Optimization in Aircraft systems

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Topics

- Aircraft system
- System Evolution
- Domain of optimization
  - ✓ Structure
  - ✓ Aerodynamic
  - ✓ Flight Control
  - ✓ Performance

For centuries, man has dreamed of flying and soaring like an Eagle high above the world below. Men starting imagined how it must be to take to the air.

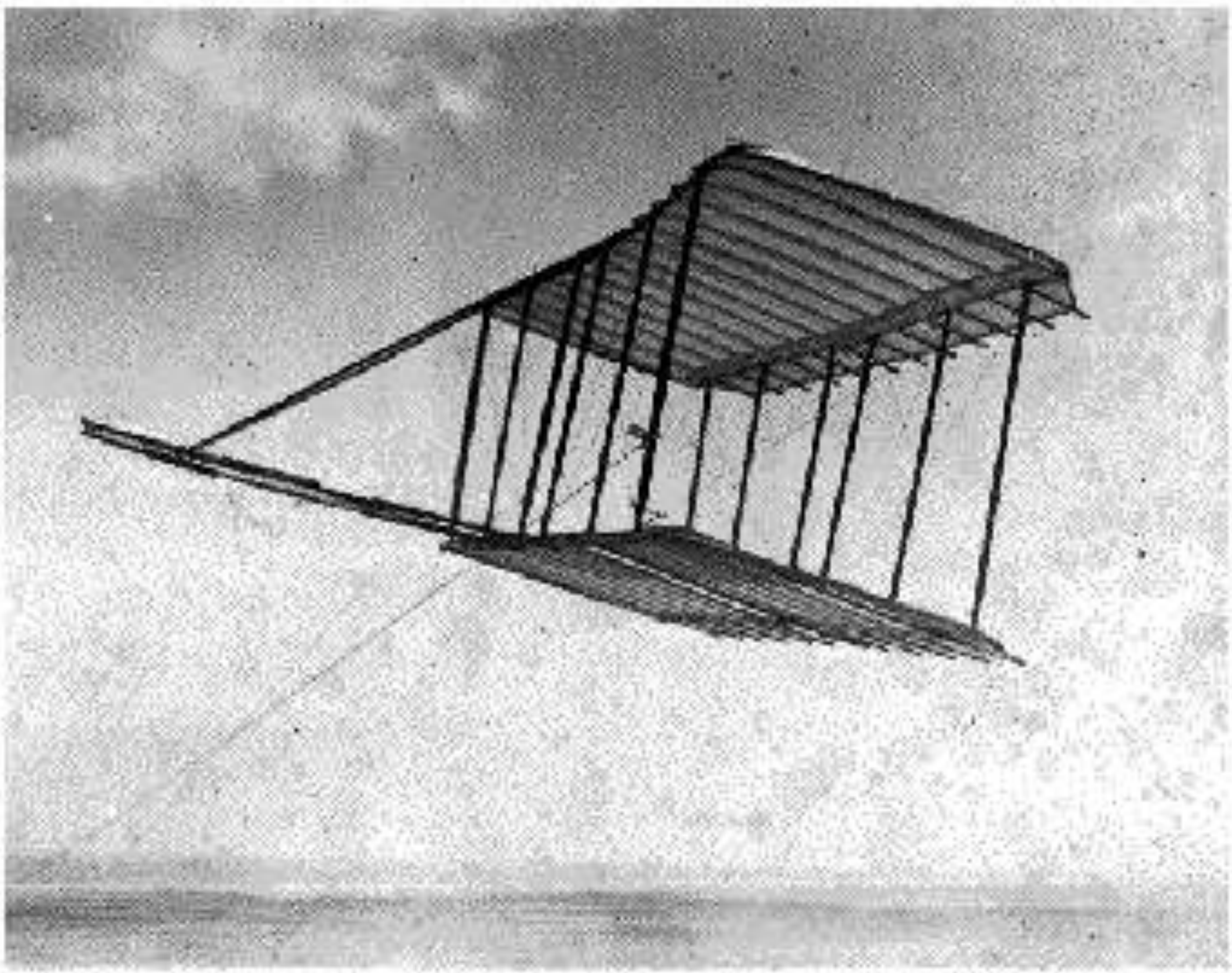
That dream and imagination is now reality.

In a short one hundred years, aviation technology was transformed from the often unreliable wooden, cloth-covered biplanes to supersonic jets and international airliners. What was it that provoked such rapid progress?

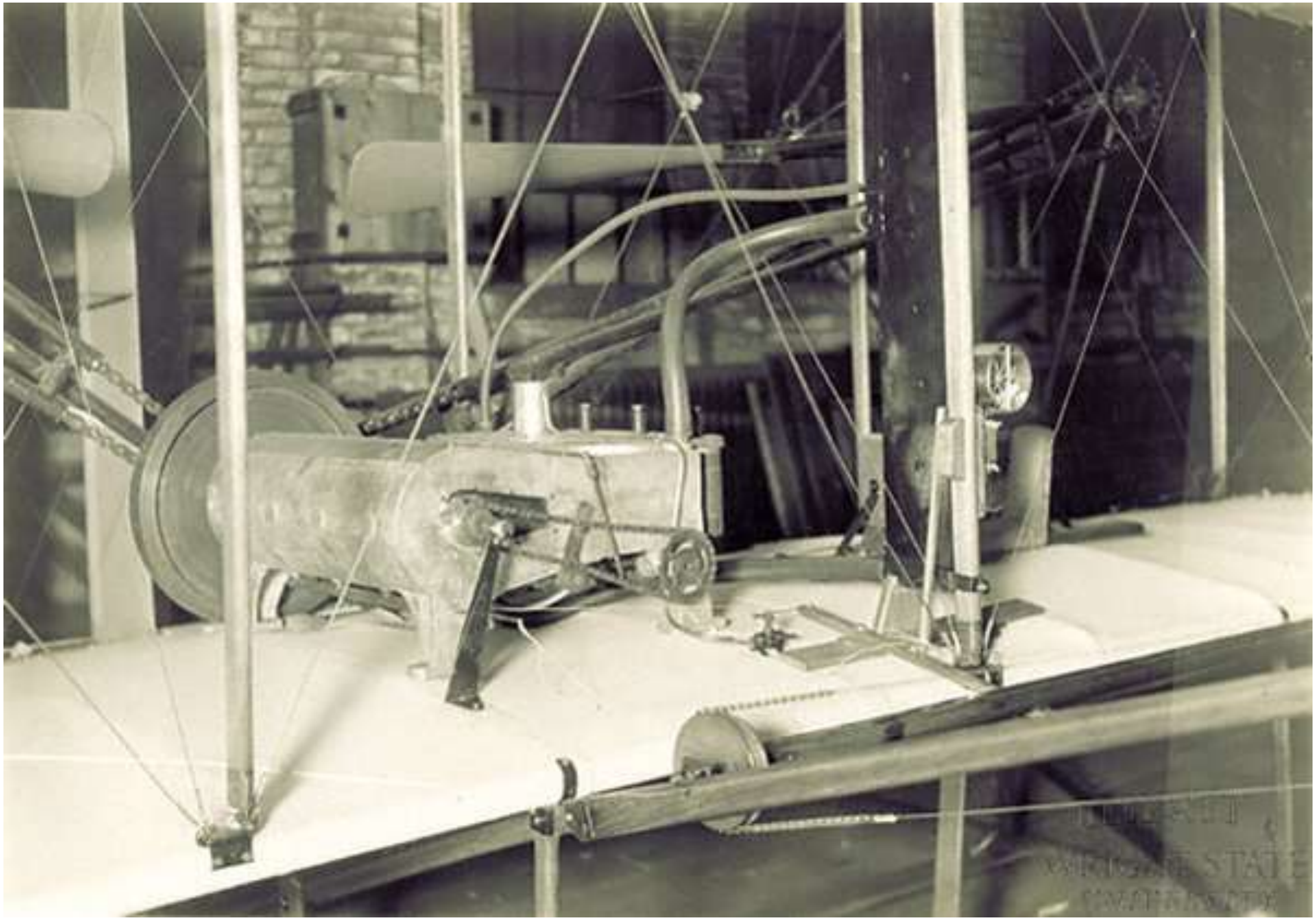
History of flight

The Early Attempts to Fly

1900: Test the Lift force

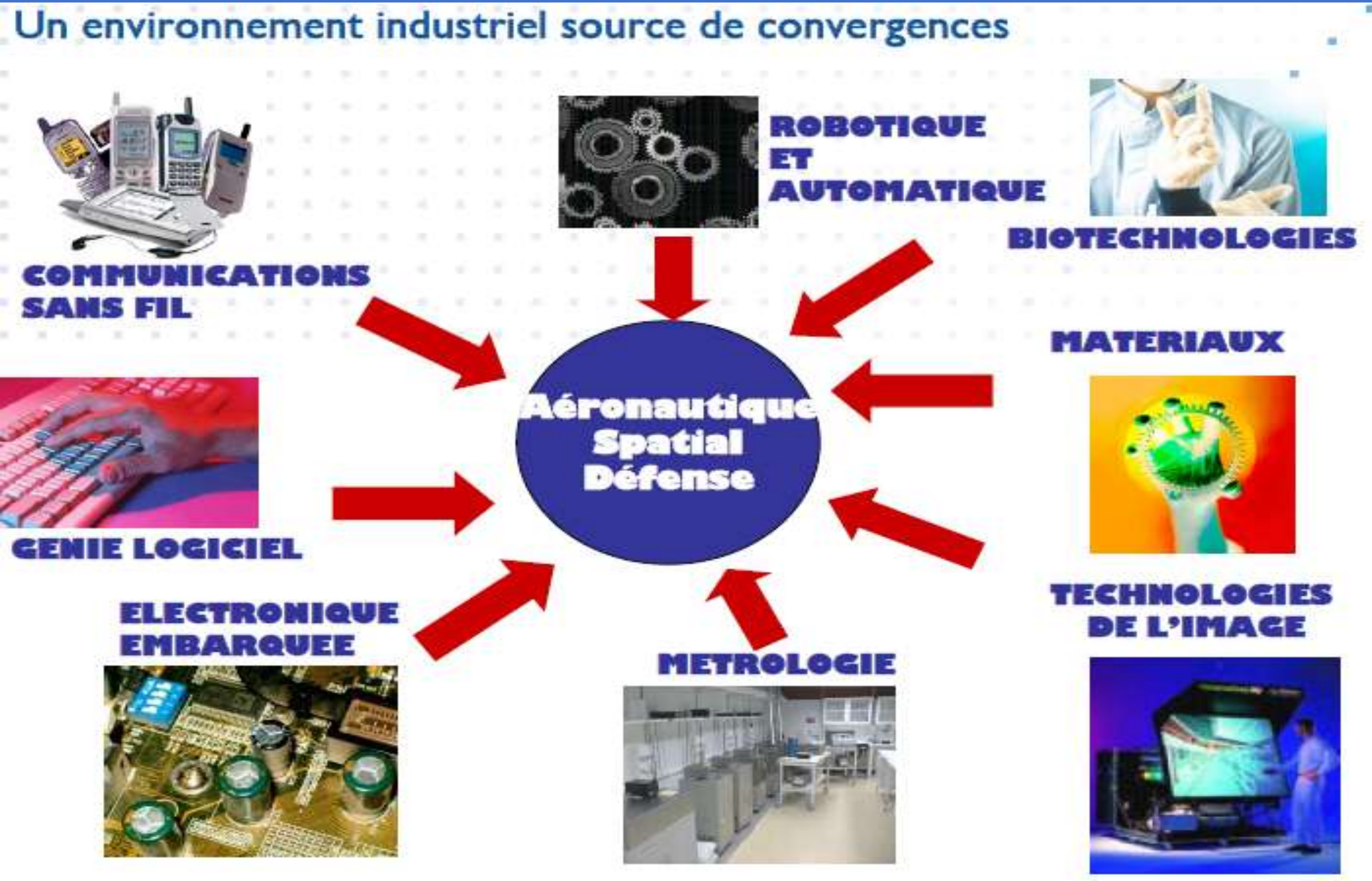


Move from 1902 Glider to the 1903 powered aircraft. Add a engine.



