CHALLENGES IN EUROPEAN AEROSPACE

5TH CEAS AIR & SPACE CONFERENCE

CEAS

Academic Course in Aircraft conceptual design and on-board system preliminary design at Politecnico di Torino

M. Fioriti, N. Viola, R. Fusaro, L. Boggero

POLITECNICO DI TORINO

Course title: Integrated Aerospace Systems Design

When: 2nd year of Master degree

Who: 25 – 30 students and 4 teachers

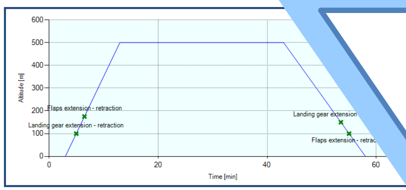
Duration: 6 months (8 ECTS)

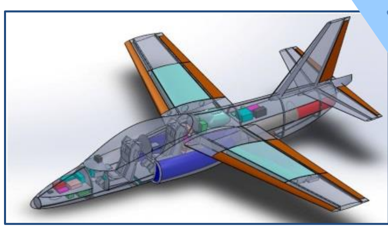
Aim of the course:
- to provide students with the capability to carry out a conceptual design of a given aircraft
- to give knowledge to perform the preliminary design of the on-board systems in an integrated way
- to enhance students' teamwork experience

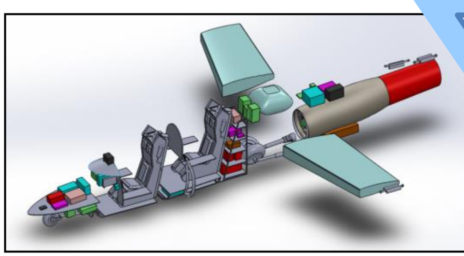
Course plan

- ✓ The attending students are divided in 6 -8 teams
- ✓ Each team is composed by around 5 students
- ✓ Each team will design an aircraft starting from some high level requirements. The aircraft test cases are changed yearly
- ✓ The requirements are adequately detailed to easy individuate the aircraft class but students have enough freedom in design choices
- ✓ During every lesson the students' work is checked and evaluated
- ✓ Once a month students present their work to the other teams and teachers

Design process – Multiple V diagram (MBSE)







High Level Requirements

HLR Verification

Analogy

Aircraft Level Requirements

ALR Verification

ASTRID (Conceptual Design Module)

