LESSONS FROM WIND TUNNEL MODELS MADE BY RAPID PROTOTYPING

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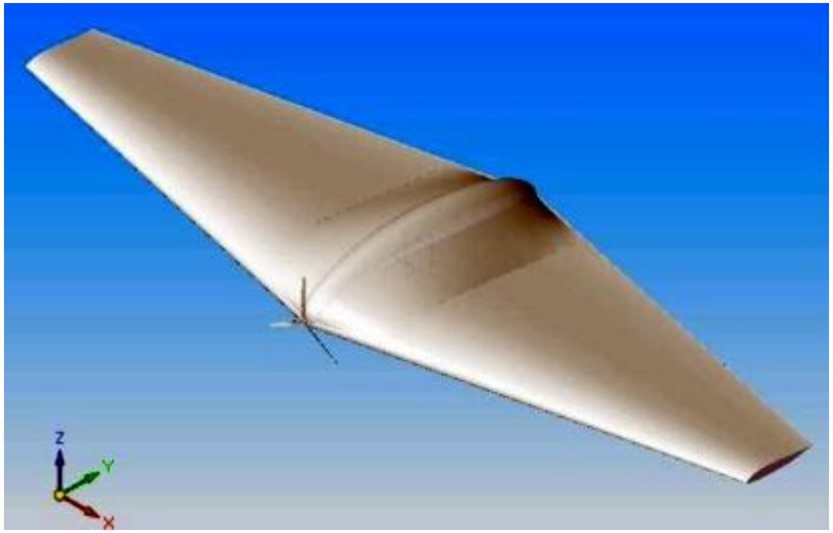
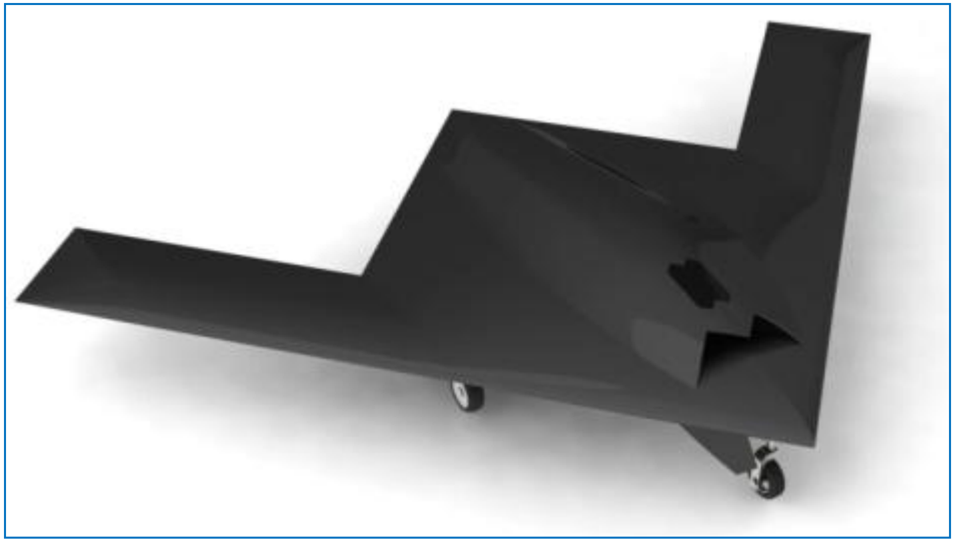
Background

- Traditionally wind tunnel test models are made of metal by using 5-axis CNC milling process.
- The result is very accurate but very expensive model
- Rapid Prototyping (RP) allows the fabrication of a physical object directly from the CAD model by using various materials, such as polymers.
- The lecture is about using Rapid Prototyping process for manufacturing of wind tunnel test models.
- The evaluation was done by using two models of students' final-year projects: ILAS and CERBERUS UAVs (both are flying wing configuration).

ILAS

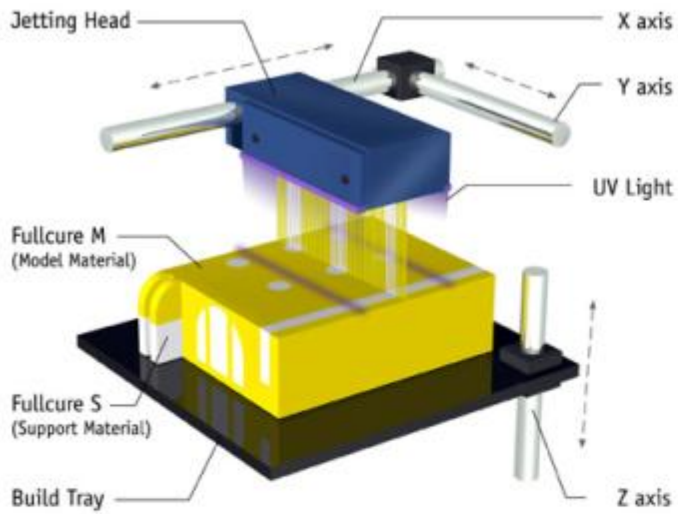


CERBERUS



Rapid Prototyping

- Building the model layer-by-layer, from the bottom up.
- We used PolyJet^{TM} technology by Objet Geometries (Israel).
- 0.1 mm resolution in X-Y, 0.16μm layer thickness (Z resolution).



Advantages offered by the RP technology

- Cost
- Time
- Geometrical Complexity
- Weight
- Accuracy
- Surface Finish
- Small Parts and Details
- Movable Parts

Disadvantages of RP for wind tunnel models

- Strength and Stiffness
- Durability
- Stability
- Maximum Size

MODEL DESIGN AERODYNAMIC CONSIDERATIONS

Tradeoff of several requirements such as:

- Cross section area of the available and economical wind tunnel.
- Actual size and shape of the aircraft to be evaluated.
- Actual performance (speed, Mach number) of the air vehicle.
- Similarity parameters.
- Reynolds number.
- Materials and production process of the model.

CERBERUS UAV WIND TUNNEL MODEL
First Iteration

Requirements:

– Design speed 0.7-0.8 Mach number

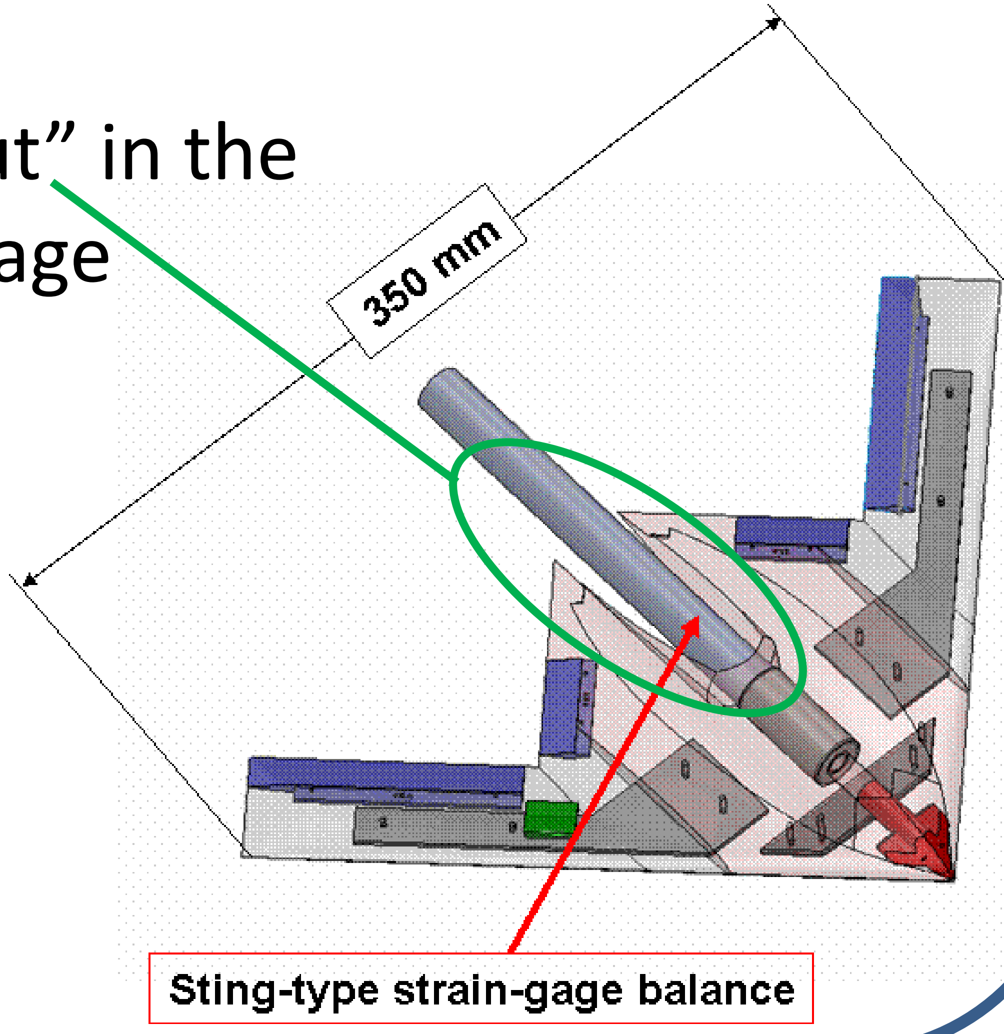
Therefore

– Use of transonic wind tunnel (where the compressible flow effects could be included)

Result With

1 : 40 Scale Model

- Too Small Model
- Excessively large "cut" in the aft part of the fuselage



CERBERUS UAV WIND TUNNEL MODEL
Second Iteration

Alternate Approach:

– Applied Similarity Parameters to correct the aerodynamic coefficients

– By considering the swept wing and the Mach number perpendicular to the wing, the following transformation can be used:

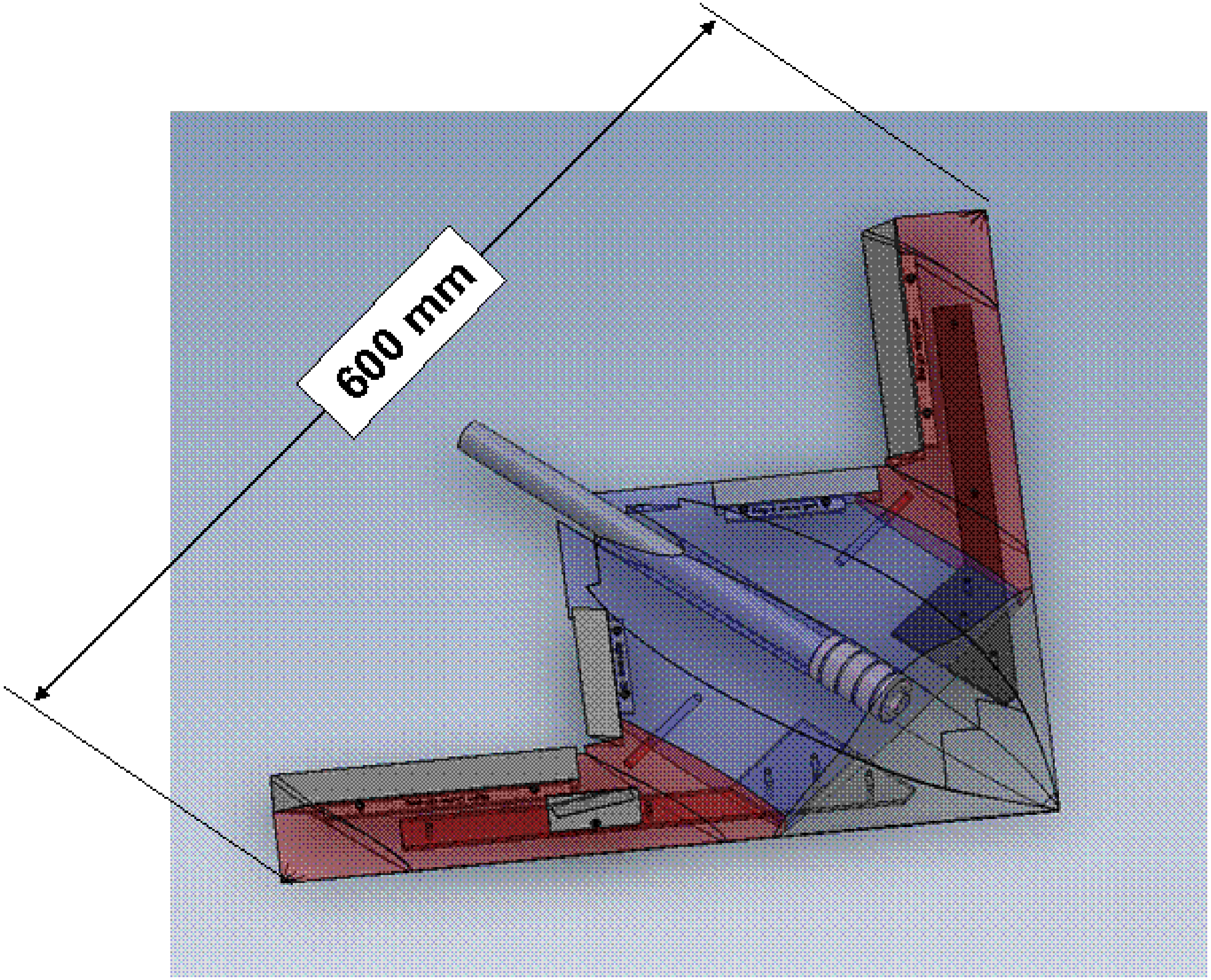
$$M_n = M_\infty \cdot \cos\Lambda = 0.8 \cdot \cos 45^o = 0.56$$

$$\frac{C_{comp}}{C_{incomp}} = \frac{1}{\beta} = \frac{1}{\sqrt{1 - M_n^{\ 2}}} = 1.2$$