Aircraft Systems

AIRCRAFT ENVIRONMENT



Aircraft systems

- **FRAME : Wood-Metal-compound Material**

    Aerodynamics
    Materials
    Chemistry

- **POWER PLANT : Turbojet/Turboprop/Turbofan**

    Material
    Theromodynamics
    Chemistry
    Heat Transfert

- **AVIONIC and EMBEDED SYSTEMS**

    Electronics
    Electricity
    Automation
    Computer Science

- **FLIGHT CONTROL SYSTEMS: Mechanical-Hydraulic-Fly by wire**

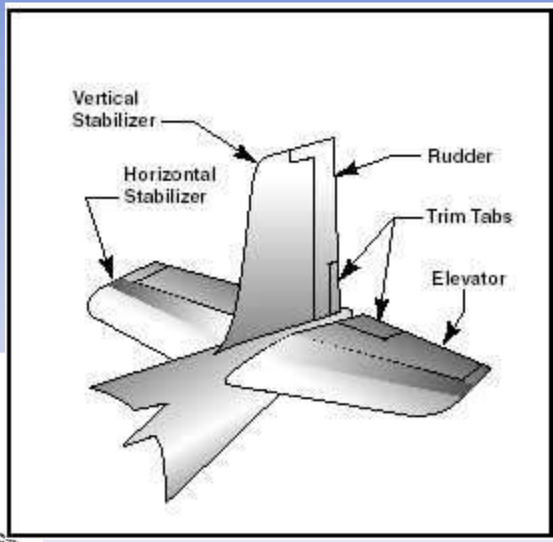
    Mechanics
    Hydraulic
    Command and control

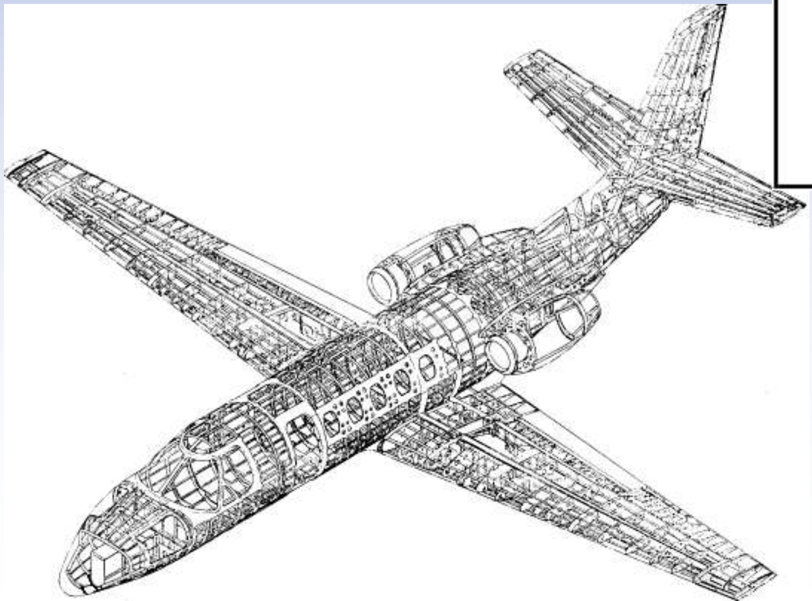
DOMAIN OPTIMIZATION

FRAME

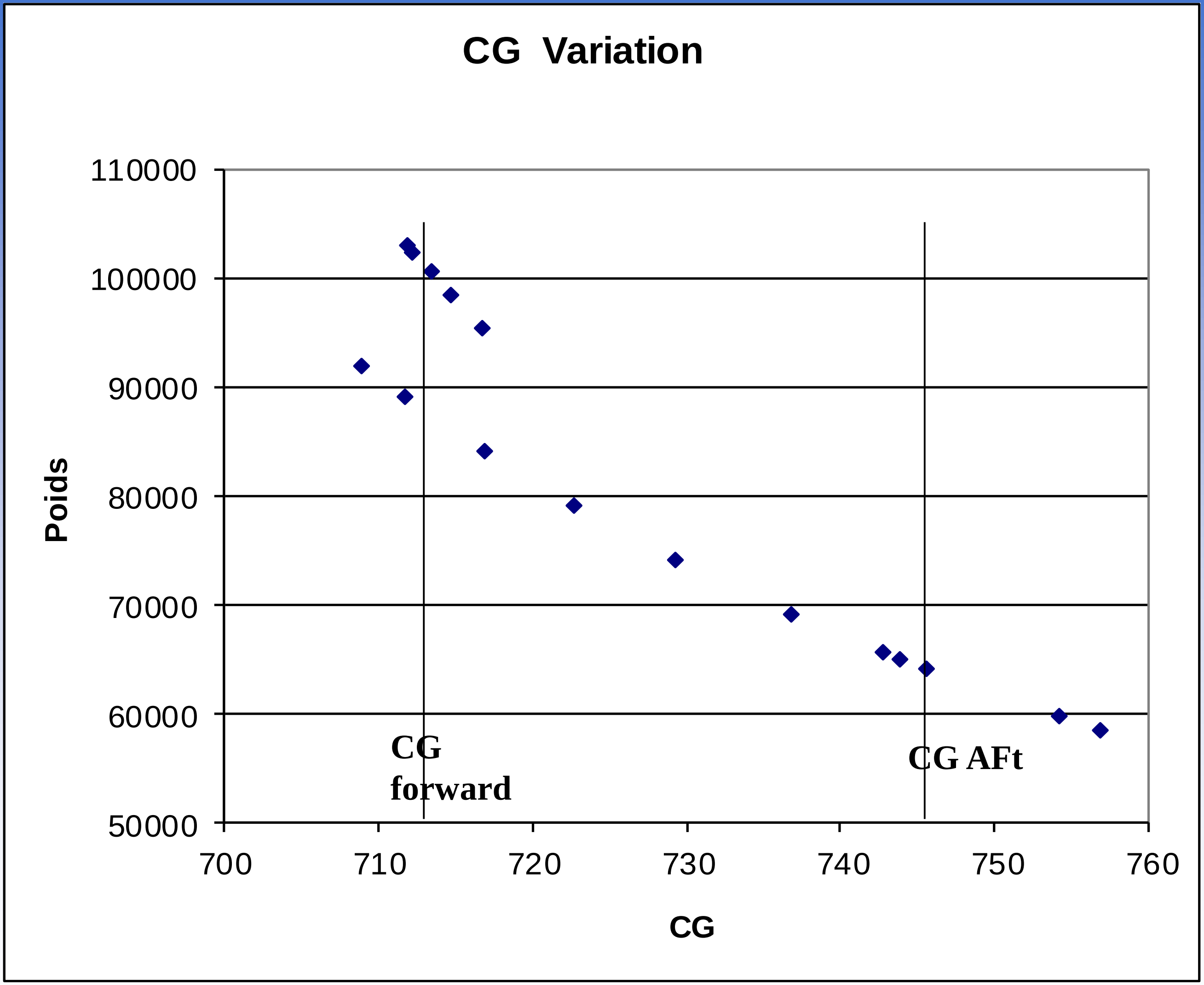
The Frame

- STRUCTURE
- AERODYNAMIC
- MATERIAL





Optimization Domain

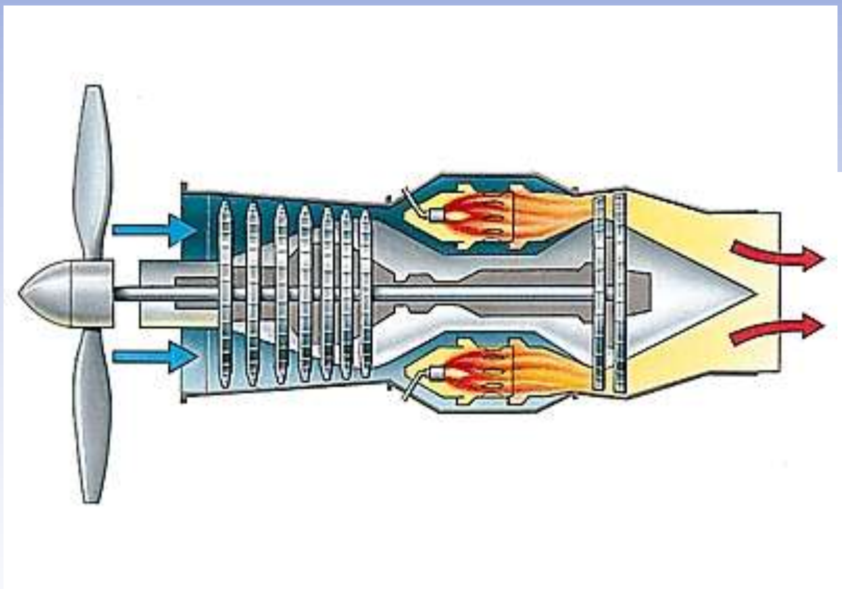


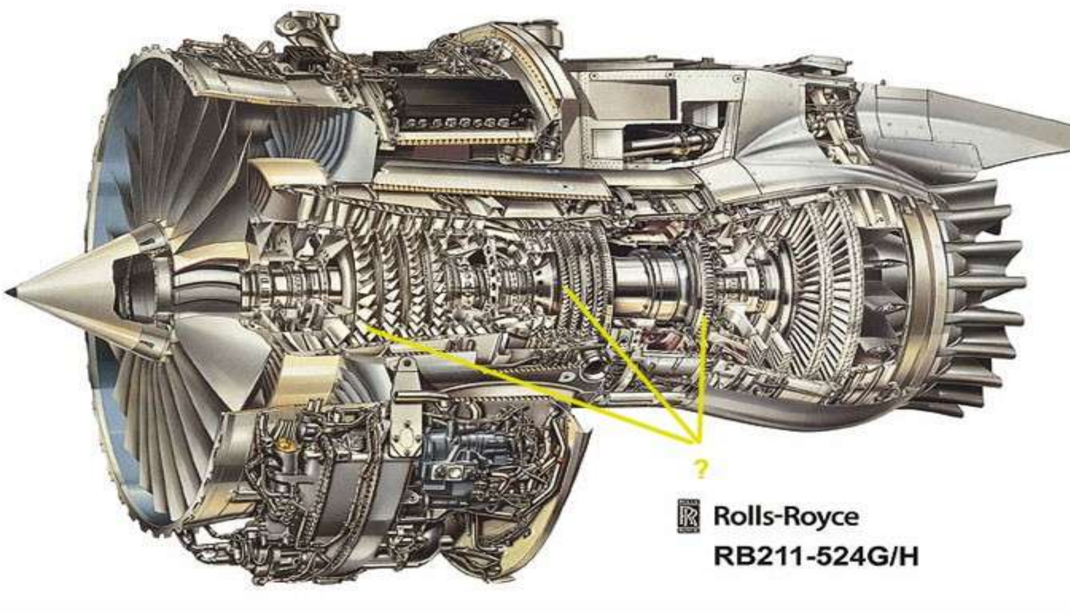
Cg Variation during Flight

POWER PLANT

POWER PLANT:

- TURBOREACTEUR
- TURBOPROPULSEUR
- SOLAIRE – MOTEUR ELECTRIQUE





Empty weight

Empty weight is also defined in categories such as:

$$W_e = W_{af} + W_{lg} + W_{eng} + W_{fe} + W_{os} \quad (1.2)$$

where

Waf = Airframe (structure) weight
Wlg = Landing gear weight
Weng = Propulsion system weight
Wfe = Fixed equipment weight (avionics, etc)
Wos = Other systems

These categories are useful for concept design

- Their weights are typically driven by different design issues. For example:
  - Airframe weight often scales with wetted area
  - Landing gear weight scales with takeoff weight
  - Fixed equipment weight is constant, etc.

