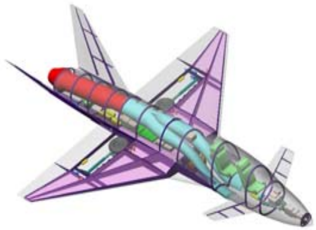
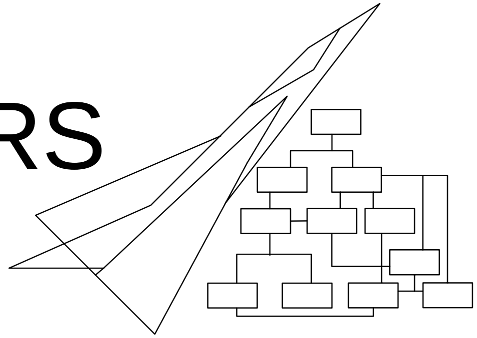
EWADE 2005 - TOULOUSE

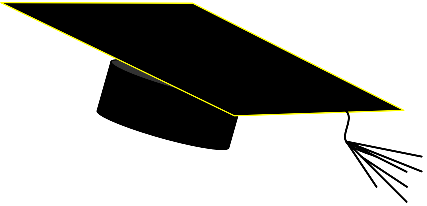


AIRCRAFT DESIGN

for



SYSTEMS ENGINEERS

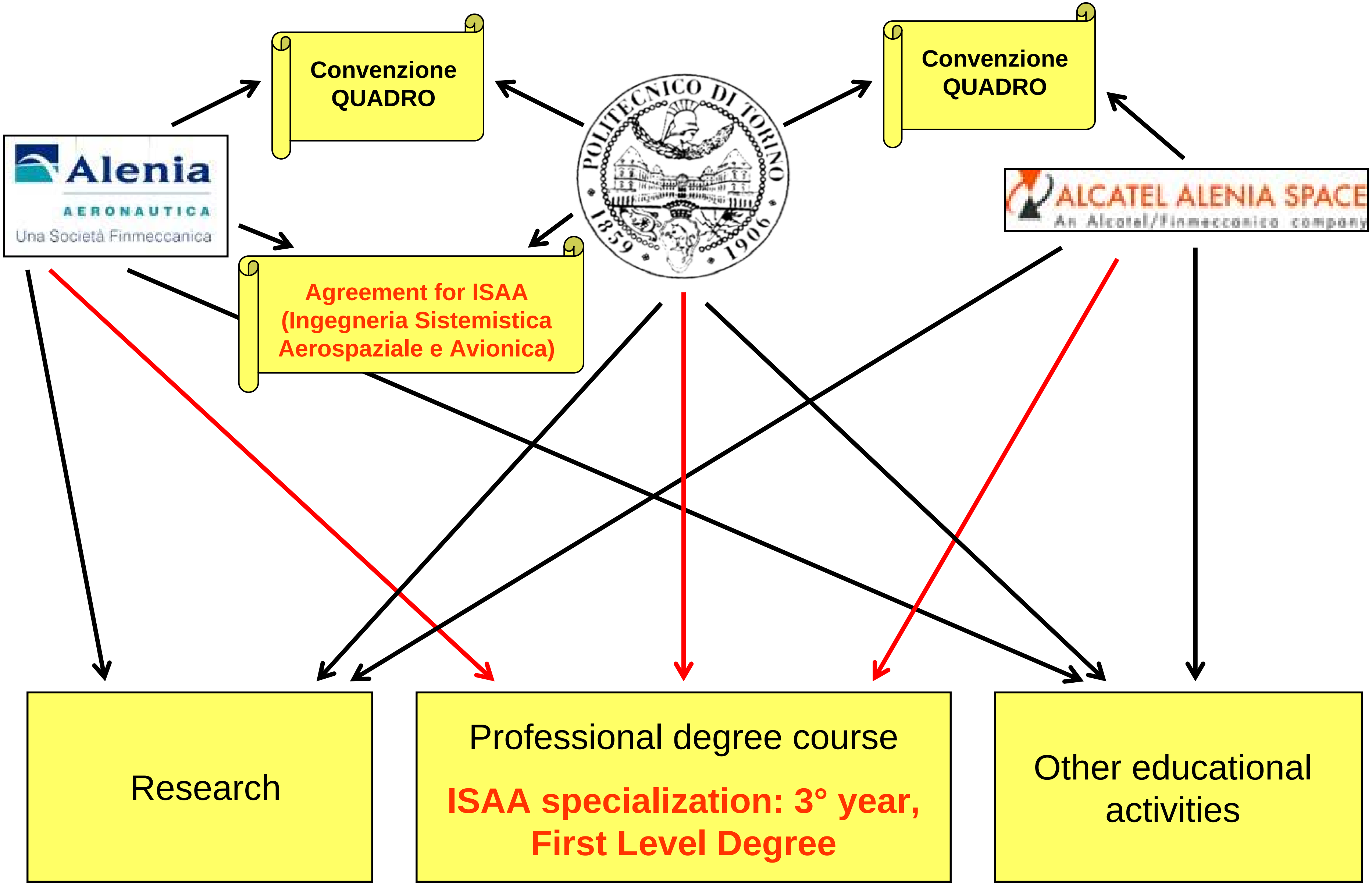


EDUCATION

at

POLITECNICO di TORINO

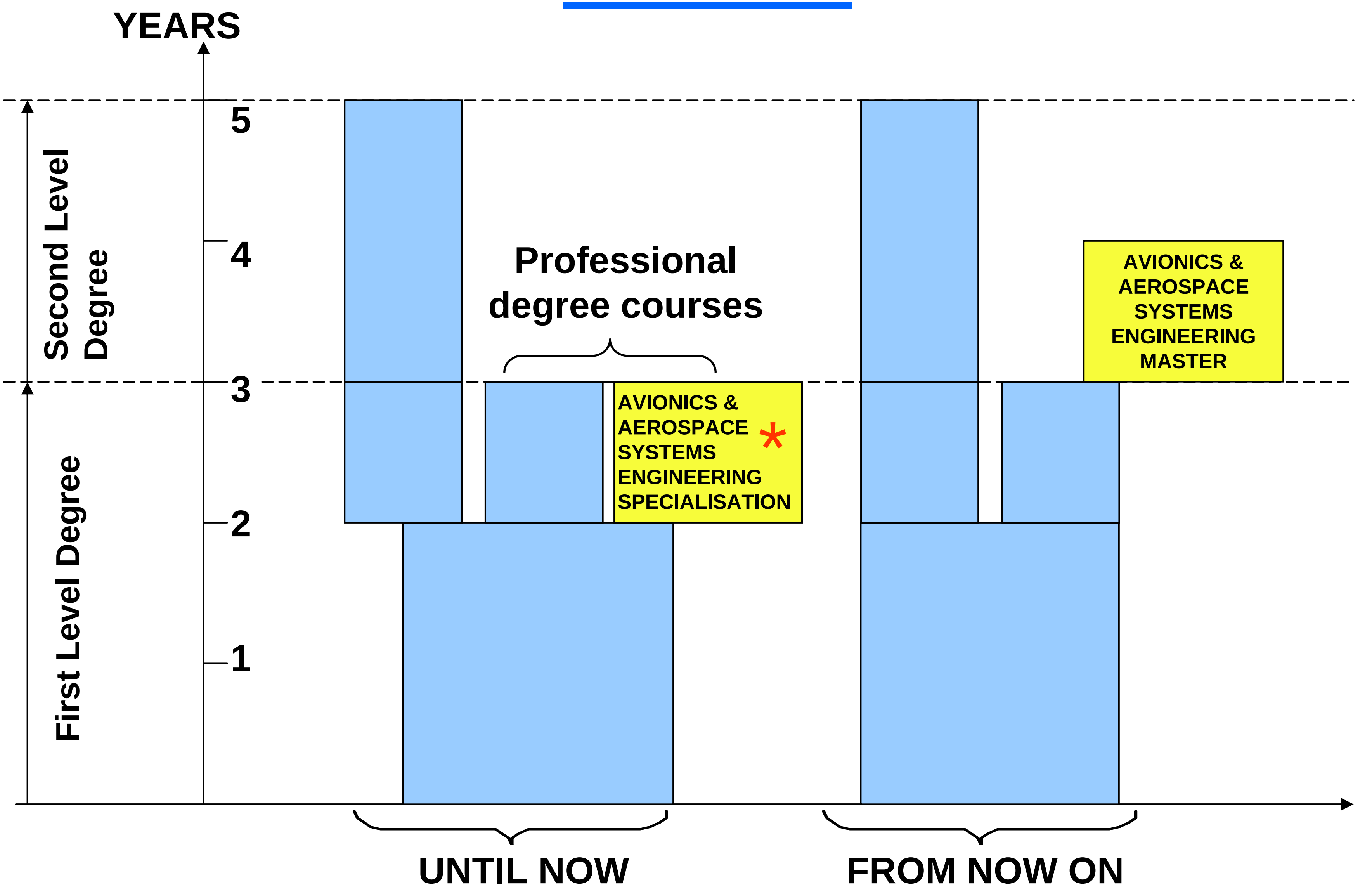
Sergio CHIESA, Sabrina CORPINO, Nicole VIOLA



Convenzione QUADRO
Alenia
AERONAUTICA
Una Società Finmeccanica
POLITECNICO DI TORINO
1859
1906
Convenzione QUADRO
ALCATEL ALENIA SPACE
An Alcatel/Finmeccanica company
Agreement for ISAA (Ingegneria Sistemistica Aerospaziale e Avionica)
Research
Professional degree course
ISAA specialization: 3° year, First Level Degree
Other educational activities

When?

* I.S.A.A

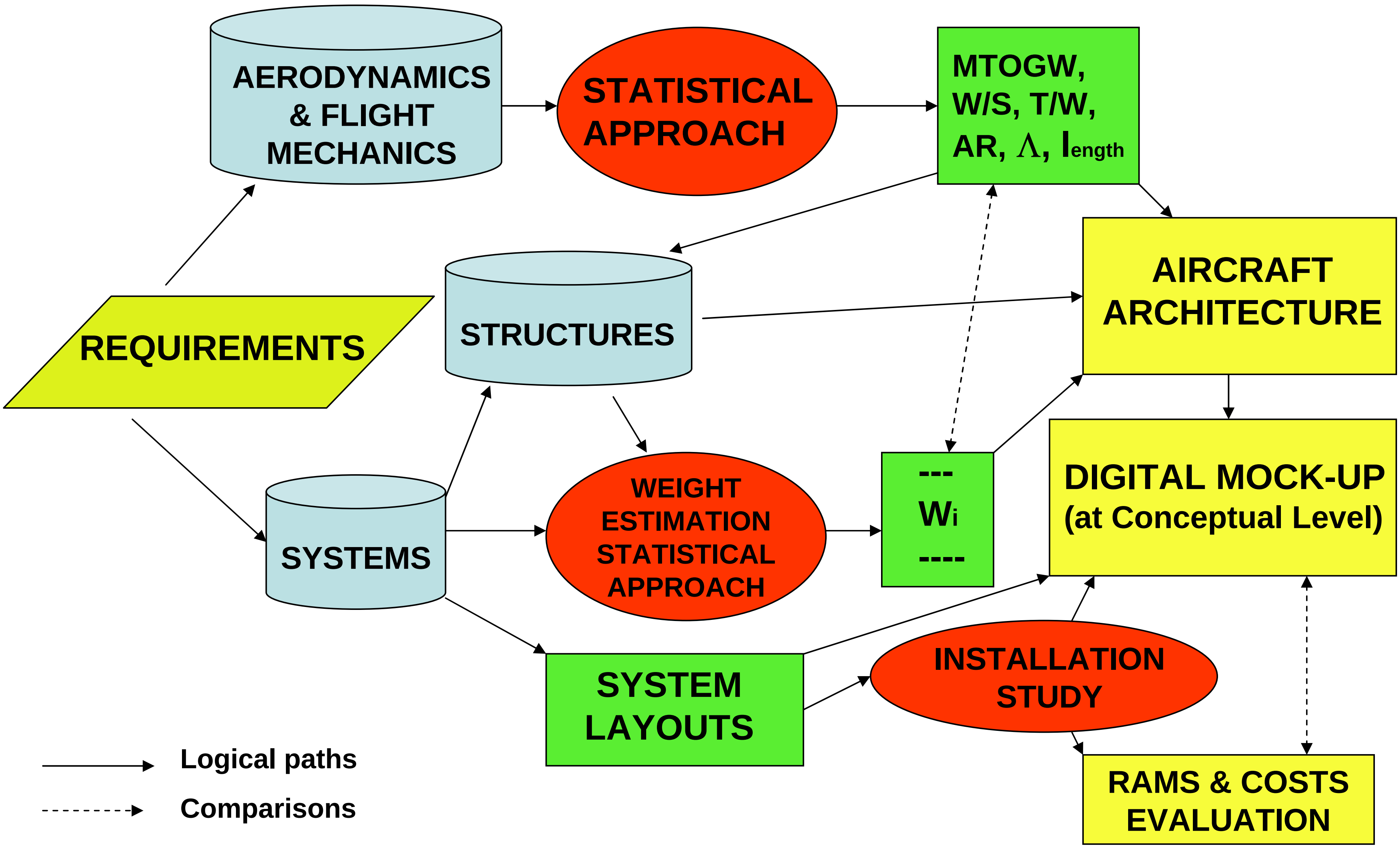


YEARS
5
4
3
2
1
Second Level Degree
First Level Degree
Professional degree courses
AVIONICS & AEROSPACE SYSTEMS ENGINEERING SPECIALISATION *
AVIONICS & AEROSPACE SYSTEMS ENGINEERING MASTER
UNTIL NOW
FROM NOW ON