– Using the Subsonic Tunnel

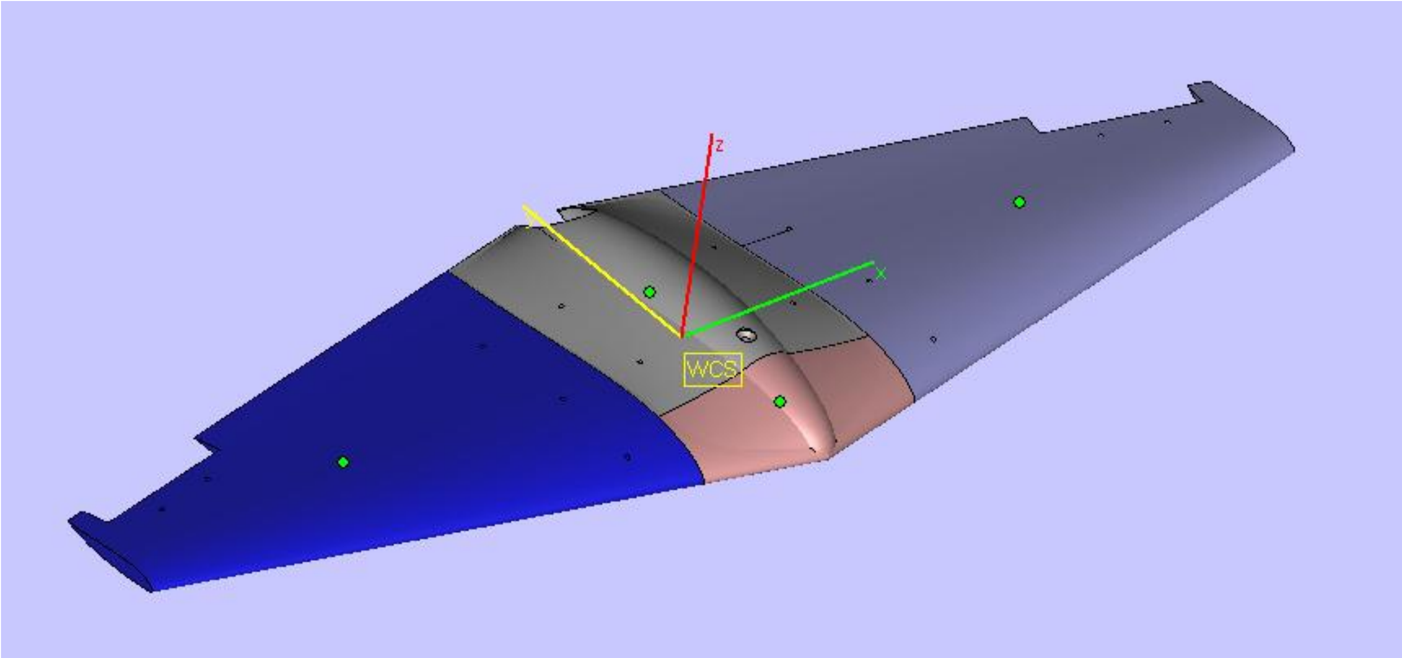
Result With

1 : 22 Scale Model



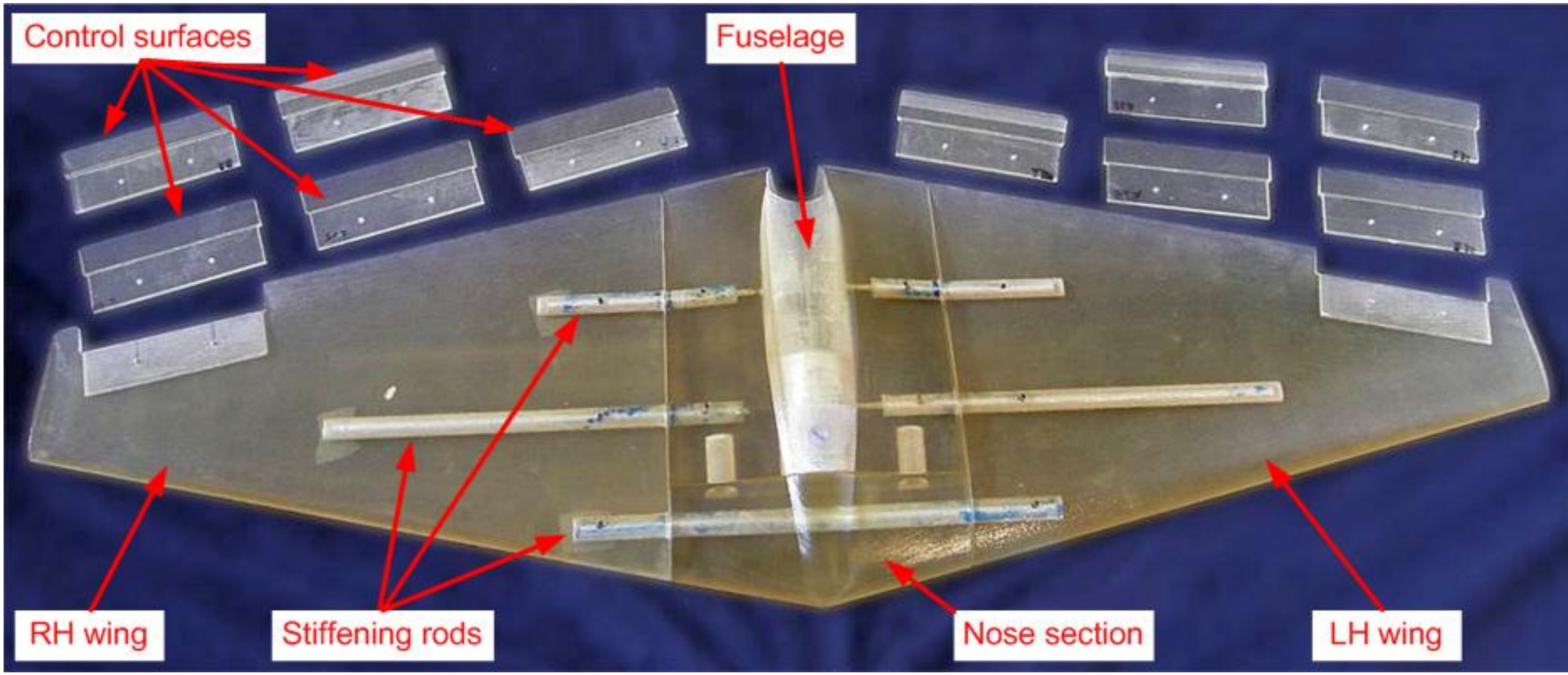
MODEL DESIGN STRUCTURAL CONSIDERATIONS

- Use of rear-mounted sting-type strain-gage balance
- Fabrication limitation of RP machine for part size

