PROJECT PLACIS: MINIBEE

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DESIGN OF THE PROJECT

The development process of lightweight subsonic aircraft can be broke down on the following procedures:

- Specification and requirements
- Initial Study
- Initial Project
- Project
- Manufacturing
- Ground Tests
- Flight Tests

These procedures were proposed by BARROS, and compose a synthesis of the four main methodologies on the aeronautic field: The works of TORENBECK, RAYMER, ROSKAN and VANDAELE

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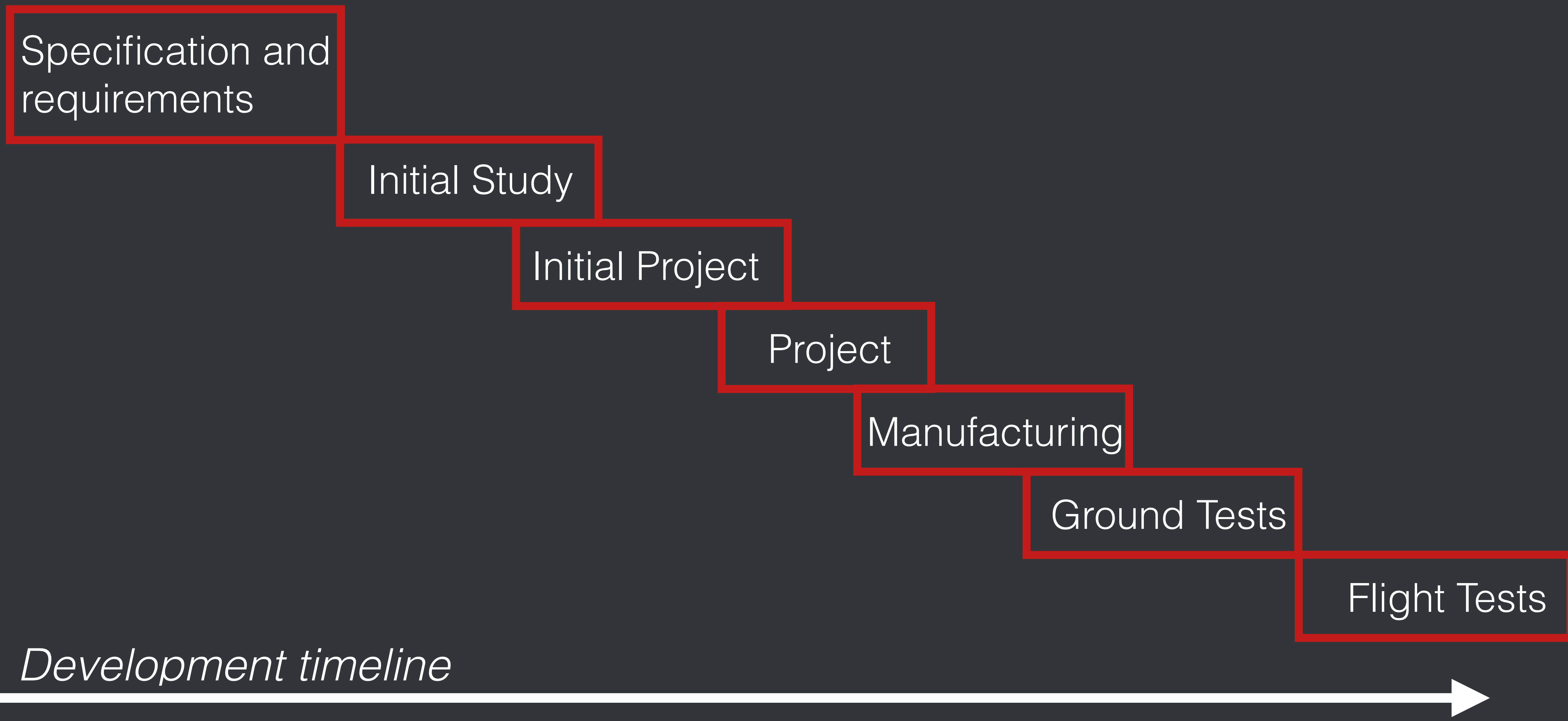

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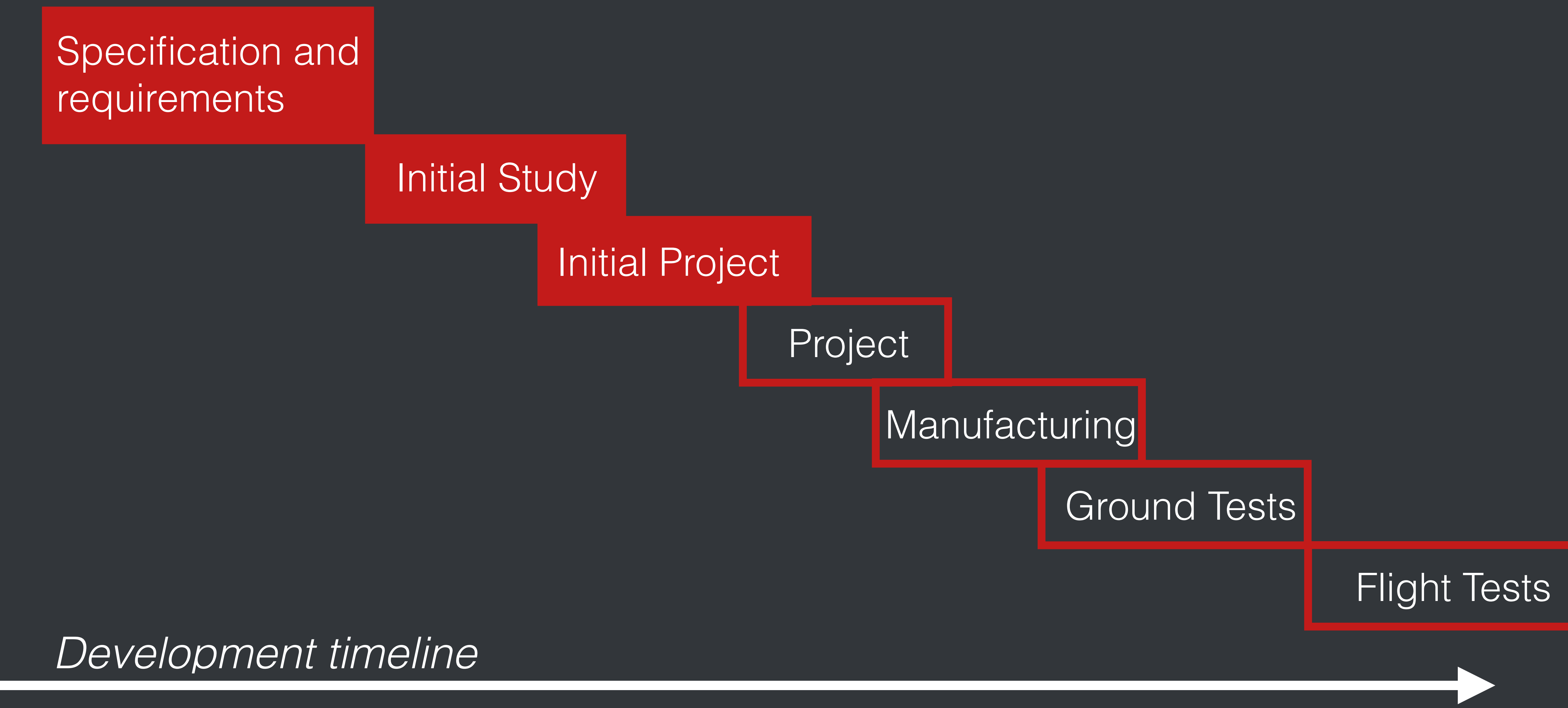

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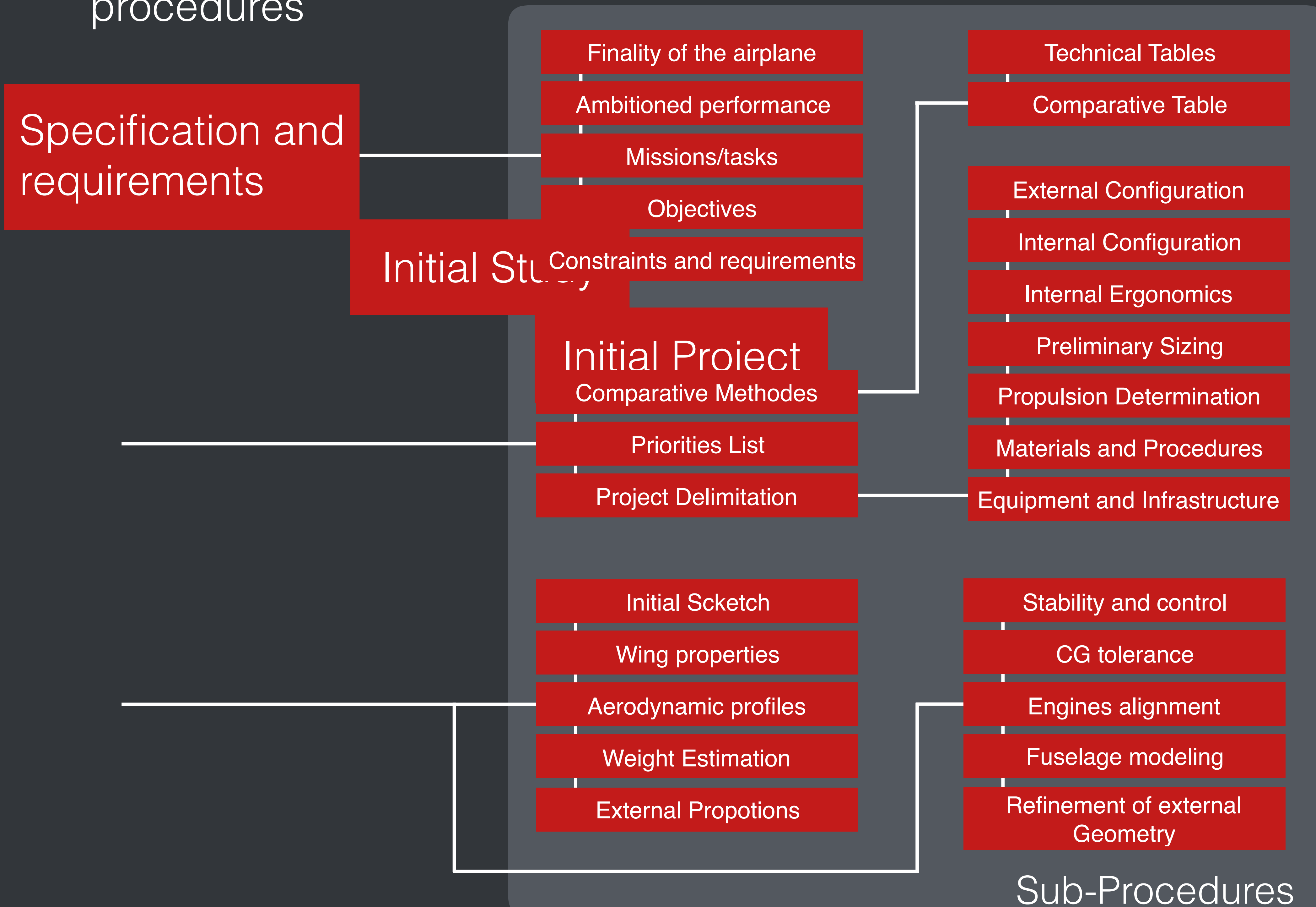
DESIGN OF THE PROJECT

Each of these procedures can be broke down in so called "Sub-procedures"



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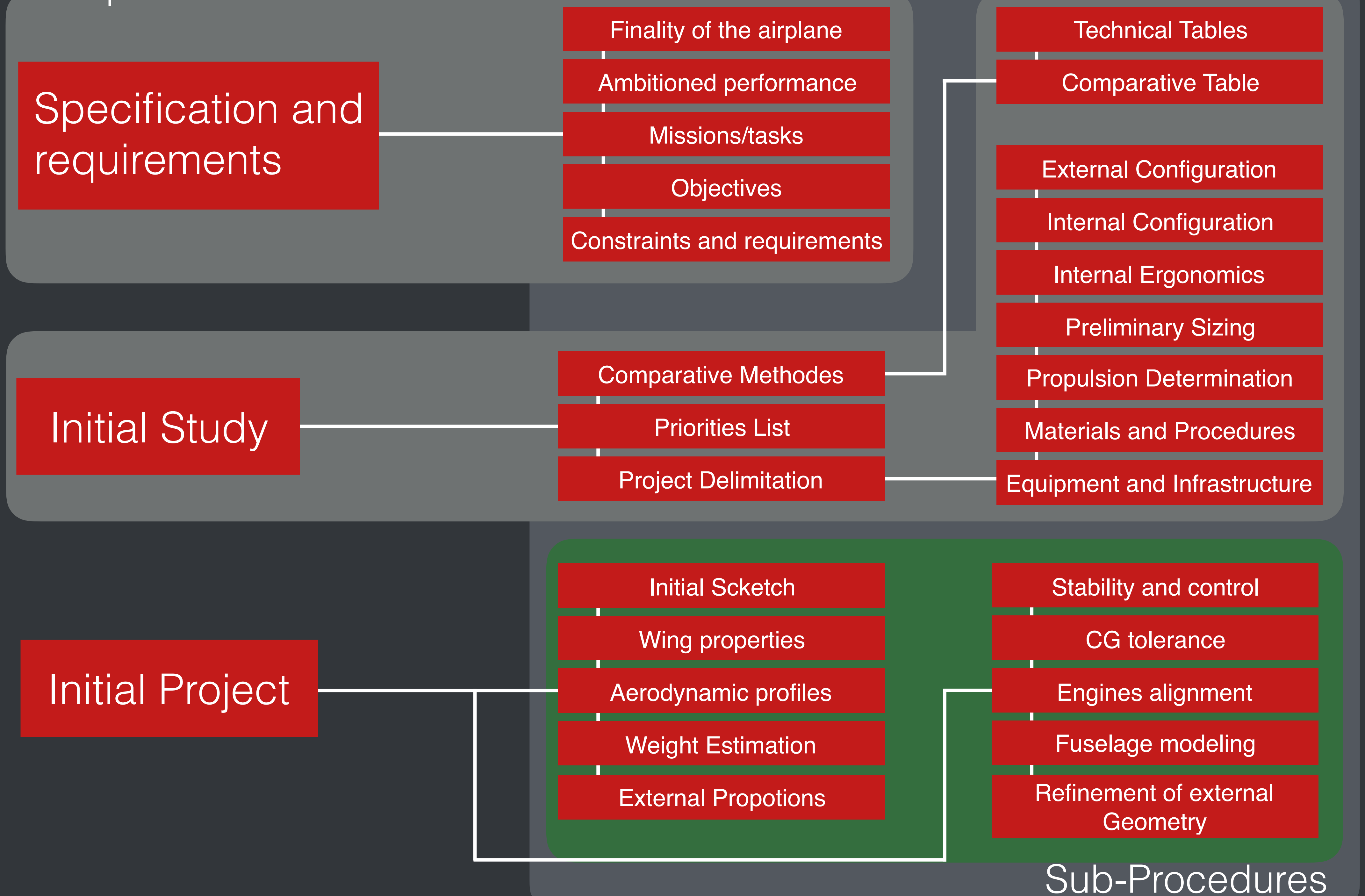

