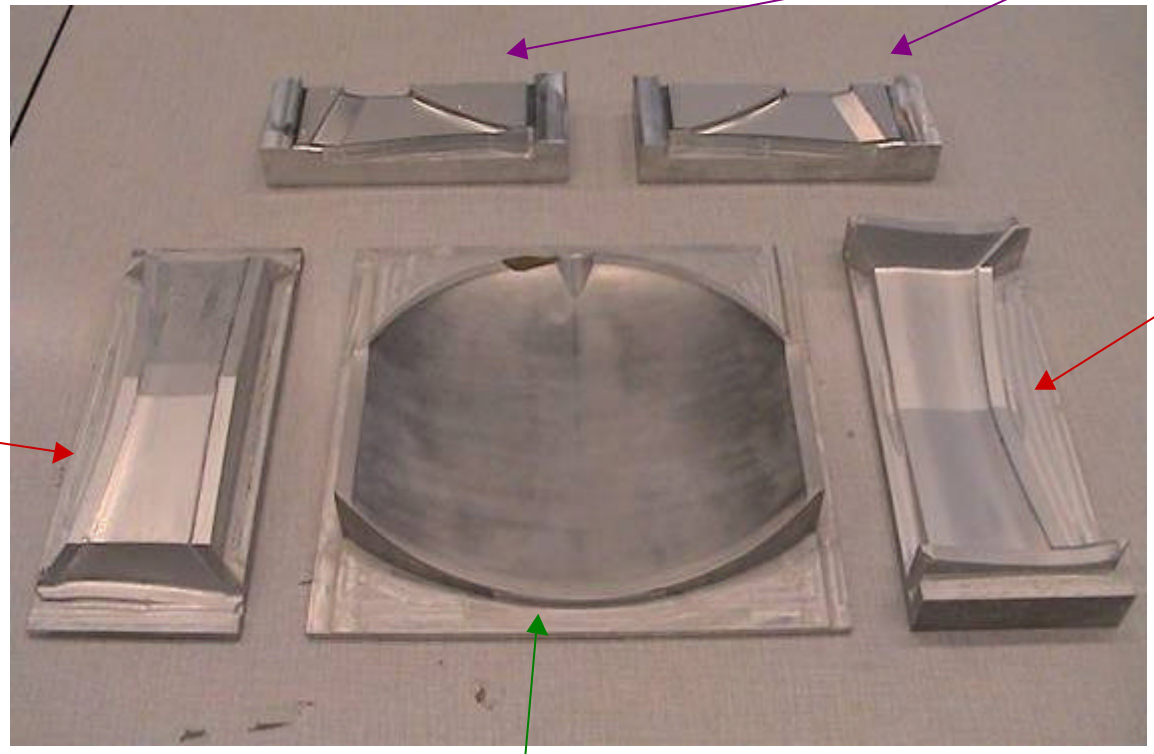
- Steel Moulds Manufactured



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Mirador : Results

- Analyse of the Support Influence
- Force Measurements - Flow Visualisation
- Prototype Tested :
  - 15 cm Wingspan
  - ABS prototyping
- Several Tests on the way about Optimum Biplane :

  stagger, decalage, gap, ...

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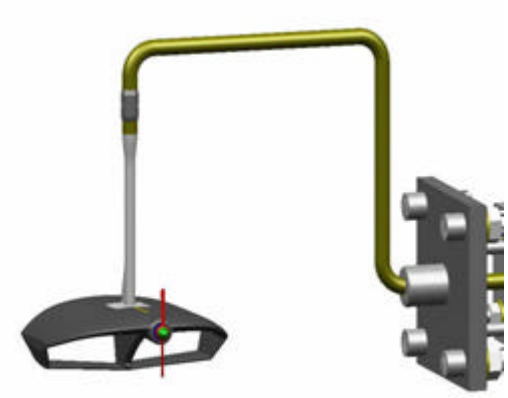
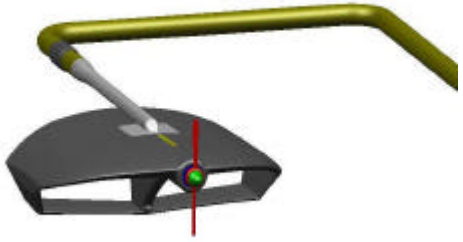
Two Ways of Fixing the Demonstrator