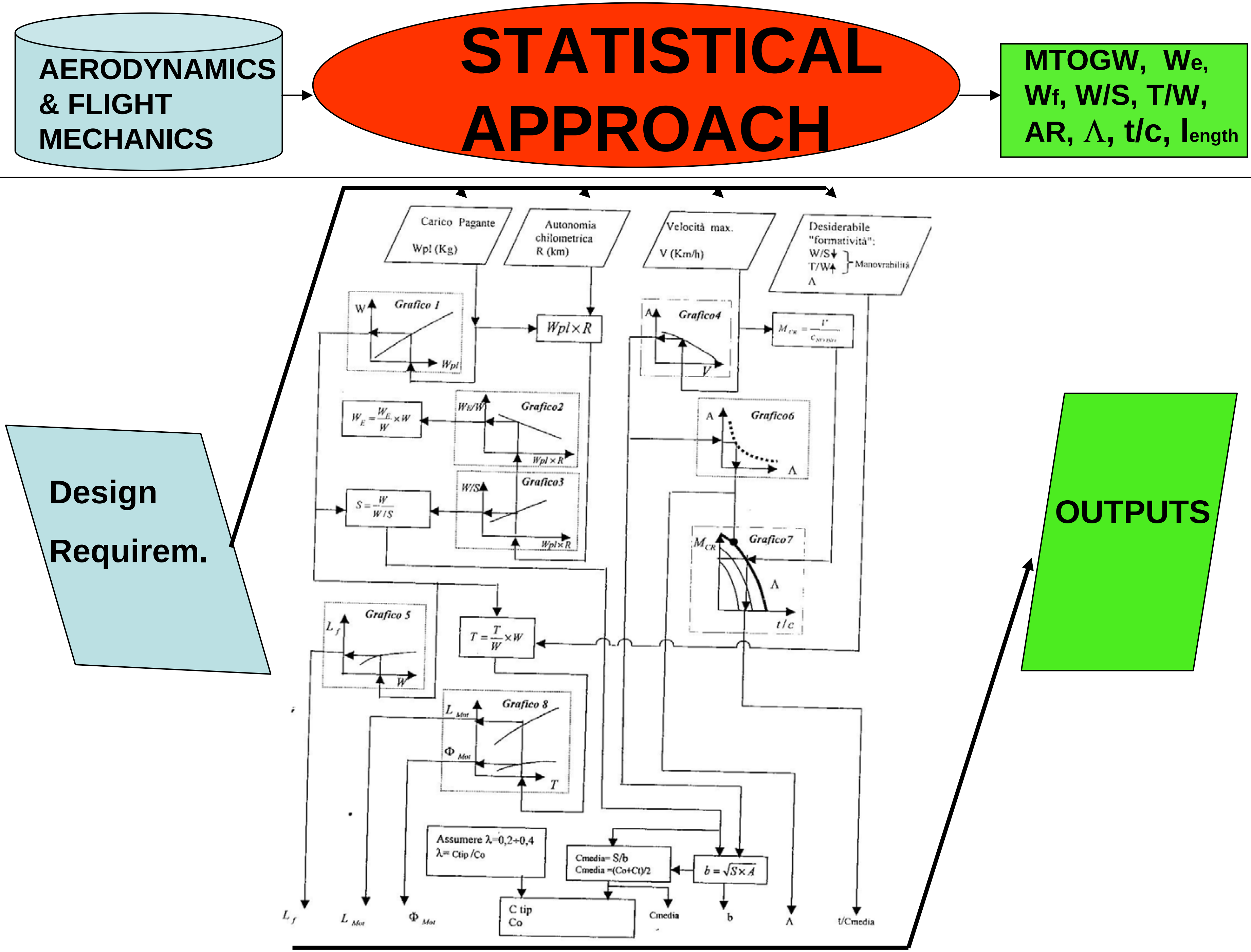
Aerospace Systems Design: why?

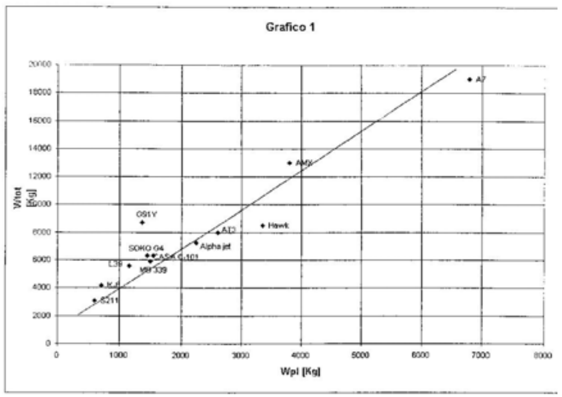
- To better understand how aerodynamics and flight mechanics influence aircraft performance
- To underline how payload and necessary sub-systems define aircraft weight & dimensions
- To learn how aircraft sub-systems can be integrated in a rational layout
- To show that the aircraft is an integrated system

How?

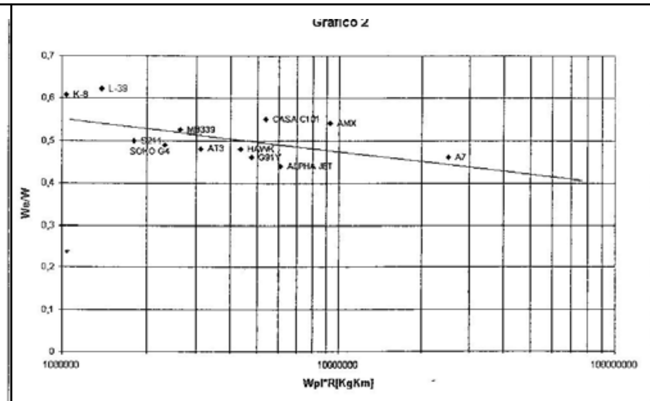


AERODYNAMICS & FLIGHT MECHANICS
STATISTICAL APPROACH
MTOGW, W/S, T/W, AR, Λ, length
REQUIREMENTS
STRUCTURES
AIRCRAFT ARCHITECTURE
SYSTEMS
WEIGHT ESTIMATION STATISTICAL APPROACH
--- Wi ----
DIGITAL MOCK-UP (at Conceptual Level)
SYSTEM LAYOUTS
INSTALLATION STUDY
RAMS & COSTS EVALUATION
Logical paths
Comparisons

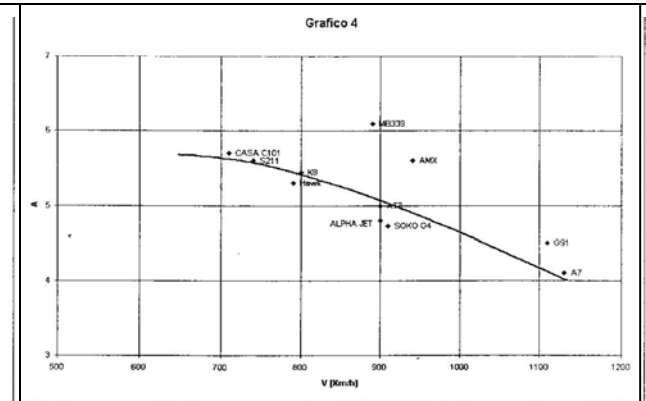

AERODYNAMICS & FLIGHT MECHANICS
STATISTICAL APPROACH
MTOGW, We, Wf, W/S, T/W, AR, Λ, t/c, length
Design Requirem.
OUTPUTS
Carico Pagante Wpl (Kg)
Autonomia chilometrica R (km)
Velocità max. V (Km/h)
Desiderabile "formatività": W/S↓ T/W↑ Manovrabilità Λ
Grafico 1
Grafico2
Grafico3
Grafico4
Grafico 5
Grafico6
Grafico7
Grafico 8
Wpl × R
Assumere λ=0,2÷0,4
λ= Ctip /Co
Cmedia= S/b
Cmedia =(Co+Ct)/2
C tip
Co
Cmedia
b
Λ
t/Cmedia



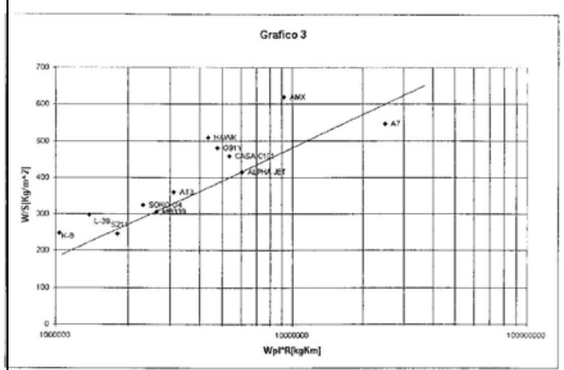
Relazione peso totale al decollo-carico pagante



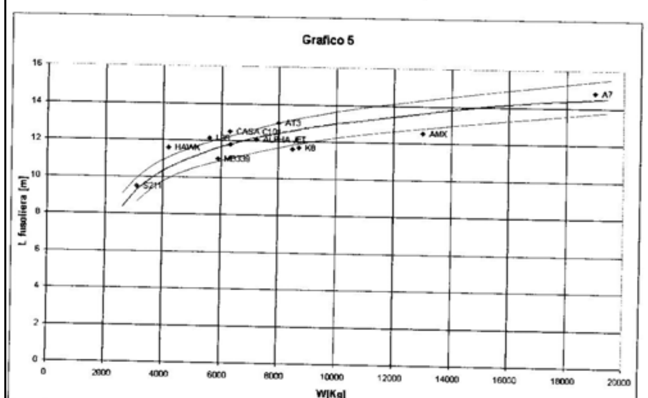
Relazione peso a vuoto/peso totale-carico pagantexautonomia chilometrica



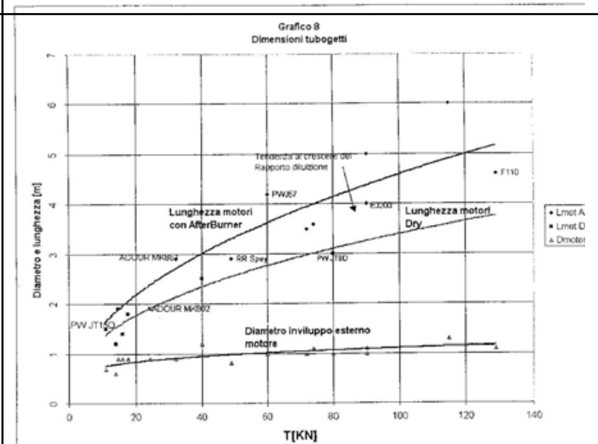
Relazione allungamento alare -velocità massima



Relazione carico alare -carico pagantexautonomia chilometrica



Relazione lunghezza fusoliera - peso totale al decollo



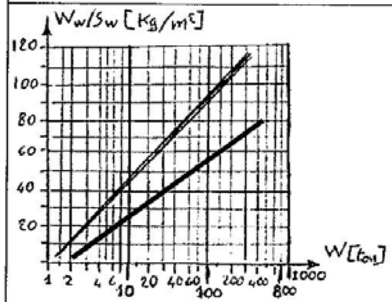
ALLEGATO: STIMA DEI PESI A LIVELLO MACRO-SISTEMI

SOTTOSISTEMI PRINCIPALI

ALA

$$W_{ALA} = \left(\frac{W_W}{S_W}\right) \cdot S_{ALA} \cdot K_{COMPOSITI} \cdot K_{\substack{PIANTA \\ ALARE}} \cdot K_{DELTA}$$

Dove:



$K_{COMPOSITI}$ =1-0.35×(percentuale compositi)

% compositi indicative:
= 0.20 solo "parti" di forma
= 0.85 anche parti di forza con elementi metallici
= 1.00 tutto composito

$K_{PIANTA\ ALARE}$: 1.1 (A>8, λ→1); 0.7 (A<2, λ→0)

A= allungamento alare
λ= Ctip/Co rastremazione

K_{DELTA} (o per collegamenti a fusoliera [corda esposta]>0.5 Lfusoliera=0.9 (1 se non Delta)

MOTORI

$$W_{Mot} = n_{Mot} \cdot W_{Mot} \cdot K_{Inst.}$$

dove $K_{Inst.}$ → 1.1 Fighters (Add.Aria Attacchi); 1.25 Trasporti (gondole)

TAIL

Peso impennaggi W_{TAIL} → Stessa procedura dell'ala; $\left.\begin{matrix}0.1\\0.3\end{matrix}\right] \times W_{ALA}$

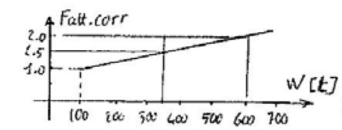
FUSOLIERA

$$W_{Fusol} = \frac{Lf}{1000} \cdot n \cdot W_{corretto} \cdot K_{COMPOSITI} \cdot K_{DELTA}$$

Lf [m]= lunghezza fusoliera
N= n° "g" max (n= fattore di contingenza)

K_{DELTA} = vedere analogo ala
$K_{COMPOSITI}$ = vedere analogo ala

$W_{corretto}$ [Kg]= W[Kg] / Fatt. corr



CARRELLO

$$W_{CARR} = K_{CARR} \cdot W$$

K_{CARR}: 2.2% ← Non retrattili; Carrelli a gamba lunga, multi ripiegatura, multi gamba → 4.5%

← semplicità

SISTEMI

$$W_{SISTEMI} = \sum_i K_{SIST_i} \cdot W$$

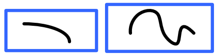
Impianto	K_{SIST_i}	
Comandi di volo	0.015÷0.04	Complessità comandi
Idraulico	0.005÷0.03	Complessità comandi / carrello
Elettrico	0.020÷0.04	Complessità comandi avionica
Combustibile	0.015÷0.02	Monomotore → plurimotore, AB
Condizionamento	0.005÷0.070	No persone → sofisticazione impianto
Avionica	0.030÷0.06	Civile → Militare
Impianto motore	0.005÷0.015	
Arredamento	0.005÷0.04	

Sistema	Min	Max	
Globale	0.07÷	0.30	per un calcolo più rapido è possibile considerare globalmente la sistemistica.