Weight Sizing

Weight fractions (empty weight, fuel and payload)

- Assumed weight fractions are traditionally used as a starting point for air vehicle sizing
- The advantage is simplicity

Weight fractions

Another commonly used form of weight *From Equation :*

$$W_e/W_0 + W_{pay}/W_0 + W_f/W_0 + W_{misc}/W_0 = 1 \qquad (1.3)$$

where by definition

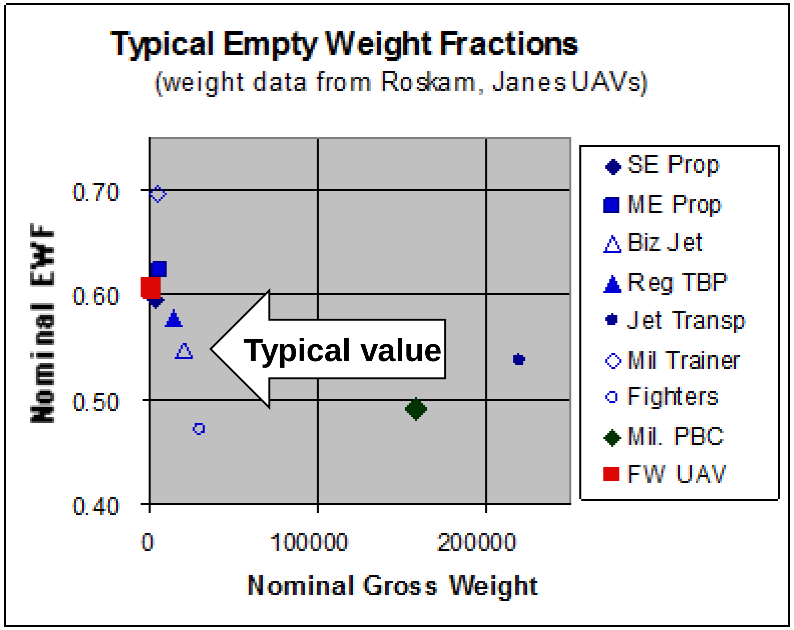
- W_e/W_0 = Empty weight fraction (EWF)
- W_{pay}/W_0 = Payload fraction (PF)
- W_f/W_0 = Fuel Fraction (FF)
- W_{misc}/W_0 = Misc. weight fraction (MWF)

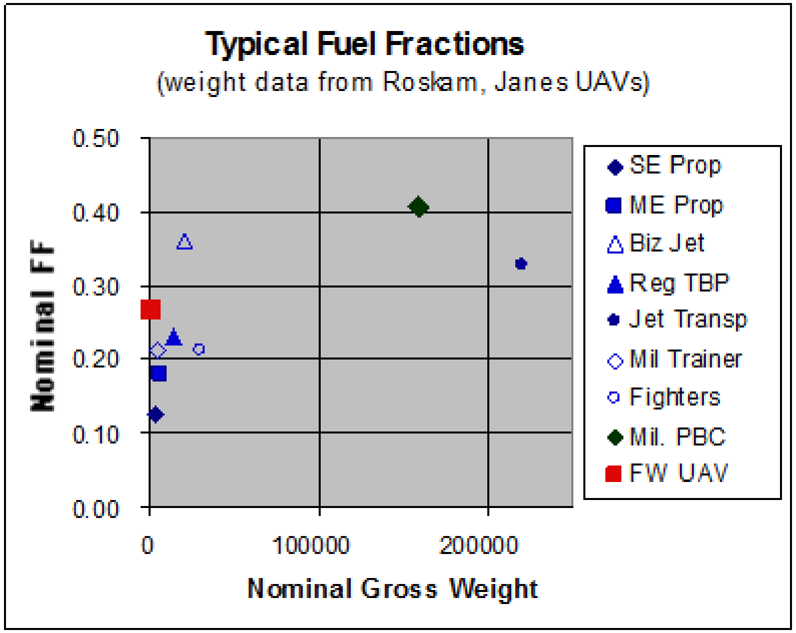
There is a similar form of Equation 1.2

$$EWF = W_{af}/W_0 + W_{lg}/W_0 + W_{eng}/W_0 + W_{os}/W_0 + W_{fe}/W_0 \qquad (1.4)$$

Weight fractions -

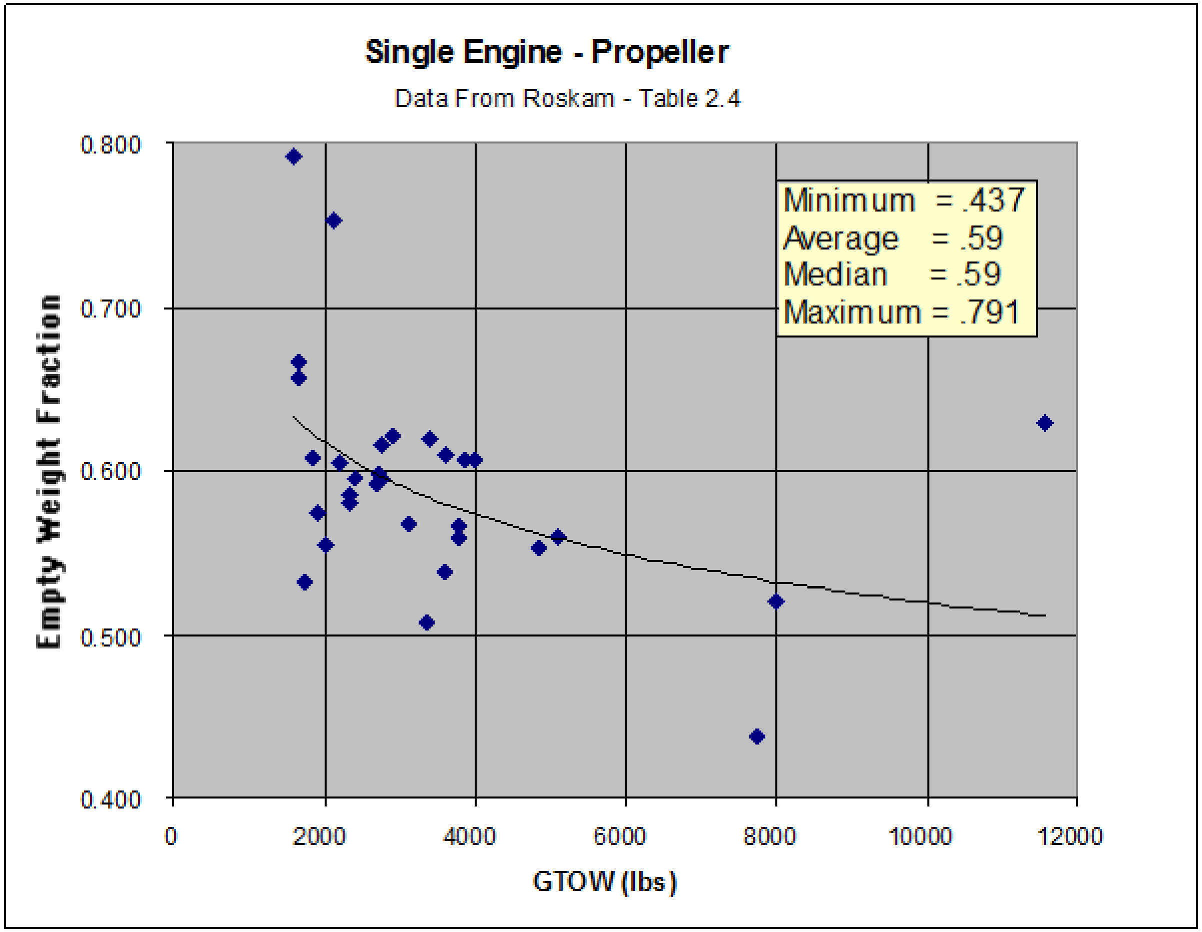
- **Empty weight fraction and fuel fraction are key design parametrics**
  - They vary widely with design mission and vehicle class
  - **Range and/or endurance, speed, payload and technology level are primary drivers.**