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PROJECT MANAGEMENT

1. Identify the main project areas, relate then, and set a hierarchy order between then

2. List the inputs and outputs of each of those areas to define the tasks that must be done

3. Relate 1 and 2 in a time board and divide the tasks between universities

PROJECT MANAGEMENT

1. Identify the main project areas, relate then, and set a hierarchy order between then
    - Concept Estimations
    - Aerodynamic Calculations
    - Performance Calculations
    - Force and Momentum Calculations
    - Structure Calculations
    - Detailed project of Systems and subsystems
2. List the inputs and outputs of each of those areas to define the tasks that must be done
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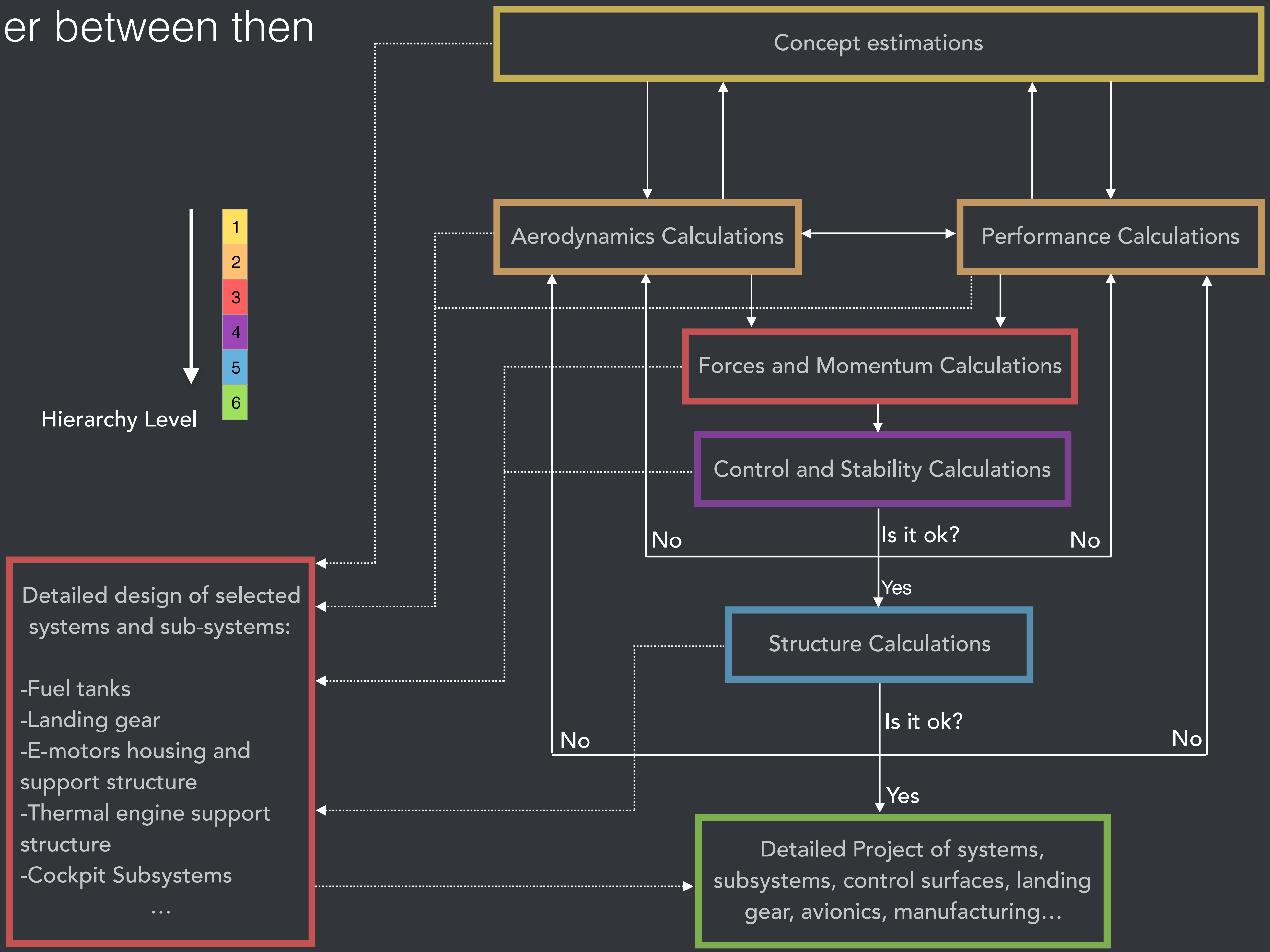

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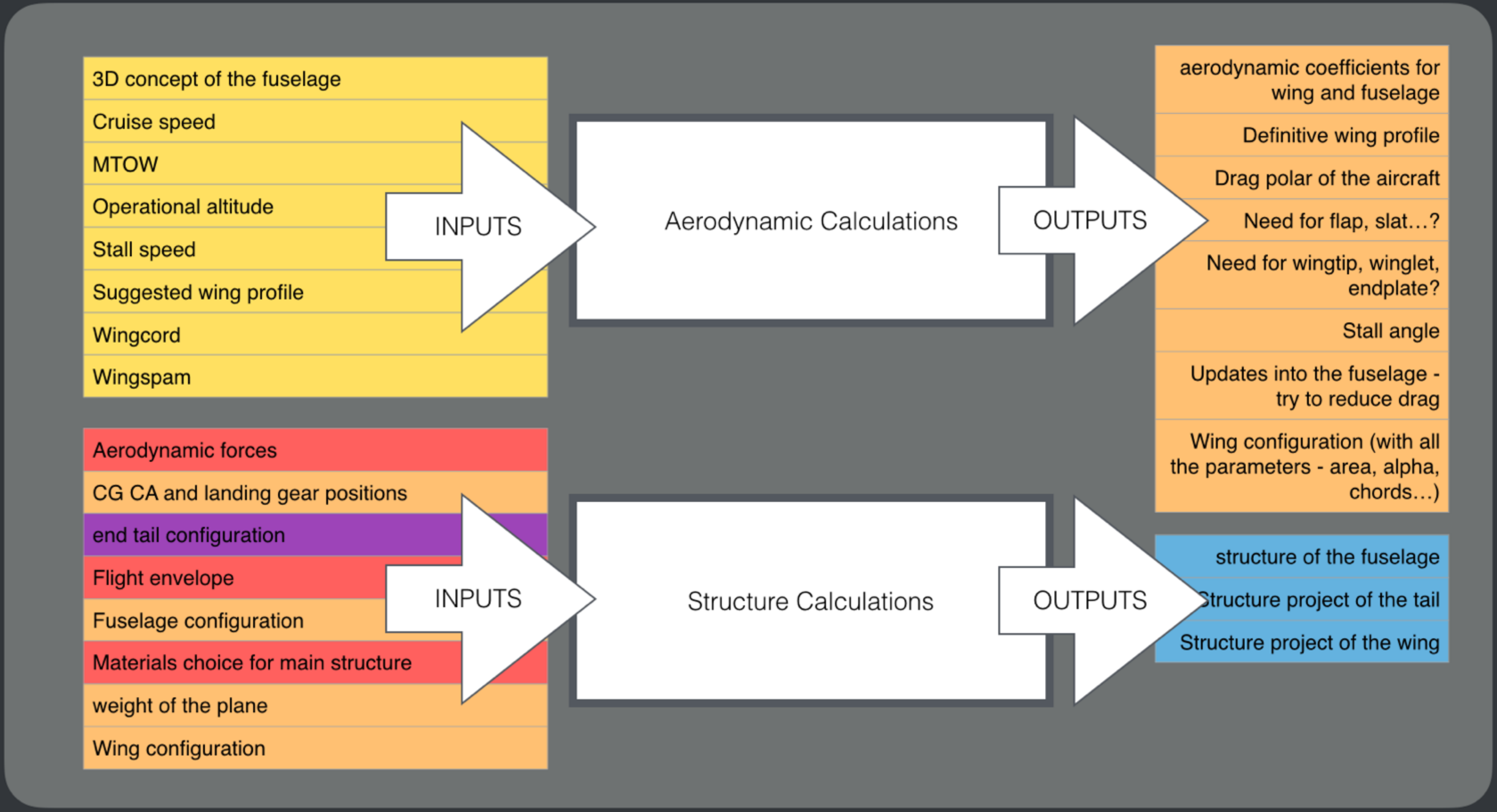

. . .

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PROJECT MANAGEMENT

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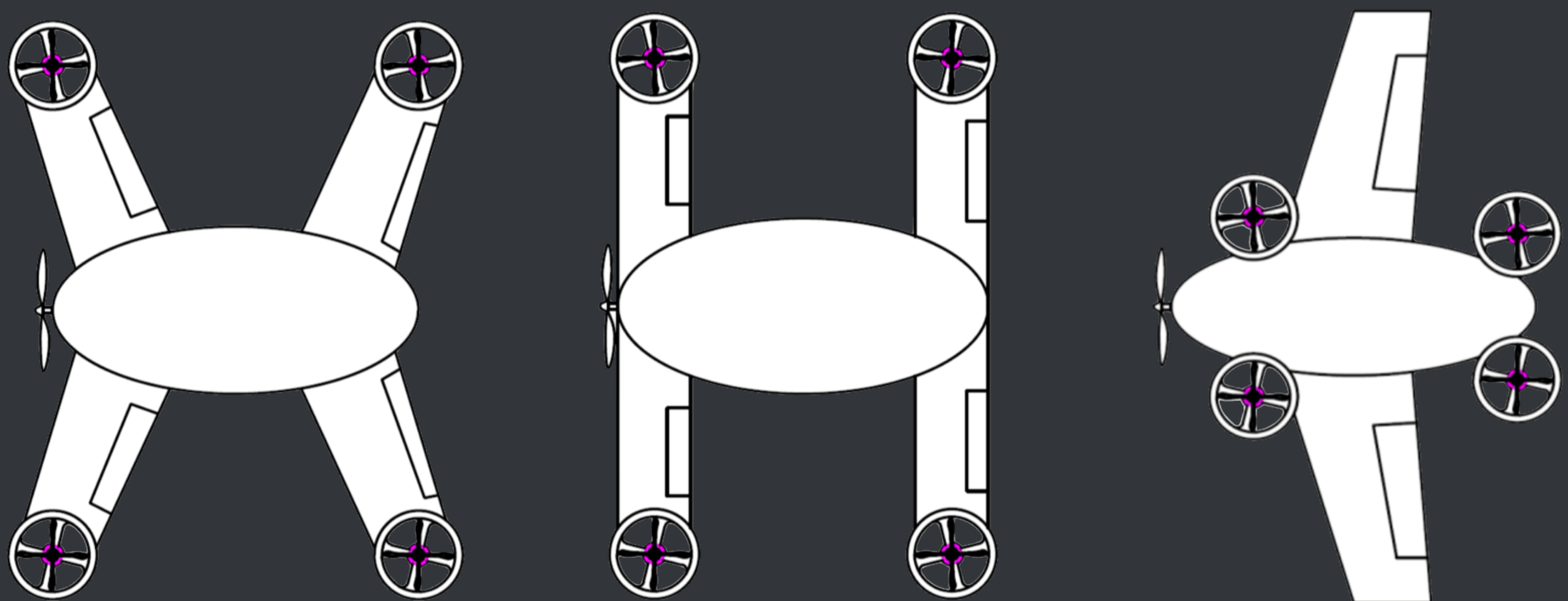
Tasks\Deadline	Completed? (/N)	11/Dec/2015	18/Dec 2015	25/Dec/2015	1/Jan/2016	8/Jan/2016	15/Jan/2016	22/Jan/2016	29/Jan/2016	5/Feb/2016
3D concept of the fuselage										
Autonomy										
Batteries estimation										
CG approximate position and allowed movement		Supméca	Supméca							
CG position		Supméca	Supméca							
Choice of engines										
Client requirements										
Cruise speed										
Early calculations and estimations										
Empty weight										
Existing products										
General dimensions										
Ideas of the team										
Law regulations										
Literature guidelines and references										
Motor caracteristics										
Motor geometry and size										
MTOW										
Number of passengers										
Operational Altitude										
Pilot visibility requirements		Estaca	Estaca							
possible comercial aplicatoins										
Propeller size and characteristics										
Proposed engines										
Sketch architecture										
Sketch geometry										
Stall speed										
Sugested propellers		Supméca	Supméca							
Suggested wing profile										
Supplied power										
Wing cord										
Wingspam										
aerodynamic coefficients for wing and fuselage		Supméca	Supméca	Supméca	Supméca	Supméca	Supméca	Supméca	Supméca	Supméca
Allowed geometry and contours for the fuel tank										
CG and CA positions		Supméca	Supméca	Supméca	Supméca	Supméca				
Critical landing forces		Supméca								
curves like power vs speed, required power vs. available power…								Central	Central	Central
Definitive batteries		Estaca	Estaca							
Definitive engine location		Estaca	Estaca							
Definitive propellers		Estaca	Estaca							
Definitive wing profile										
Drag polar of the aircraft		Supméca	Supméca	Supméca	Supméca	Supméca	Supméca	Supméca	Supméca	Supméca
Fuel consumption		Polito								

Fuselage configuration		Supméca	Supméca							
Geometry of the plane										Supméca
Landing gear position			Estaca							
Major systems and subsystems position		Polito								
Material choice for the fuselage		Estaca								
Maximum speed				Central	Central	Central				
Minimum speed				Central	Central	Central				
e-Motor location		Estaca								
Need for flap, slat…?						Supméca	Supméca			
Need for wingtip, winglet, endplate?		Supméca	Supméca	Supméca	Supméca	Supméca	Supméca	Supméca		
Position of the thermic engine		Estaca								
Rate of ascent		Central	Central							
Required power		Central	Central							
Stall angle						Supméca	Supméca			
Static stability parameters		Estaca								
take off speed				Central	Central	Central	Central			
Updates into the fuselage - try to reduce drag							Supméca	Supméca	Supméca	
Velocity of the plane				Central	Central	Central				
Weight of the plane		Supméca	Supméca							
Wing configuration		Supméca	Supméca	Supméca	Supméca	Supméca	Supméca	Supméca	Supméca	Supméca
Wing configuration (with all the parameters - area, alpha, chords…)		Supméca	Supméca	Supméca	Supméca	Supméca	Supméca	Supméca	Supméca	Supméca
Wing dimensions		Supméca	Supméca	Supméca	Supméca	Supméca	Supméca	Supméca	Supméca	Supméca
Aerodynamic forces									Supméca	Supméca
Cockpit internal geometry				Estaca	Estaca	Estaca				
Detailed project of e motor housing		Supméca				Supméca	Supméca	Supméca	Supméca	Supméca
detailed project of fuel tank				Polito	Polito	Polito	Polito			
Detailed project of landing gear			Supméca	Supméca	Supméca	Supméca				
Flight envelope								Central	Central	Central
Forces and momentums needed for control and stability								Central	Central	Central
Forces and momentums needed for the structures calculations								Central	Central	Central
Fuel tank geometry and location			Polito							
Fuel tank weight				Polito	Polito	Polito	Polito			
e-Housing and structures geometry		Supméca								
Landing gear geometry			Supméca	Supméca	Supméca	Supméca				
Materials choice for main structure							Estaca	Estaca	Estaca	
passenger diposition on cockpit				Estaca	Estaca	Estaca				
Structure requirements of cockpit							Estaca	Estaca	Estaca	
Command surfaces configuration and dimensions										
Dimension and position of end tail										
end tail configuration										
structure of the fuselage										
Structure project of the tail										
Structure project of the wing										

3. Relate 1 and 2 in a time board and divide the tasks between universities

AIRCRAFT CONFIGURATION

The first dilemma of MiniBee:



X H A

AIRCRAFT CONFIGURATION

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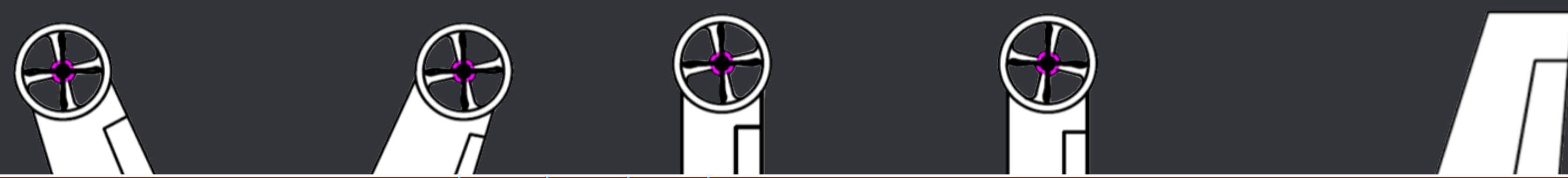
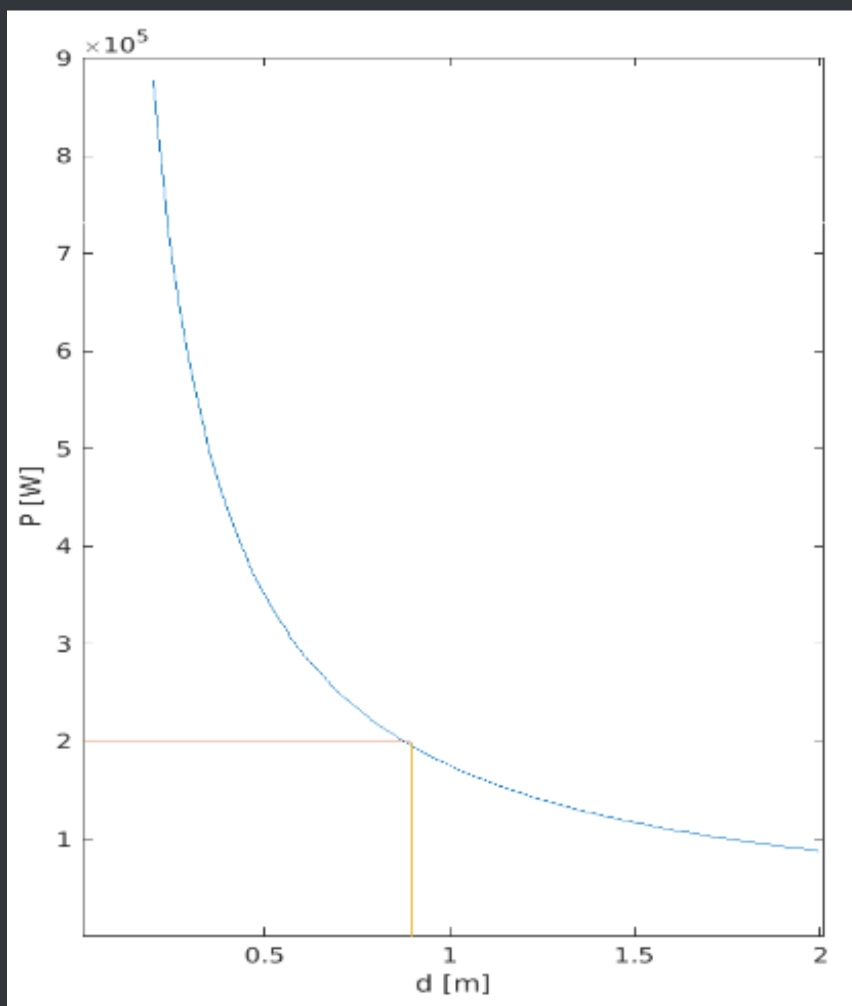


	A	X	H	
ROTORS LOCATION	2	5	5	1=DIFFICULT TO CONTROL/LOWER STABILITY
SMALL CONTROL SURFACES	4	2	2	5=EASY TO CONTROL/HIGH STABILITY
SWEEP ANGLE	4	1	4	
WING LOCATION	4	1	2	1=NOT "CLEAN" AERODYNAMICS
ROTORS LOCATION	3	1	1	5="CLEAN" AERODYNAMICS
SWEEP ANGLE	5	2	5	1=HEAVY STRESSED STRUCTURE
ROTORS LOCATION	4	2	2	5=LIGHT STRUCTURE
SUM	26	14	21	

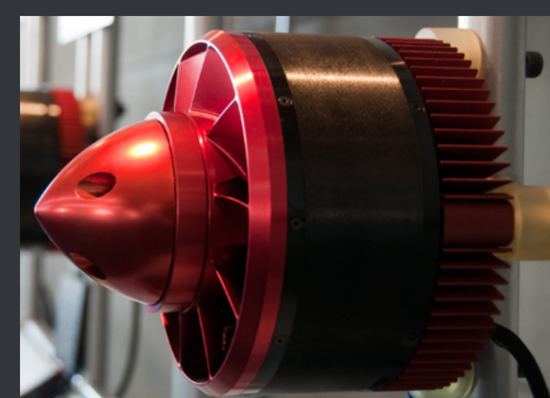
Power and diameter estimation



Power: 200 kW
Diameter: 0.9 m

Comparison

		Yuneec Power Drive 40	Siemens Concept	Emrax 268
Dimensions	Length	163 mm		91 mm
	Width	240 mm		268 mm
	Height	240 mm		268 mm
Weight		19 kg	50 kg	20,3 kg
Power		40 kW at 2400 rpm	260 kW	80 kW at 4000 rpm
Power to weight ratio		***2,1 kW/kg***	***5,2 kW/kg***	***4 kW/kg***



Yuneec Power Drive 40

Emrax 268

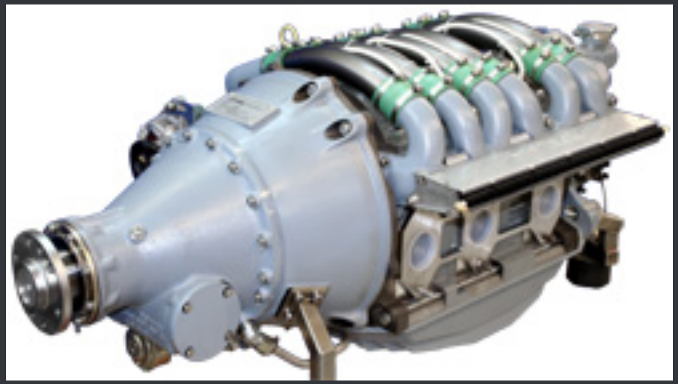
Siemens Concept

Thermic engine position

- Tractor installation
- Pusher installation

Diesel Engine vs Rotary Engine

Characteristic	SMA SR305-230E		MISTRAL G300	
	Data	N	Data	N
Reliability		2		2
Robustness		2		3
Smooth rotation of the shaft		1		3
No thermic shock cooling		1		3
Low purchase cost	75,000 $	2	50,000€	3
High power to weight ratio	1.1(=230hp/206Kg) hp/kg	1	1.7(=300hp/177kg) hp/kg	3
Compact size	834*931*784 [mm]	1	632*1145*486 [mm]	3
Simple construction		1		3
Temperature gradient		3		1
Low cost fuel	Diesel 8.06 $/gallone	3	10LL avgas 12.68 $/gallone	2
TOT		17		26

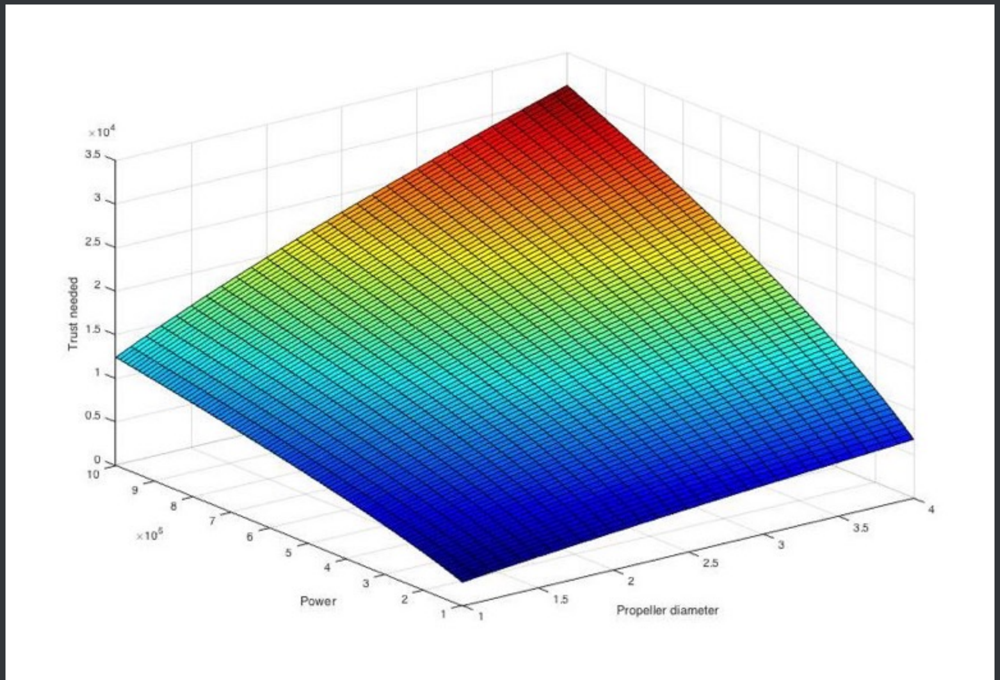


Mistral G300

SMA SR305-230E

PROPELLER DESIGN

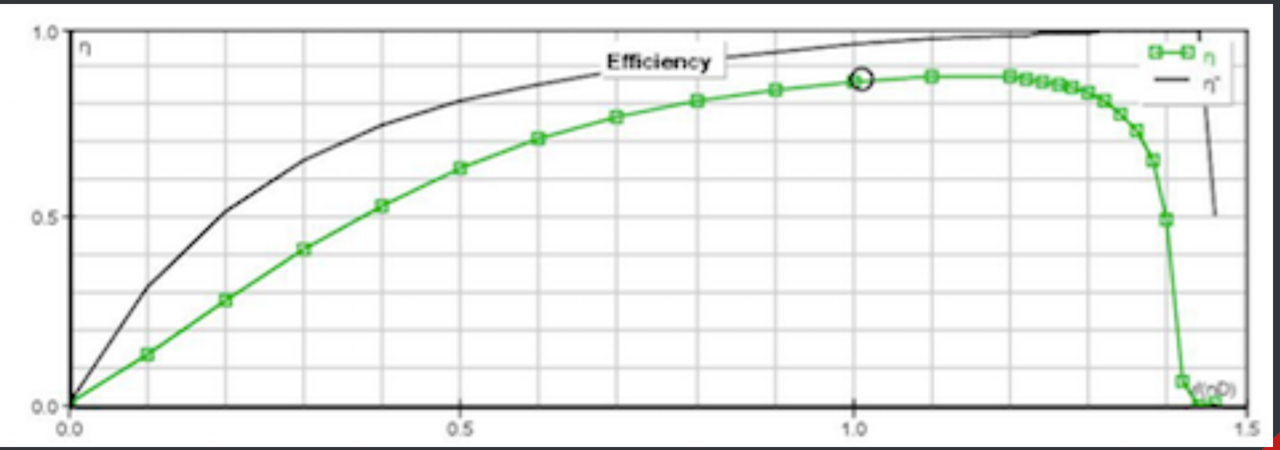
First sizing and DAT



Design

- Blades number: 3
- Flow axial velocity (v): 84 m/s
- Propeller diameter: 2.2 m
- Profiles used for blades
- Available Power: 220 kW
- Air Density: 1.22 kg/m^3

Analysis



Pitch:

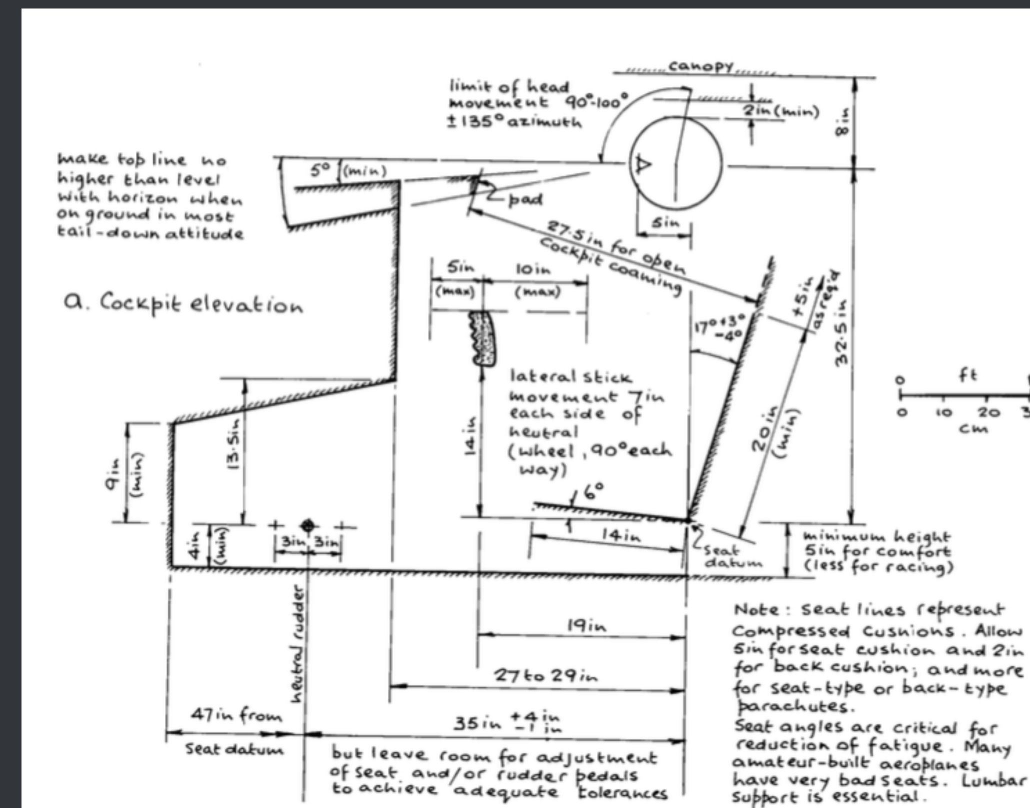
- Fixed pitch
- Variable pitch on the ground
- Variable pitch

DESIGN OF FUSELAGE

Fuselage is a very important part during the design of an aircraft because it should housing both payload and systems and it is also the structural element who takes together all the aircrafts parts.

Characteristics	Mark
Pressurization	1
Pilot position and visibility	2
Payload	3
Aerodynamic	3
Access door	2
Engine position	1
Boarding system	2
Wings and electric propeller position	1
Structure	2
Vertical and horizontal tail	2
Low cost	1

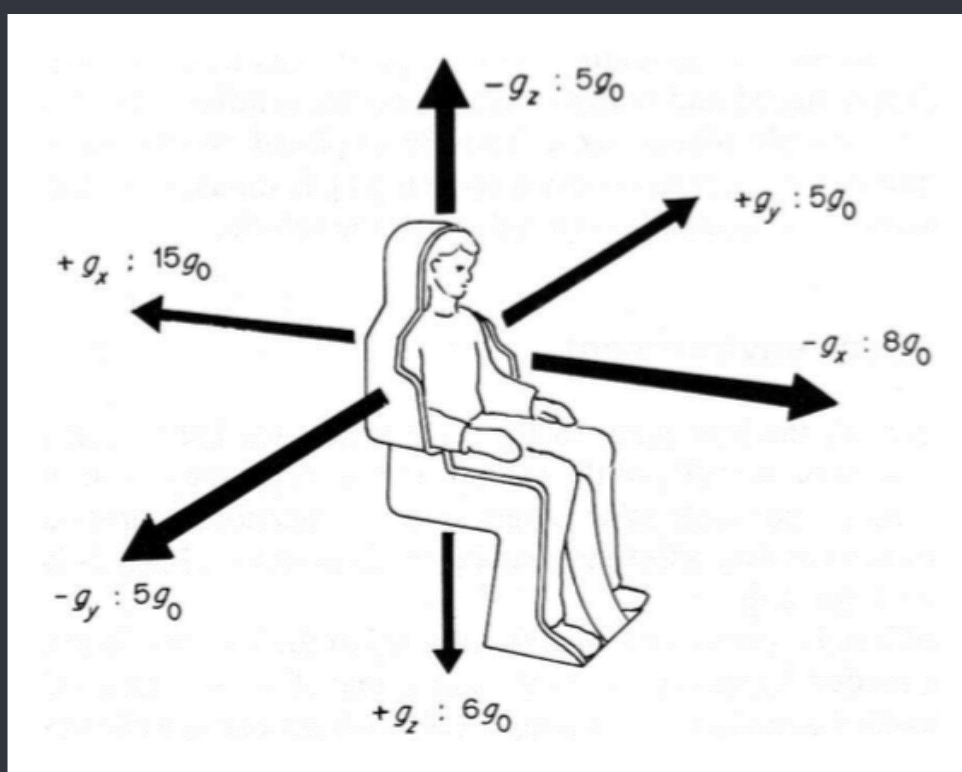
Pilot position and visibility



Pressurization:

- Low differential pressure
- Normal (high) differential pressure
- No pressurisation

Payload



Access door:

- wings and rotors presence
- possibility of transport of patiences

Back door

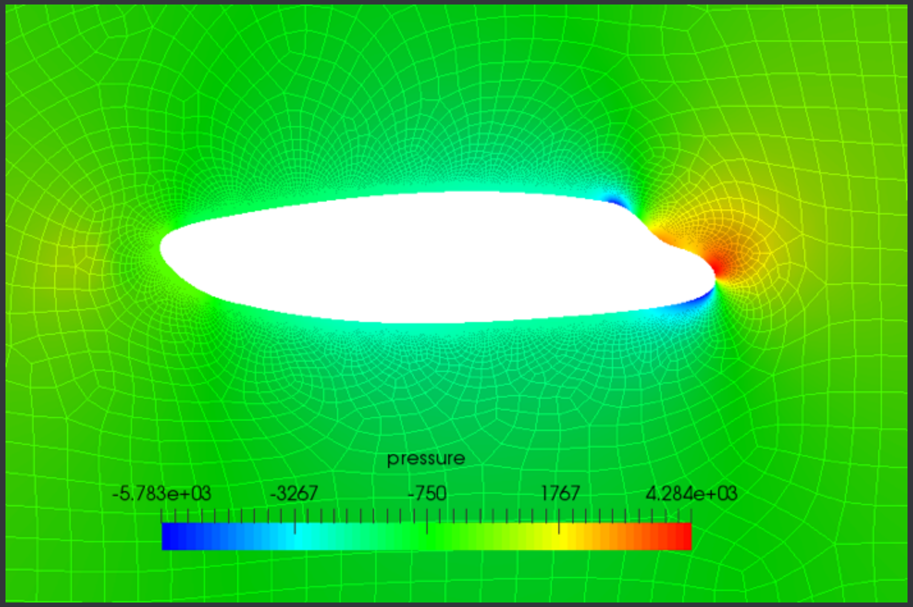
Boarding system

DESIGN OF FUSELAGE

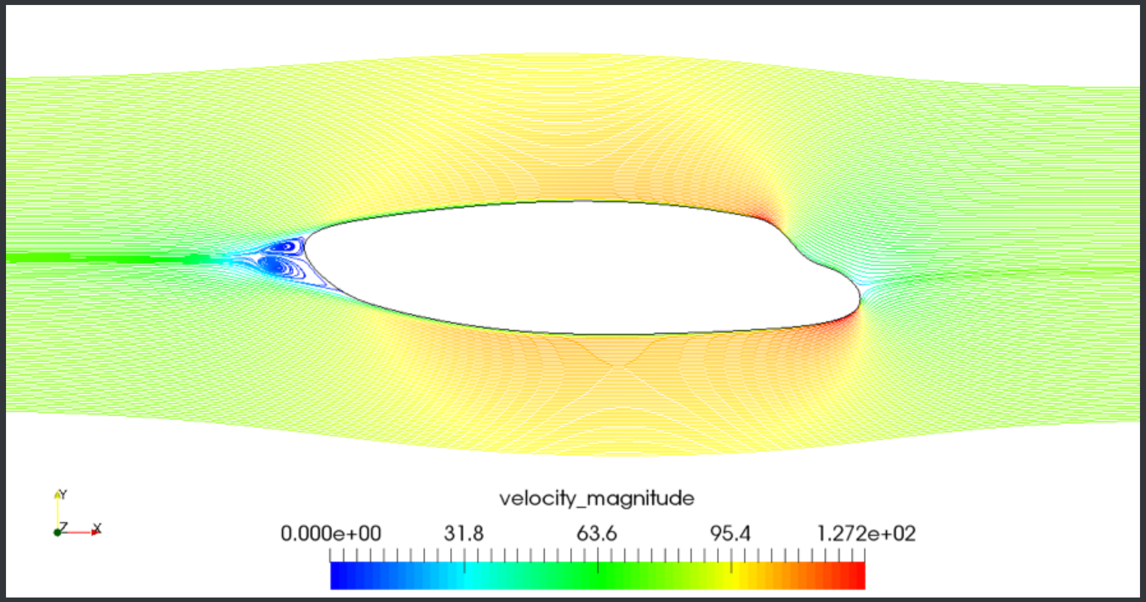
Aerodynamic study

It has been decided to carry out a 2D cross-section fuselage CFD analysis. It is possible to note how the profile of the fuselage can be update to reduce Drag.

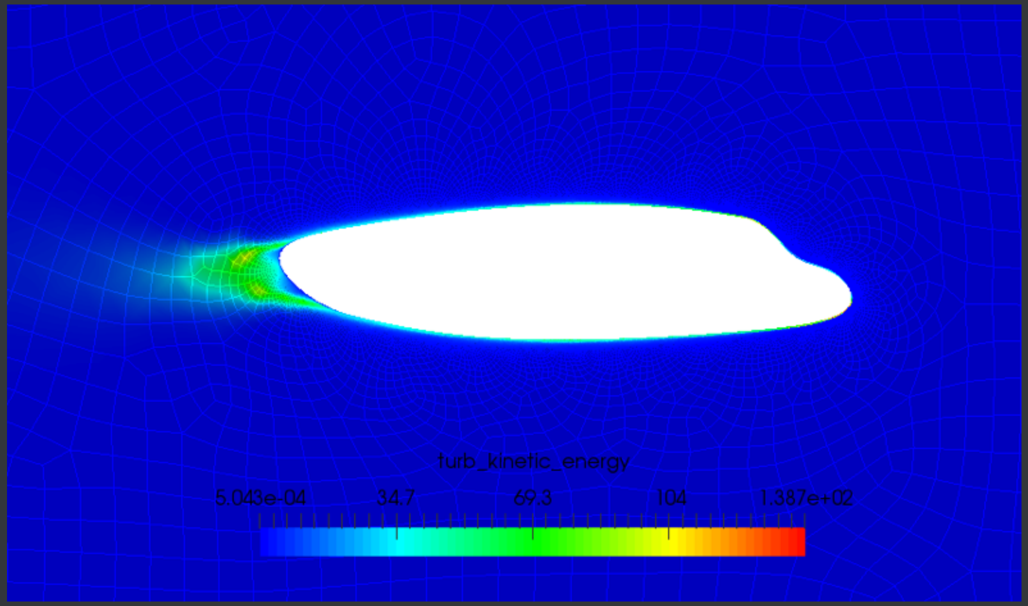
Pressure



Velocity magnitude



Turbulent kinetic energy



DESIGN OF FUSELAGE

Engine position
Tractor configuration
Front position

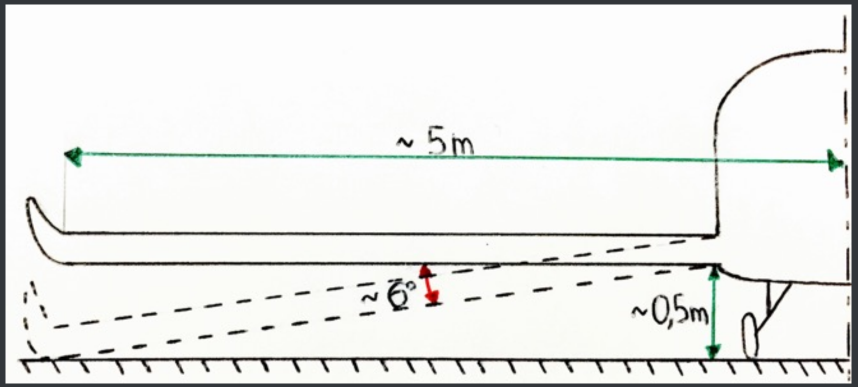
Vertical and horizontal tail
Single central vertical tail
High horizontal tail

Structure:
Simplicity in construction
Low level of stress

Low cost

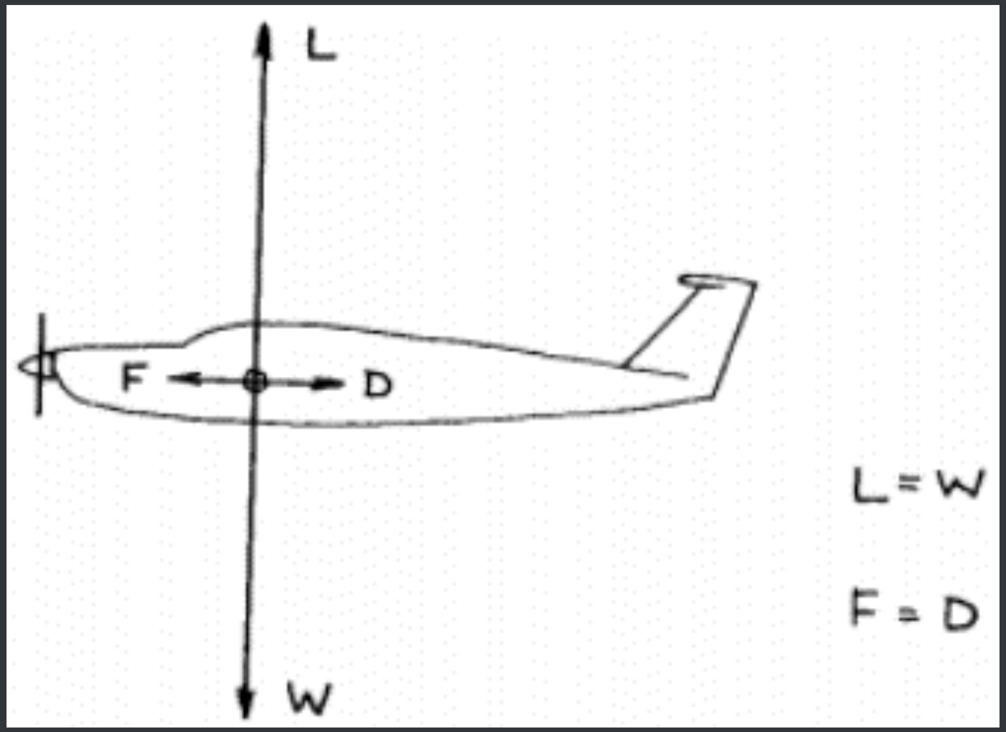
Wings and electric propeller position:
Possible wings position:
-Midi wings
-Low wings
-High wings

	Mid wing	Low wing	High wing
aerodynamics	3	2	2
stability	2	1	3
structure	1	3	3
visibility	2	1	3
landing inclination	2	1	3
	10	8	14



Electric propeller position:
Medium Height

WING DESIGN

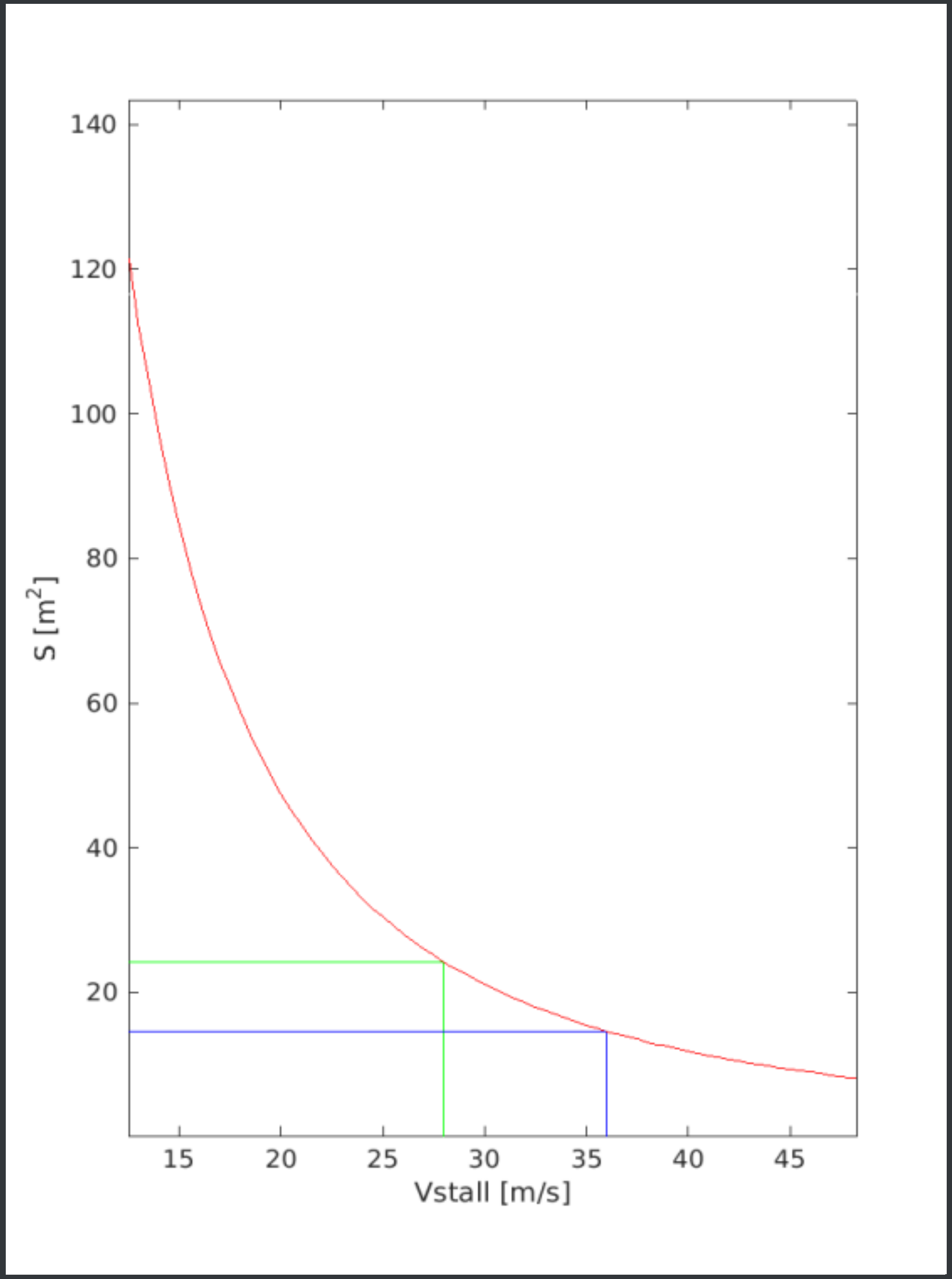


$$L = MTOW = \frac{1}{2} * \rho * Vstall^2 * Clmax * S$$

Maximum Take Off Weight

Stall Speed

Maximum Cl coefficient

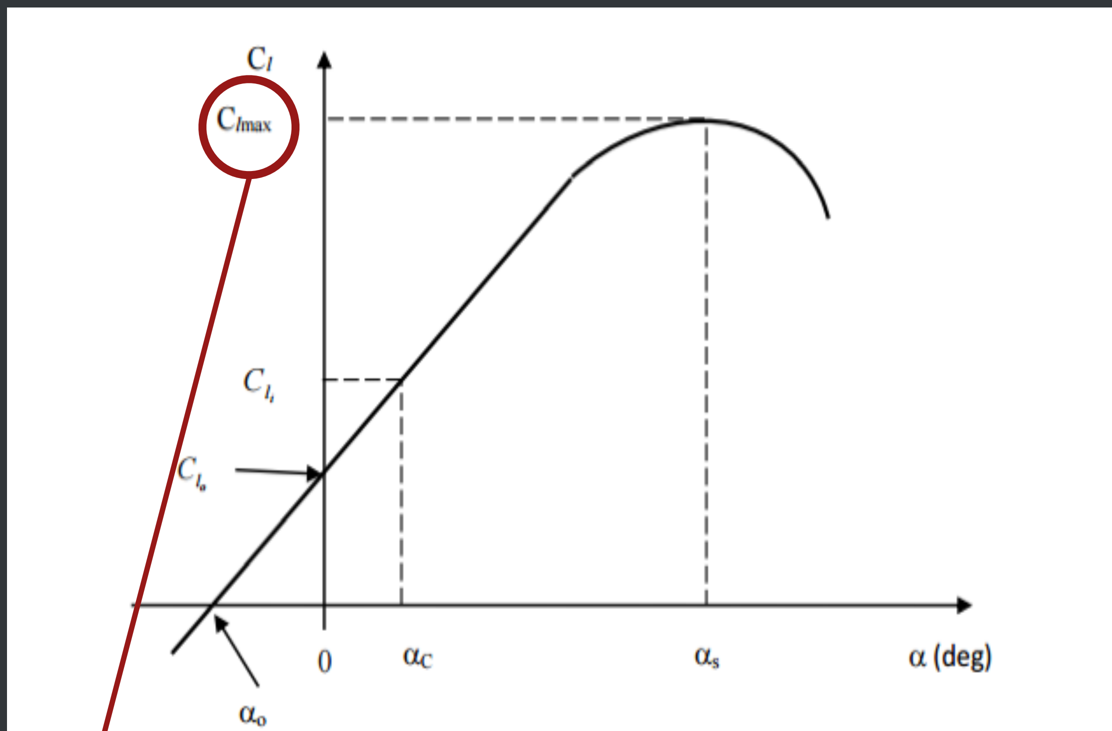


STALL SPEED = 130 KM/H

WING SURFACE = 18 M2

WING DESIGN

Requirement		NACA 23018	NACA 65_2-415	NACA 64_2-415	NACA 65_1-412
Highest maximum lift coefficient	30%	4	5	5	5
Proper ideal lift coefficient	25%	4	4	4	4
Lower minimum drag coefficient	25%	3	5	4	5
Highest lift-to-drag ratio	10%	2	3	3	4
Lowest Cmo	5%	2	3	3	4
Stall quality	5%	2	4	4	3
Proportional sum		3,35	4,4	4,15	4,5