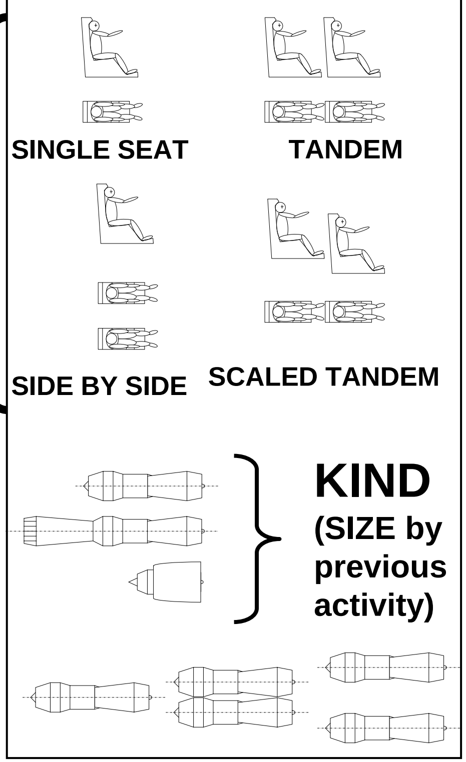
STRUCTURES → **AIRCRAFT ARCHITECTURE** ← MTOGW, W/S, T/W, AR, Λ, l_{ength}

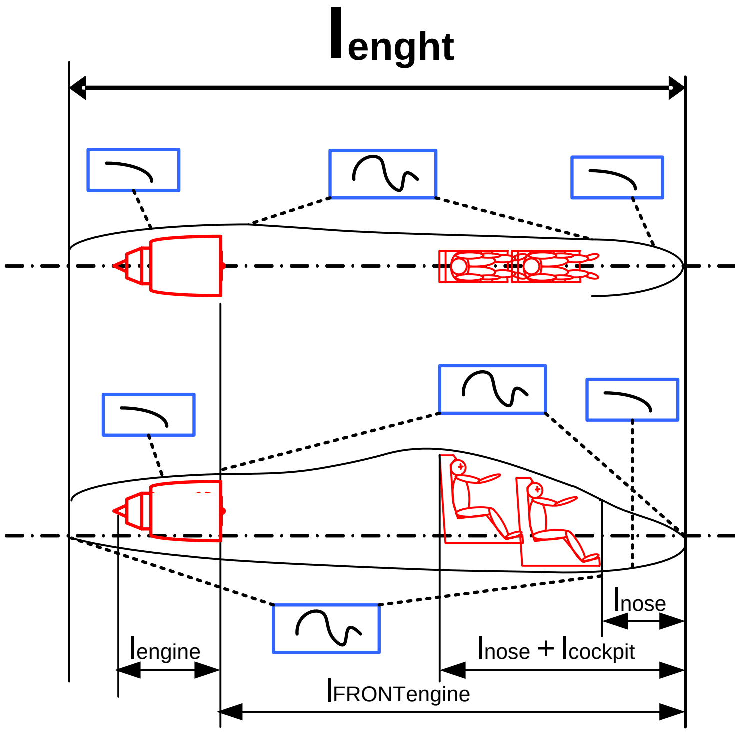
STEPS

- **Horizontal e side view establishment; basis l_{ength}**
- **Cockpit lay-out & location**
- **Propulsion systems CHOICE & location**
- **Drawing fuselage boundaries with very simple tools like them of Microsoft Visio**



ALTERNATIVES





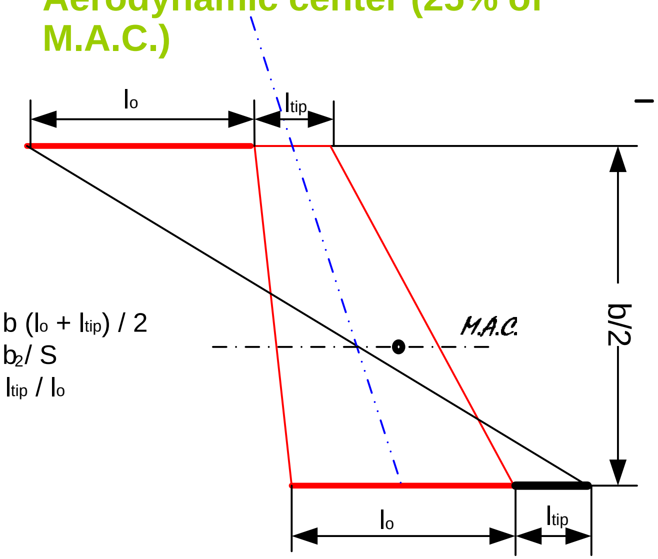
- l_{nose} → assumed (influence of avionic system sophistication)
- $l_{cockpit}$ → assumed "a priori"
- l_{engine} → defined in previous activity
- $l_{FRONTengine}$ → TBD following next activities

STRUCTURES

AIRCRAFT ARCHITECTURE

MTOGW, W/S, T/W, AR, Λ, l_{ength}

- **<u>Wing design</u>**
- **Horizontal view drawing (parameters values by previous acticivity)**
- **Estimation of M.A.C. and of Aerodynamic center (25% of M.A.C.)**



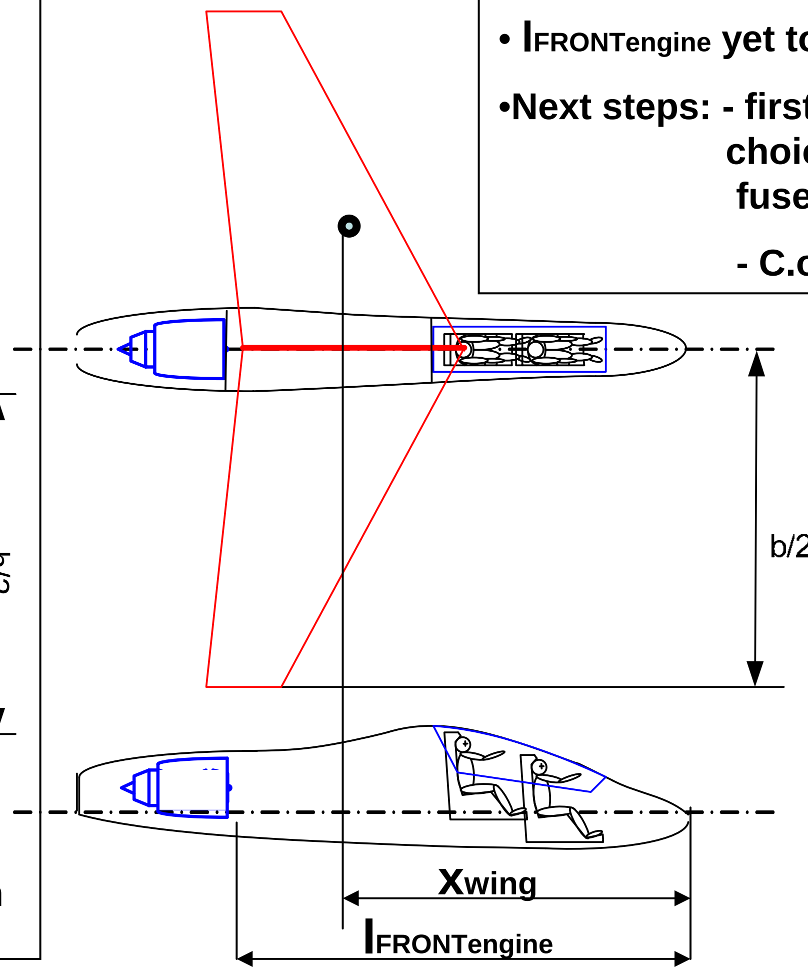
$S = b\,(l_o + l_{tip}) / 2$

$A = b_2 / S$

$\lambda = l_{tip} / l_o$

- **Next Step: wing-body integration**

- **Wing longitudinal position (X_{wing}) tentative choice**
- **$l_{FRONTengine}$ yet to be defined**
- **Next steps: - first structural lay-out choices: wing SPARS and fuselage main RIBS**
  - C.o.G. calculation



<u>X_{CoG} calculation inputs:</u>

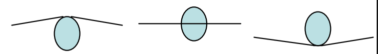
- **Previous Weight estimation outputs**
- **Logical assunptions on Xi of elements: for example $X_{body} = l/2$**

STRUCTURES

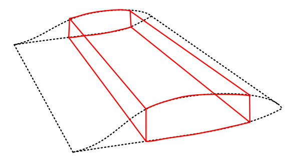
AIRCRAFT ARCHITECTURE

MTOGW, W/S, T/W, AR, Λ, l_{ength}

•1- Choice position of wing on body

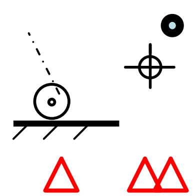


•2 -Tentative choice of wing spars configuration



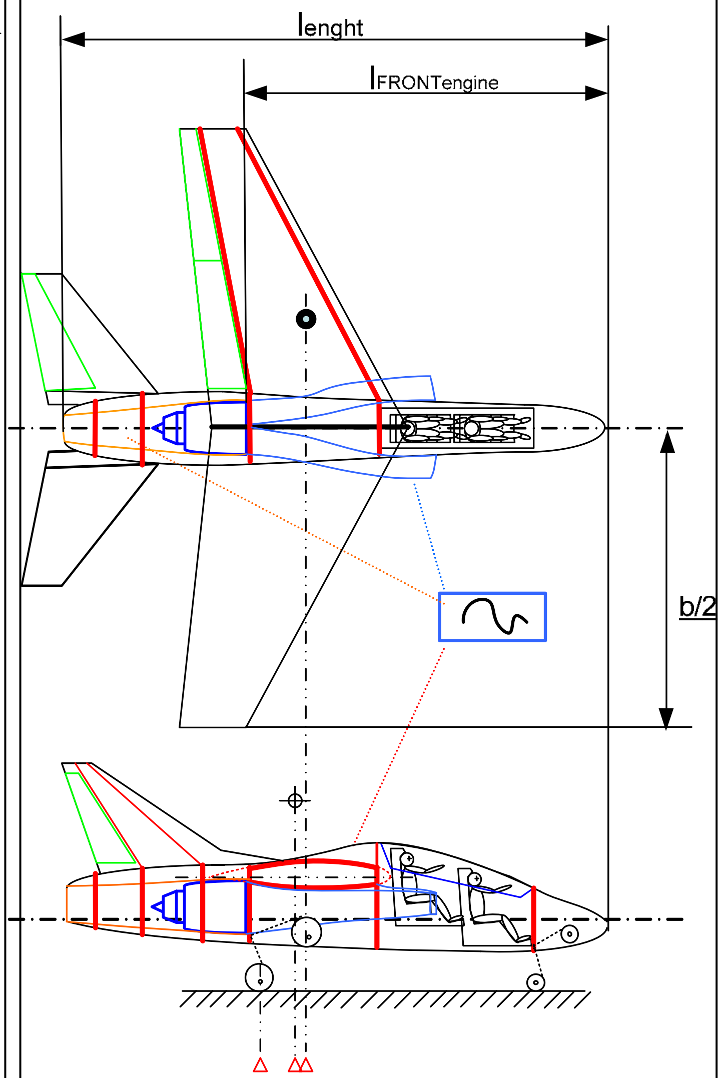
•3 - Tentative first definition of main ribs of fuselage, in particular the ones connected to the wing spars

•4 – Moving longitudinally wing and engine (in the example the same fuselage rib support the after spar, the engine and the main landing gear) find a good mutual position of wing, CoG, and main L.G.



$$X_{CoG} = \frac{\Sigma \; X_i \; m_i}{\Sigma \; m_i}$$

•5 – Complete with air induction ducts, exhaust duct, tail surfaces and aerodynamic control surfaces.