EWF variation

Within a given aircraft class, EWF will also vary - *widely*

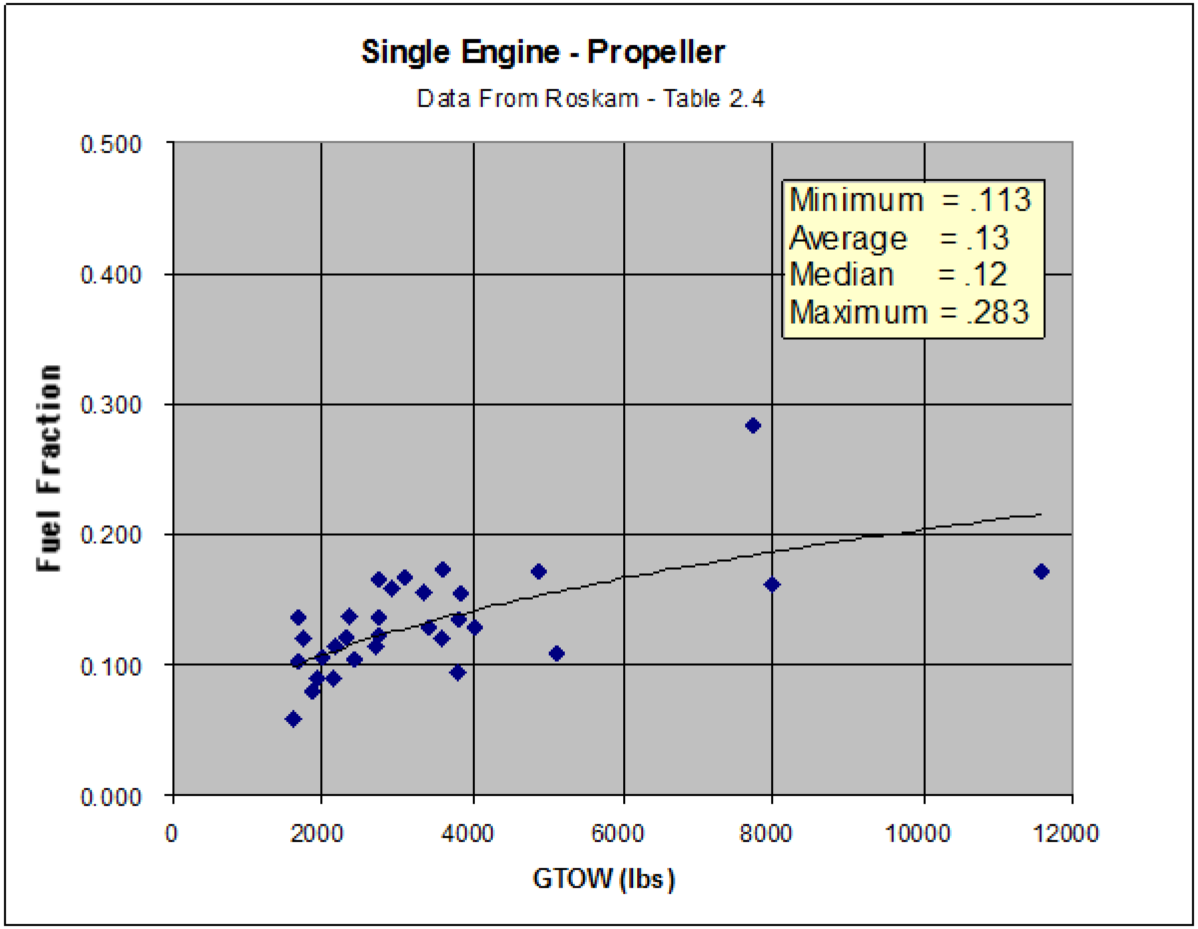


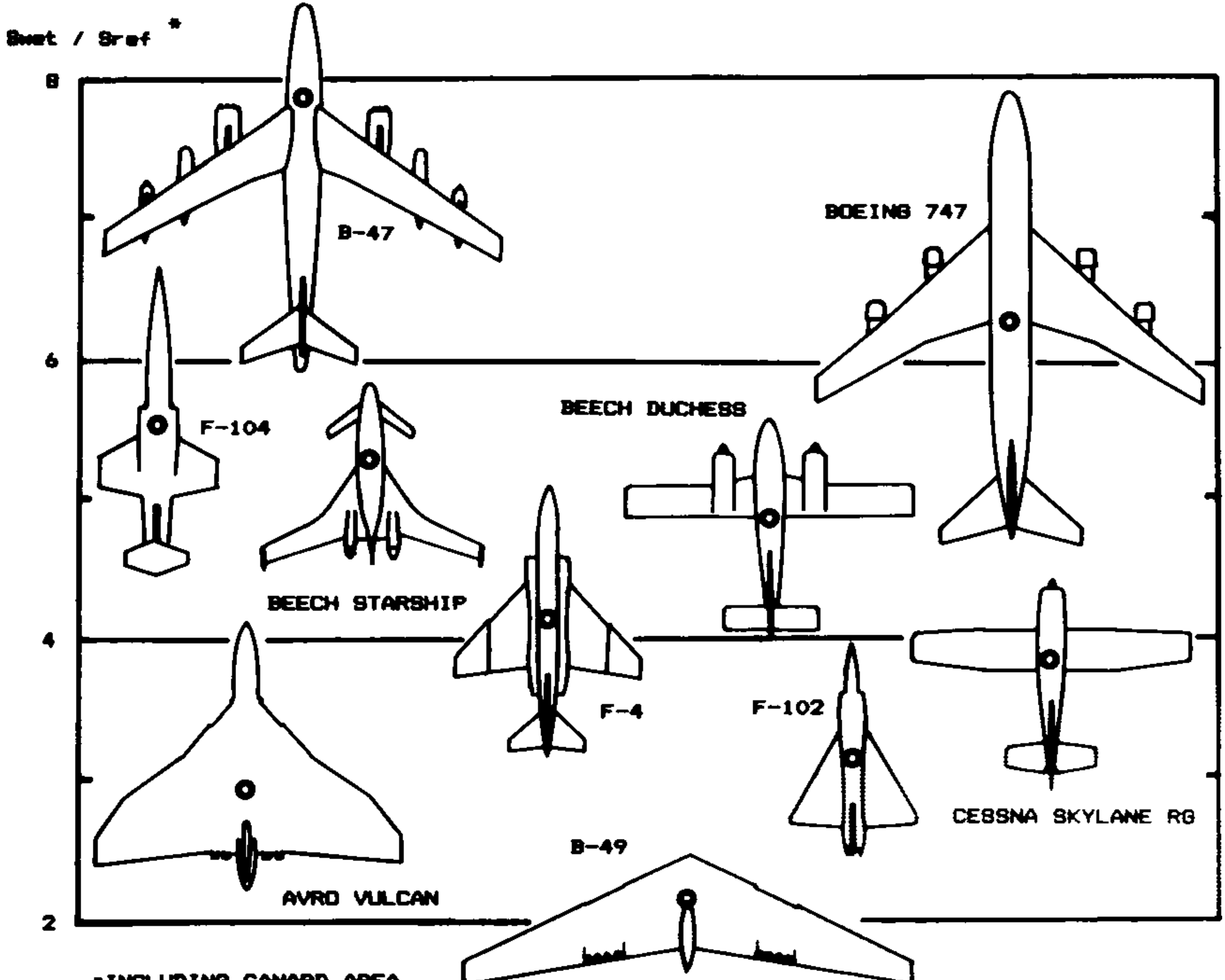
Data source - Roskam, (RosAD.1)

Fuel Fraction variation

- **Ditto for fuel fraction (FF).**

Data source - RosAD.1, Table 2.4





Wetted Area Ratio

Sailplane equivalent* aspect ratio $= 4.464\ (\text{best } L/D)^{.69}$

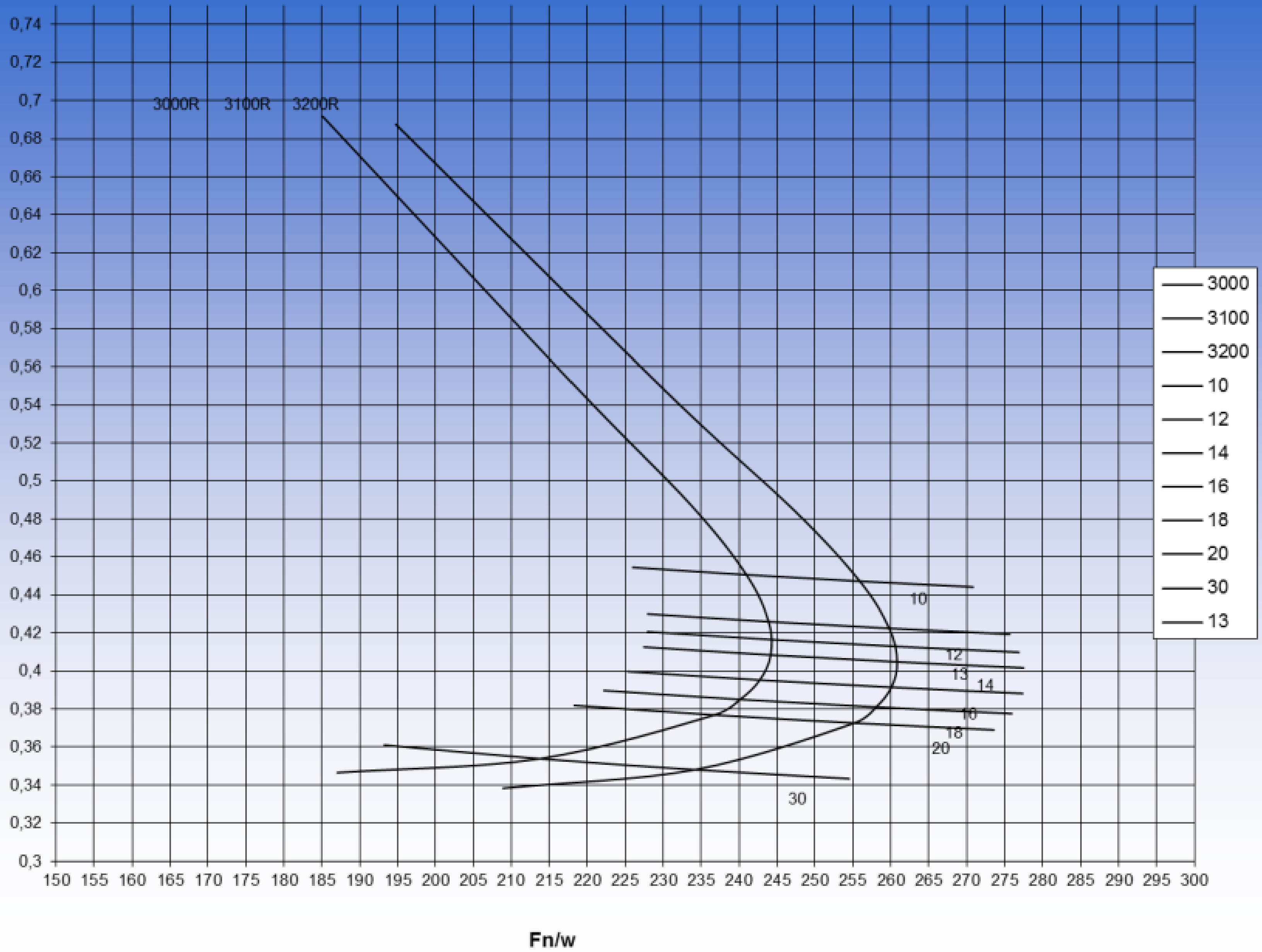
Propeller aircraft	Equivalent aspect ratio
Homebuilt	6.0
General aviation—single engine	7.6
General aviation—twin engine	7.8
Agricultural aircraft	7.5
Twin turboprop	9.2
Flying boat	8.0

	Equivalent aspect Ratio $= aM_{max}^{C}$	
Jet aircraft	a	C
Jet trainer	4.737	−0.979
Jet fighter (dogfighter)	5.416	−0.622
Jet fighter (other)	4.110	−0.622
Military cargo/bomber	5.570	−1.075
Jet transport	7.50	0

*Equivalent aspect ratio = wing span squared/(wing and canard areas)