3d CAD

X-Plane

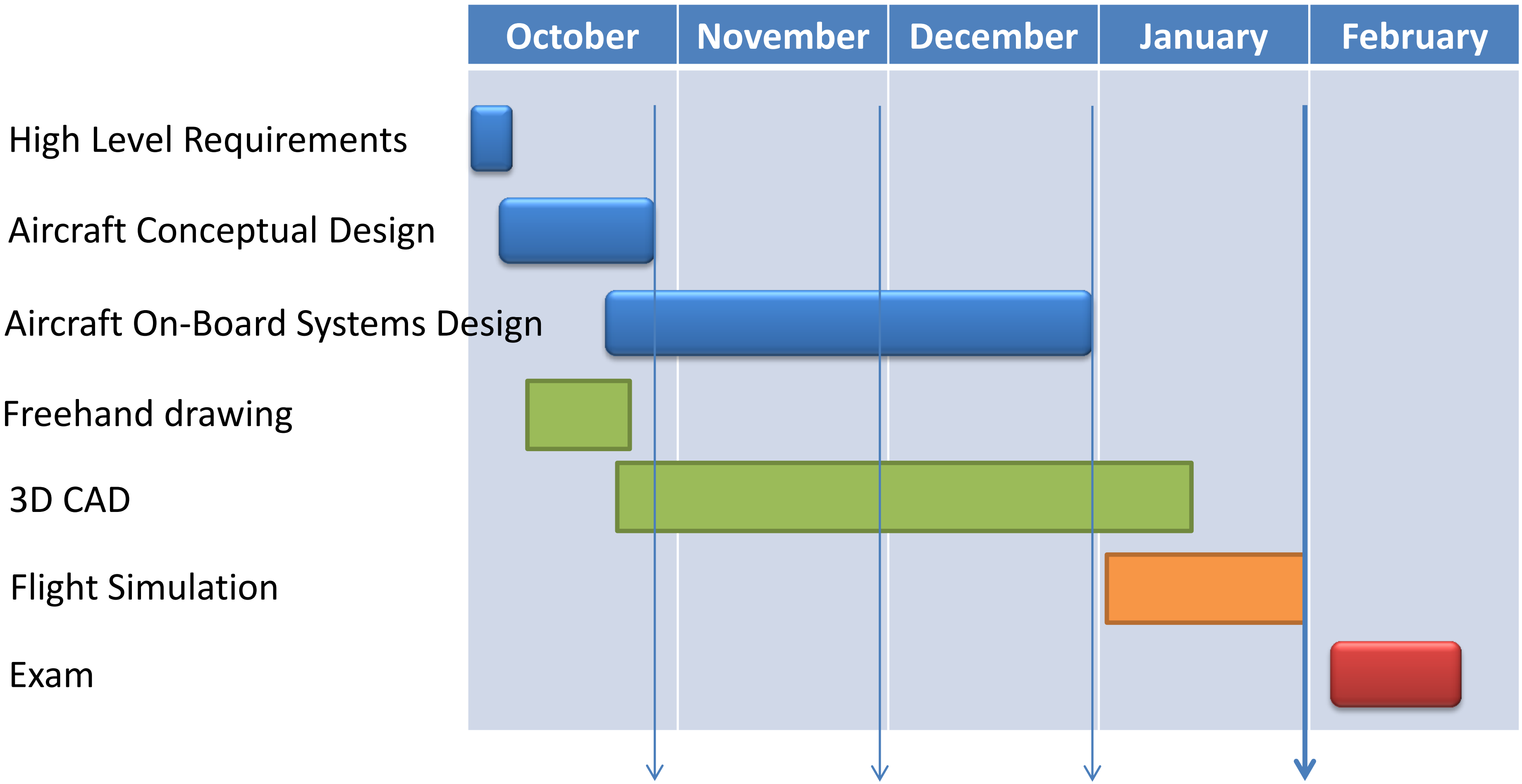
On-Board System Level Requirements

OSLR Verification

ASTRID (On-Board Systems Design Module)

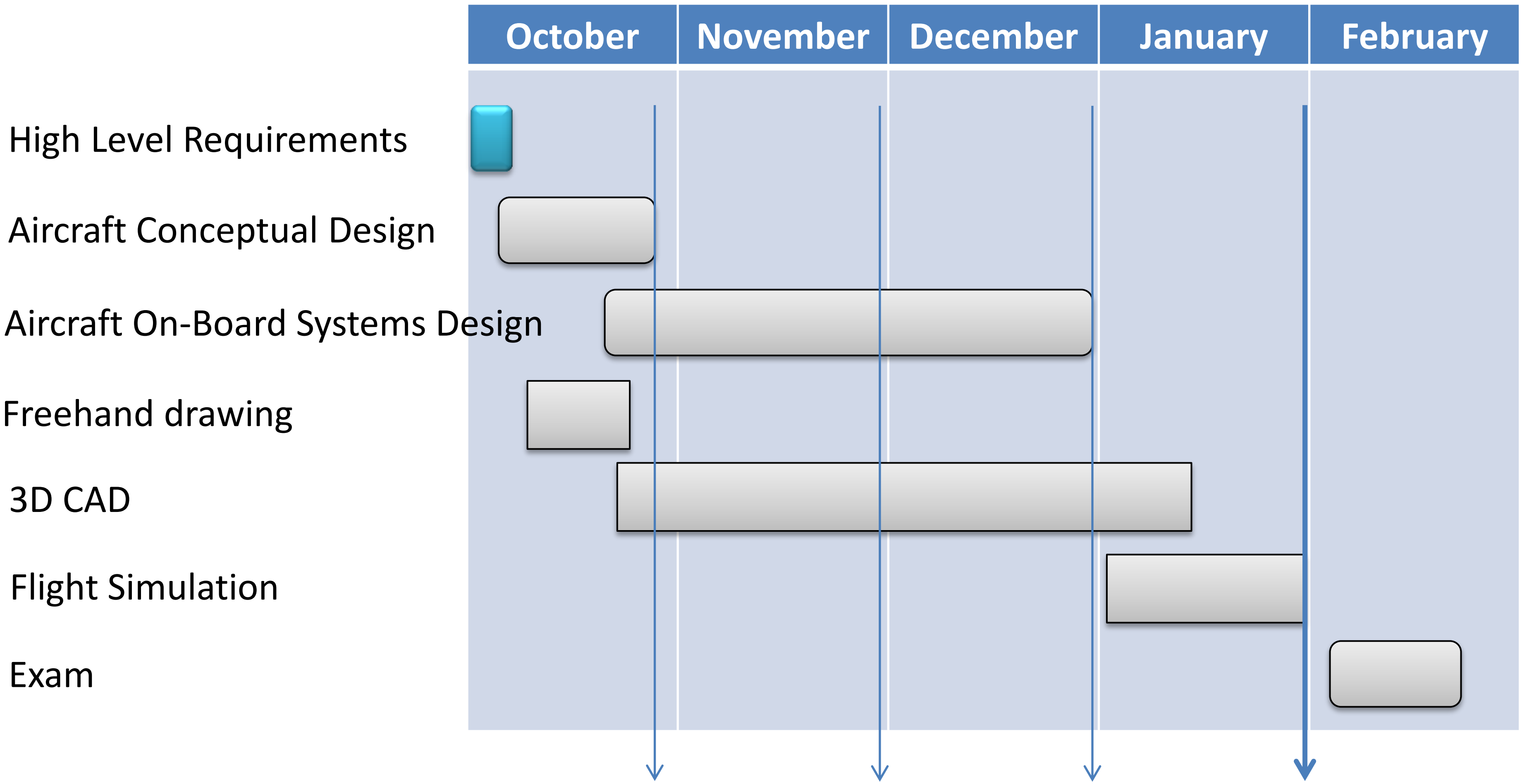
3d CAD

Design process – Time schedule



Presentation to teachers and other teams
(the chairman of final presentation is the director of Alenia Aermacchi preliminary design office)