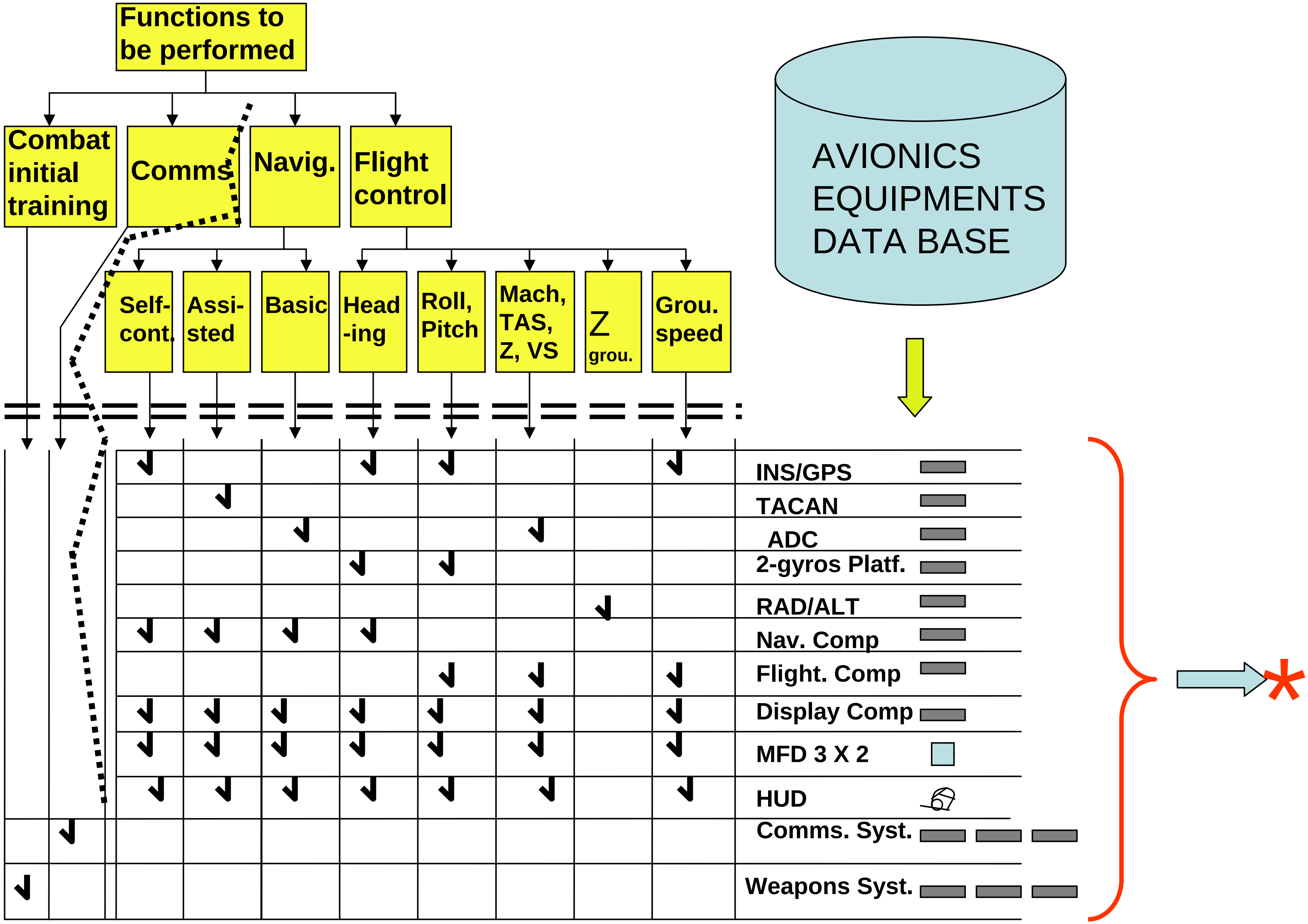


SYSTEMS DEFINITION

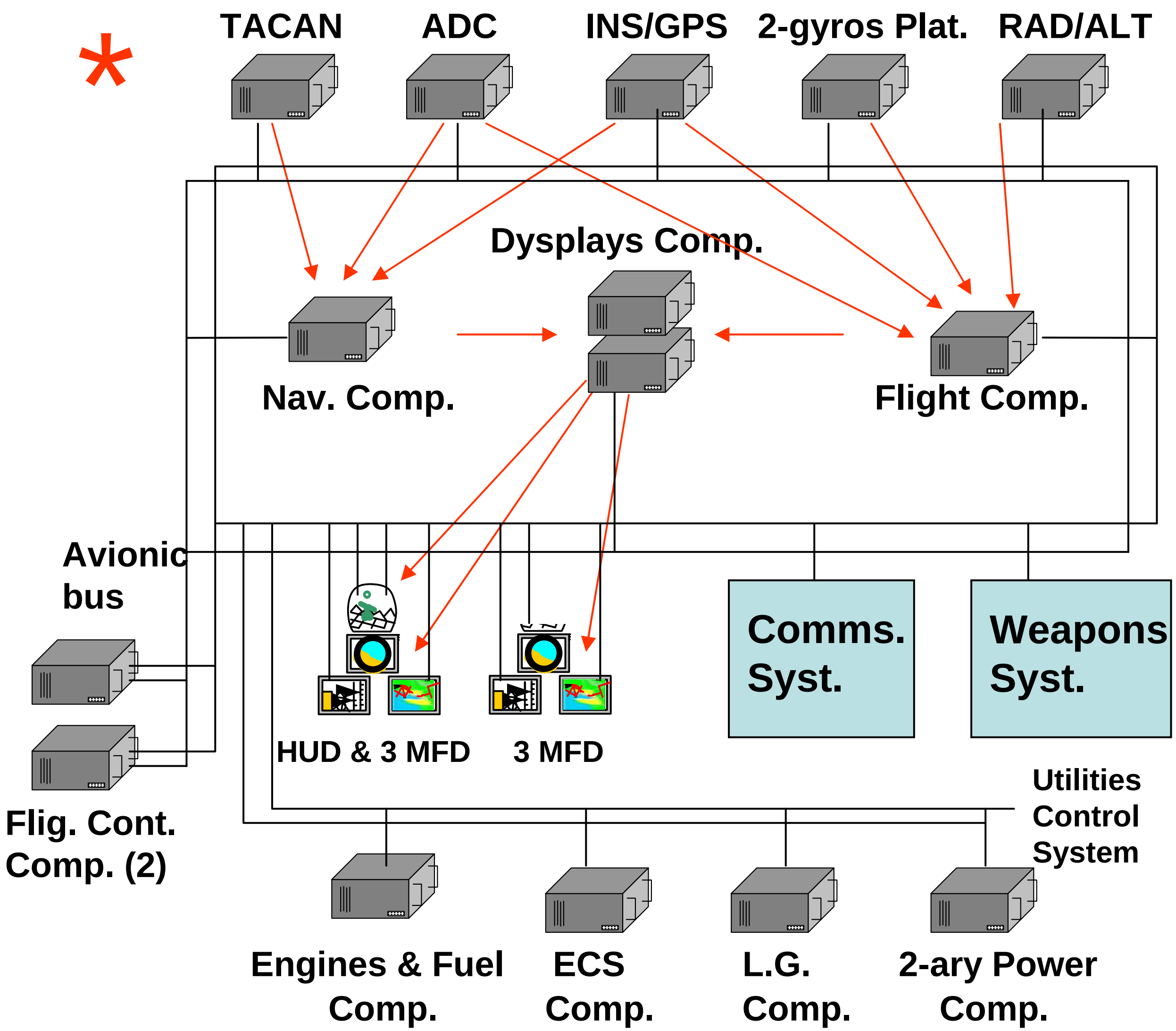
- **Avionics at "State of the Art"**
- **Systems fully integrated by computerized control**
- **Flight Control Systems fully "FLY-BY-WIRE"**
- **Flight Controls redundancies:**
  - **Flaps surfaces can be used as reversionary ailerons**
  - **Ailerons can be symmetrically turned down as flaps**
  - **One half-elevator enough for pitch control**
  - **All surfaces driven by duplex electro-mechanical actuator**
- **2-ary Power Choices:**
  - **No hydraulic system**
  - **No hydraulic devices except wheel brakes and steering**
  - **High voltage DC System; 2 Switched Reluctance Starter/Generators**
  - **APU normally running in flight**
- **Environmental Control System: traditional air cycle**

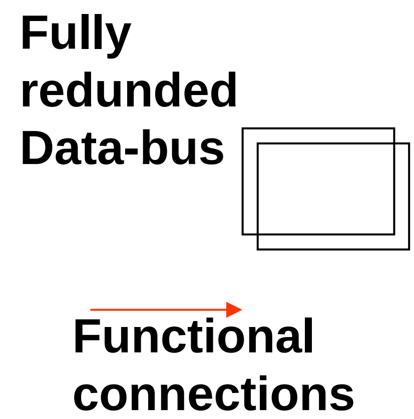
An example of a possible choice of subsystems level requirements made by Students. They must explain it in a report.

Avionics System Definition (1)



Avionics System Definition (2)

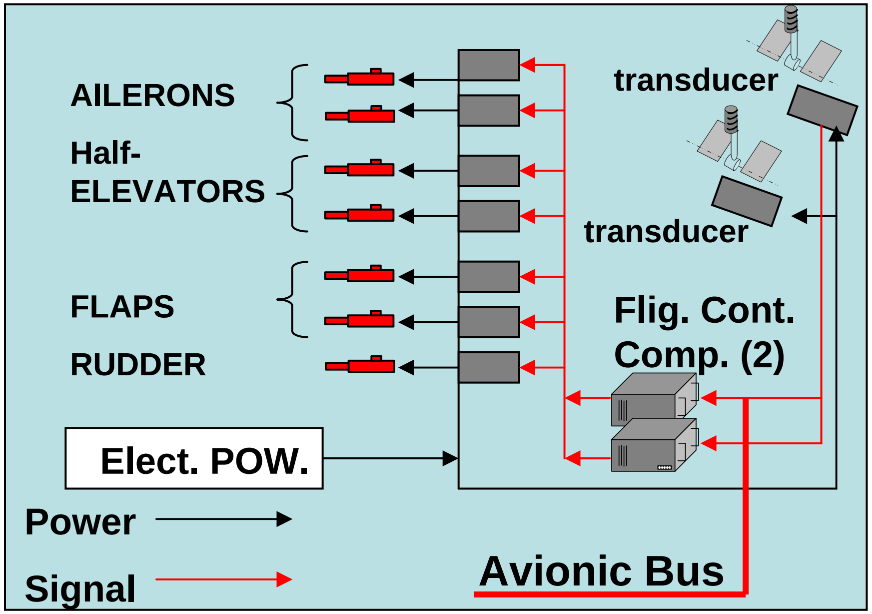


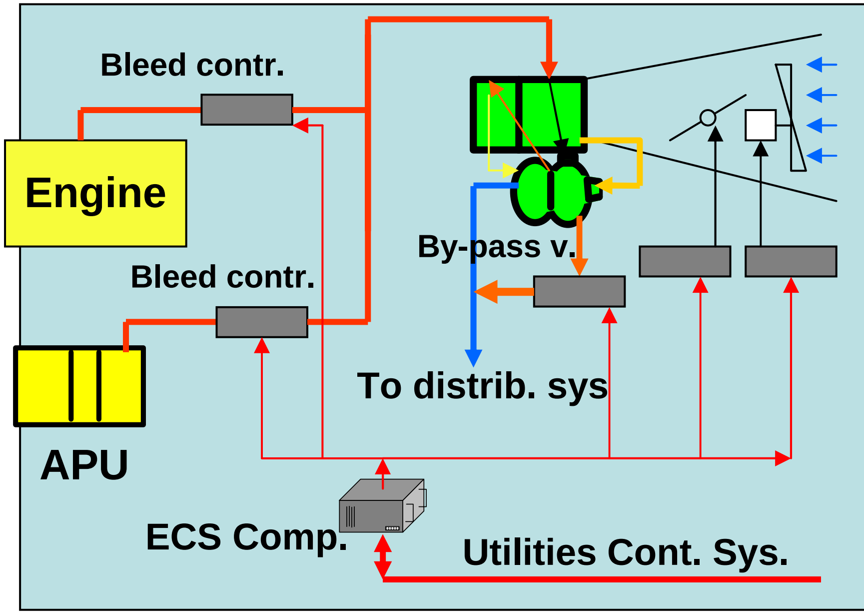


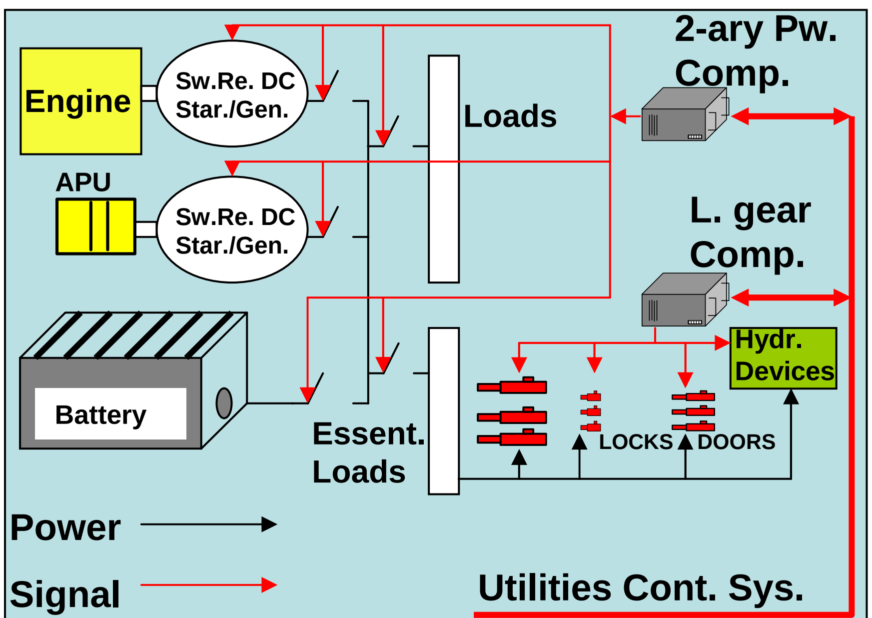
EQUIPMENTS UTILISATION % vs INSTALLATION