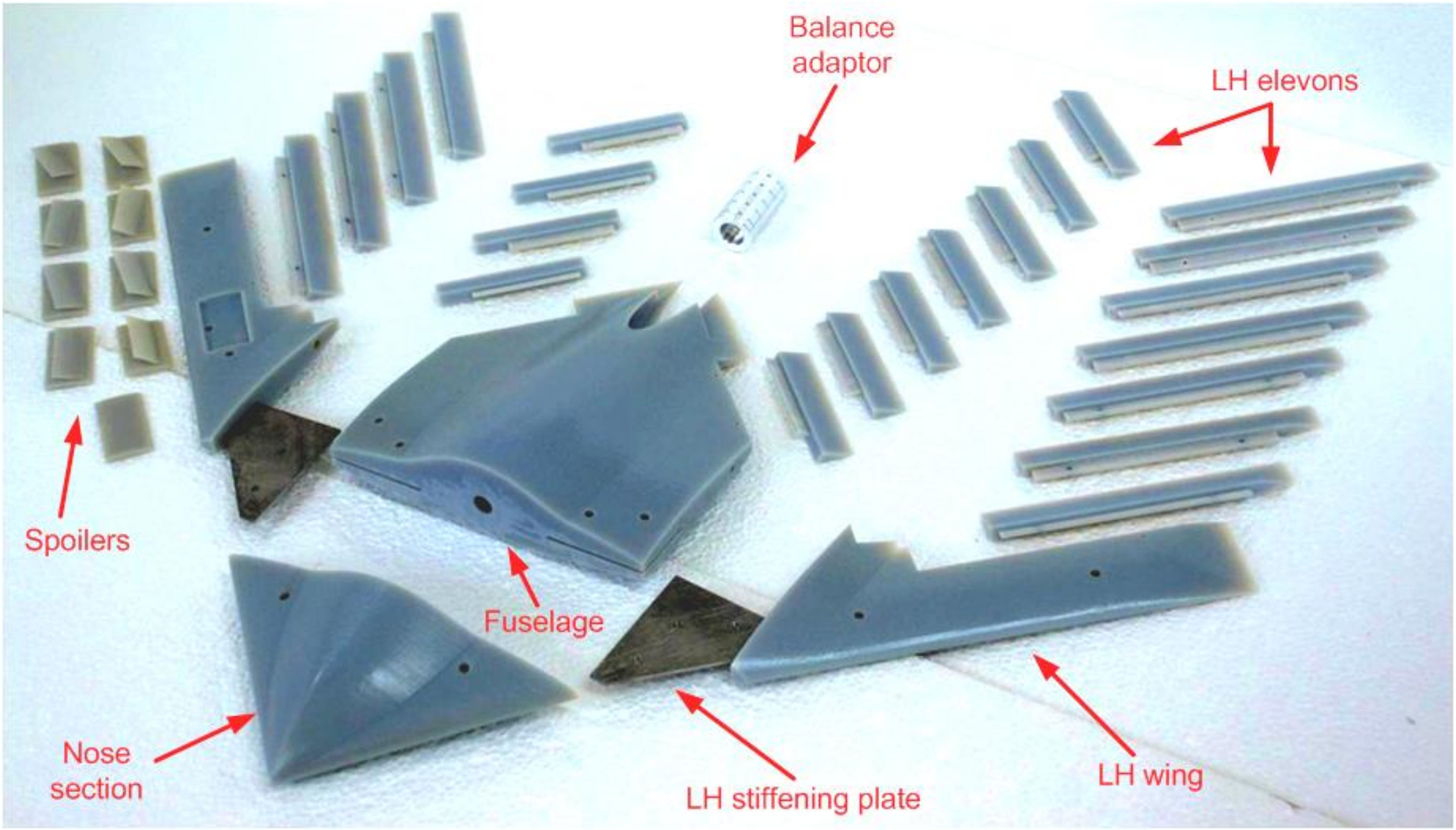


ILAS model - four main parts: fuselage, nose section and two wings.