Design process – High Level Requirements



Presentation to teachers and other teams
(the chairman of final presentation is the director of Alenia Aermacchi preliminary design office)

Test cases – High Level Requirements

1st Team: Conventional jet-liner with innovative on-board systems

- Number of passenger 132+4
- Single aisle 6 abreast
- Max range 5000 km
- Max speed (@ 10000 m) 880 km/h
- Field length 2000 m
- Innovative on-board systems

2nd Team: General aviation long range

- Number of passenger / pilot : 4 / 2 or 5 / 1
- Max range 3500 km
- Max speed (@ 3500 m) 350 km/h
- Field length 1000 m
- Galley, toilet
- Relative high passenger comfort (cabin luminosity, noise reduction)

3rd Team: acrobatic general aviation / Screener

- Number of passenger / pilot: 1/ 1 or 0/2
- Max range 2500 km
- Max speed (@ 7000 m) 400 km/h
- Field length 900 m
- Acrobatic flight envelop
- Hybrid propulsion (piston + electric)

4th Team: Regional turboprop advanced architecture

- Number of passengers: 90
- Max range 1500 km
- Max speed (@ 8000 m) 650 km/h
- Field length 1000 m
- Laminar wing and fuselage

5th Team: Light jet-trainer
- Number of pilot: 2
- Tandem configuration
- Max range 1100 km
- Max speed (@ 7000 m) 750 km/h
- Field length 500 m
- Rate of climb (s.l.) 22 m/s
- Load factor: +7 / -3
- Low weight, low dimensions, low fuel consumption and operating cost

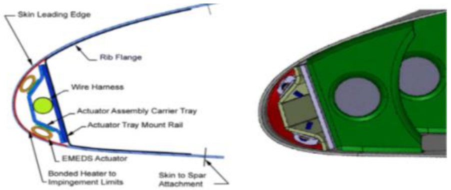
6th Team: MALE UAV civil missions
- Payload weight: 650 kg
- Max endurance: 33 hours @ 14000 m
- Field length 1600 m
- Advanced on-board system architecture (more or all-electric)

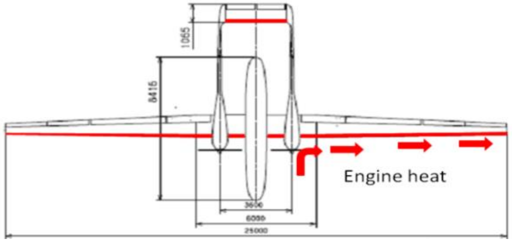
7th Team: BeePlane
- Number of passenger: 220
- Max range 5000 km
- Max speed (@ 10000 m) 880 km/h
- Field length 1700 m
- Detachable fuselage