VERTICAL



HORIZONTAL



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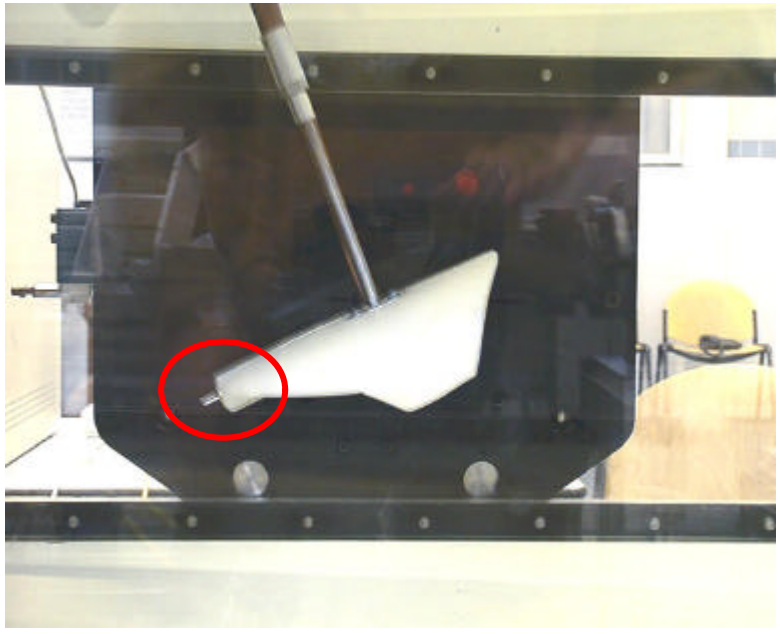
Harmful Effect on the Angle of Attack

VERTICAL



HORIZONTAL

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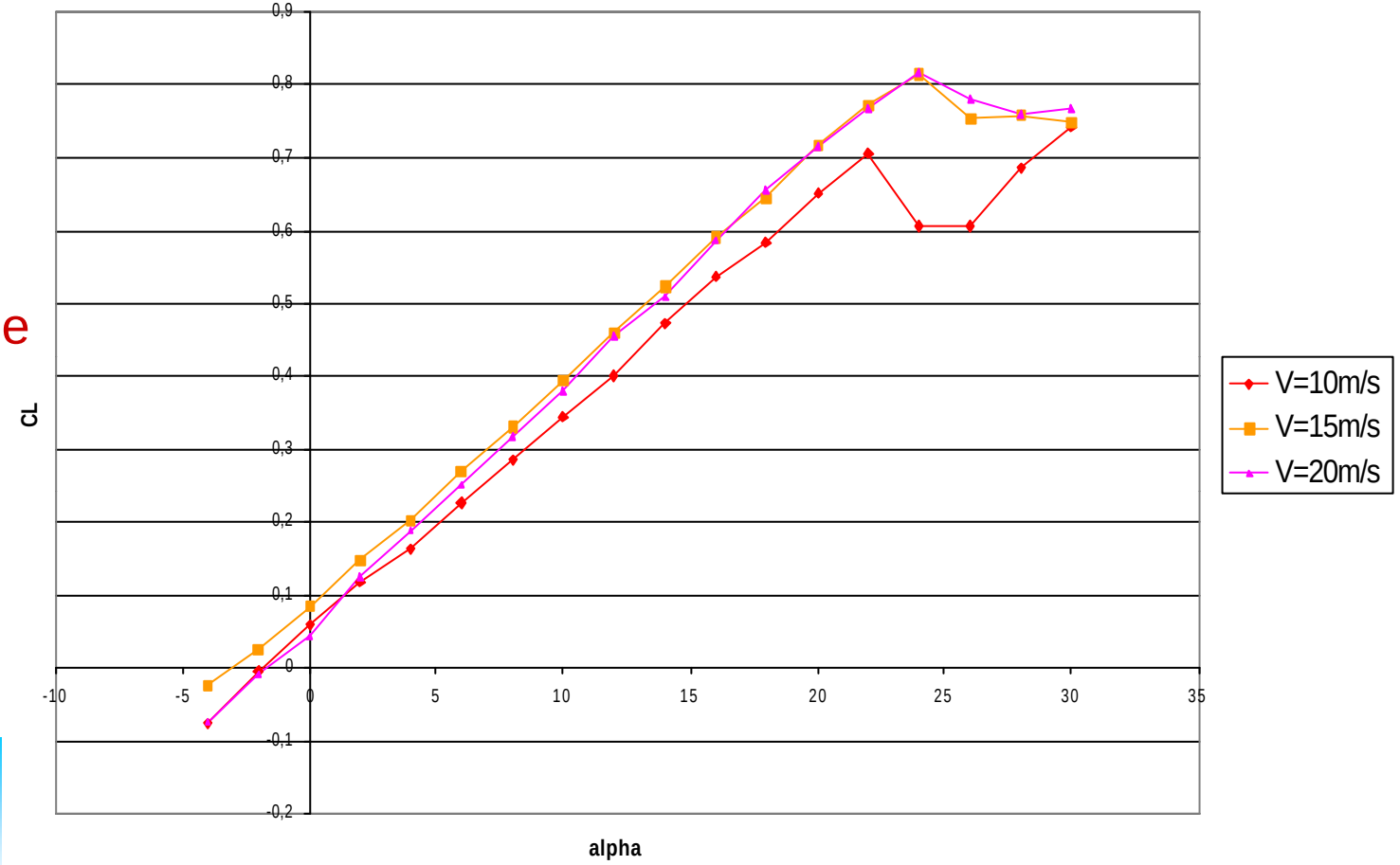
More Vibrations with Horizontal Support !