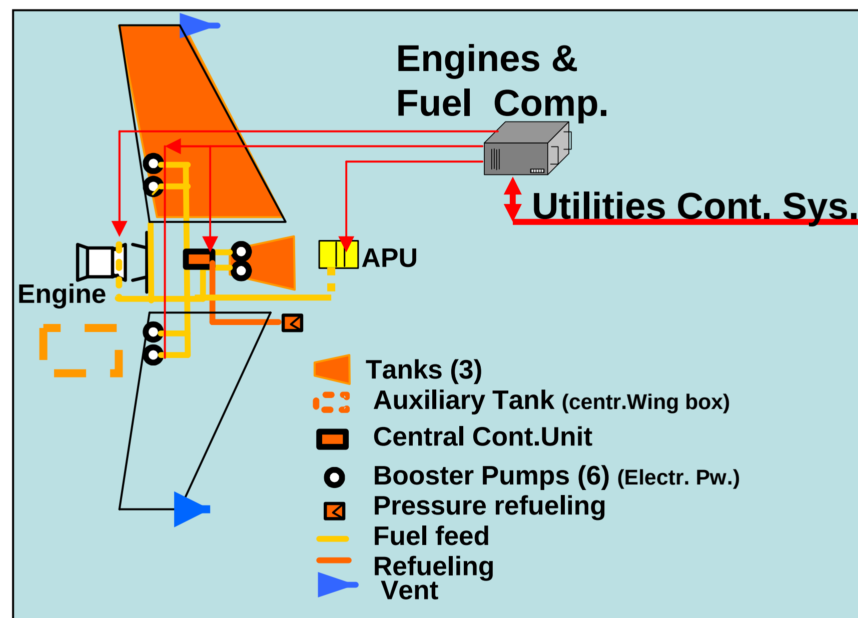
Equip.	Miss.%	Installed
ADC	100%	ac
Tacan	60%	ac
Wp. S.	10%	Ext.Pod

SYSTEMS DEFINITION

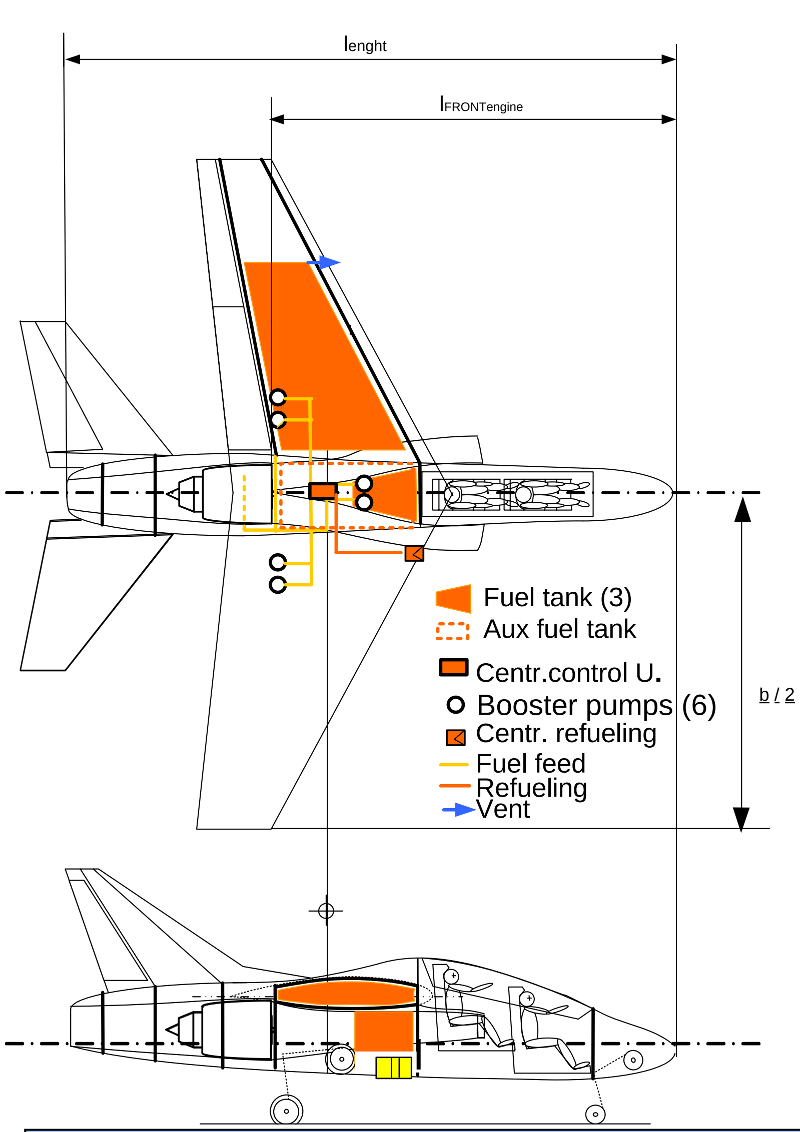


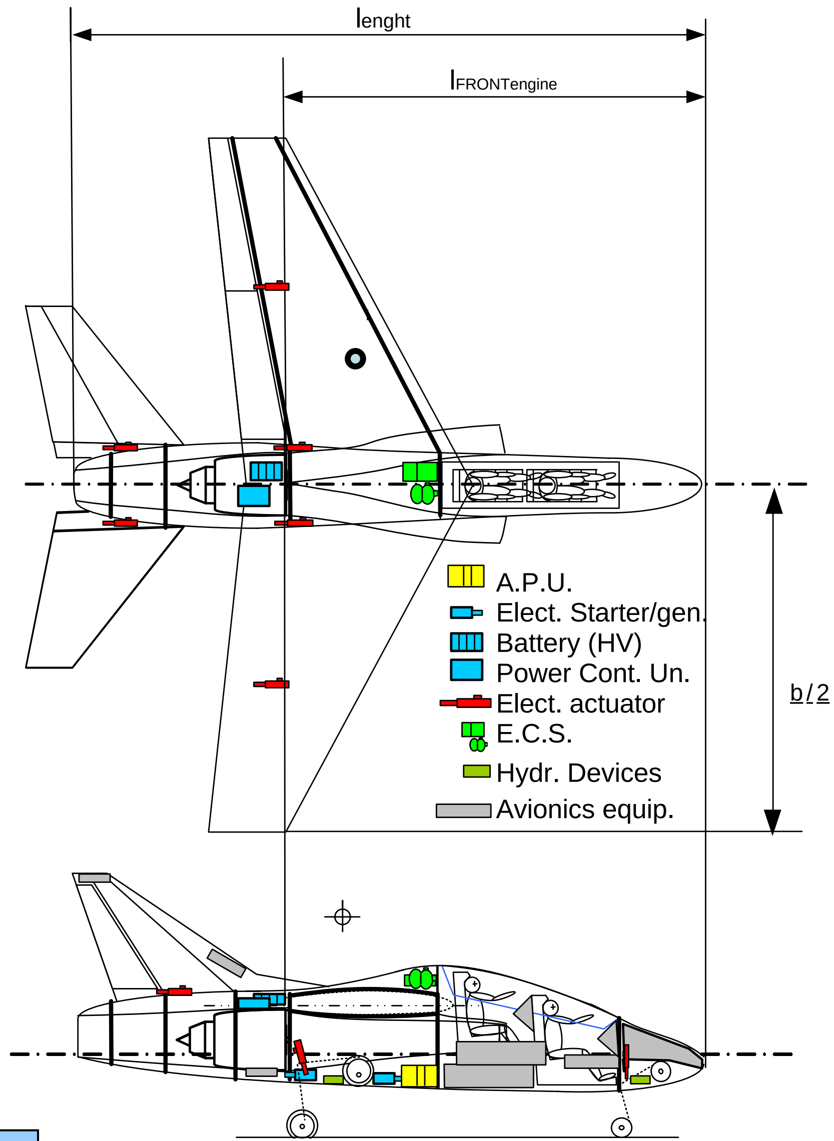






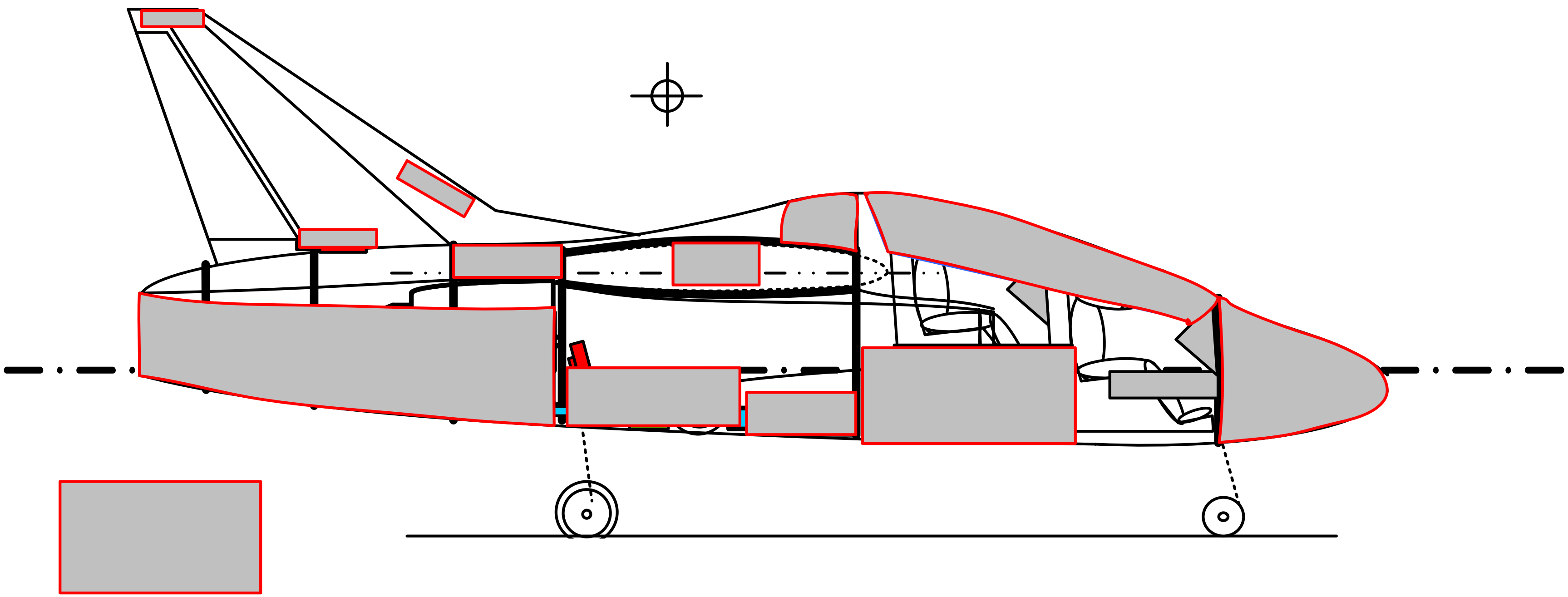
SYSTEM'S FIRST DEFINITION





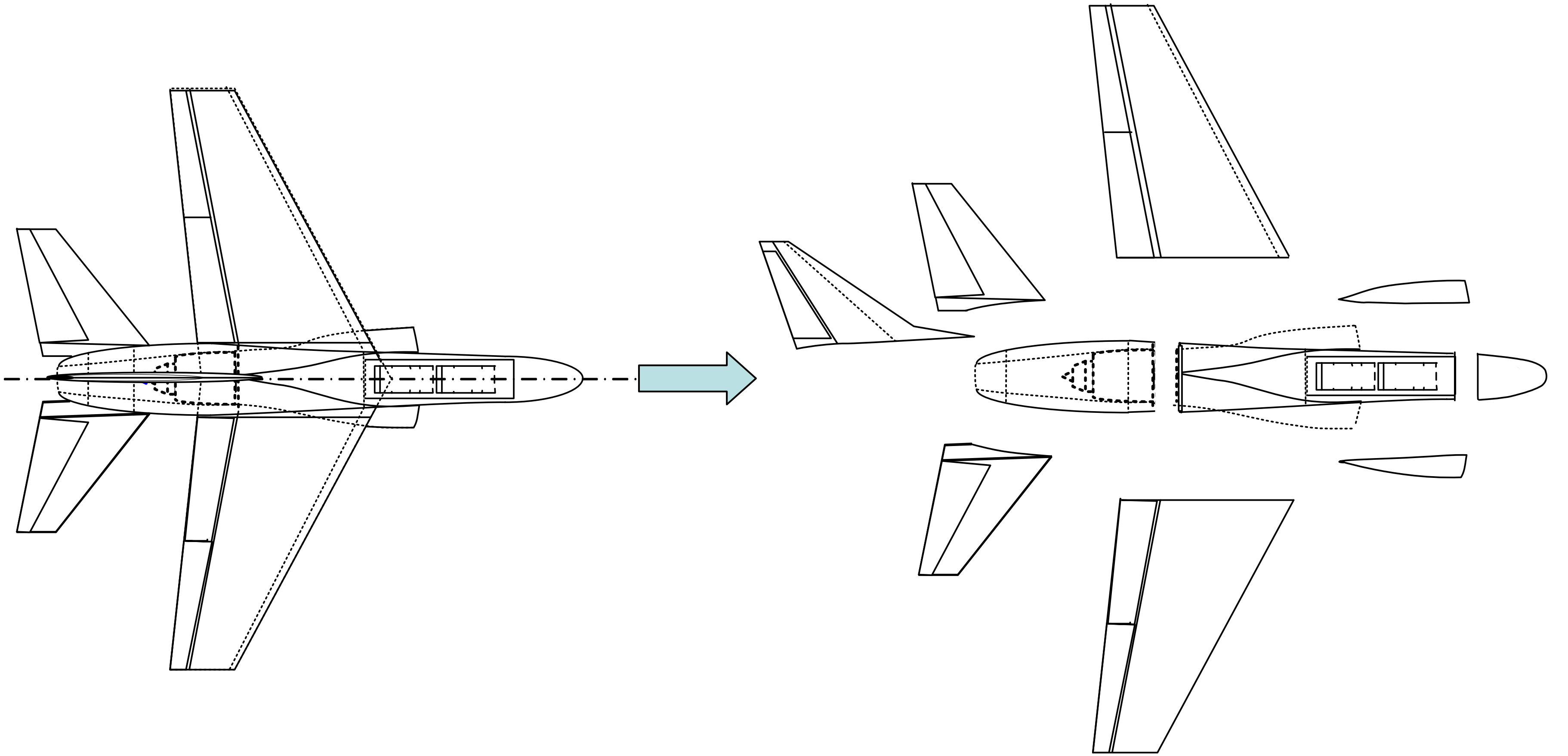
- Check available volume for fuel
- Check change of CoG location with fuel consumption