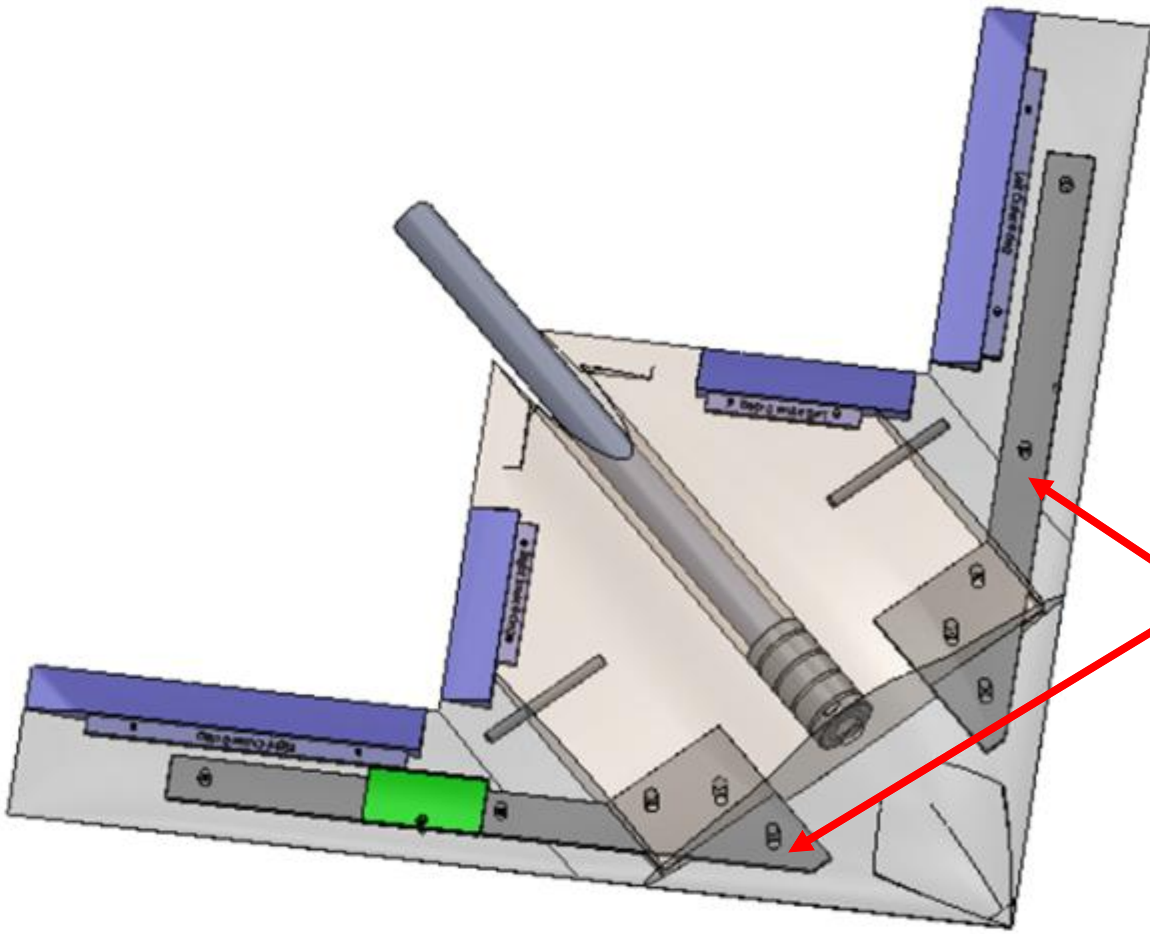
ILAS UAV model parts



CERBERUS UAV model parts

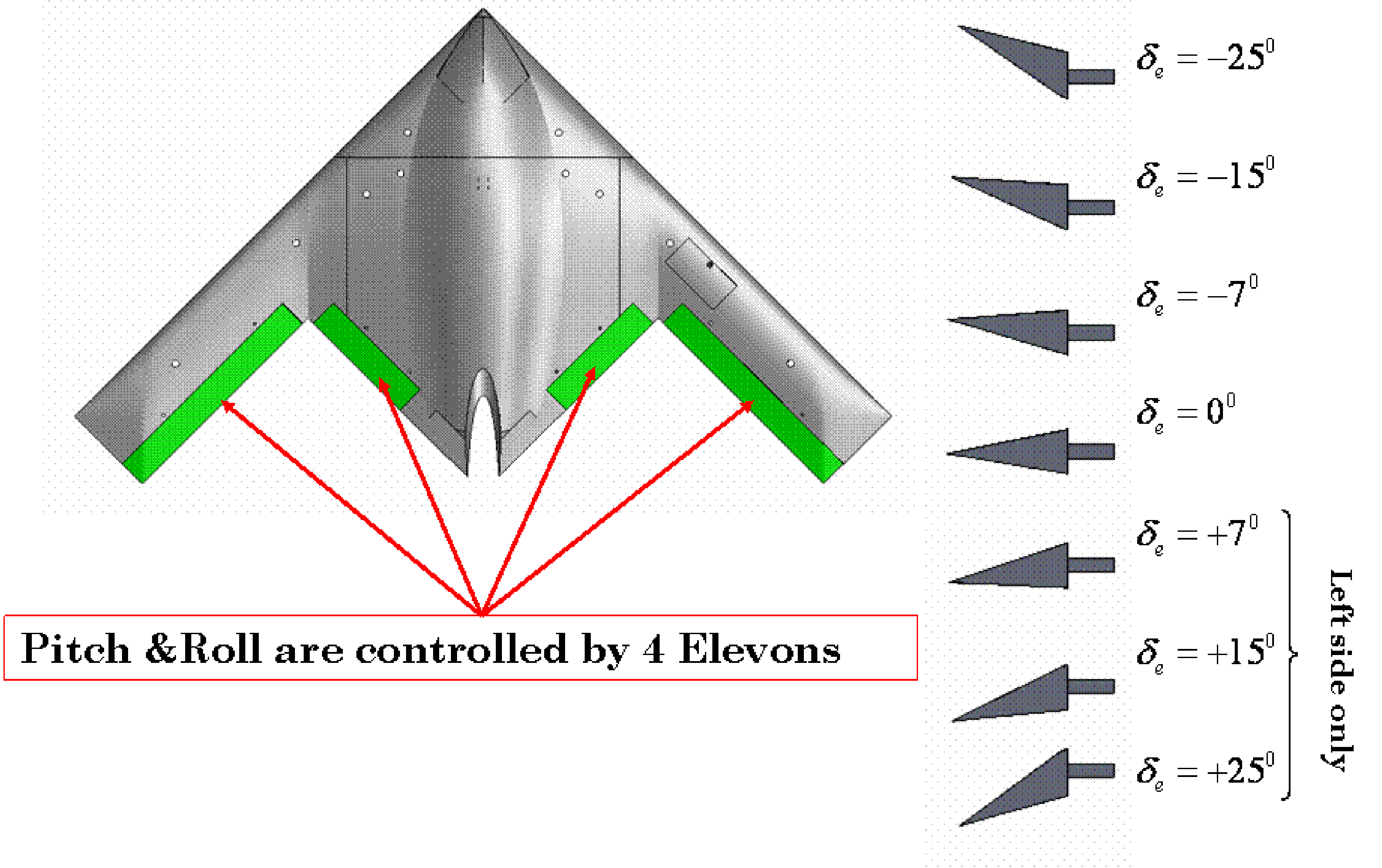


CERBERUS model with two reinforcing steel plates

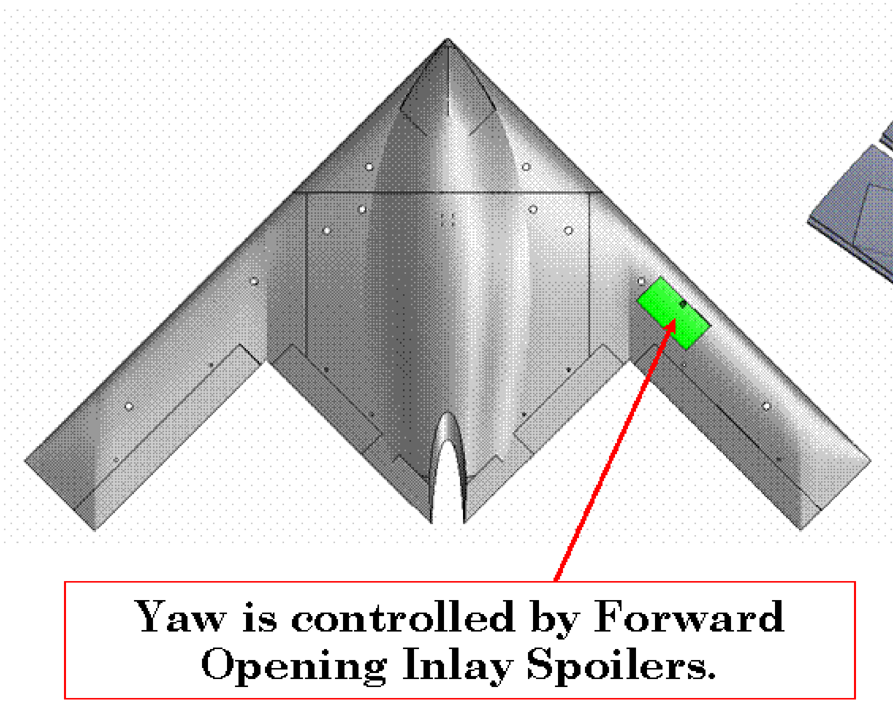


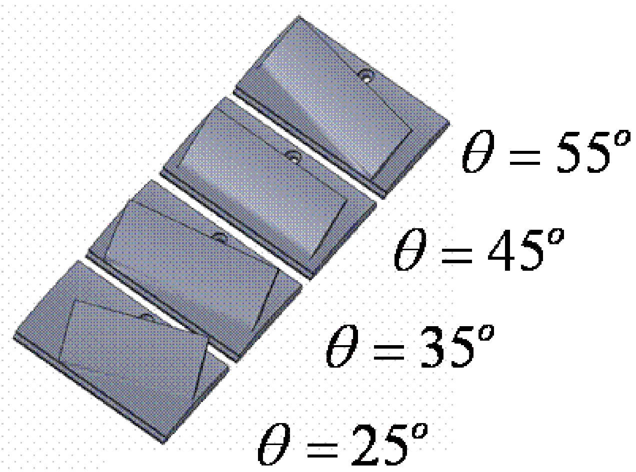
Stiffening plates

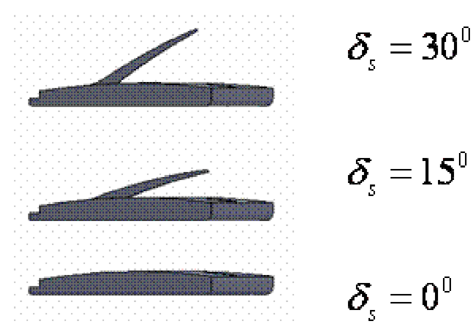
CERBERUS
pitch and roll control surfaces (elevons)



CERBERUS
yaw control surface (spoiler)