CL Measurements Vertical Support

$C_{L\ max}$=0,8

No noticeable Hysteresis effect



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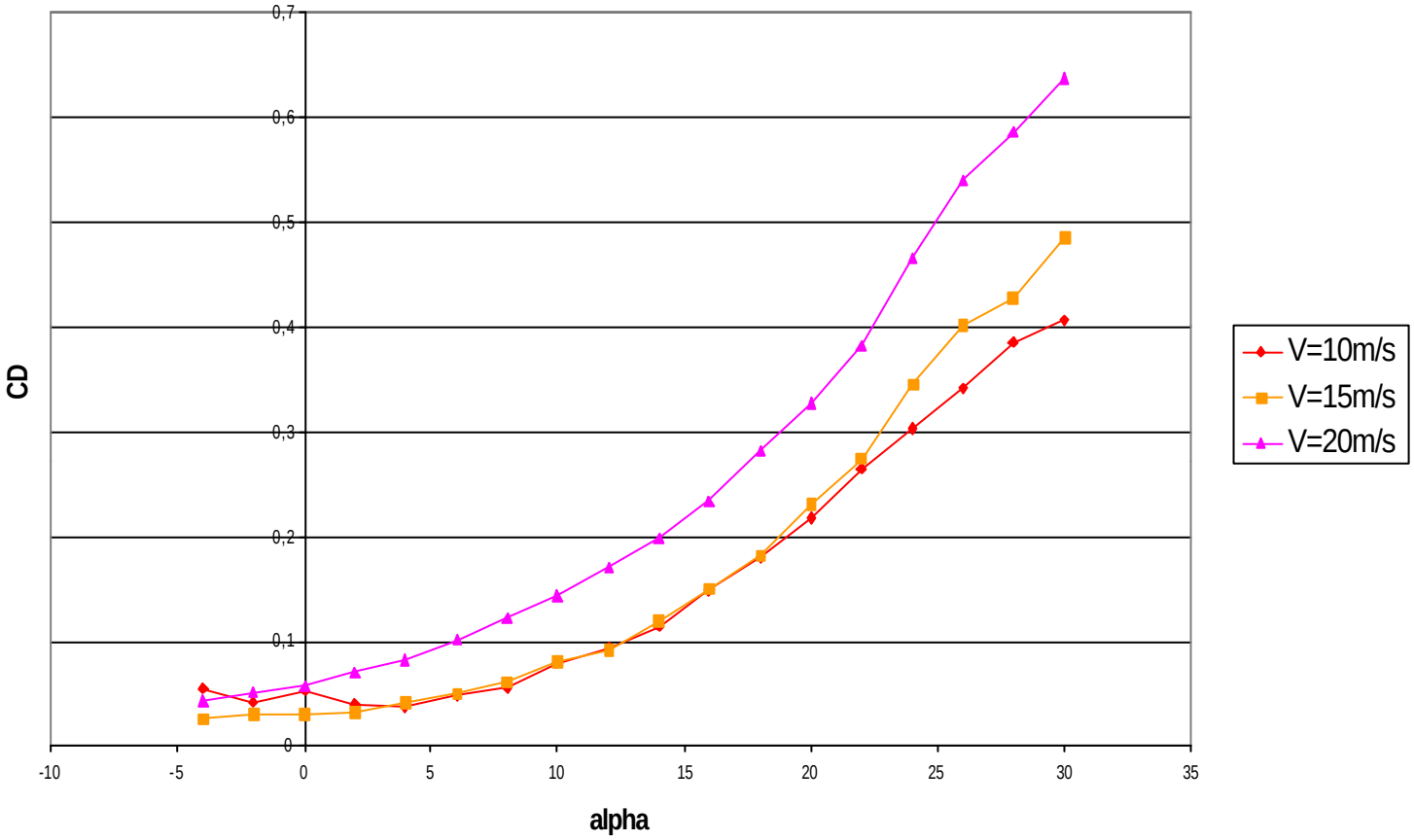
CD Measurements Vertical Support