Mantainability Studies

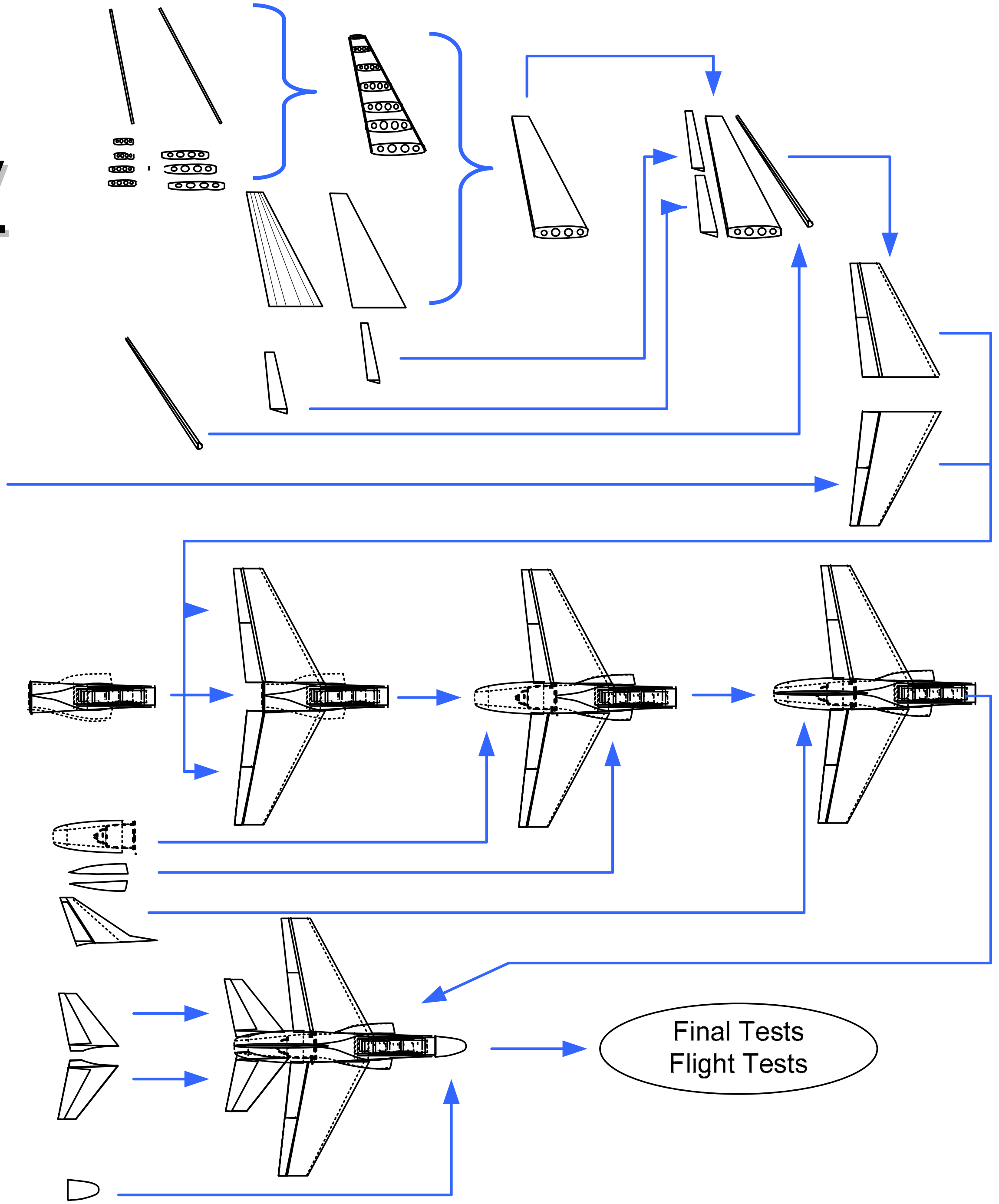


Access doors

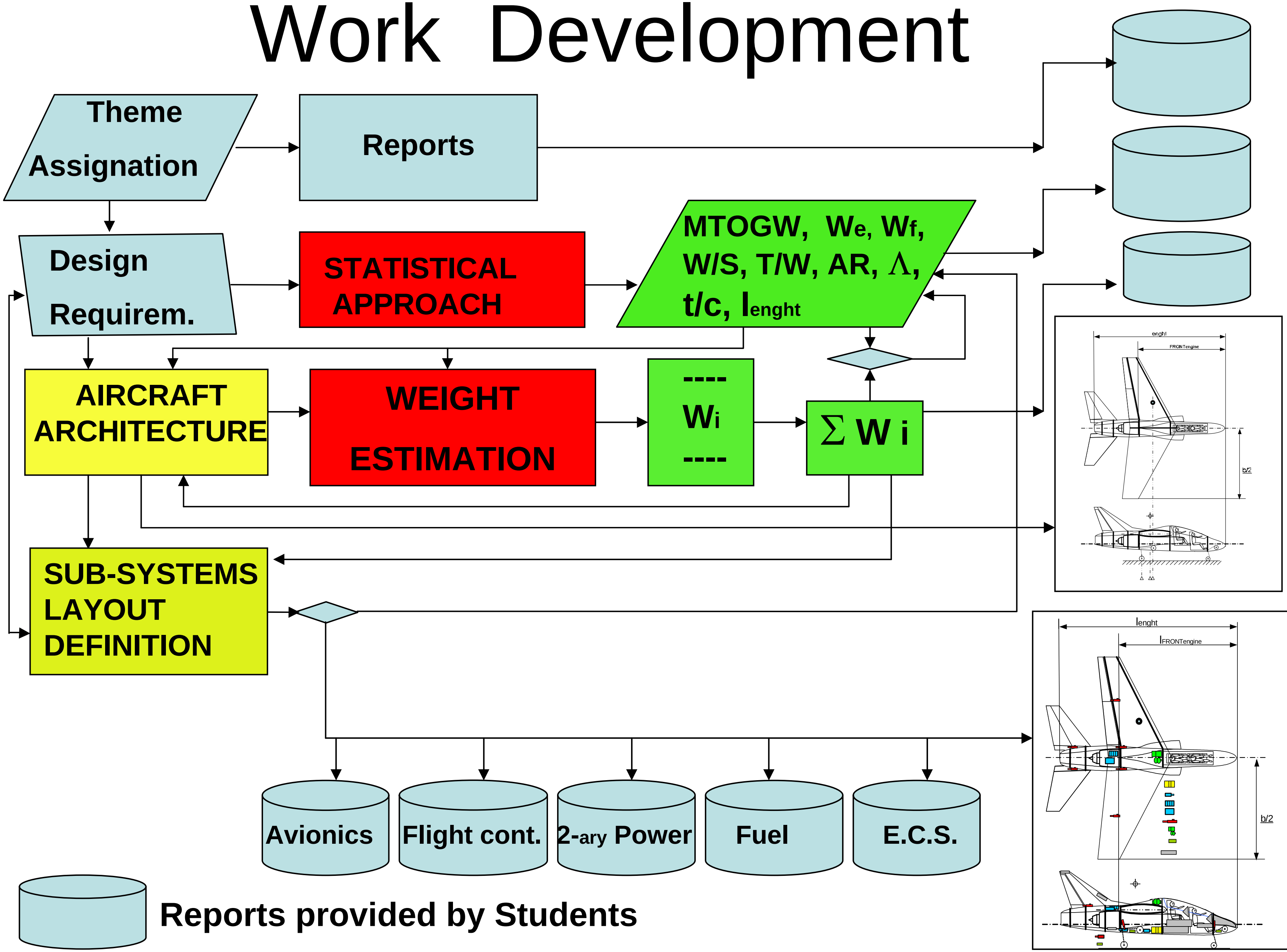
Aircraft segmentation for manufacturing



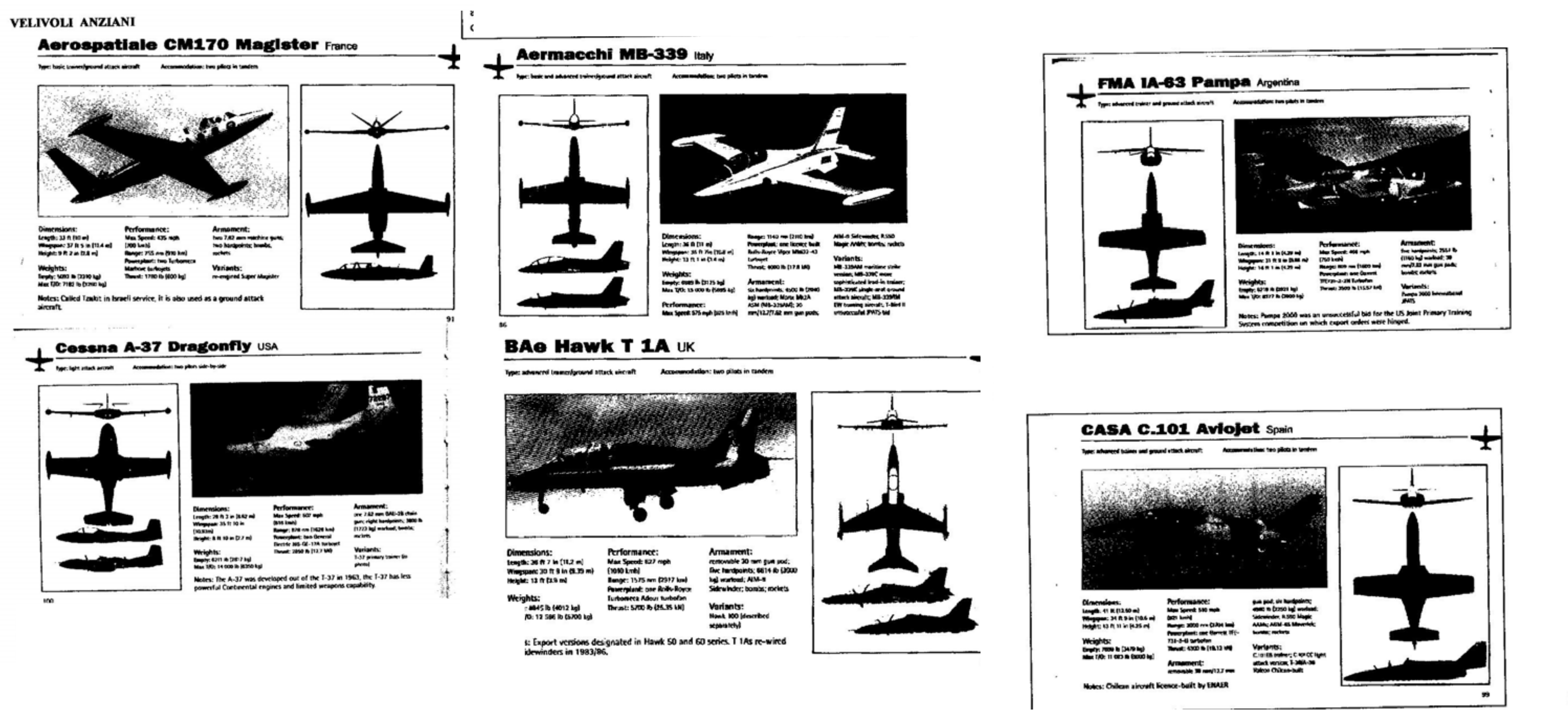
Preliminary assembly study



Work Development



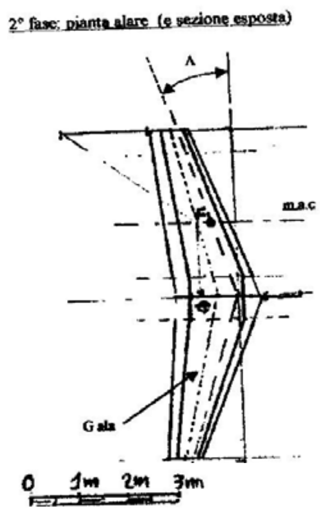
EXAMPLES FROM A STUDENTS TEAM WORK



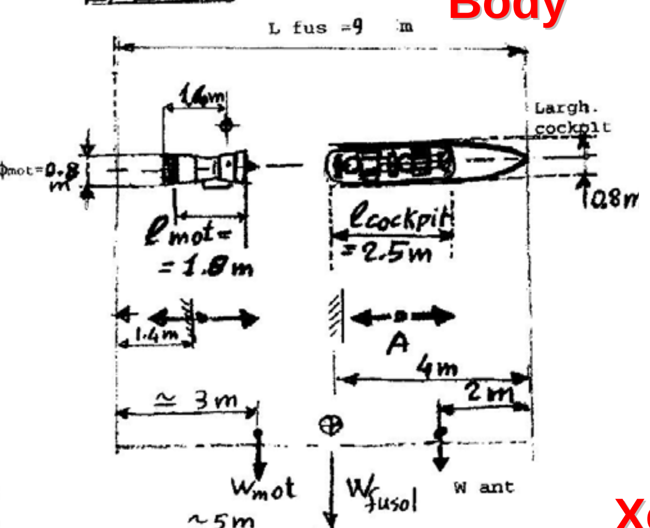
Reading up on similar existing aircraft