Aspect Ratio

ENGINE DESIGN OPTIMIZATION



Optimization Domain

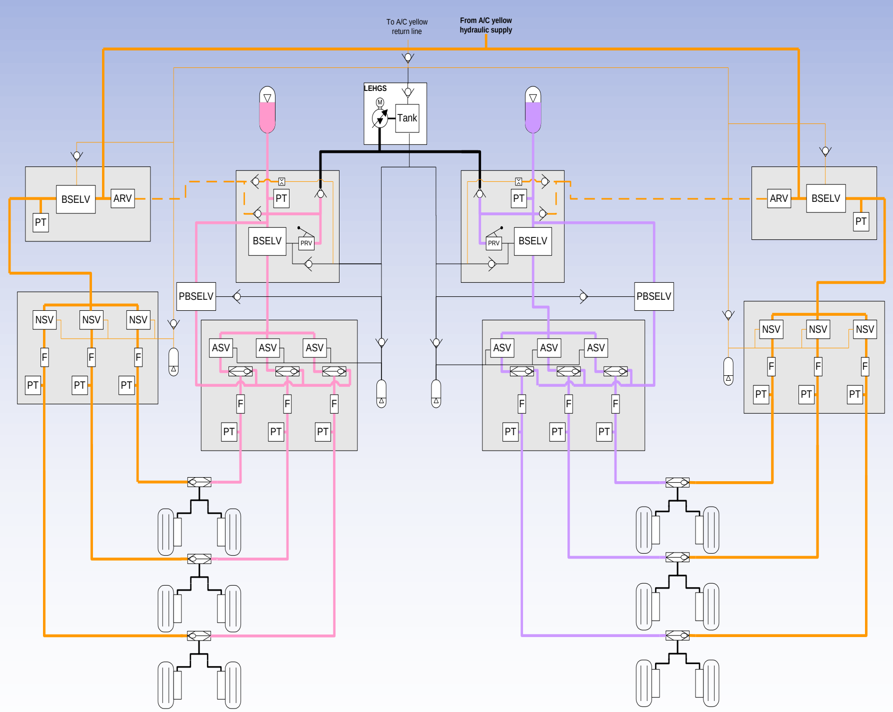
AVIONICS :

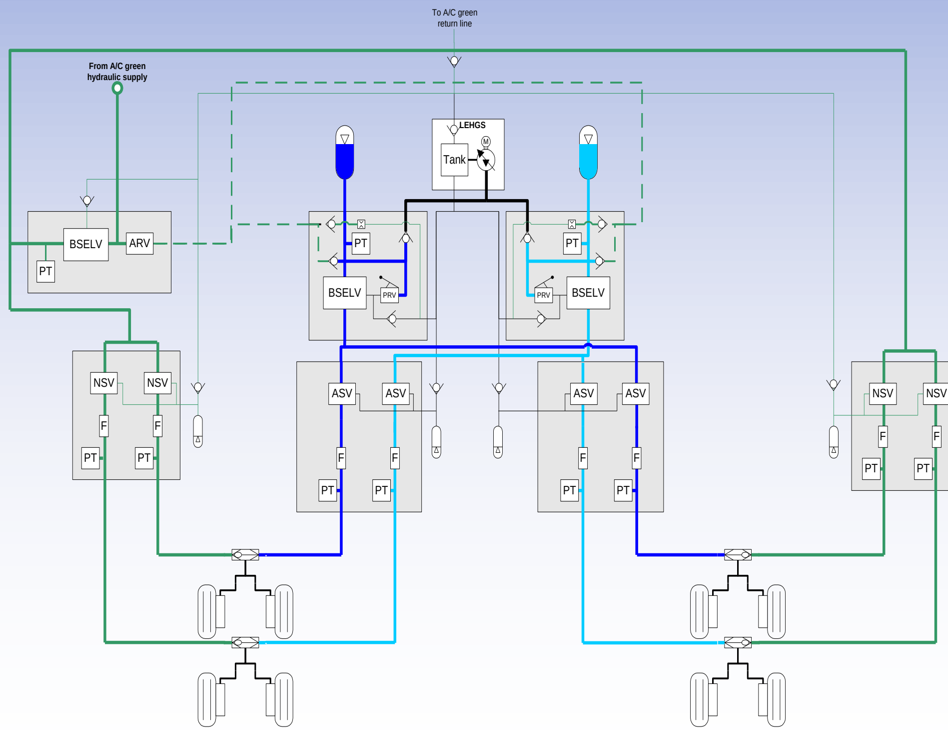
- système radionavigation(Rdar – GPS-,,,,etc)
- Les commandes de vol Autopilot
- FMS

Optimization Domain

Flight Control System

- Hydraulic SYSTEM
- Electric SYSTEM
- Fuel SYSTEM
- Oxygène SYSTEM





AVION ET SON ENVIRONNEMENT

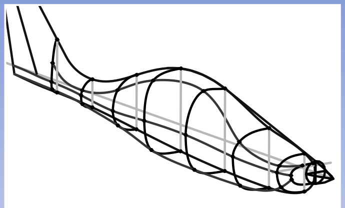
les systèmes vitaux de l'avion

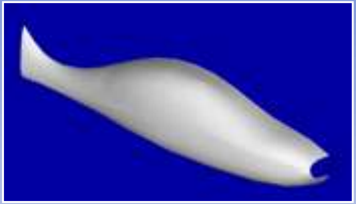
- Anti-Icing
- Dicing SYSTEM

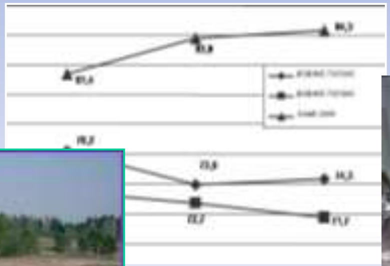
METIERS DE L’AERONAUTIQUE

Métiers étudiés à dominante technique (industrie)

- **Ingénieur d’Etude et développement de programme:**







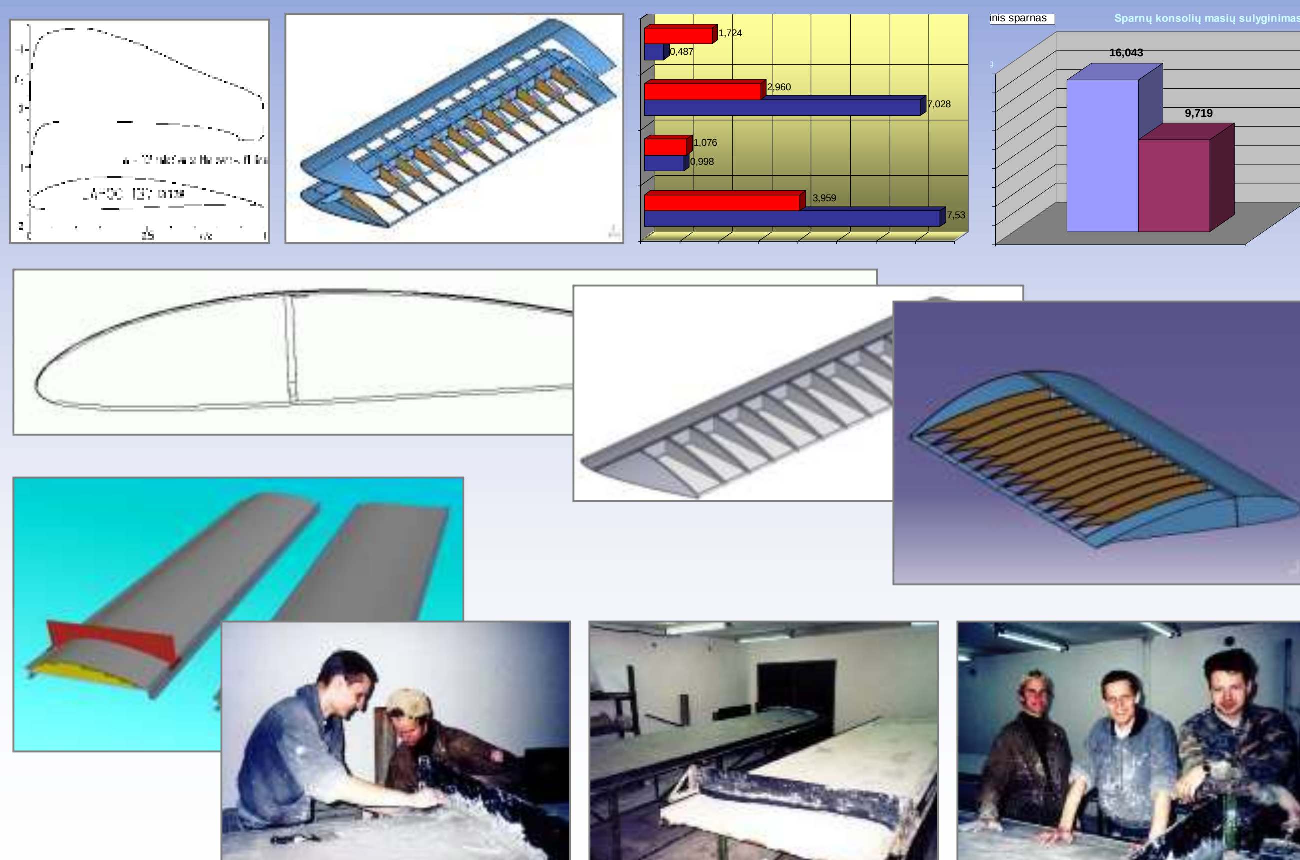




AIRPLANES DEVELOPMENT

Full cycle of aircraft structures development – building the wing for the UL airplane:

Research → **Design** → **Production** → **Testing**



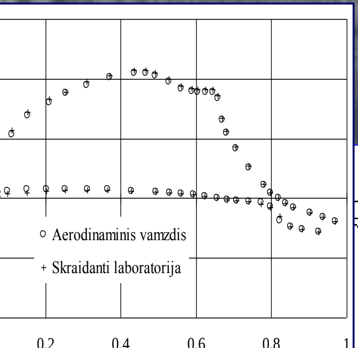
Low speed aerodynamics

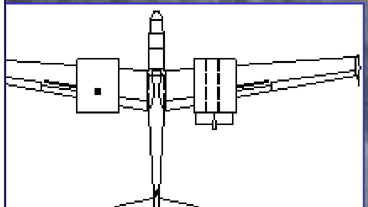
Aerodynamic works

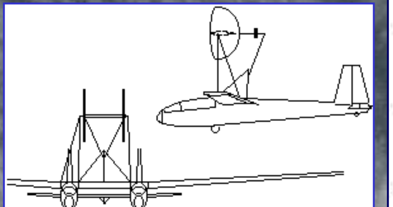
- Low speed airfoils research and development for sport and light airplanes.

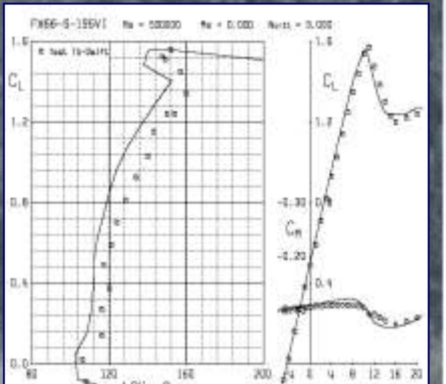
- Nonlinear aerodynamic of a finite span wings.

- Computer based airflow modeling.