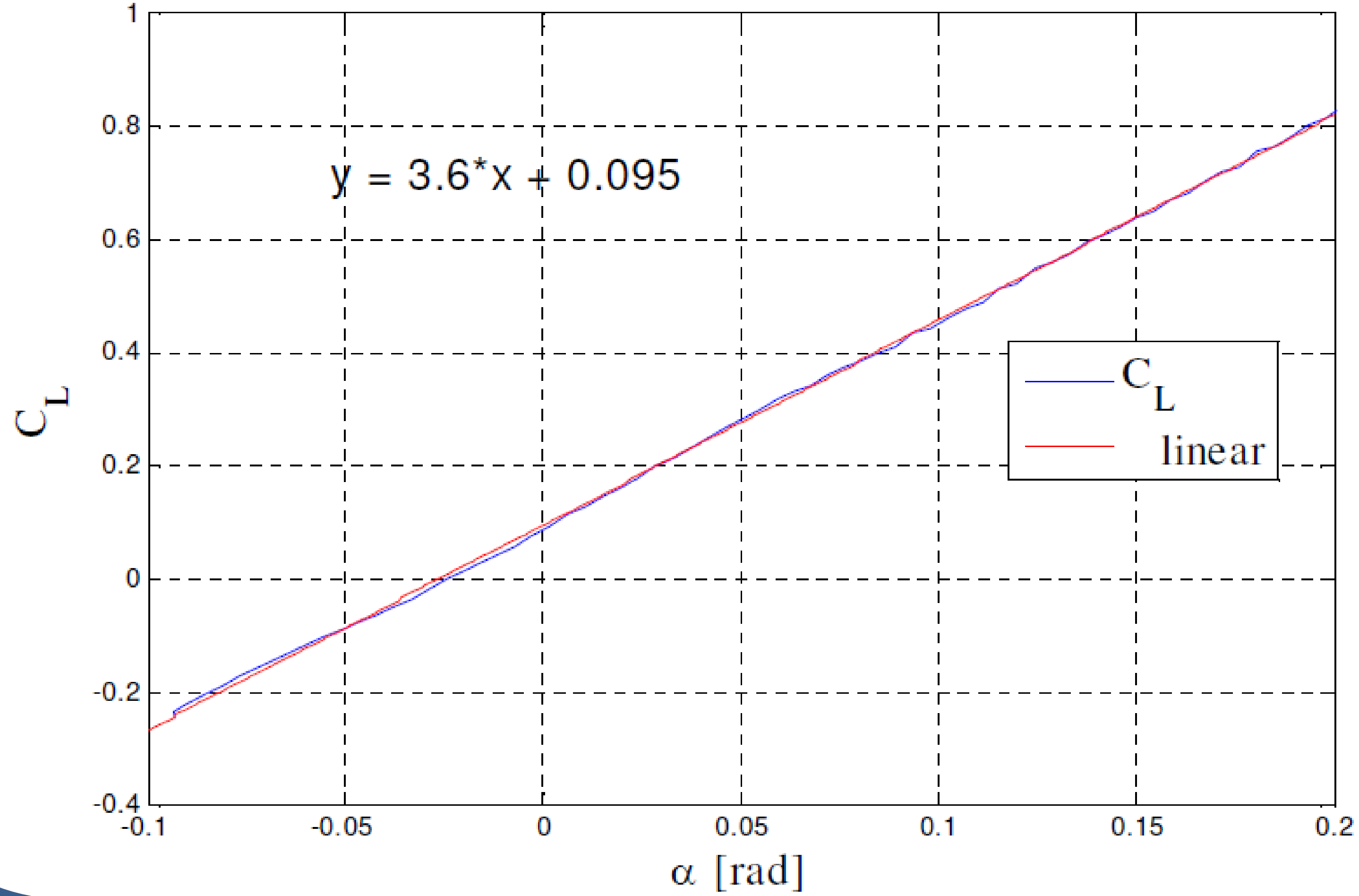
CERBERUS Model
in the wind tunnel measurements