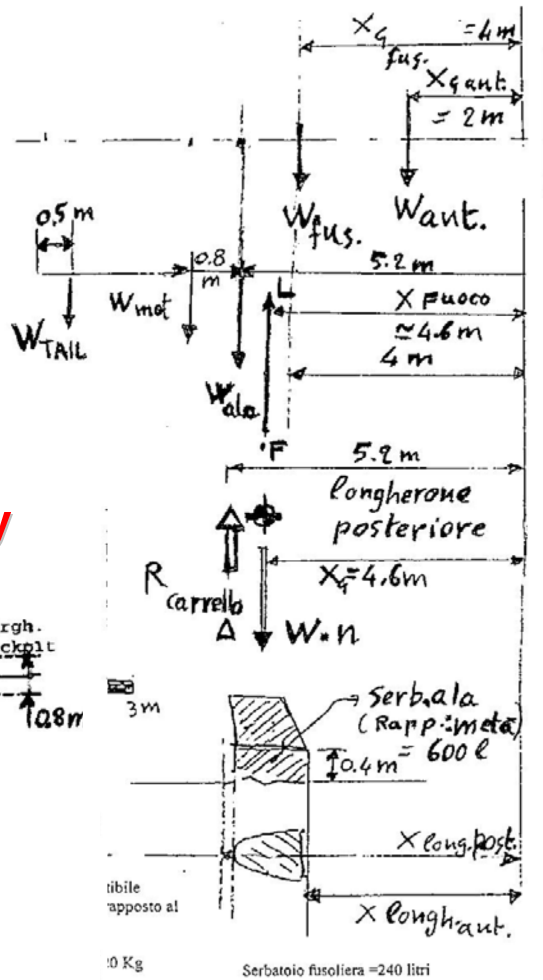
Sizing and architectural definition

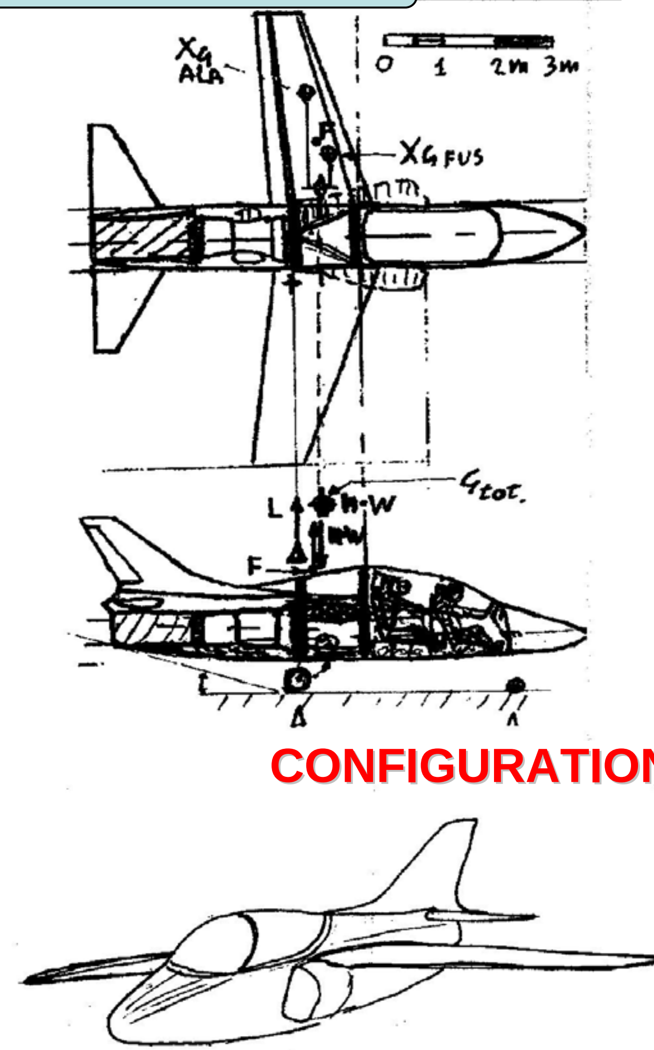
WING



Body





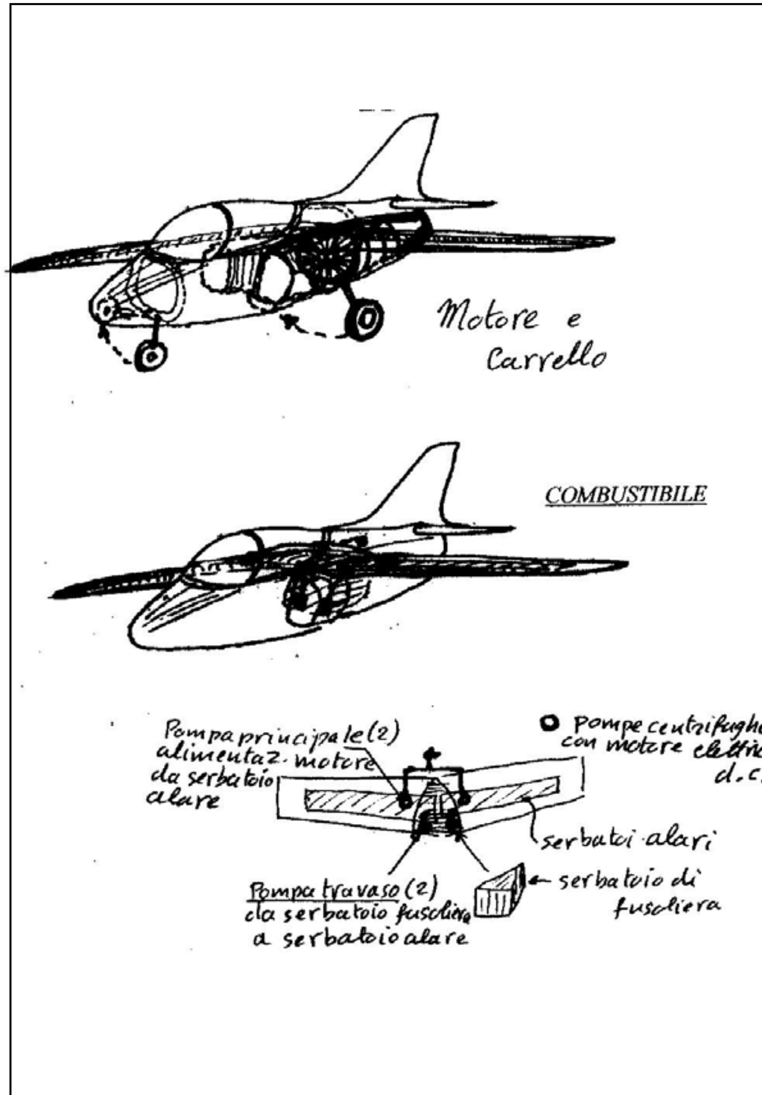


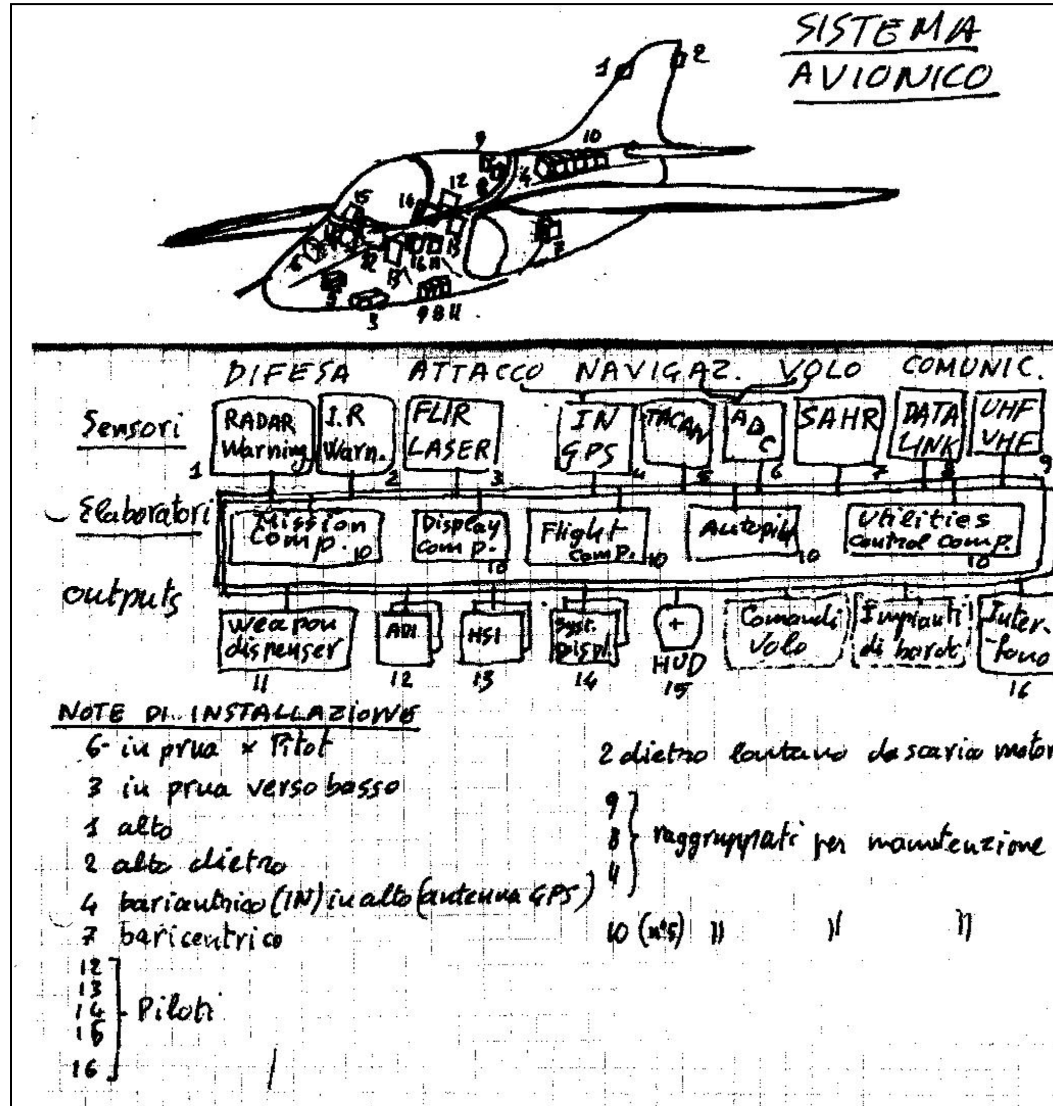
CONFIGURATION

X_{CoG}, Fuel volume, X_{wing}

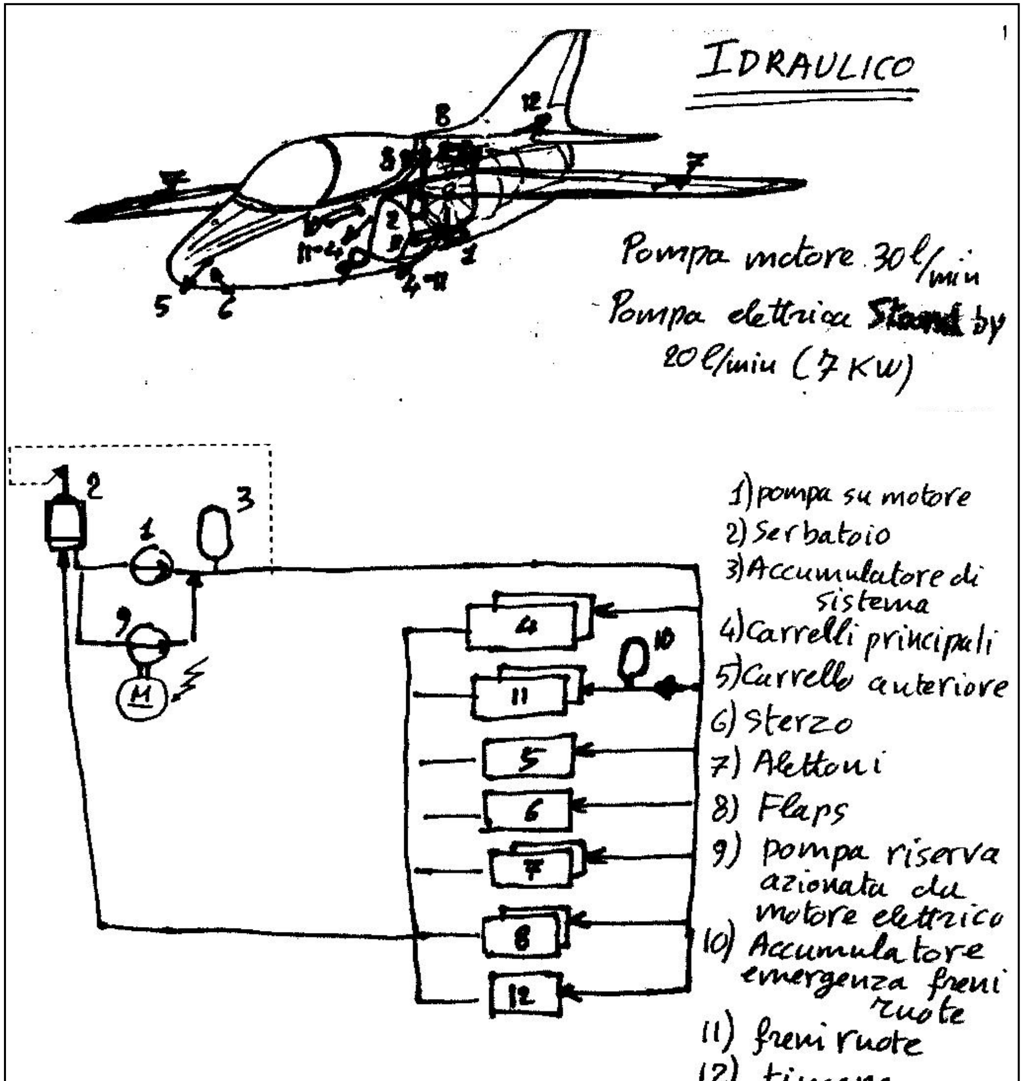
Please note that this example is derived from one of the team works, with some differences in comparison with reference solution above presented