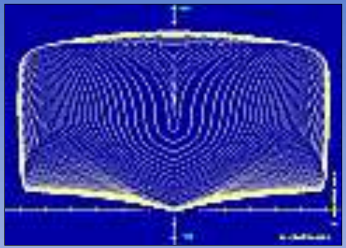


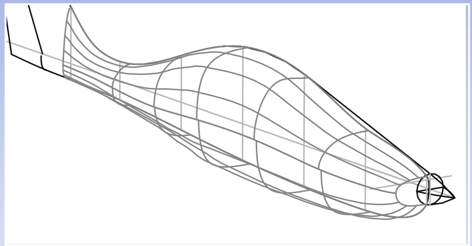


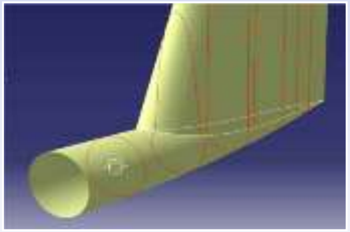


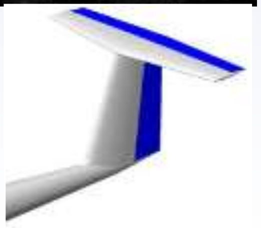
3D Aircraft design :

Digital 3D design methods of complex aircraft surface models using modern CAD-CAM software







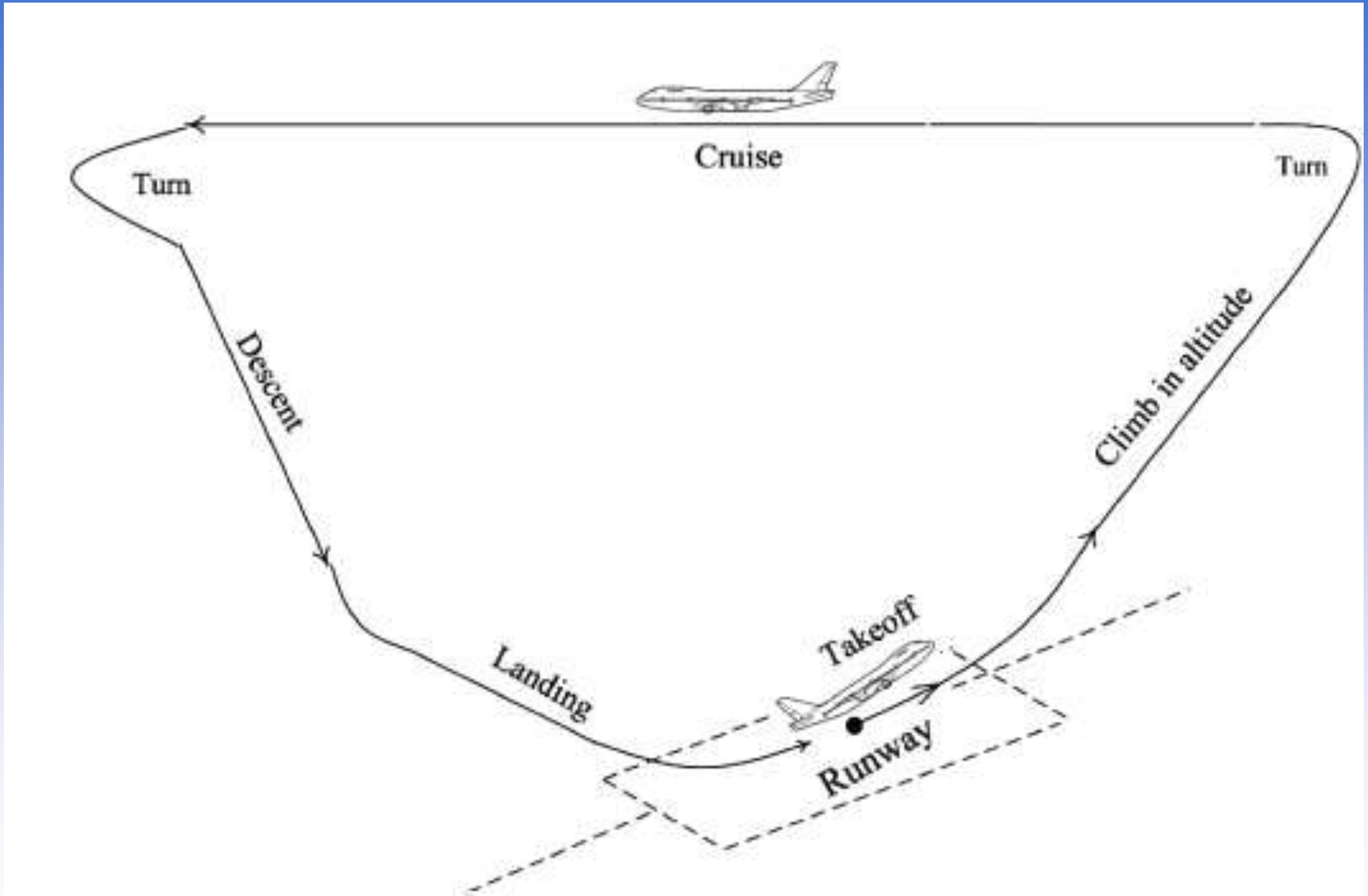


PERFORMANCE OPTIMIZAION

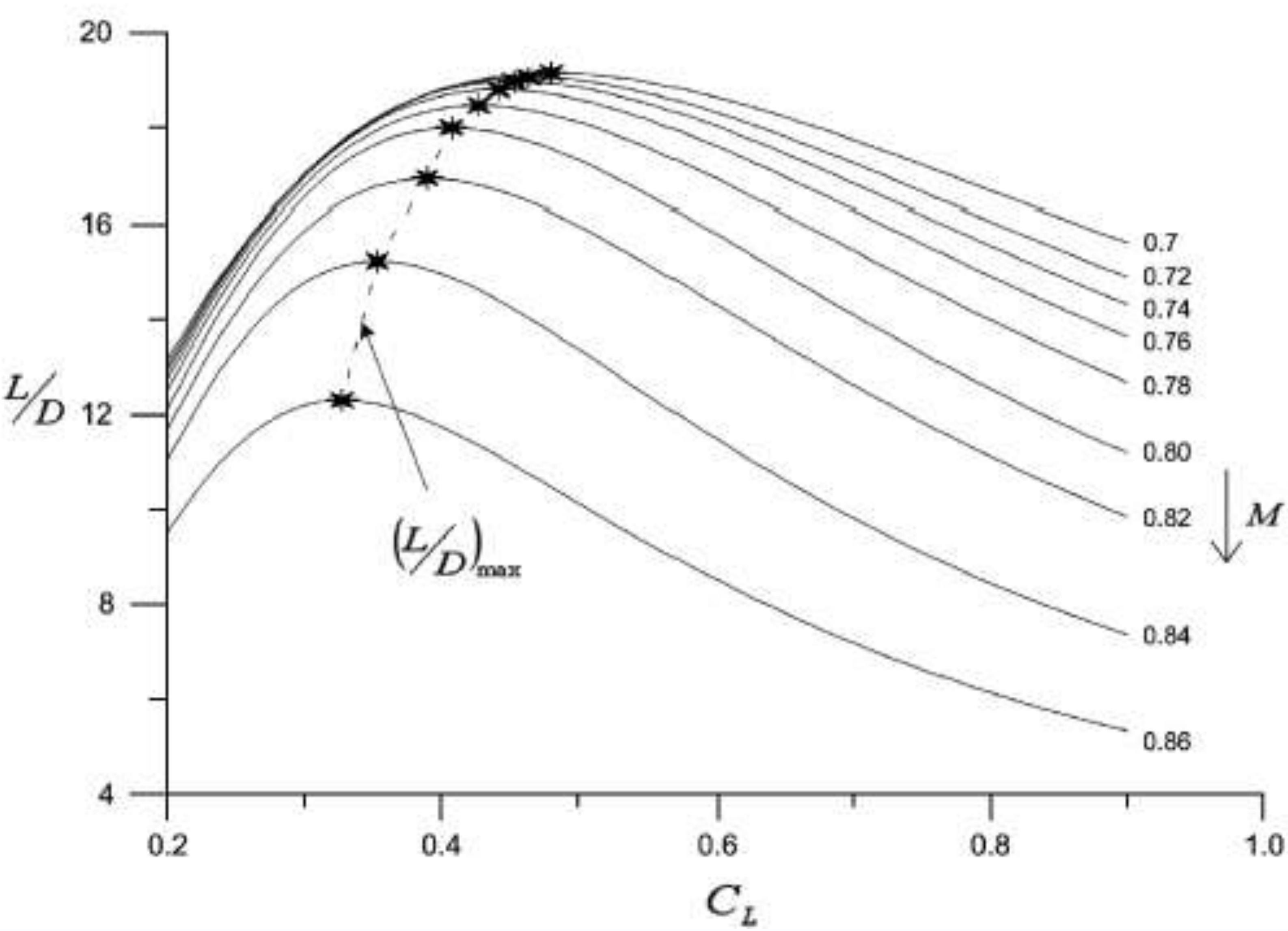
Flight Missions and Constraints Analyses

- The optimum match point between an engine and a configuration of an aircraft is mutually dependant on the
- available engine propulsive performance,
- flight mission profile and
- the constraints.
- The optimization process includes aerodynamics and flight performance module coupled with another module for engine performance prediction.

Typical flight mission profile for a passenger airplane



Lift to Drag Ratio Vs Mach Number : Cruising



The Parameters of Concern to Reach Cruising Altitude

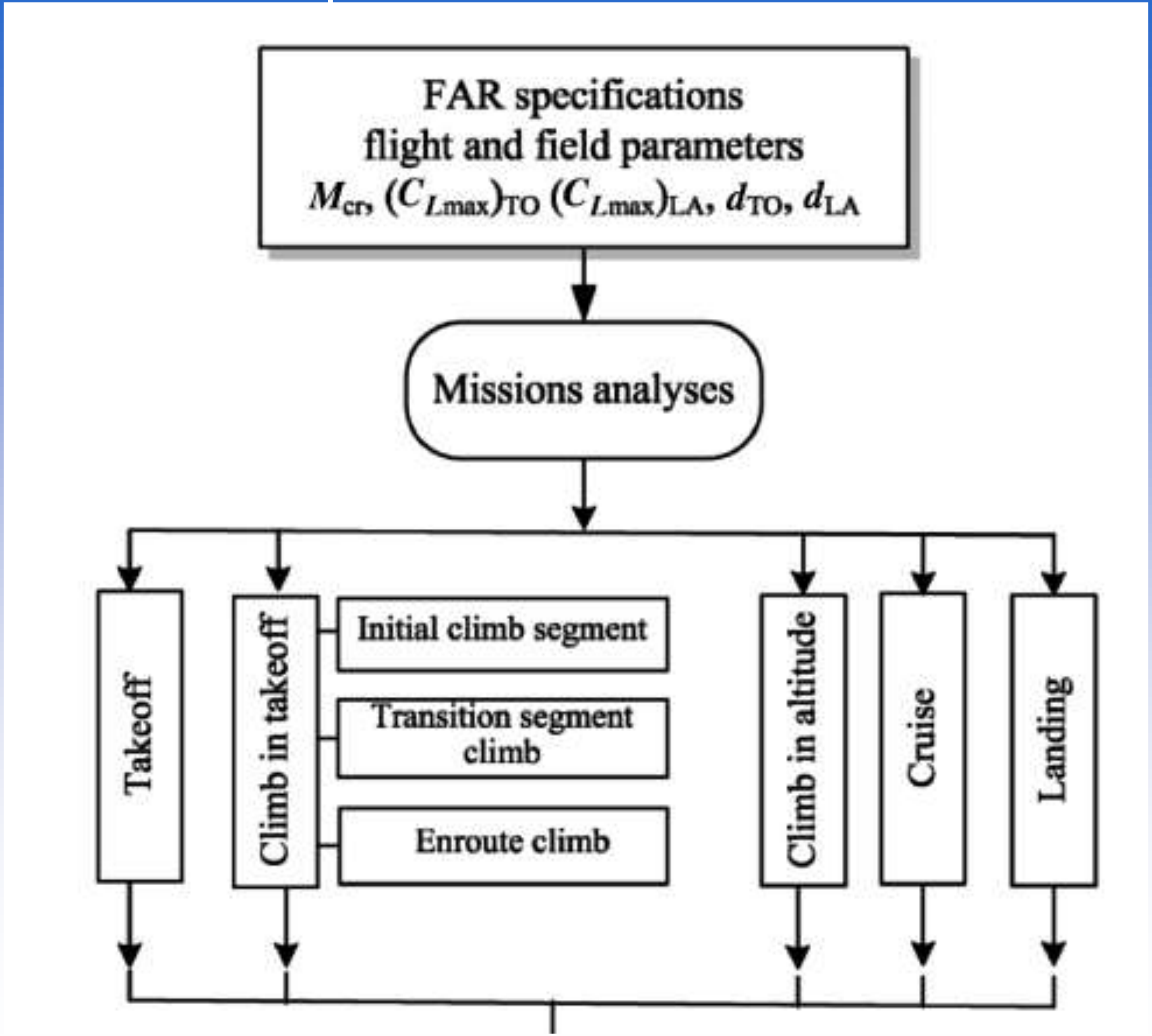
- The parameters for reaching the cruising altitude:

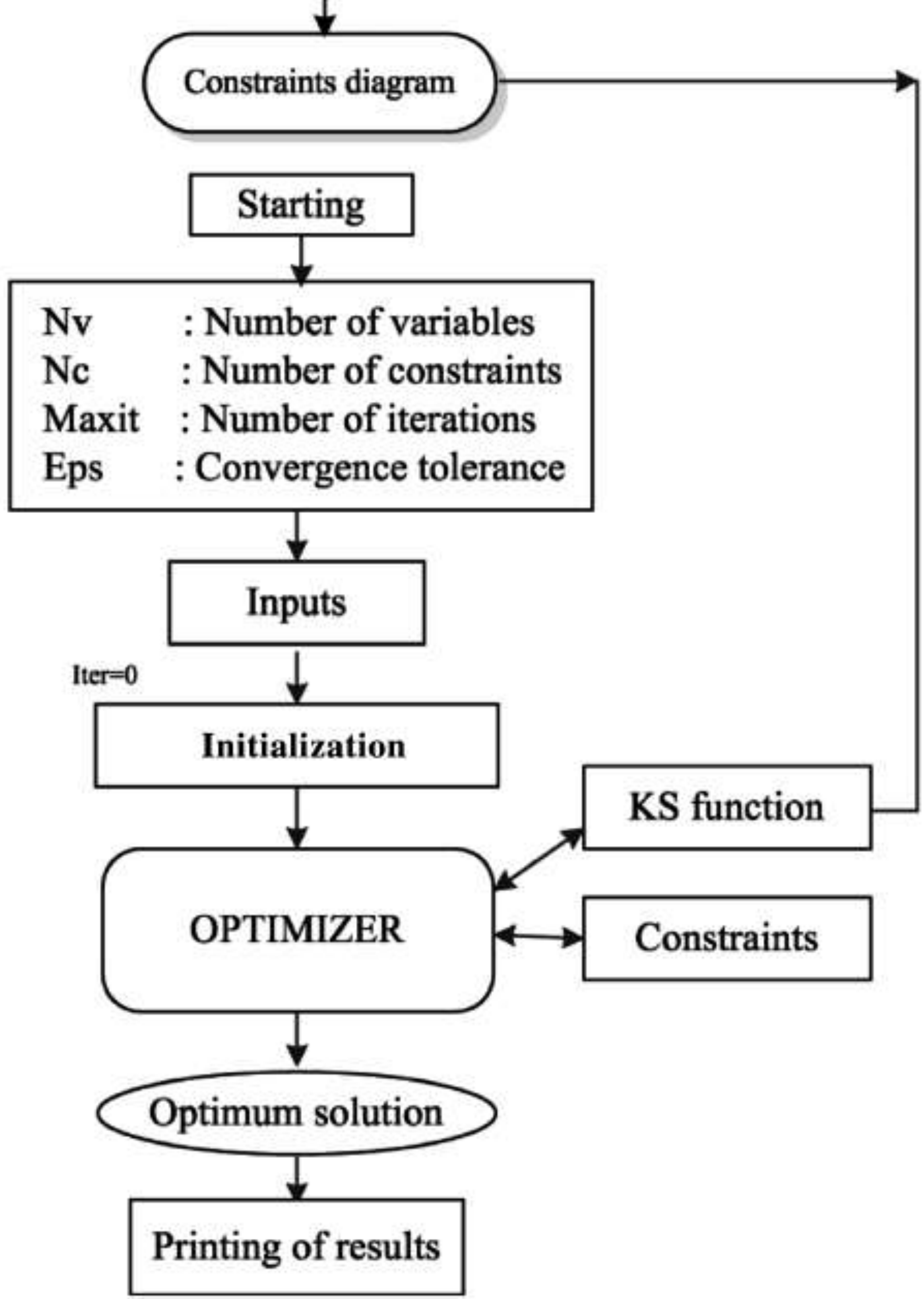
	$(T/W)_{\mathrm{TO}}(N/N)$
Initial climb segment ICS	0.2873
Transition segment of climb TSC	0.283
En route climb segment RCS	0.2663

considered as the critical phases".

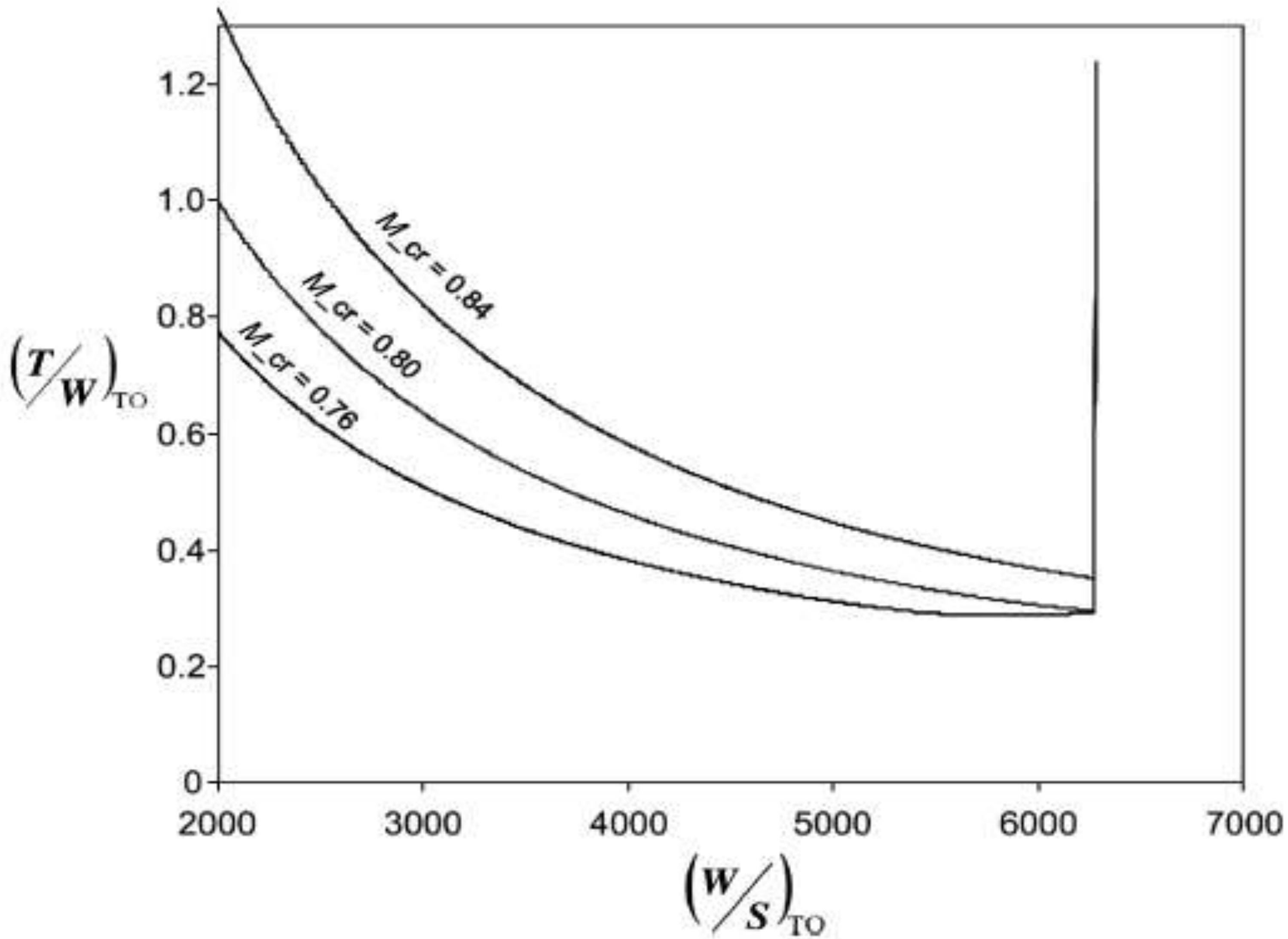
- These phases are assessed separately in terms of
- thrust-to-weight ratio T/W_{TO}
- and wing loading W/S_{TO} referring to takeoff conditions.