Highest maximum lift coefficient

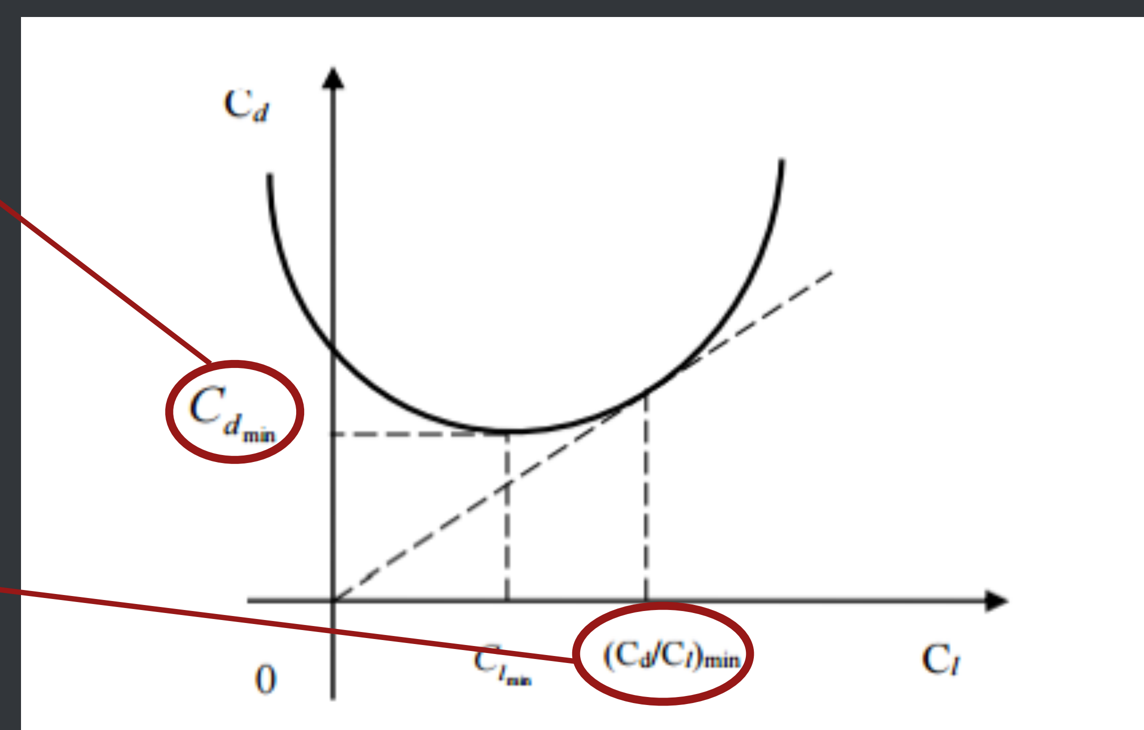
Lowest stall speed

Lower flightcost and the higher maximum cruise speed

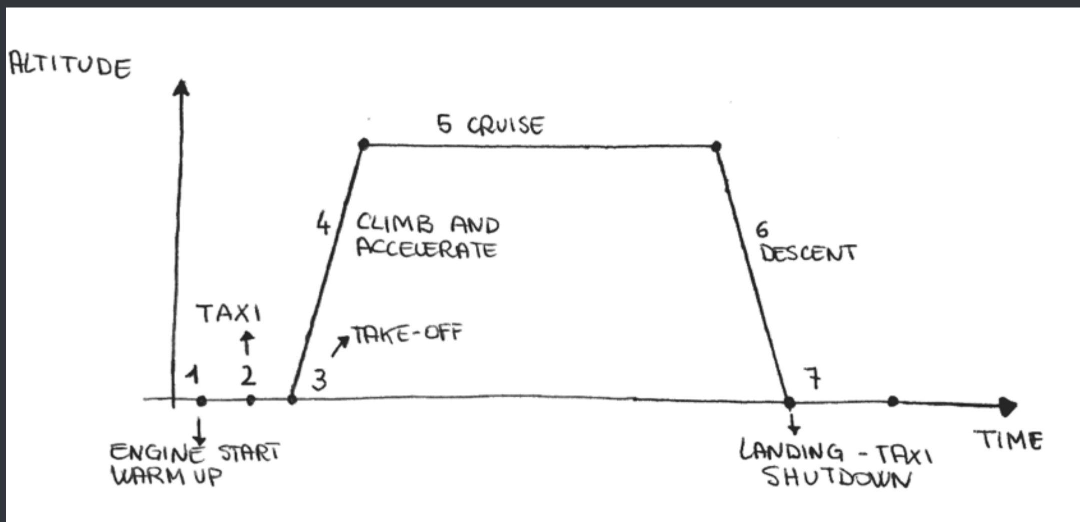
Minimum drag coefficient

Highest endurance

Highest lift-to-drag ratio



WEIGHT ESTIMATION

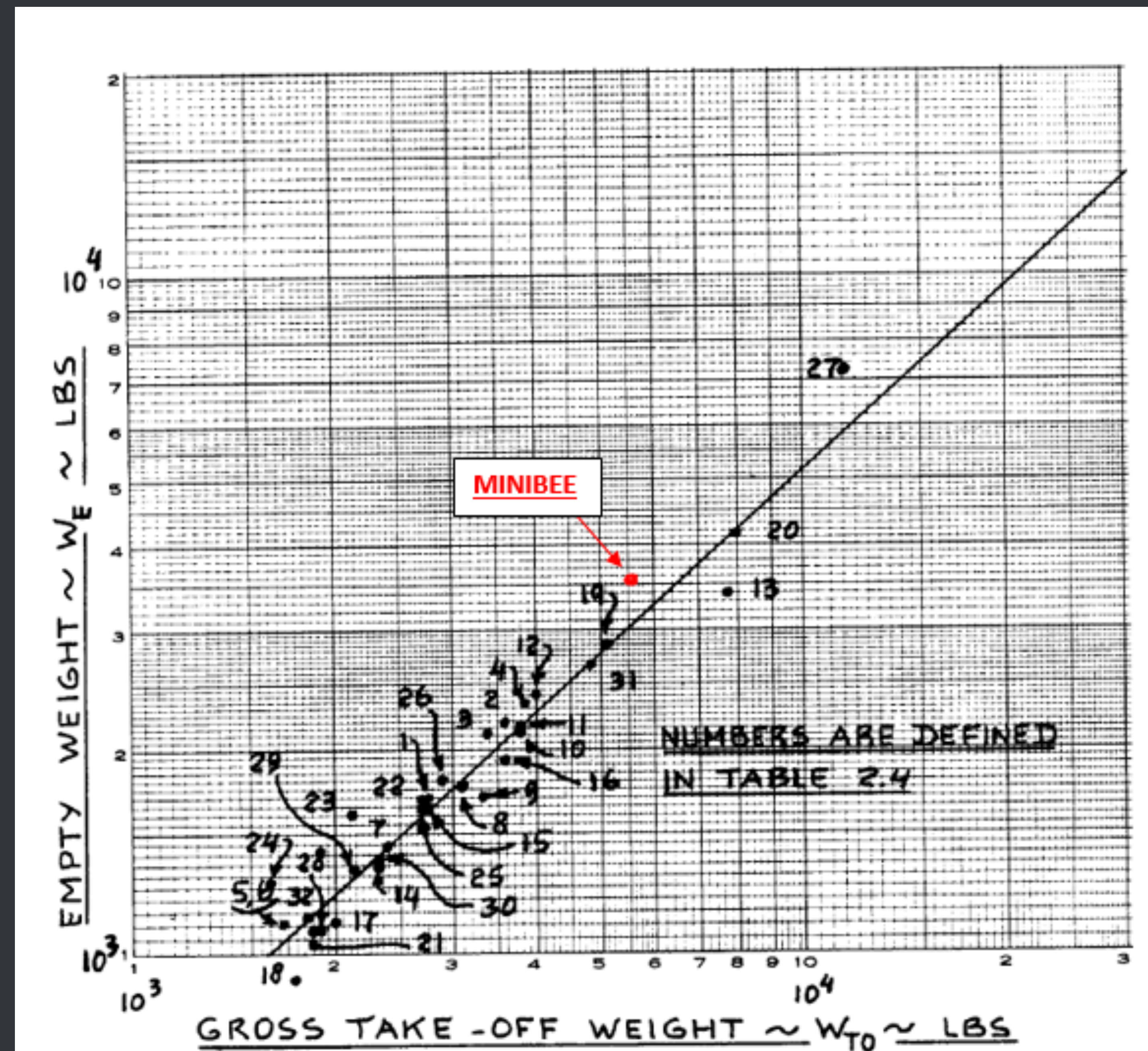


$$MTOW = Woe + Wf + Wpl$$

Fuel Weight

Operating empty weight 1665 kg

Payload Weight



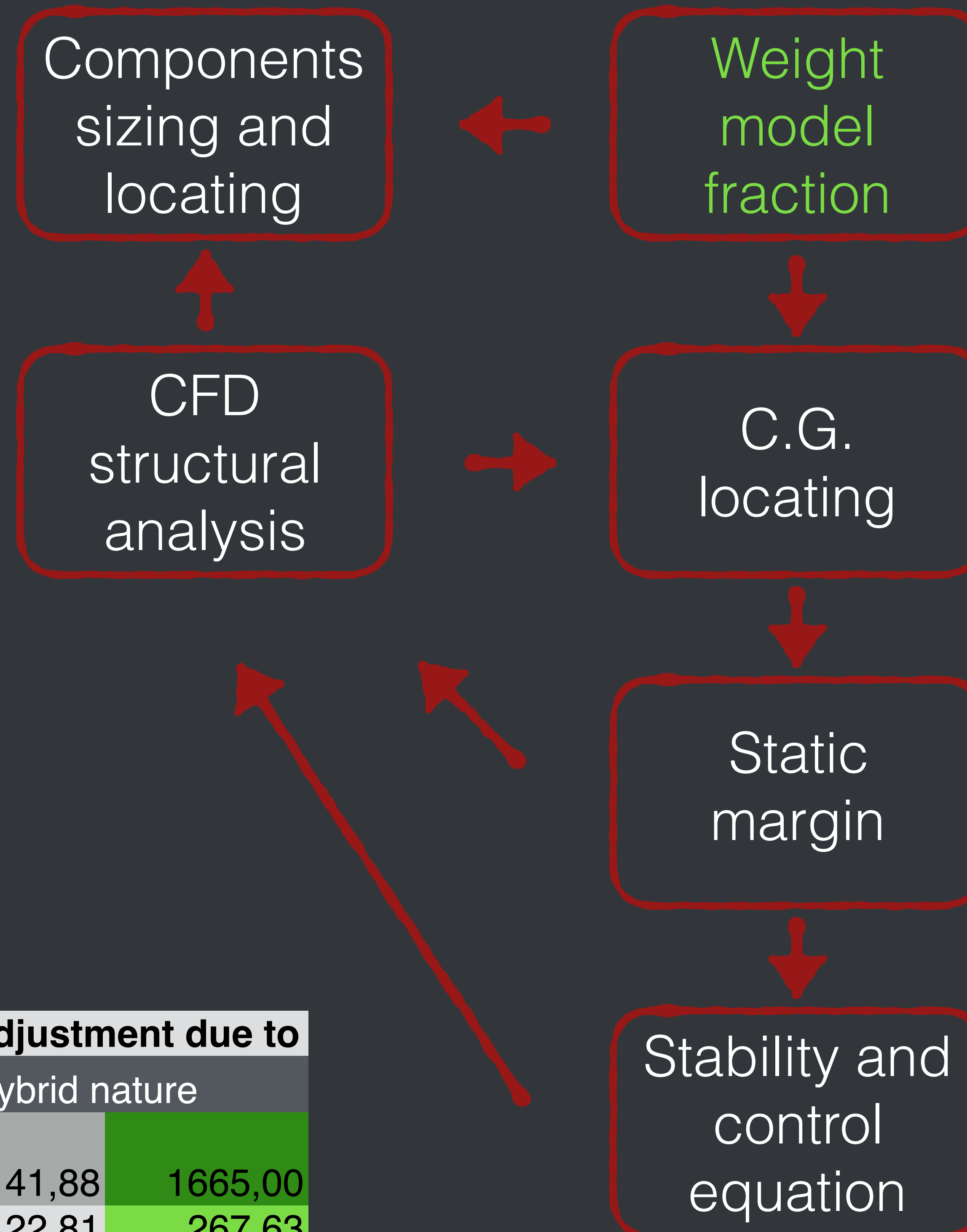
WEIGHT ESTIMATION

CESSNA 210 J

CESSNA 310

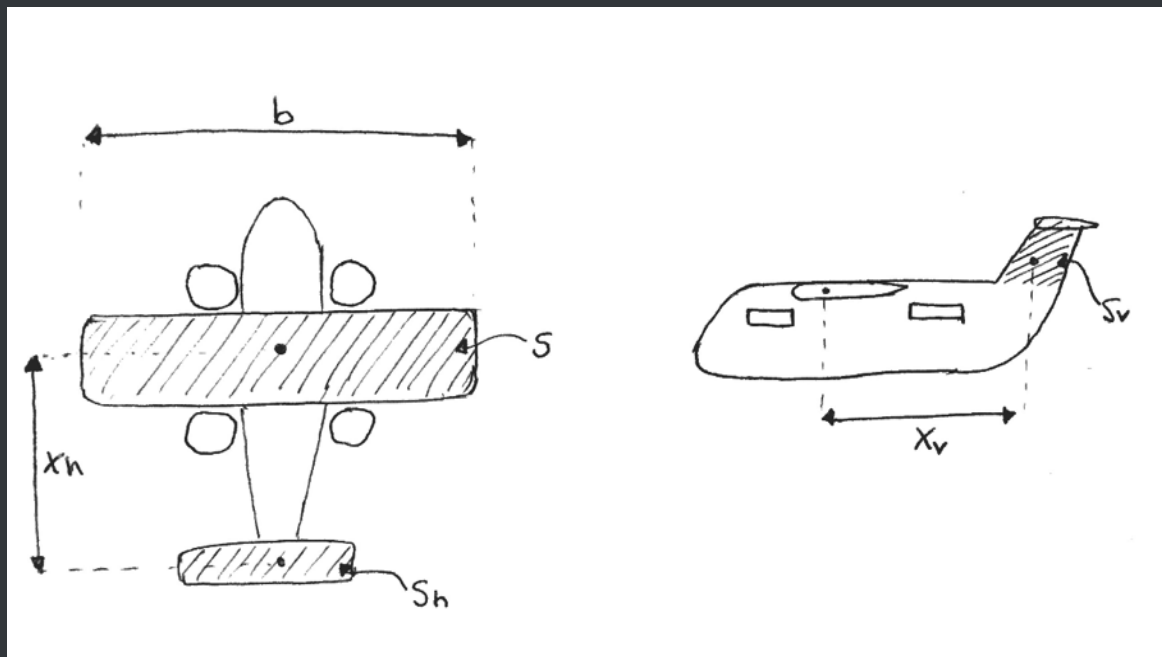
BEECHCRAFT 95

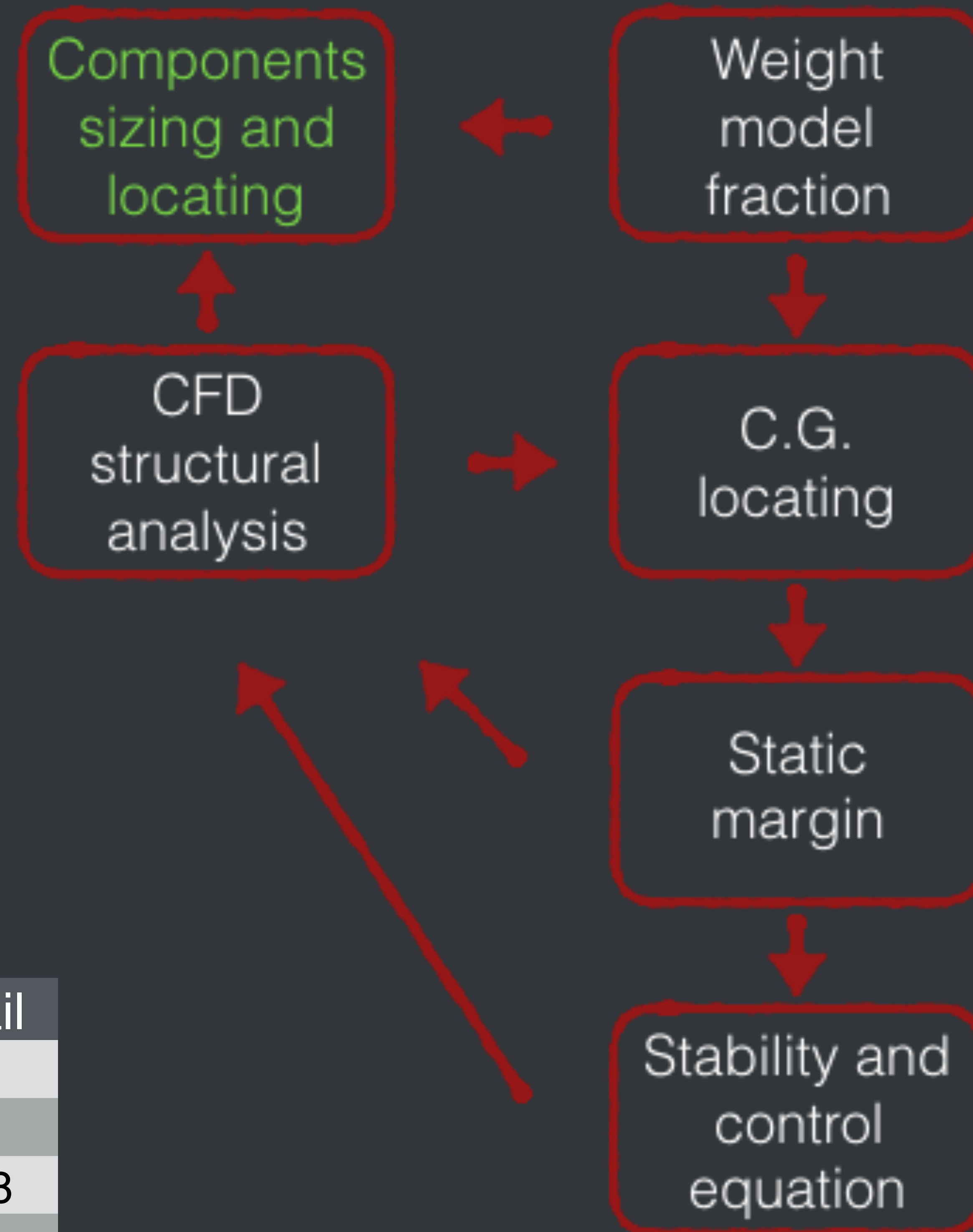
CESSNA 182



		AVERAGE Weigh	Adjustment due to		Adjustment due to	
MTOW [KG]			round-off errors		hybrid nature	
EMPTY WEIGHT/ WTO	0,609	1566,26	-43,14	1523,12	141,88	1665,00
FUSELAGE/WTO	0,101	251,76	-6,93	244,83	22,81	267,63
WING/WTO	0,099	247,24	-6,81	240,43	22,40	262,82
TAIL/WTO	0,023	58,40	-1,61	56,79	5,29	62,08
POWER PLANT/ WTO	0,213	533,61	-14,70	518,91	48,34	567,25