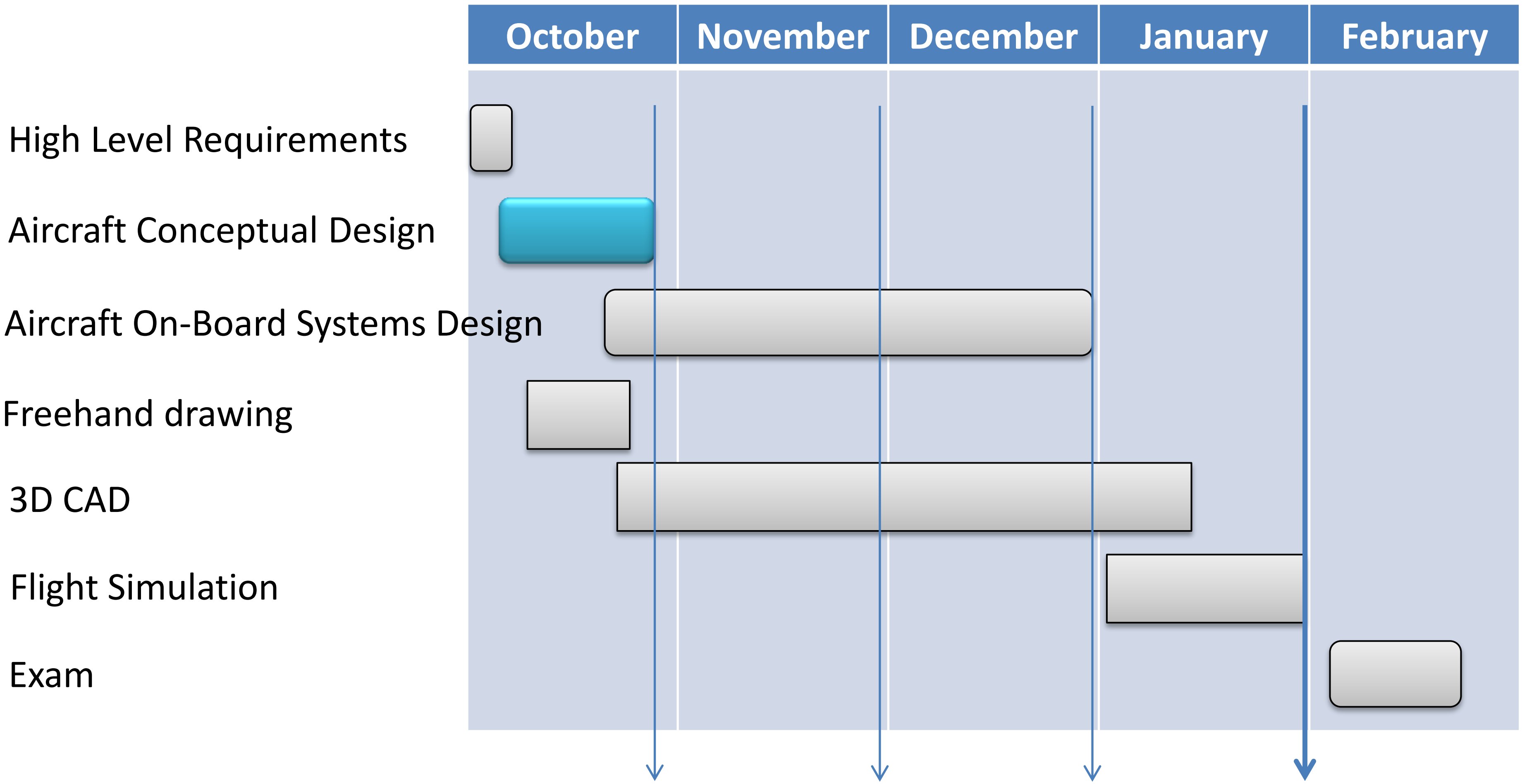
Collaboration with university Supméca (Paris) and other industries (in 2014, Alenia Aermacchi and Technoplane)

PLACIS
- supméca
- POLITECNICO DI TORINO
- Technoplane

PLACIS
- supméca
- POLITECNICO DI TORINO
- AleniaAermacchi



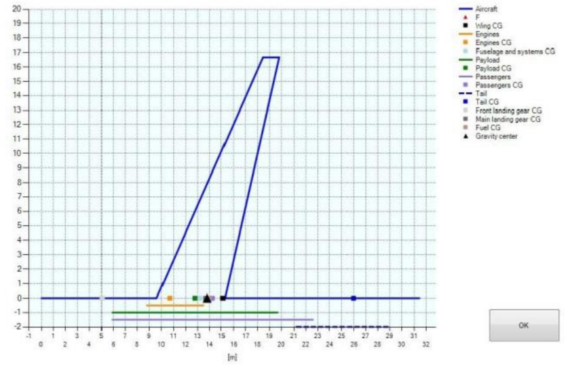




Presentation to teachers and other teams
(the chairman of final presentation is the director of Alenia Aermacchi preliminary design office)

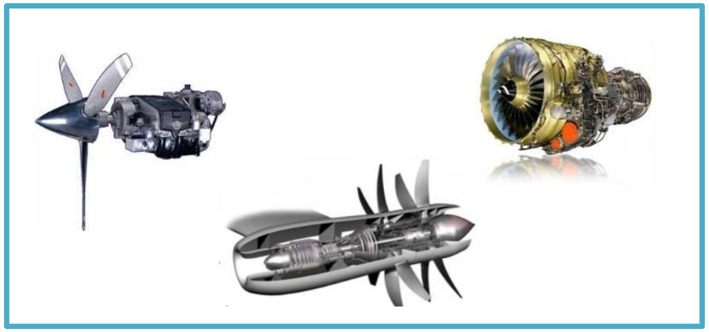
Output from aircraft conceptual design module