Pitch measurements

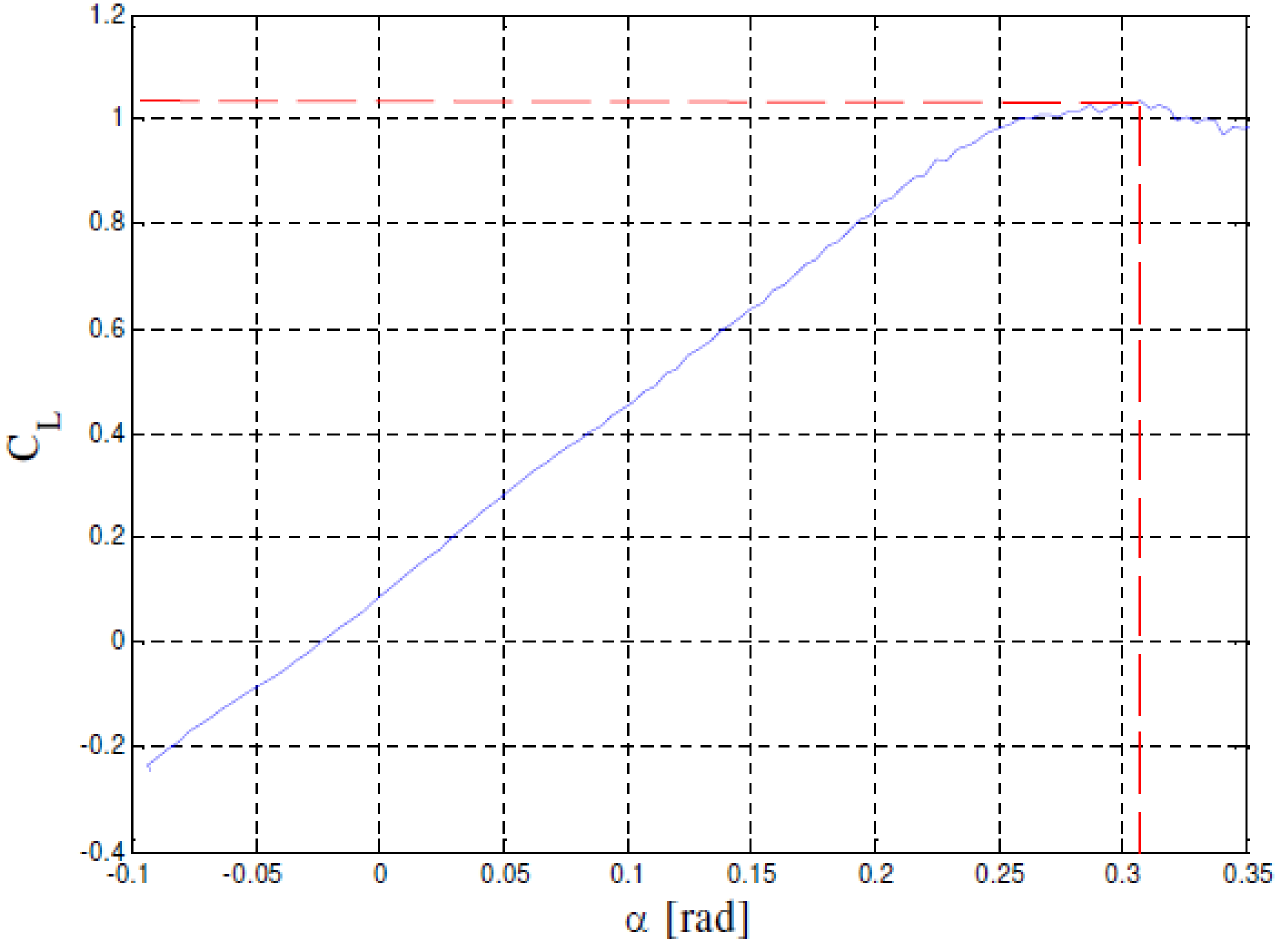
Yaw measurements

TEST RESULTS

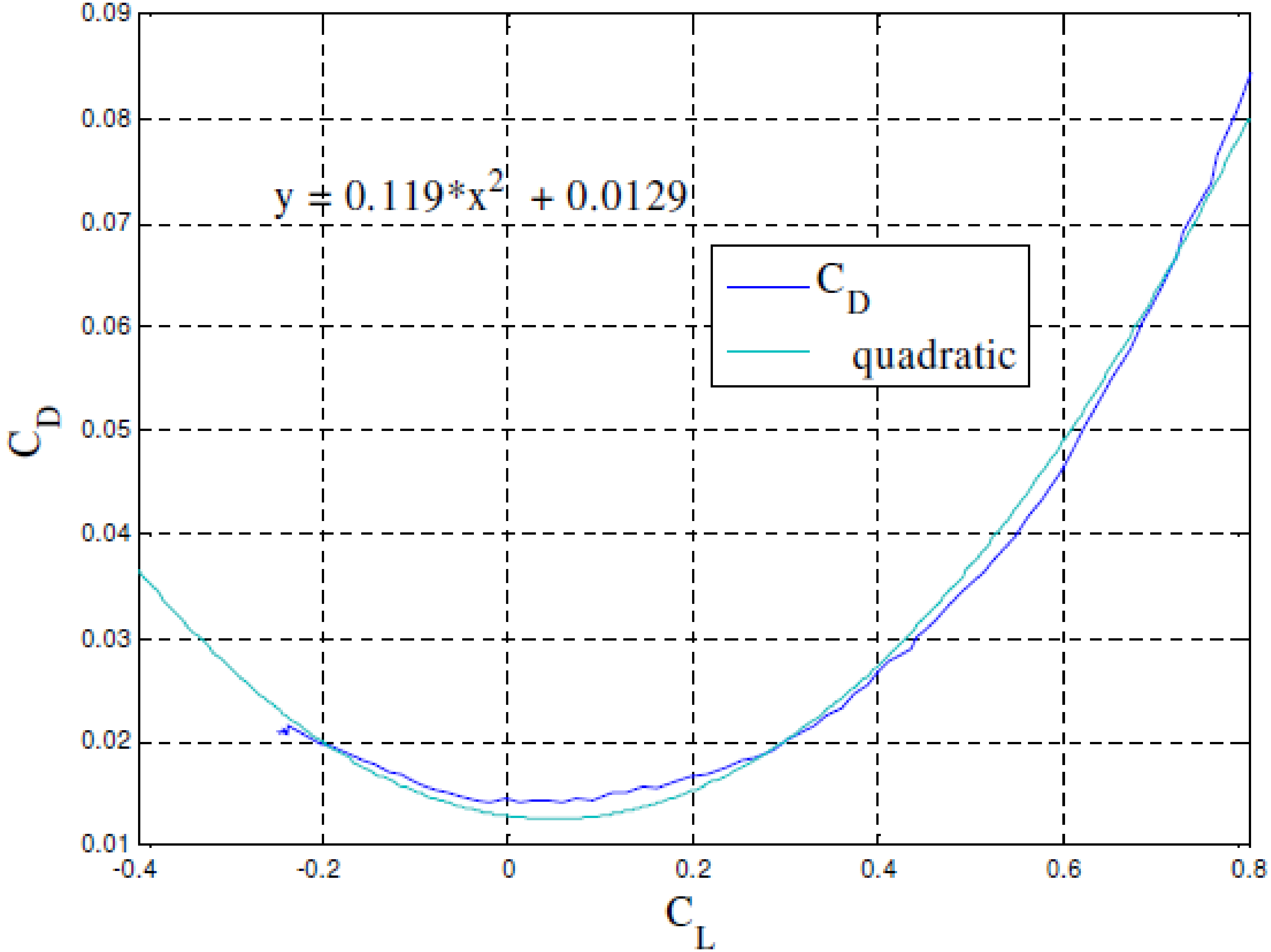
Comparison between the measured and calculated (linear) lift coefficients as a function of the angle of attack.



The measured lift coefficient as a function of the angle of attack; $C_{L\,max} = 1.04$ at $\alpha = 17.6°$.



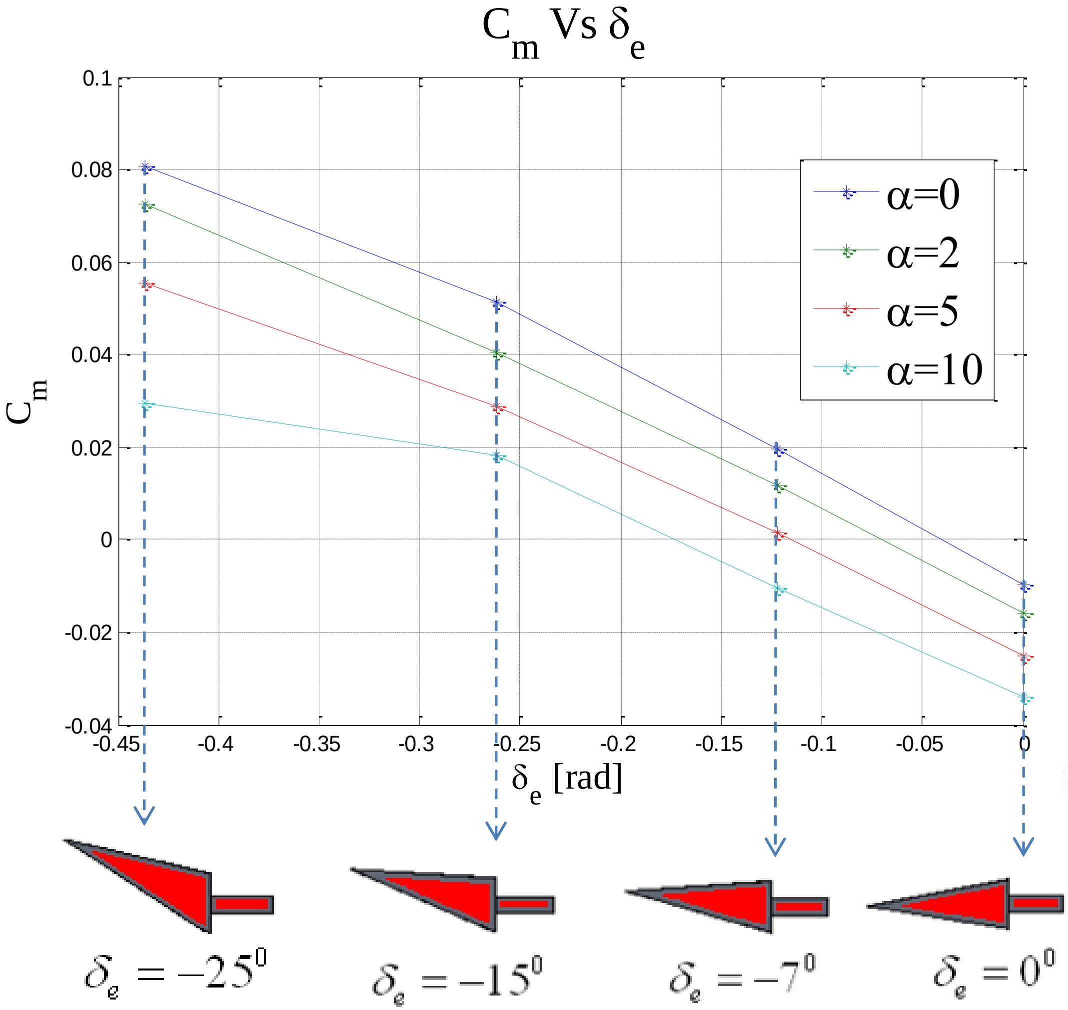
Measured and calculated (quadratic) drag coefficient vs. lift coefficient