LAND GEAR/ WTO	0,054	134,36	-3,70	130,66	12,17	142,83
FIX EQUIP/WTO	0,136	340,89	-9,39	331,50	30,88	362,38

WEIGHT ESTIMATION



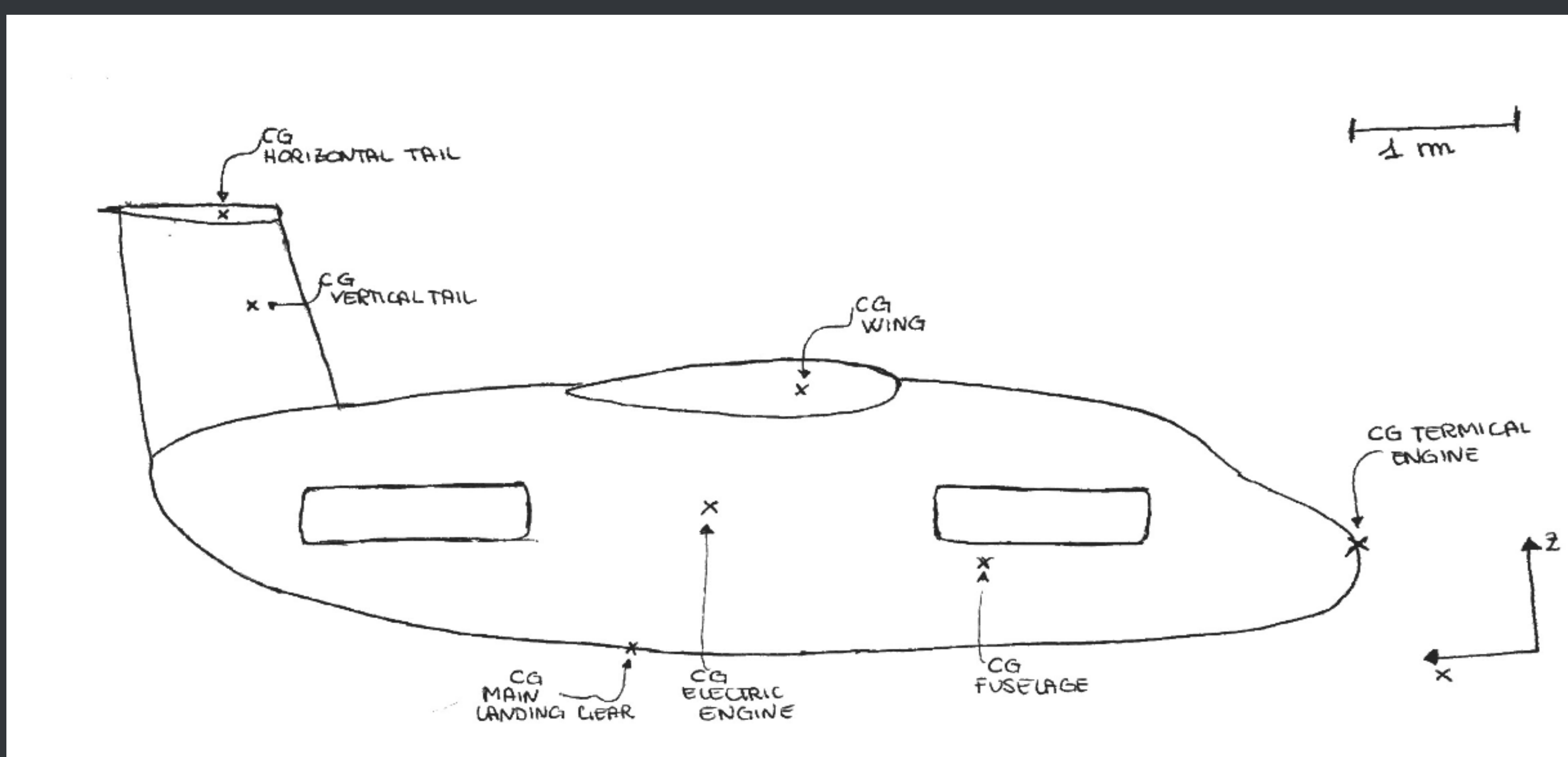


	Horizontal tail	Vertical Tail
Sweep angle	7°	30°
Dihedral Angle	0°	90°
Airlfoil	NACA 0009	NACA 0018
Incidence Angle	variable	0°
Aspect ratio	5,2	1,7
Volume coefficient	0,8	0,07
S	5 m2	2 m2

GRAVITY CENTER

MINIBEE

- Fixed Equipment
- Landing Gear
- Power Plant
- Empennage
- Fusolage
- Passengers + baggages
- Wing group
- Fuel
- Crew



Weight model fraction

Components sizing and locating

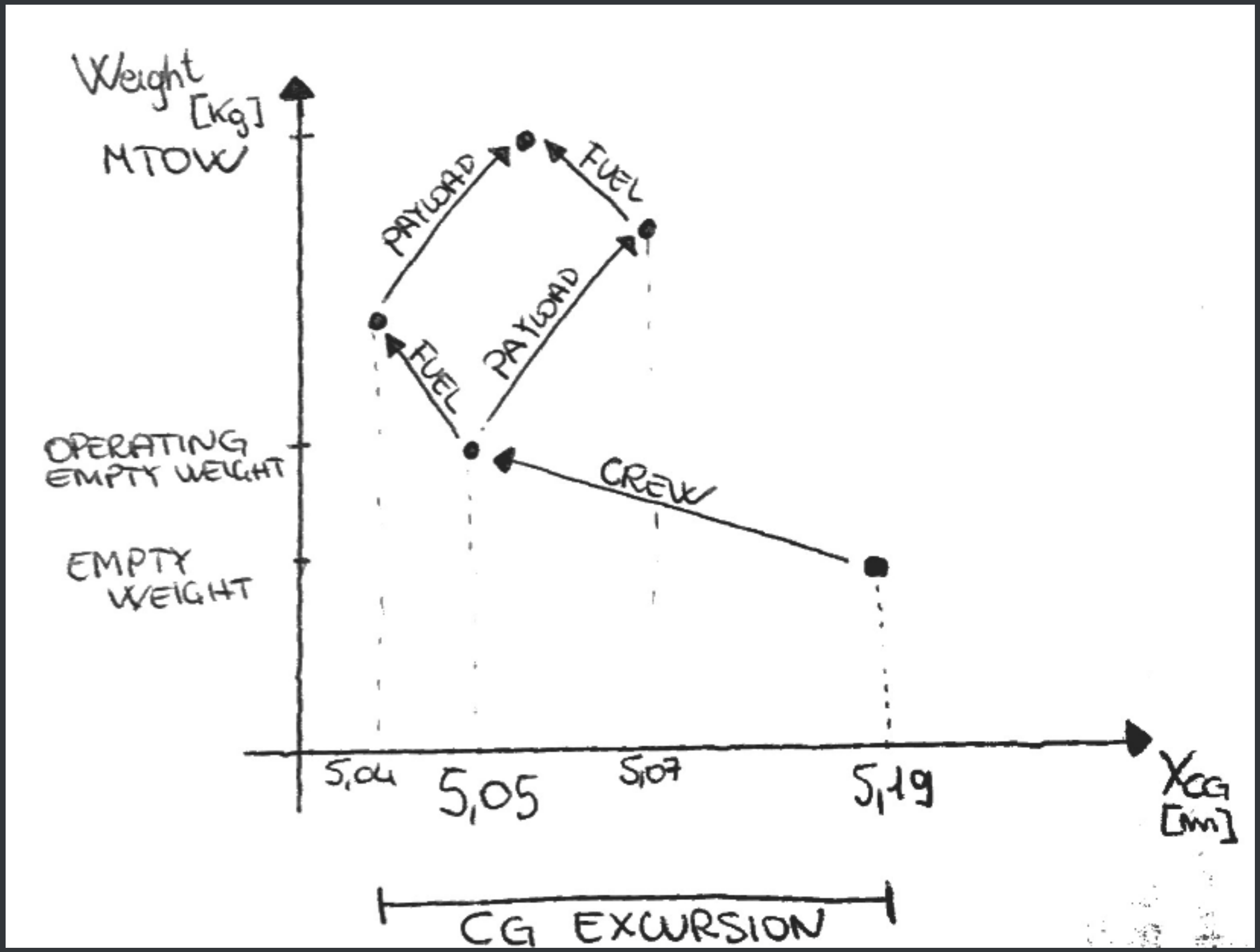
CFD structural analysis

C.G. locating

Static margin

Stability and control equation

GRAVITY CENTER



MAXIMUM CENTRE OF GRAVITY EXCURSION = 0,15m

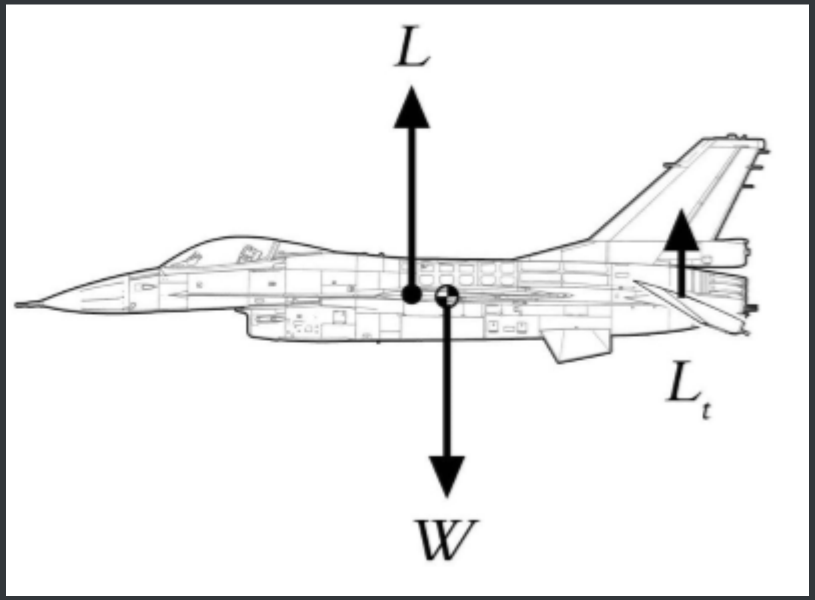
Empty weight

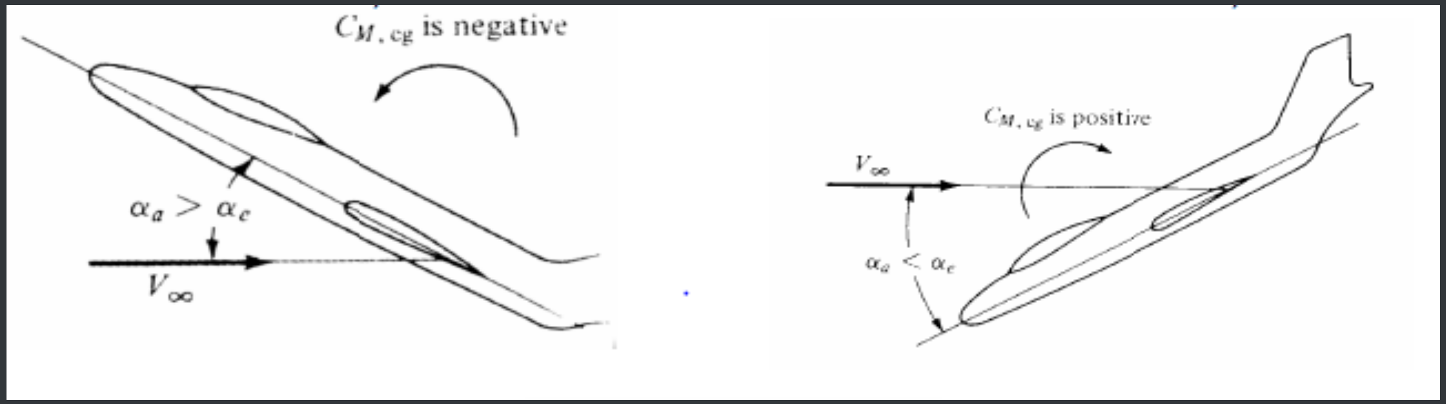
Empty weight + crew

Empty weight + crew + fuel

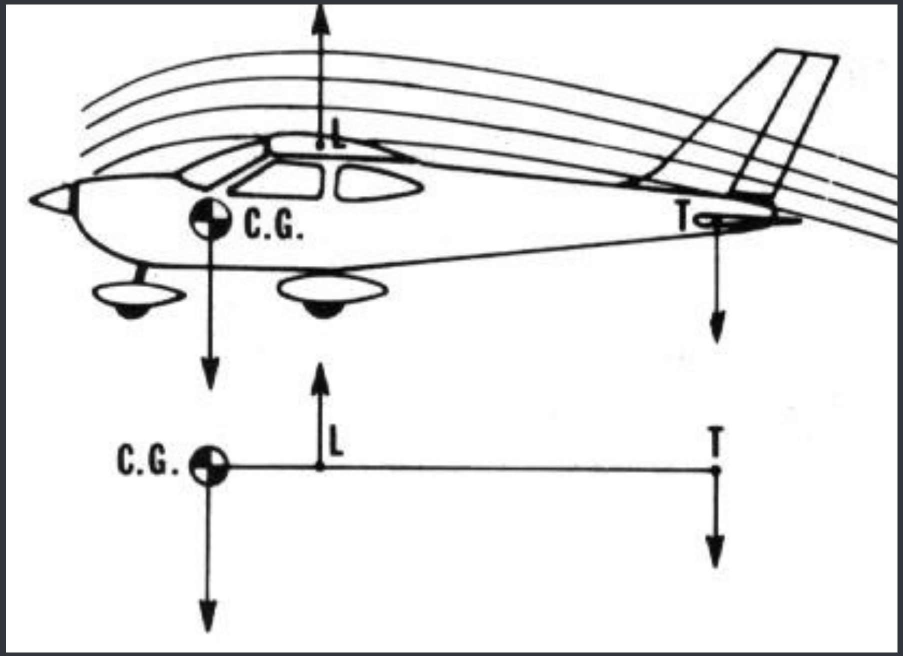
Empty weight + crew + fuel + payload = MTOW