Optimization for Match Point

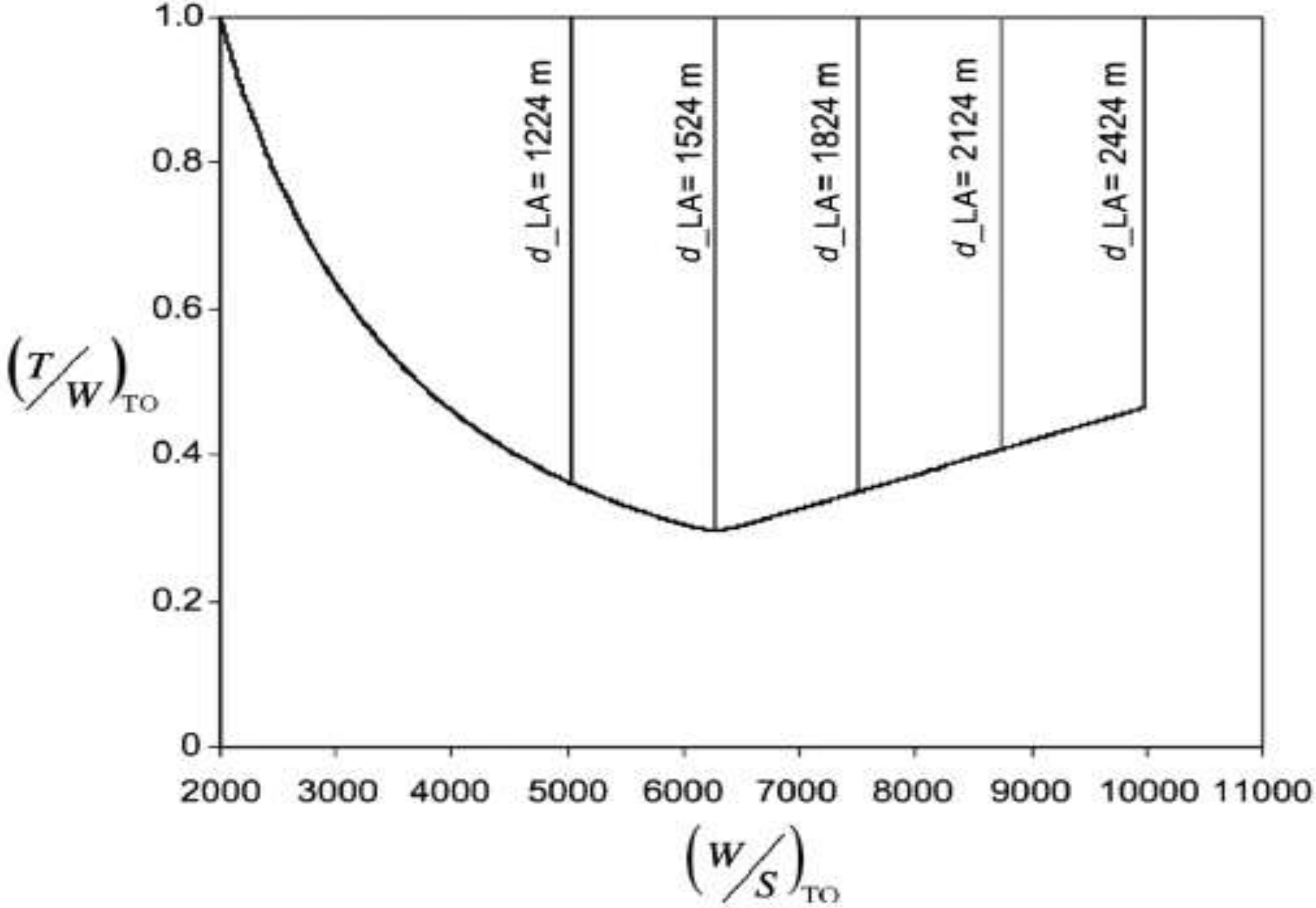



Constraints diagram
Starting
Nv : Number of variables
Nc : Number of constraints
Maxit : Number of iterations
Eps : Convergence tolerance
Inputs
Iter=0
Initialization
KS function
OPTIMIZER
Constraints
Optimum solution
Printing of results

Feasible Domains for Constraints

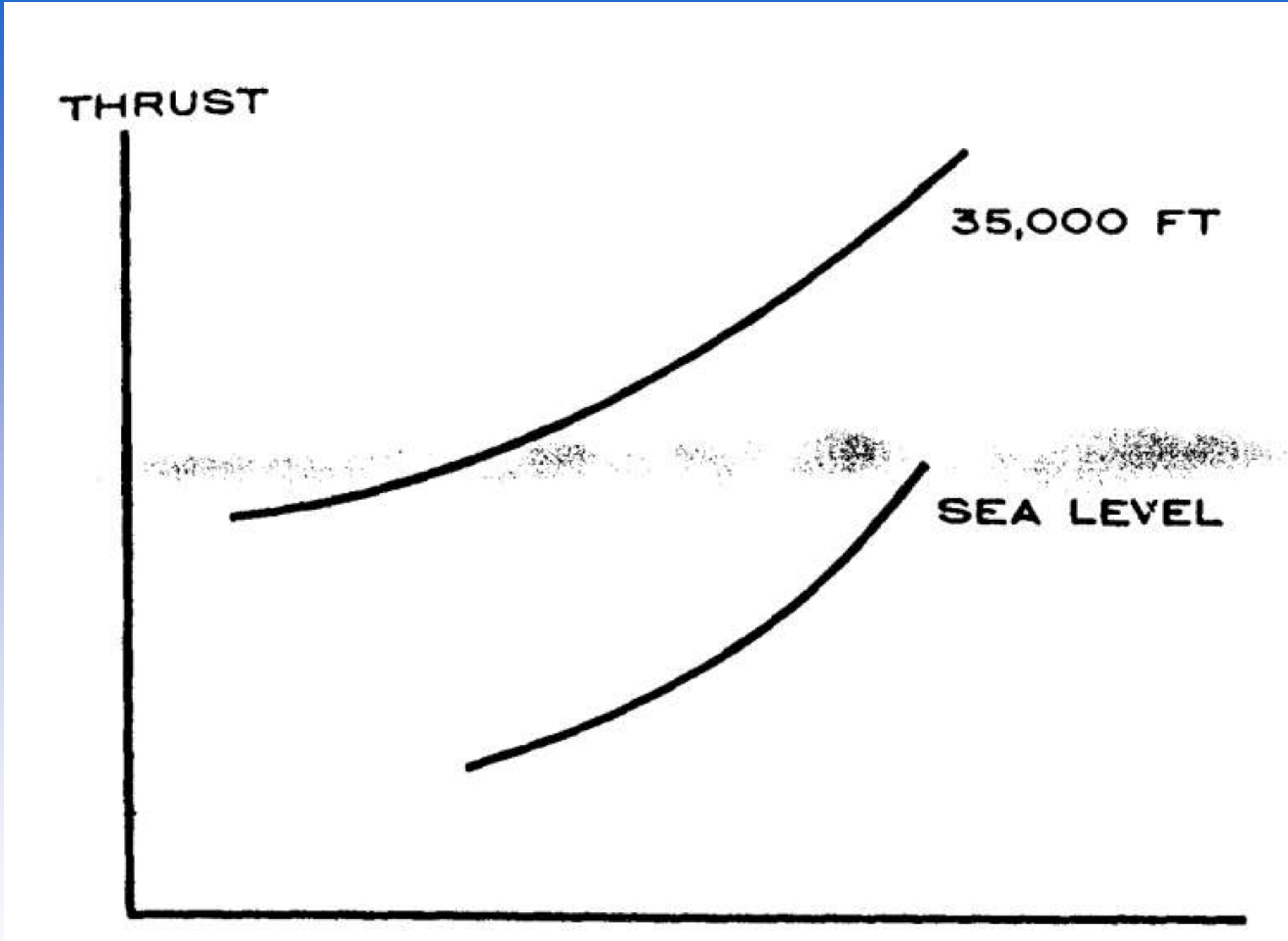


Feasible Domains for Constraints



Typical Airplane Characteristics

Characteristics	Values
Maximum weight at takeoff, kg	181,437
Ratio of weight at descent/takeoff	0.80
Ratio of fuel weight/takeoff	0.398
Maximum fuel capacity, liters	91,380
Range, km	9700–11,065
Typical cruise speed and Mach	851 km/h, 0.80
Cruise altitude, m	10,668
Wing lift surface, m^2	283.35
Span, m	47.60
Aspect ratio	7.99
Engines: two high by pass turbofan	—



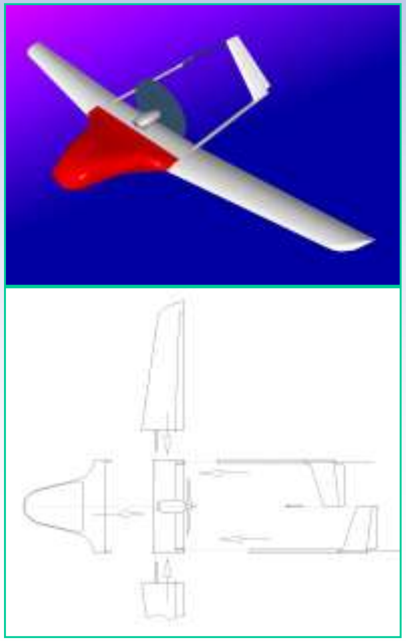
Flight Velocity

Technical Diagnostics and Non-Destructive Testing

- **Visual Testing (JAR-145 certificate)**
  - Borescopes, Fiberscopes, Microscopes, Optical Micrometers, photo and video recording
- **Eddy Current Testing (JAR-145)**
  - Surface and subsurface braking flaws, electrical conductivity test, coating thickness measurements
- **Magnetic Particle Testing (JAR-145)**
  - Fluorescent ink, UV black lightning, all magnetizing methods
- **Ultrasonic Testing**
  - A-scan, thickness gauges, composite materials testing
- **Penetrant Testing (JAR-145)**
  - Fluorescent and visible dye penetrants, sensitivity level 3

Analysis and development of Unmanned Aerial Vehicles (UAV)

UAV's (Unmanned Air Vehicles) are one of the most perspective types of light airplane structures to develop (for civil or/and defence purposes) .



Development of UL SYSTEM FOR TRAINING

The initial flight training system using ultralight aircrafts (gliders and airplanes) is designated to promote professional pilot’s career.

Profession

METIERS DE L'AERONAUTIQUE

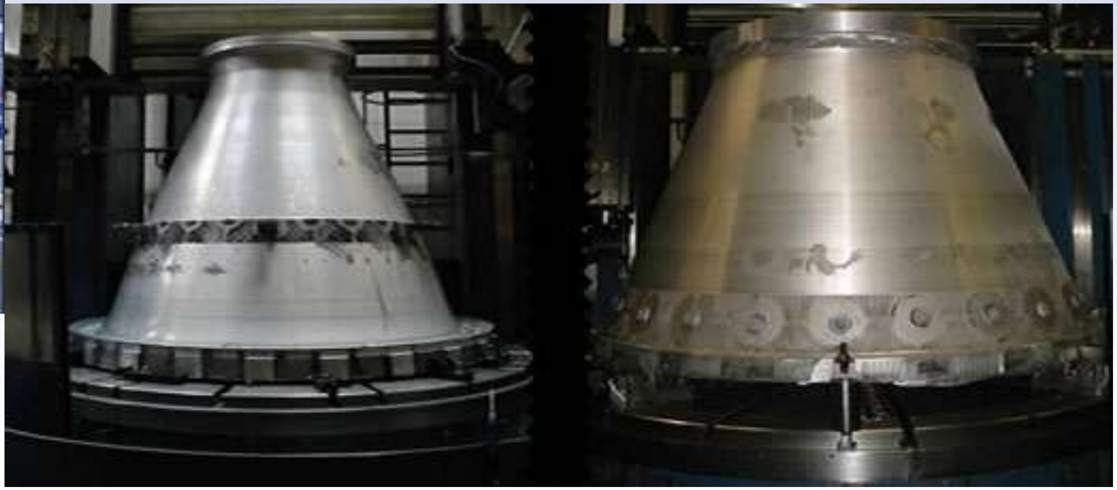
Métiers étudiés à dominante technique (industrie)

- **INGENIEUR DE CONSTRUCTION**

FABRICATION MOTEUR

PRATT&WHITNEY

- Fabrication de pieces pour les moteurs d`avions



Matériaux Aéronautiques

- Compound material
- Metalic material

METIERS DE L'AERONAUTIQUE

Métiers étudiés à dominante technique (industrie)

- **Ingénieur de Maintenance**

Défi

Concevoir un avion de papier qui devra franchir différentes épreuves.

Épreuve 1

Distance parcourue

Épreuve 2

Durée de vol

Épreuve 3

Atterrissage de précision

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