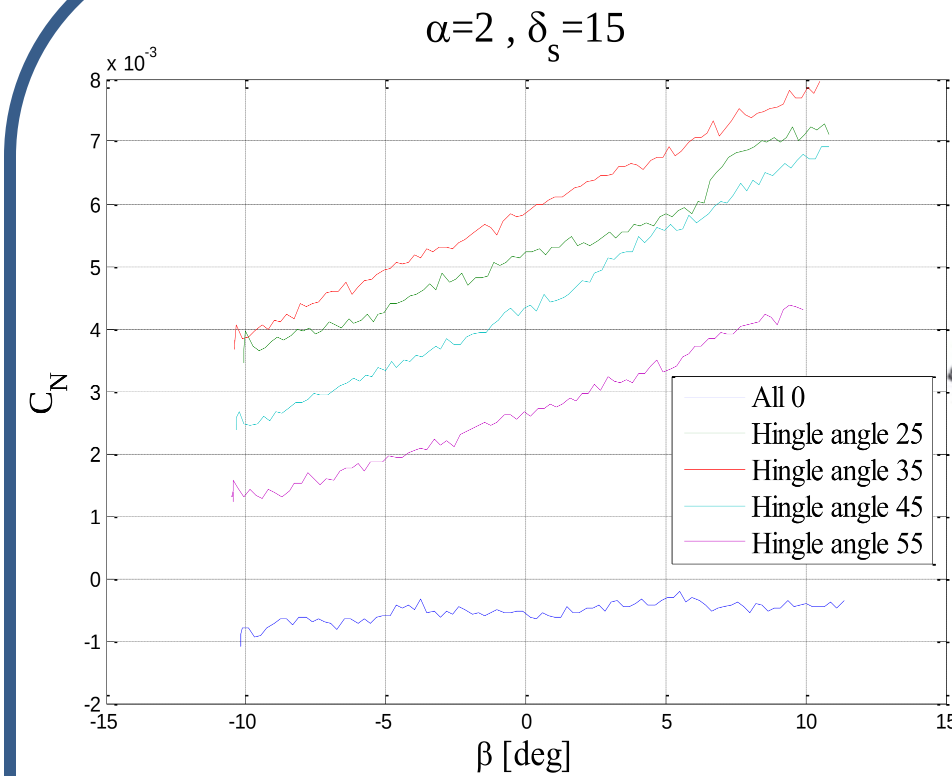
The wind tunnel test results showed very good compatibility with the theory and similarity to the analysis results

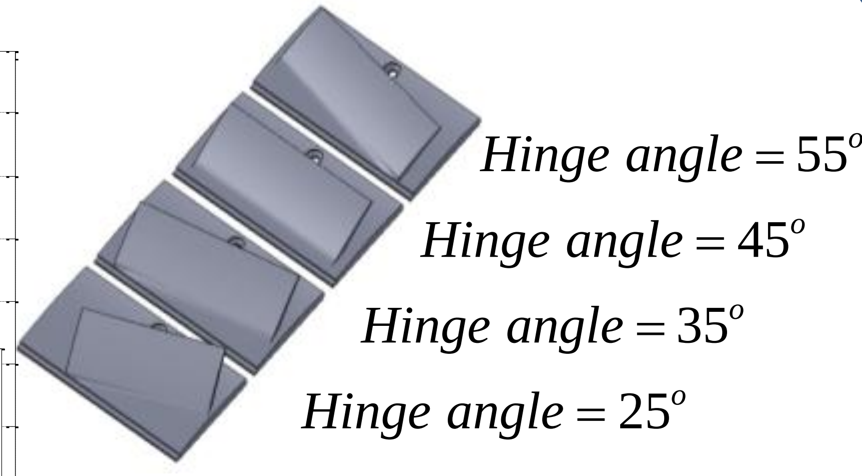
After establishing the level of confidence and proving the adequacy of the RP model, several tests for the controllability of the air vehicle have been conducted

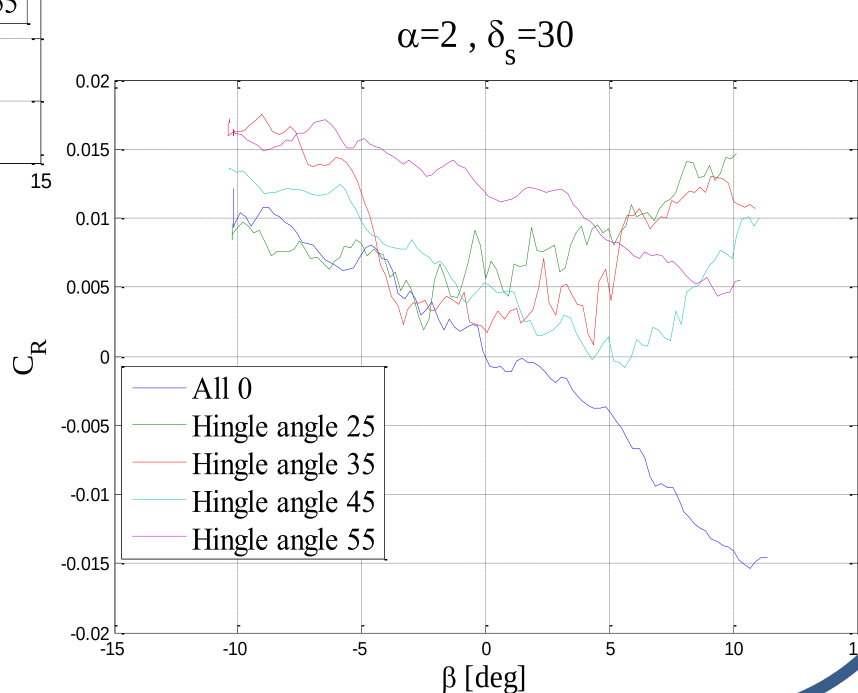
Measured elevator's influence



$$C_{m_{\delta e}} \cong -0.2[1/rad]$$







Spoiler at hinge angle of 35 deg produces the highest yawing moment, while having a low rolling moment

CONCLUSIONS & RECOMMENDATIONS

- Significant cost savings compared to traditional CNC machining of metal models.
- Significant time savings for the model production.
- Aerodynamic data of acceptable quality can be collected from RP models.
- Using RP techniques for production of wind tunnel models is adequate and sufficient for obtaining quick and accurate enough results.
- RP can definitely be used for quick, low-cost performance evaluation of new air vehicles and for verification of analyses results.

Questions ?

Small, detailed spoilers fabricated for the wind tunnel testing