Weight and balance

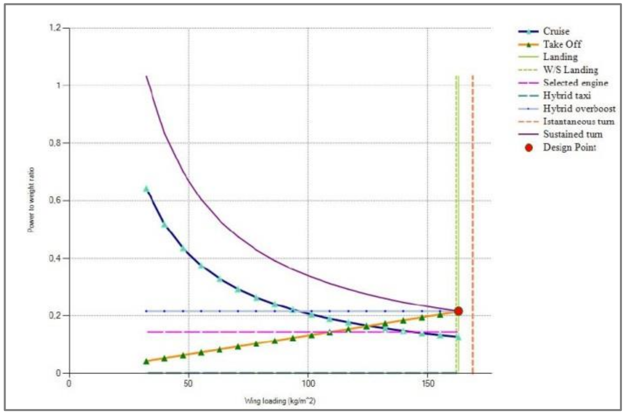


Aircraft geometry and aerodynamic coefficients

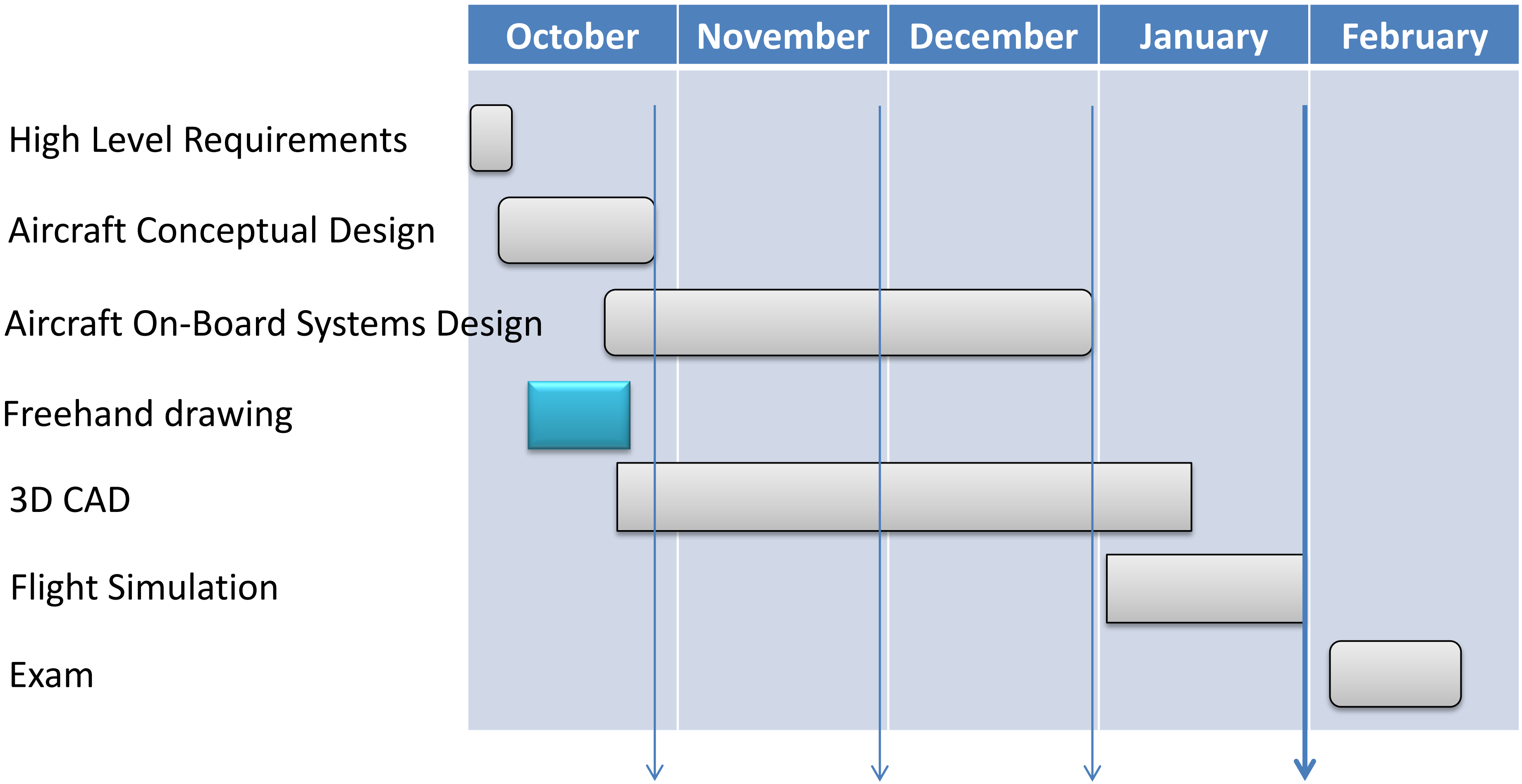
Engine selection



Design point

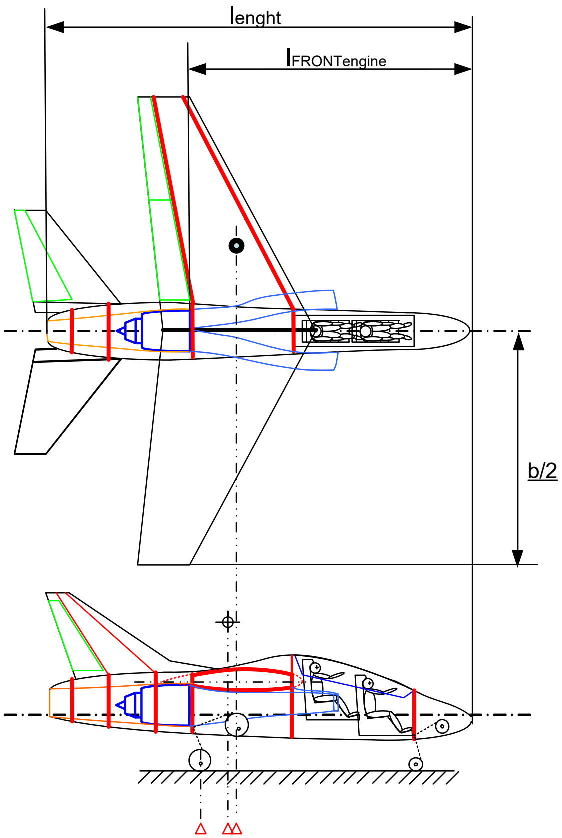