Conventional static stability

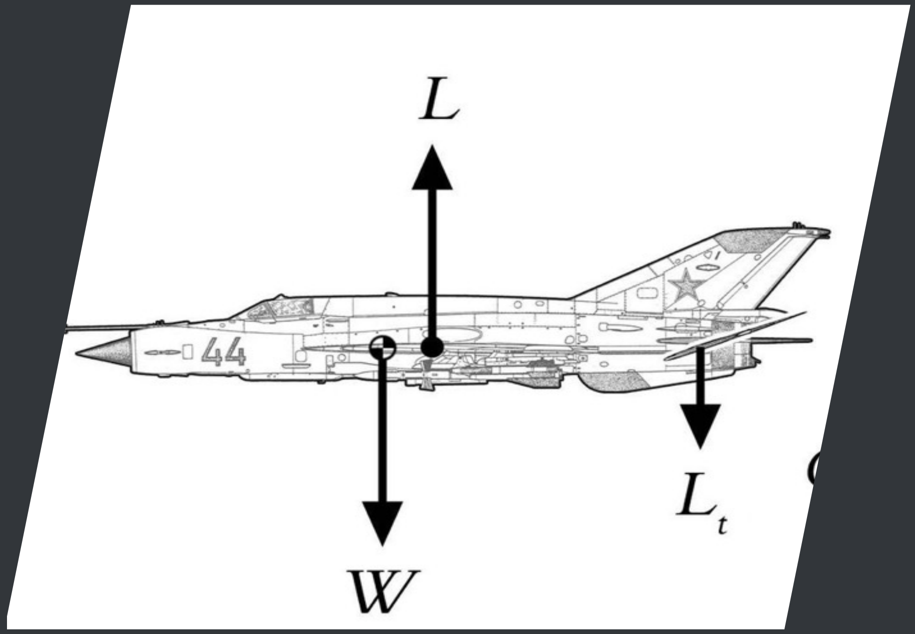




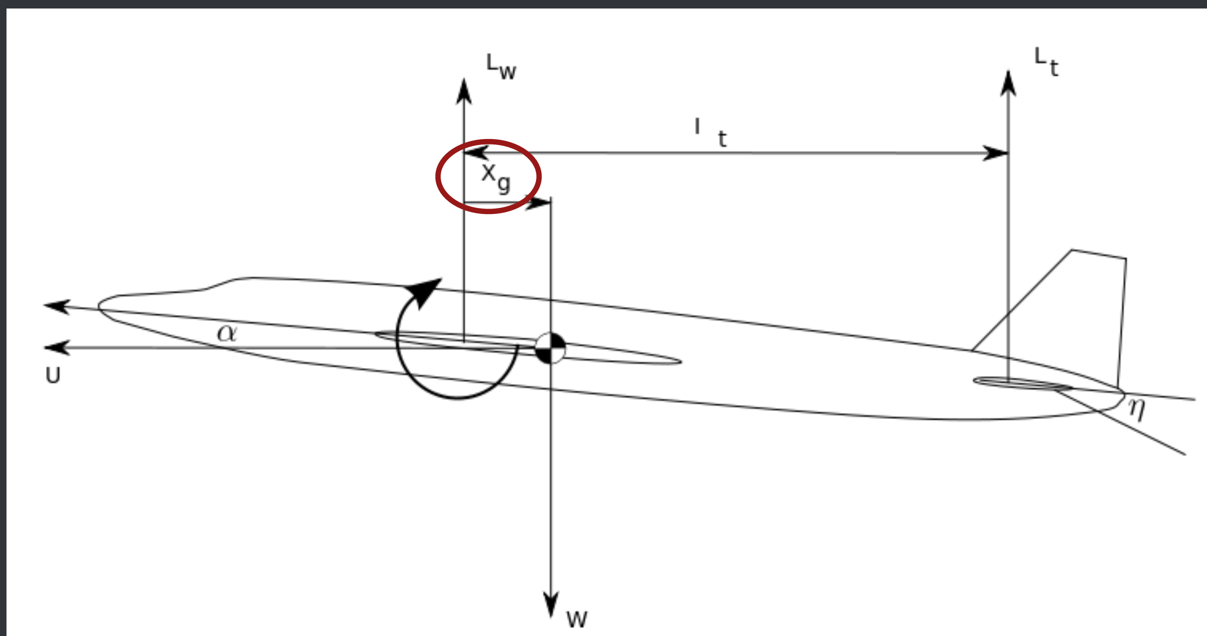
LONGITUDINAL STATIC STABILITY

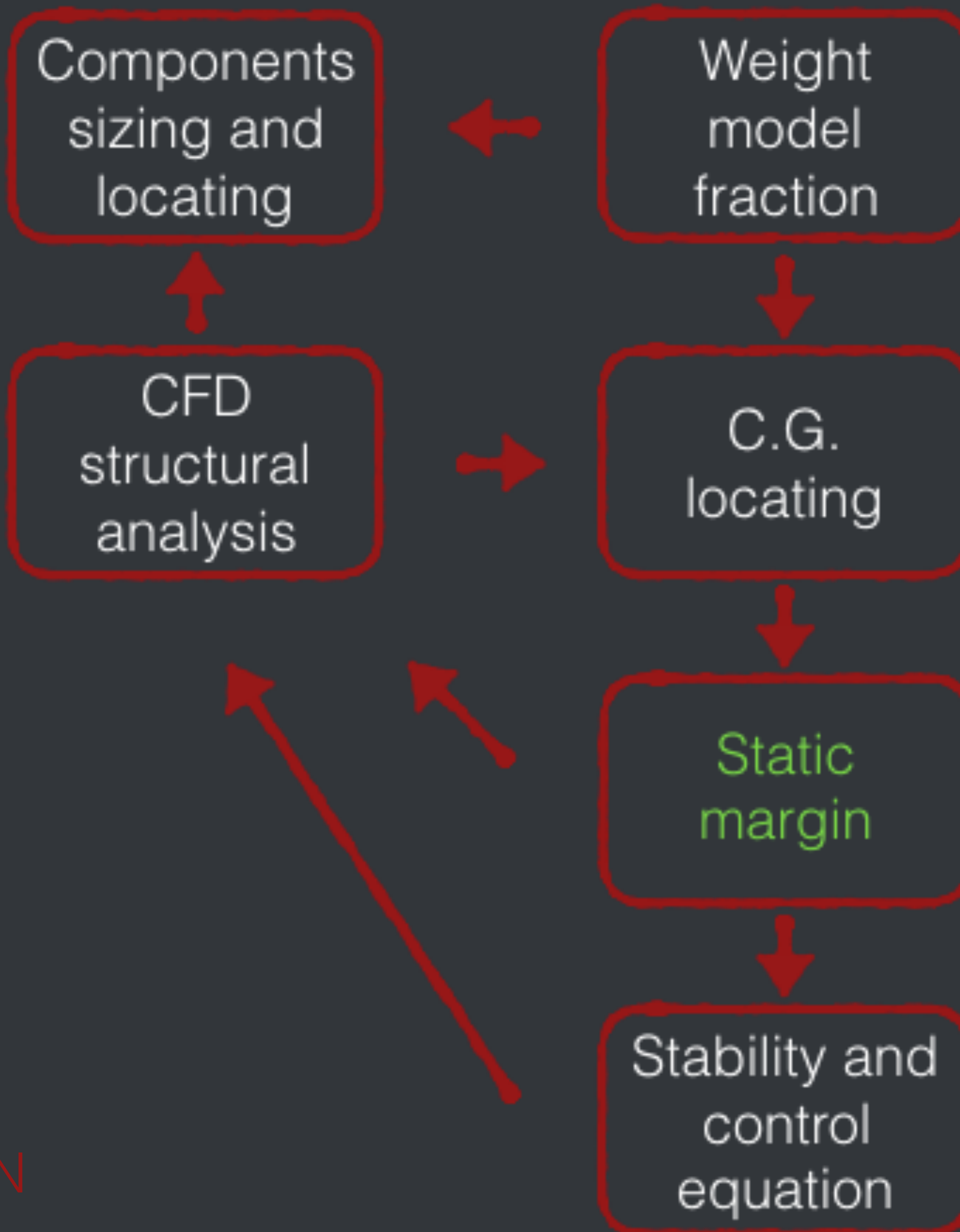


Relaxed static stability



STABILITY





$$W = Lw + Lt$$

$$M = Lw * xg - (lt - xg) * Lt$$

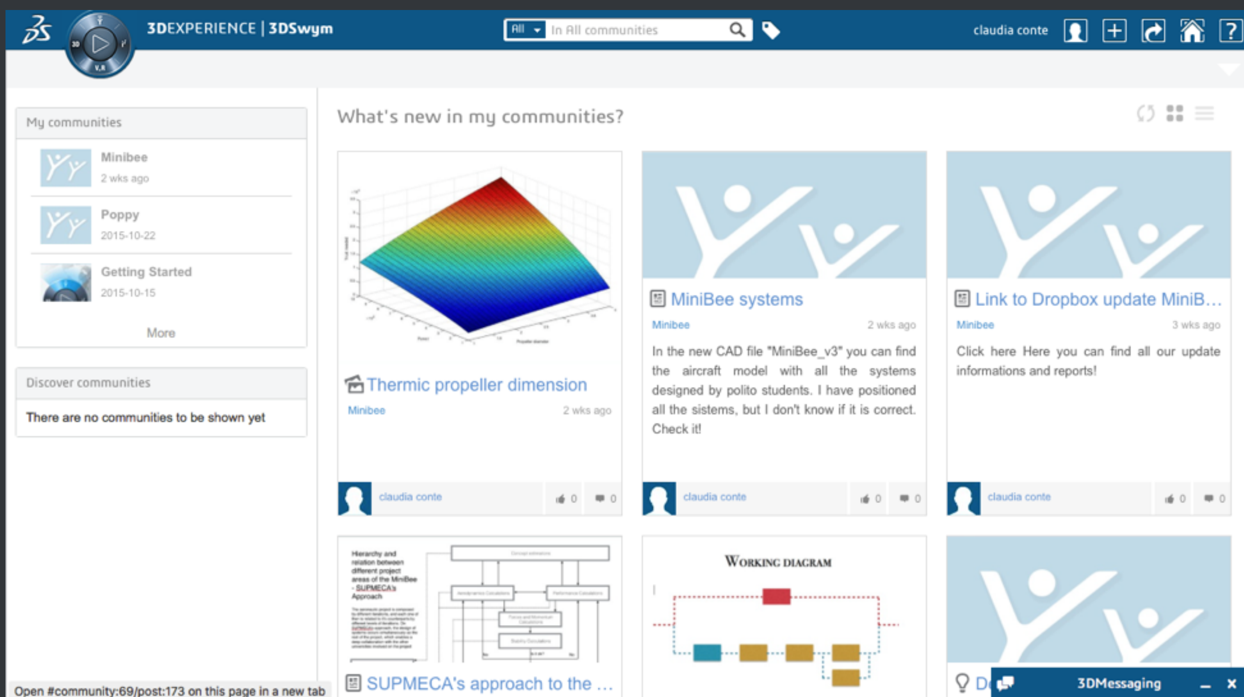
$$M = h * (Lt + Lw)$$

STATIC MARGIN

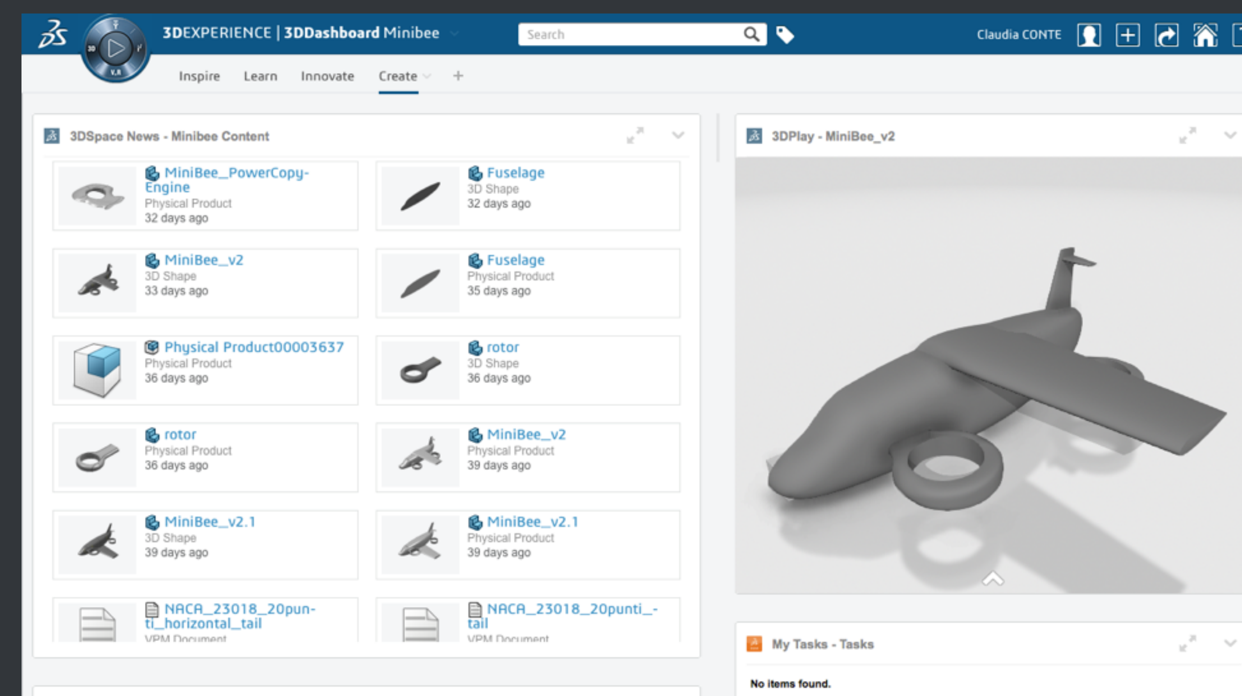
$$\frac{\partial M}{\partial \alpha} < 0$$ → $h<0$

xg < 0.66 m

PARAMETRIC CAD



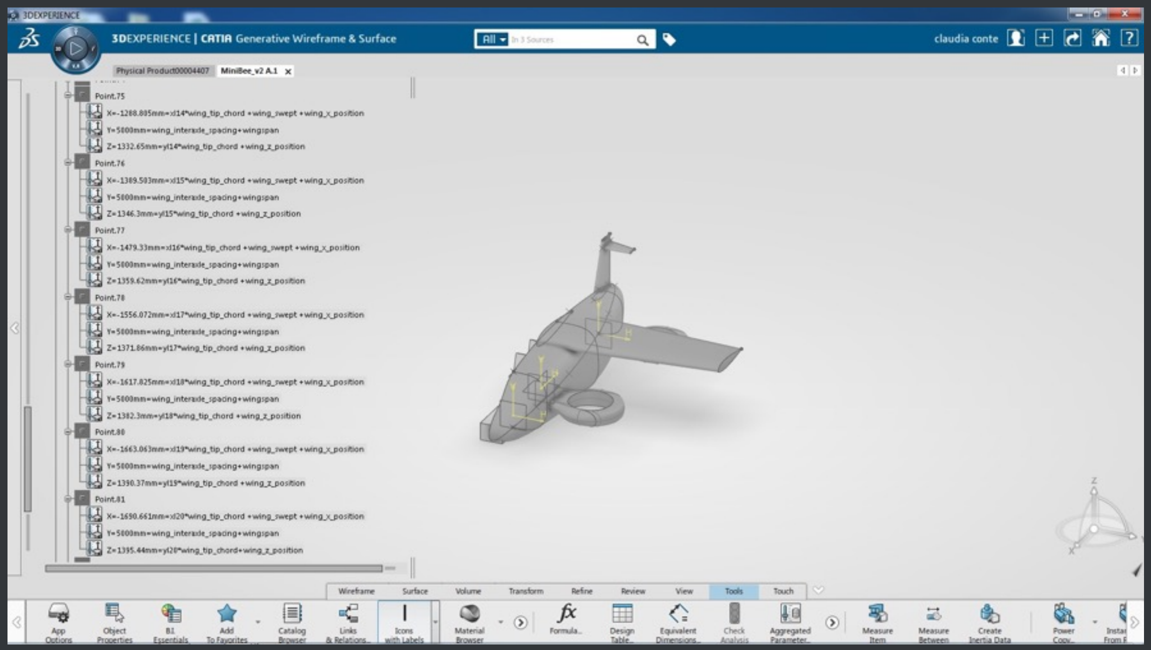
Introduction of 3Dexperience
Advantages vs Disadvantages