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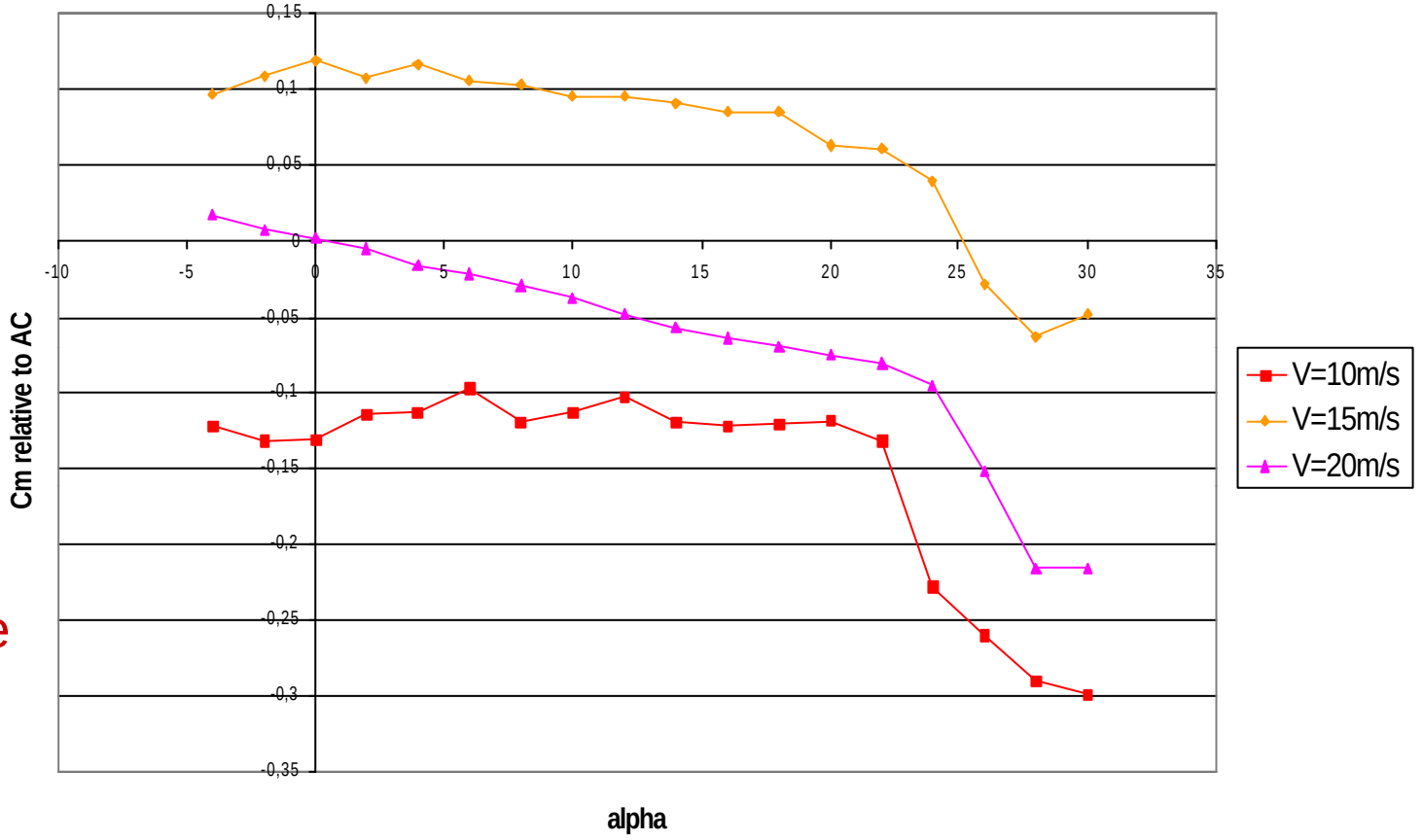
Cm Measurements Vertical Support