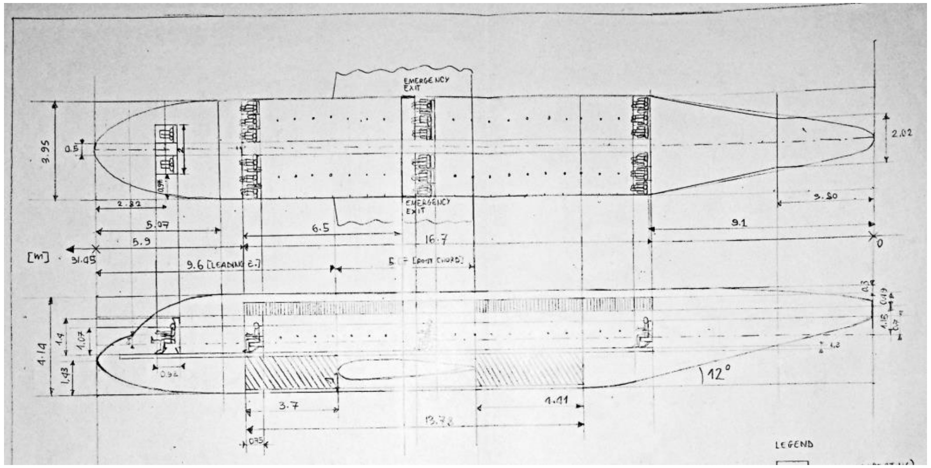
Design process – Freehand drawing

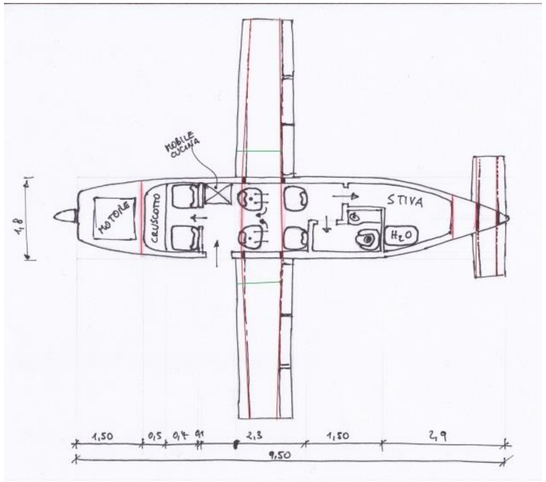


Presentation to teachers and other teams
(the chairman of final presentation is the director of Alenia Aermacchi preliminary design office)