What is a parametric CAD:

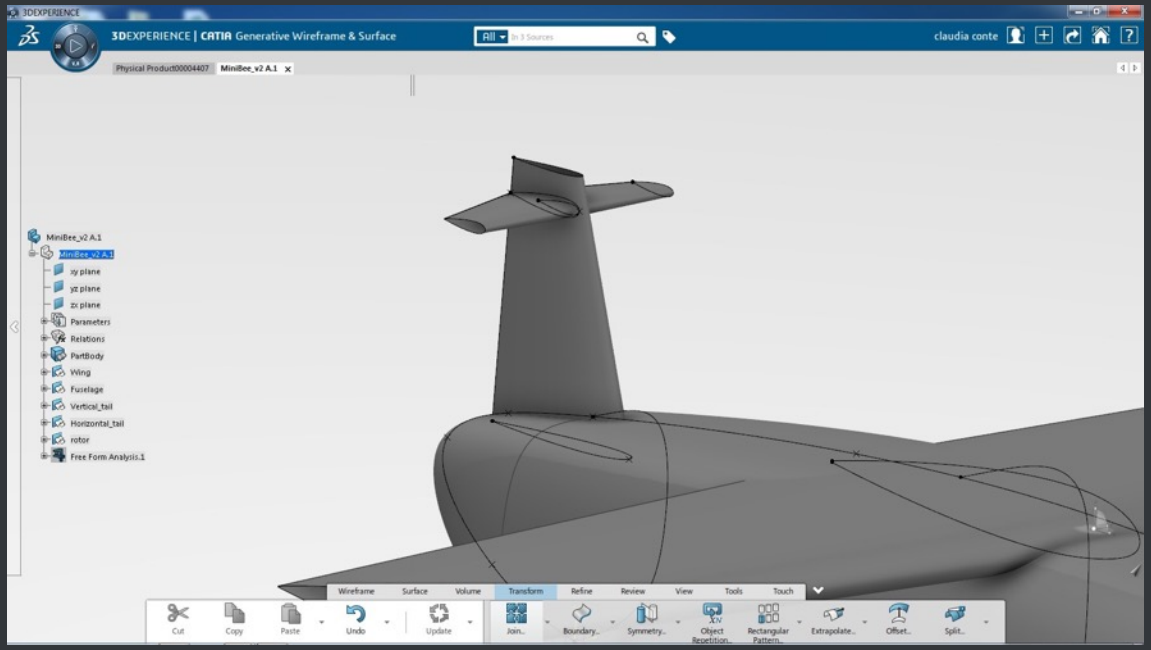
- parameters
- formules
- external link

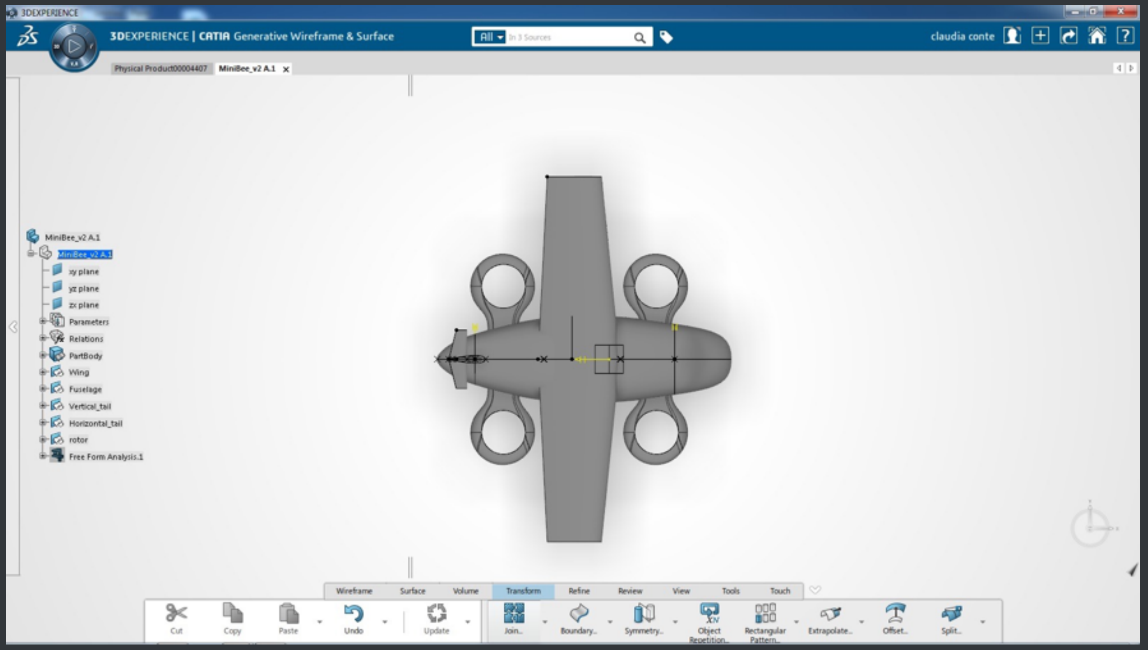
PARAMETRIC CAD



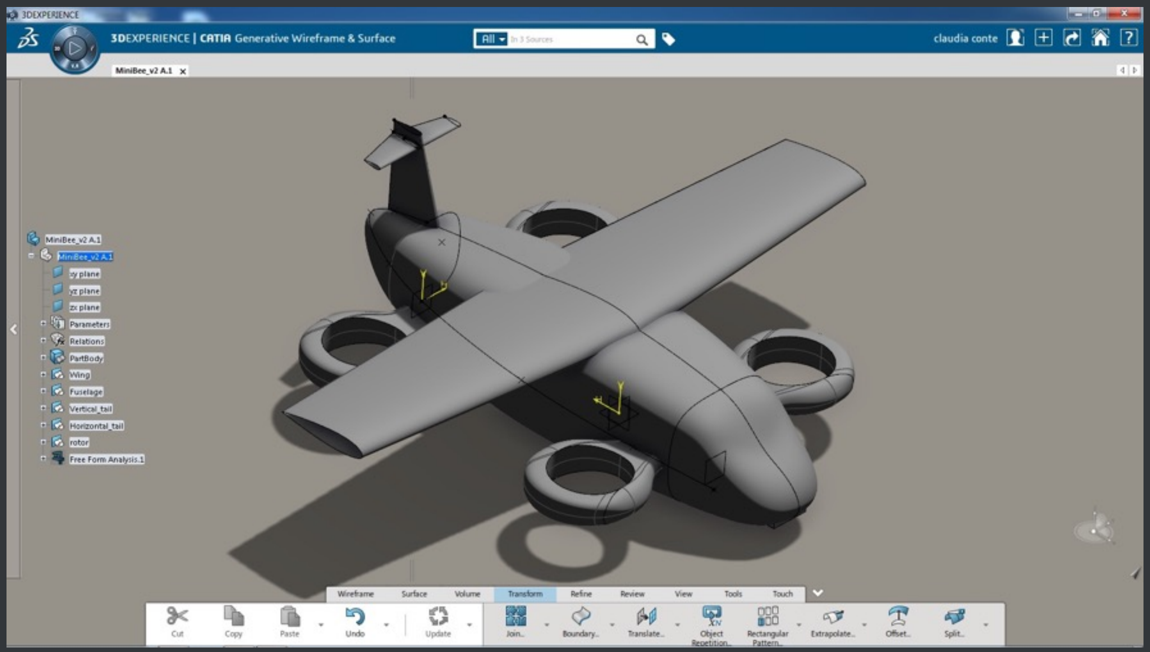
MiniBee specific use:

- Link to external excel table
- Design points through formulas
- Additional parameters
- Surface constrains
- Vertical and Horizontal tail definition
- Electric rotors definition

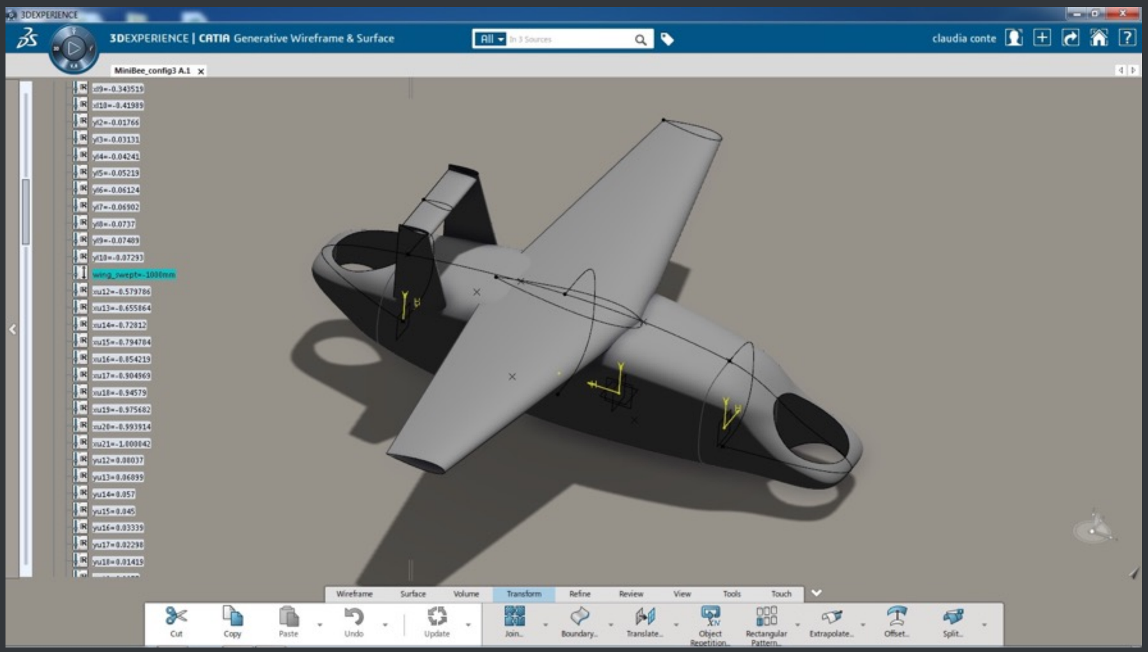




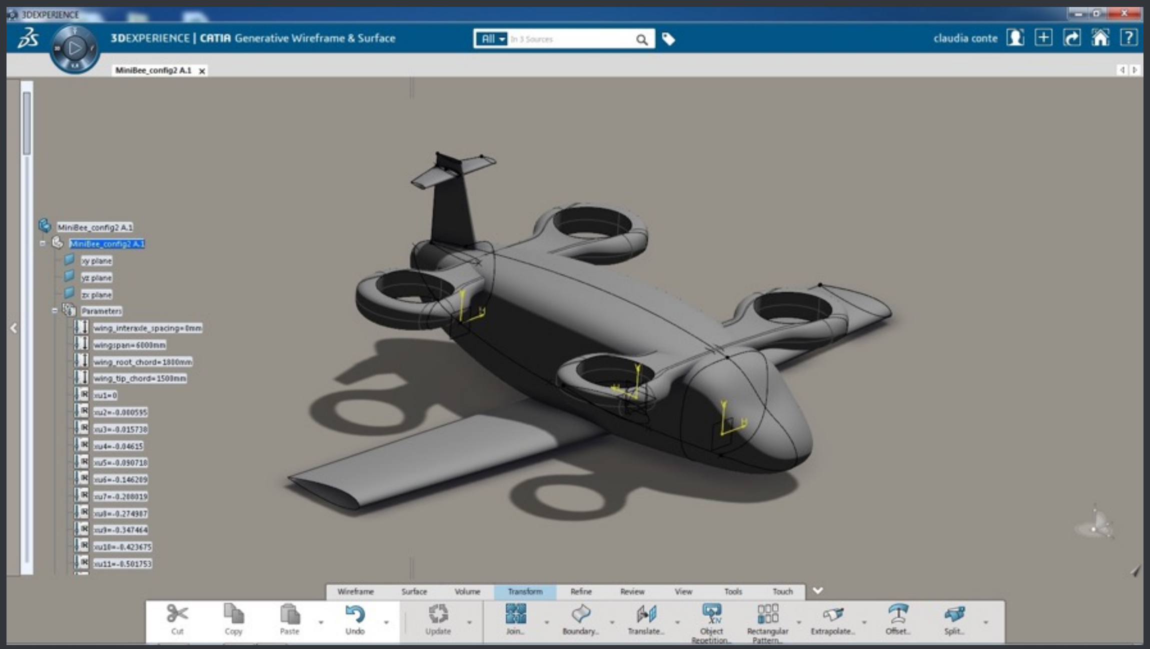
The power of parametric CAD



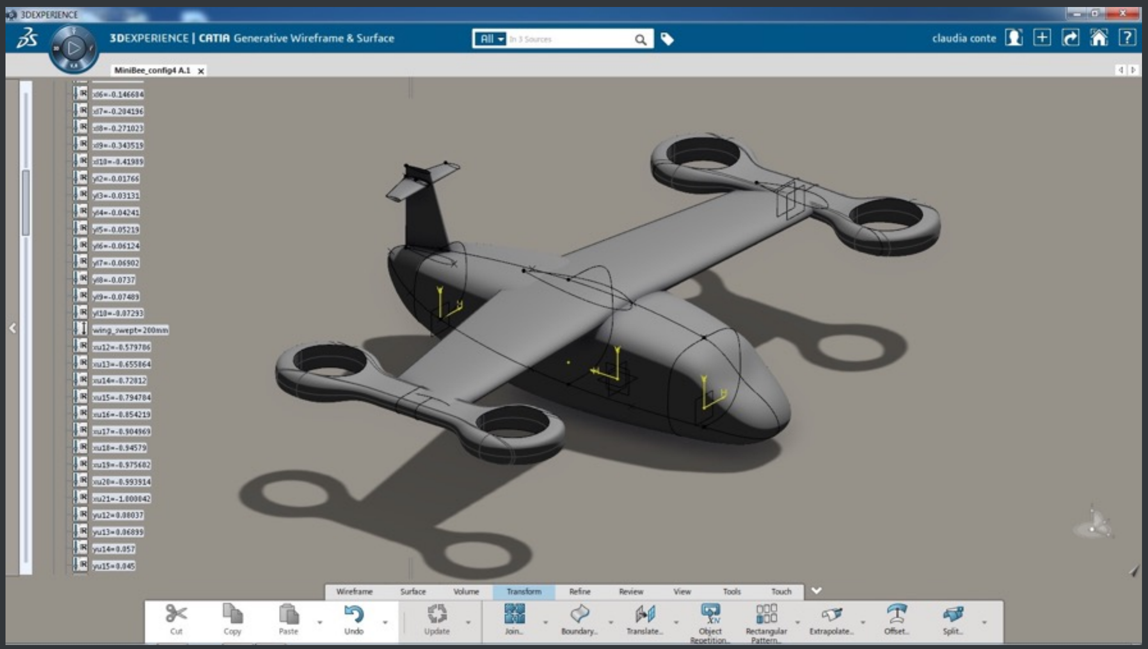
Configuration 1



Configuration 3



Configuration 2



Configuration 4