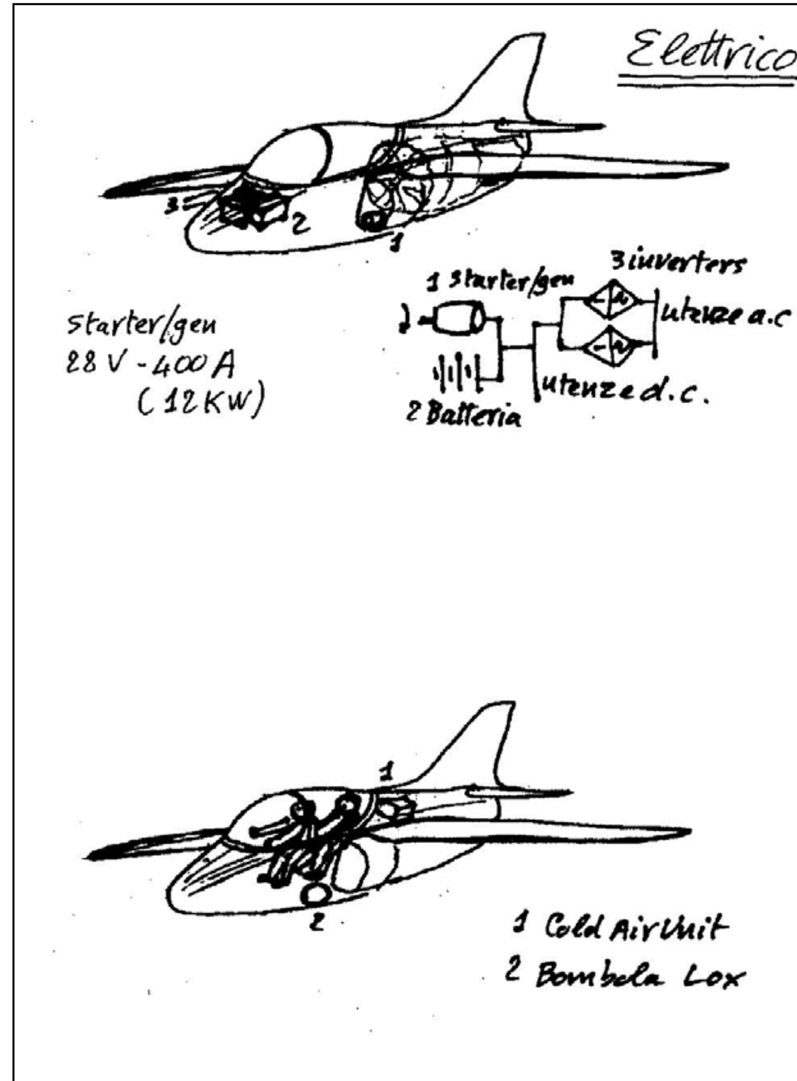
Sub-systems definition and integration (1/2)



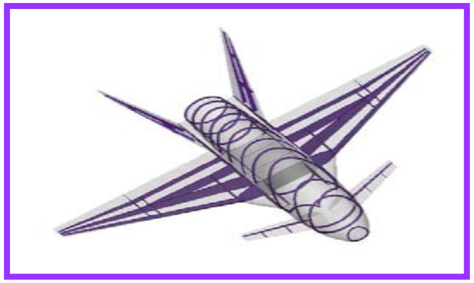


Sub-systems definition and integration (2/2)

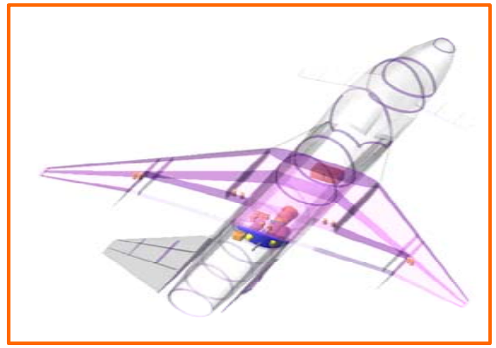




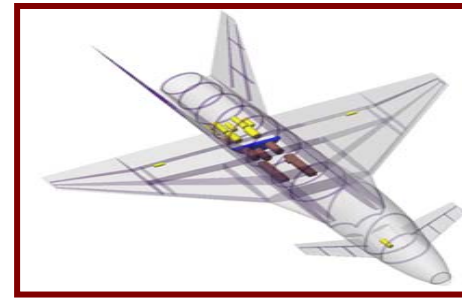
DMUCL: Digital Mock-Up at Conceptual level (SCALT study)



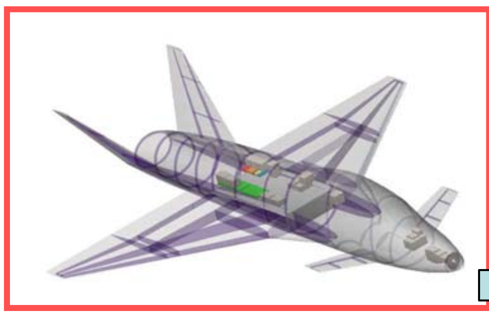
Structural layout



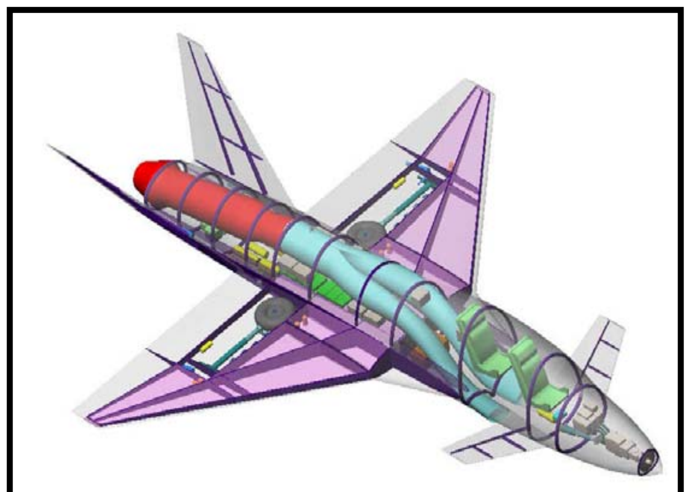
Fuel System

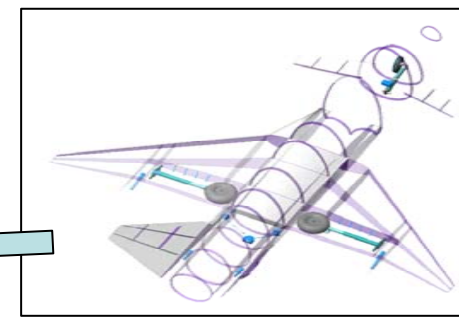


Electrical and hydraulic systems

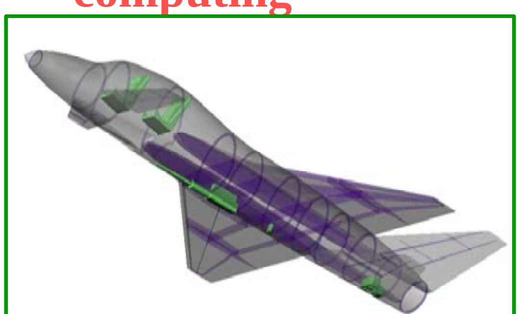


Avionic system and computing

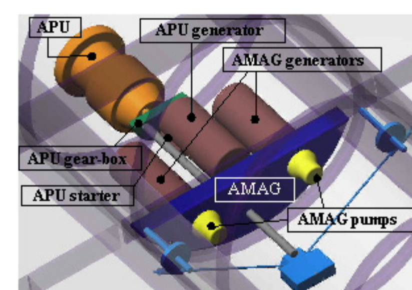




Flight controls and landing gears



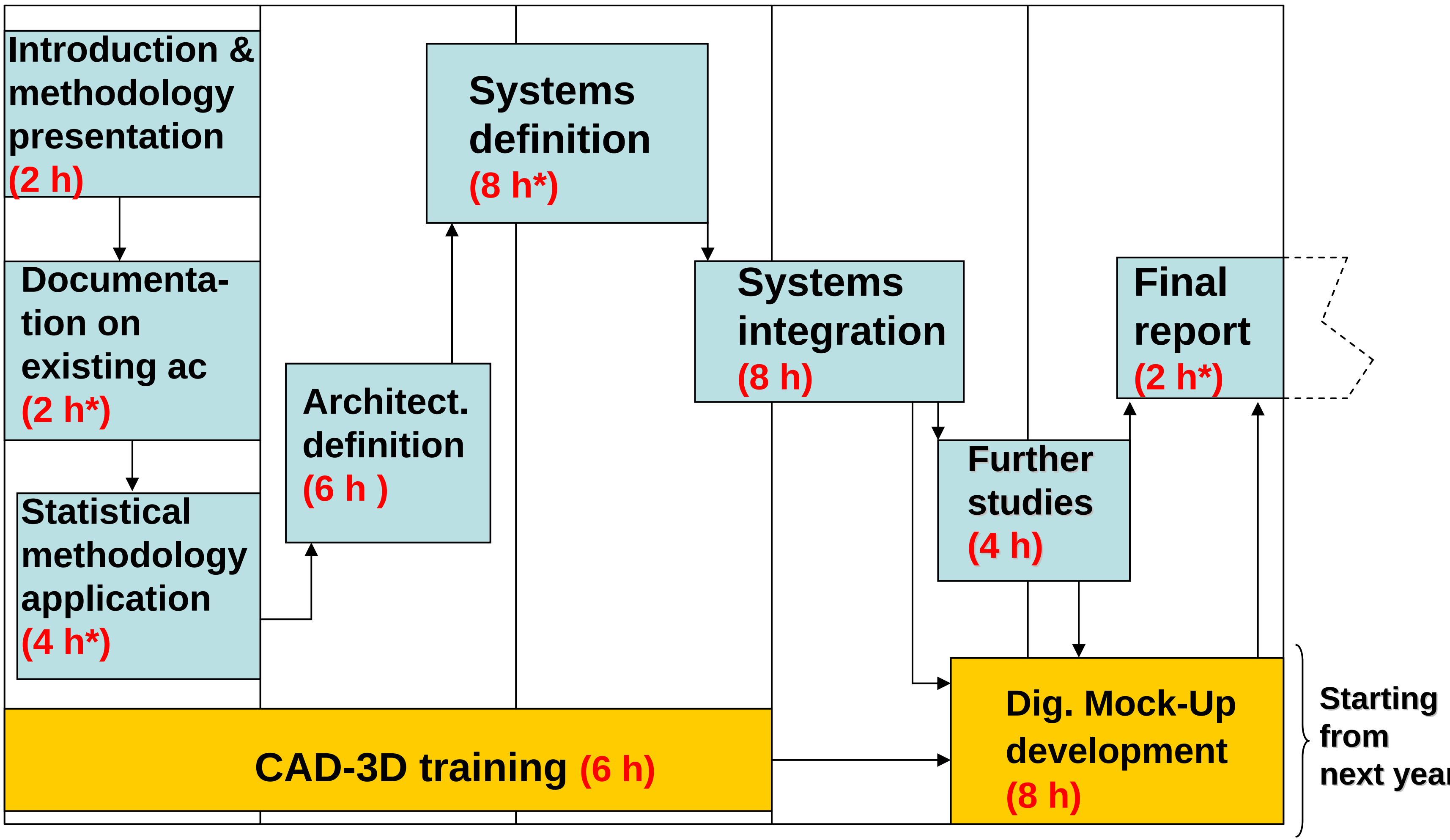
Armament and furnishing



2-ary Power

Course Plan

5 weeks - 10 hours / week (plus individual work)



* plus Individual work

FINAL REPORT ORGANISATION

- Kind of a.c. to be defined and quantitative requirements
- Documentation on similar existing a.c.
- General basic choices and explanation
- Statistical methodology application and results discussion
- Statistical Weight estimations, and, if necessary, feed-back
- Architectural definition and reporting with comments
- General basic choices on (Sub-) Systems
- (Sub-)Systems definition and relevant report
- (Sub-)Systems integration on a.c. and, if necessary, feed-back
- CAD-3D Digital Mock Up (at Conceptual Level: DMUCL)
- A.c. subdivision and construction assembly flow hypothesis
- RAMS and LCC preliminary evaluation