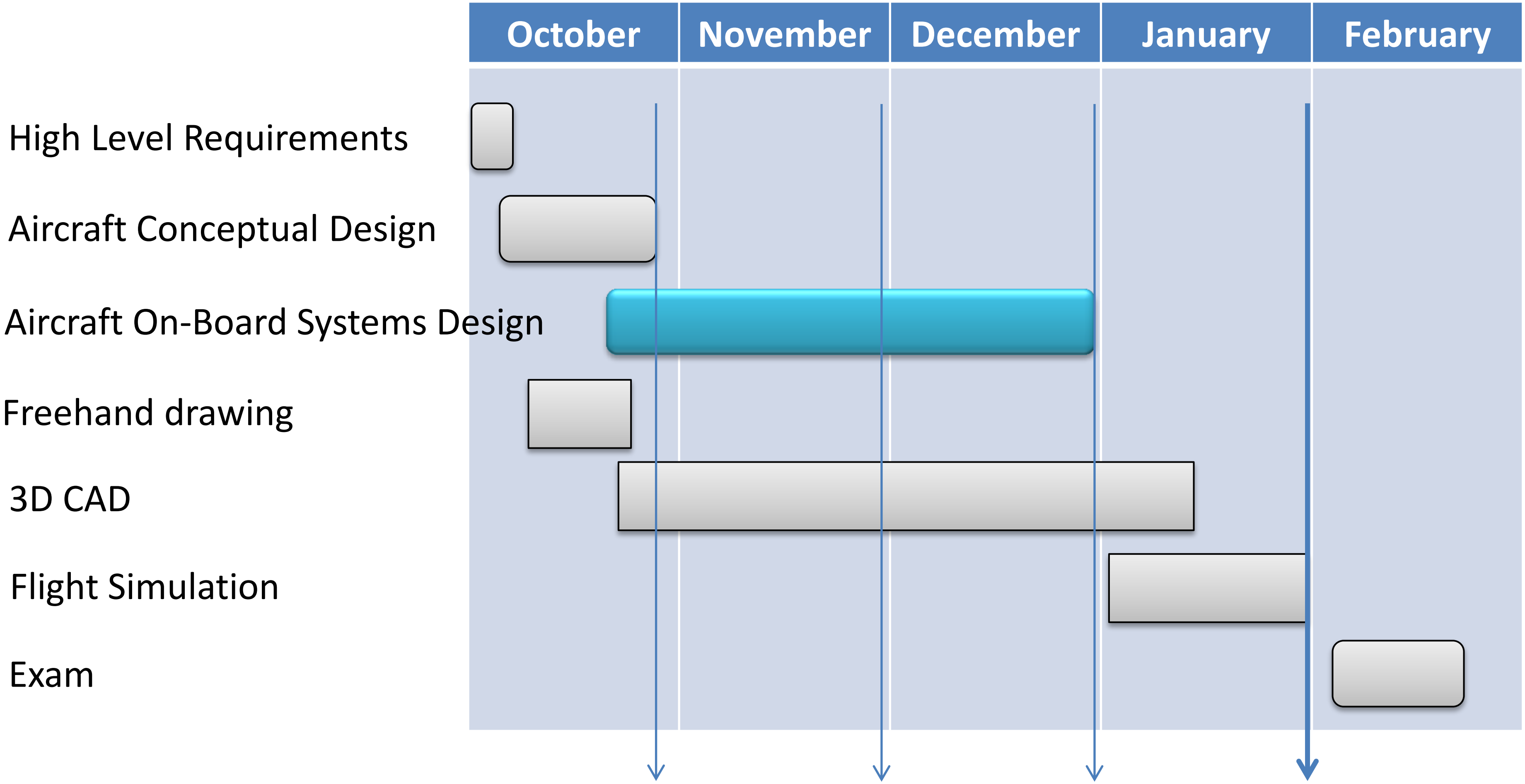
- Aircraft configuration
- Main dimensions
- Position of main elements (payload, engines, main structural elements, etc..)