$C_{m0} > 0$
Slope < 0

→ Stable

$C_{m0} < 0$
Slope < 0

→ Not Stable



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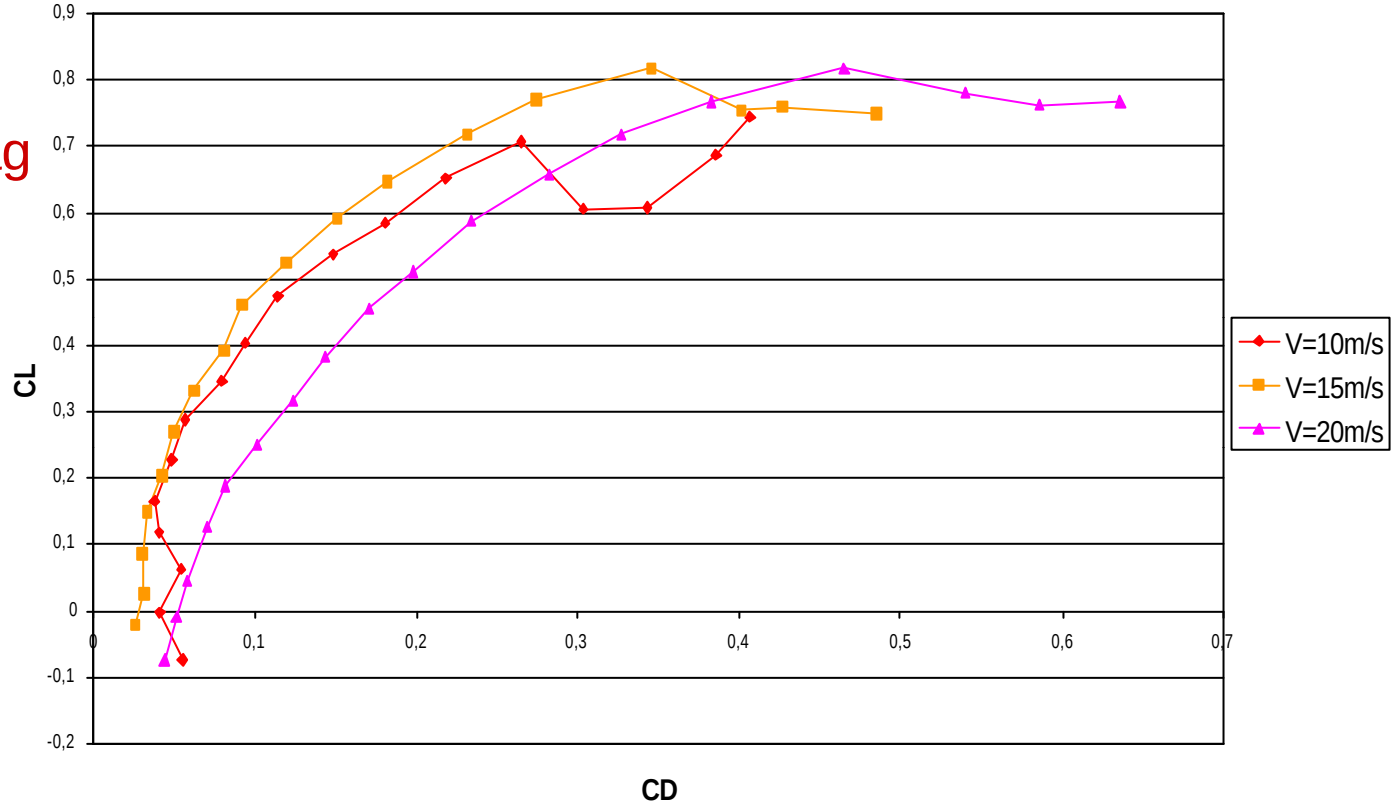
Polar Curve - Vertical Support

Max lift-to-drag ratio = 5,5



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Flow Visualization

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Conclusions

The RMA has:

- Outstanding equipment
- Scientific Approach
- Conceptual Design
- MIRADOR MAV demonstrator (on the way)

Next step:

- Apply PIV Measurement Technique
- Flight Testing

WE ARE READY FOR THE FUTURE

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