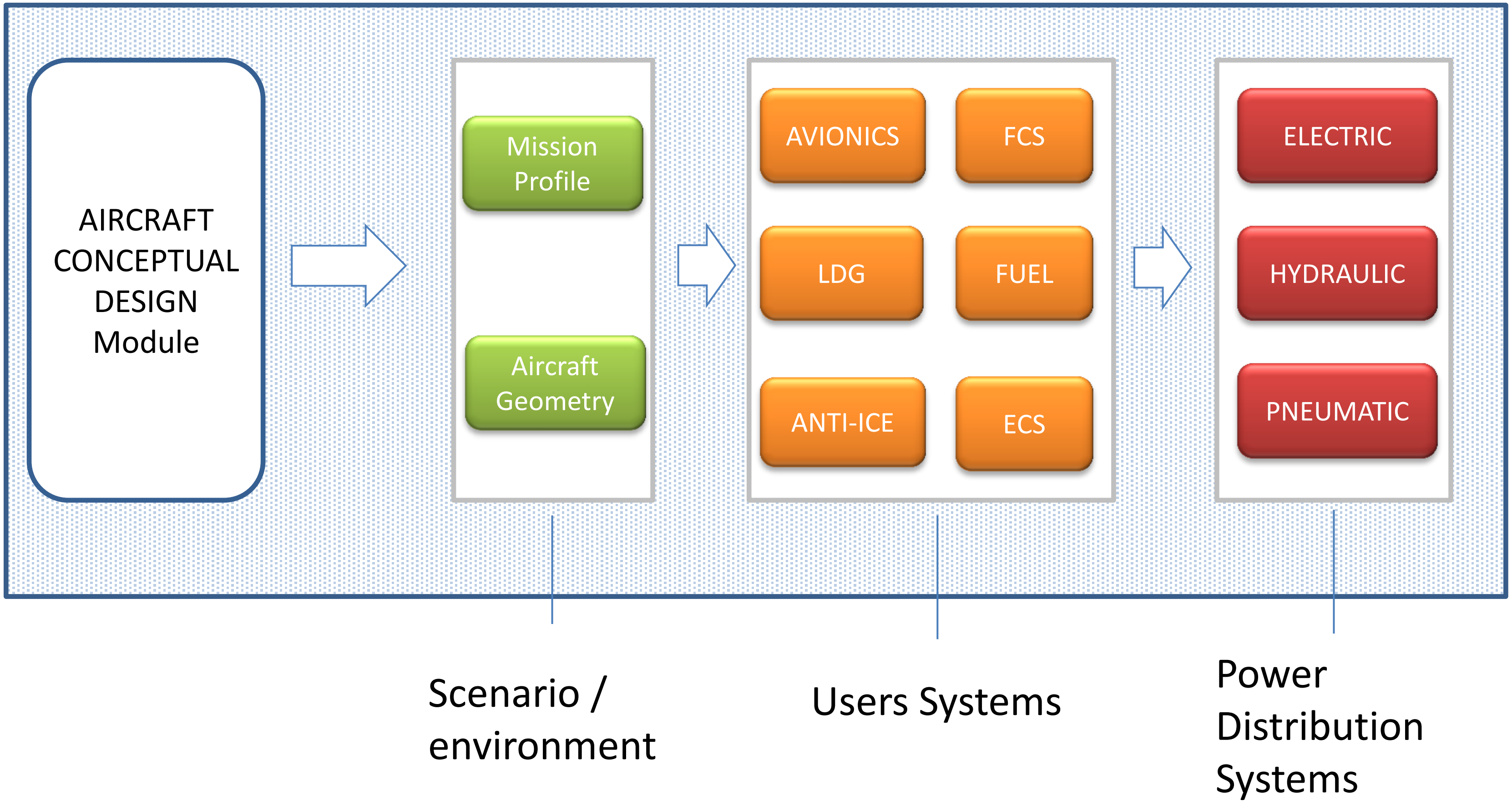


Design process – Aircraft On-Board Systems Design



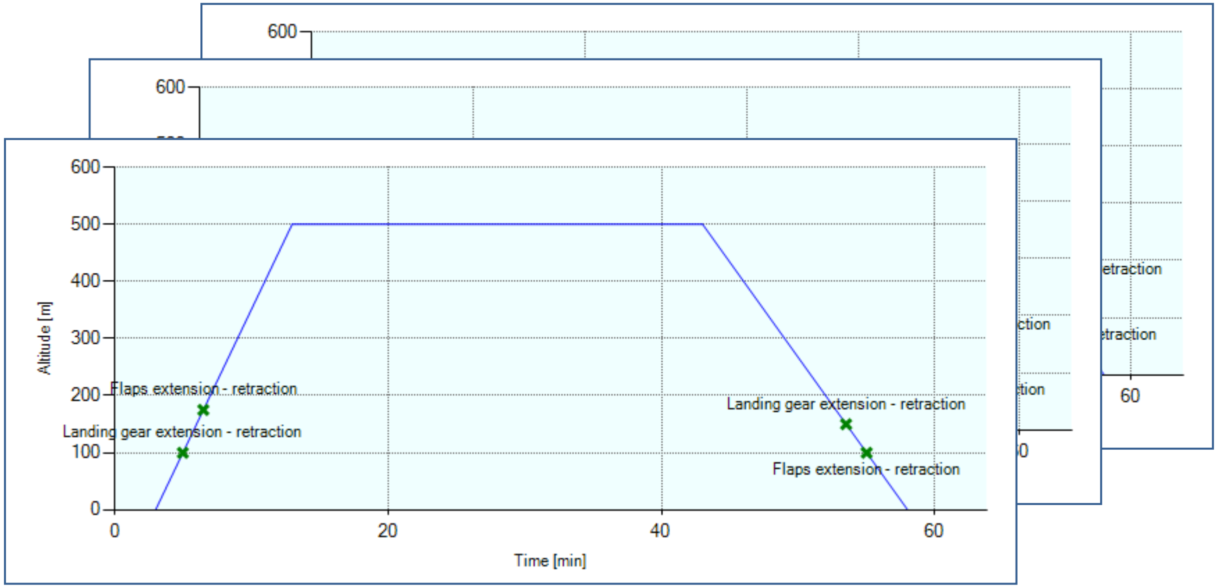
Presentation to teachers and other teams
(the chairman of final presentation is the director of Alenia Aermacchi preliminary design office)

ASTRID software ----- Internal Modules

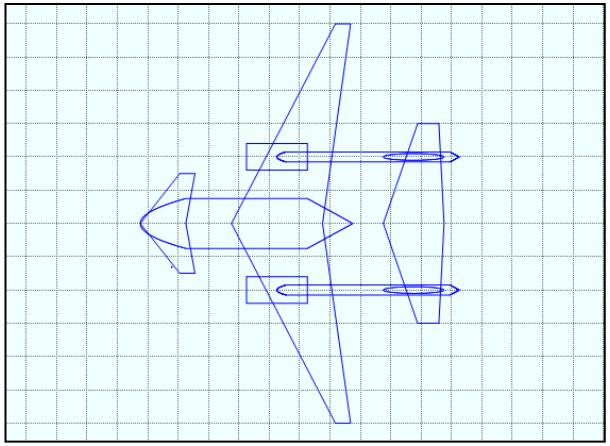


ASTRID global input

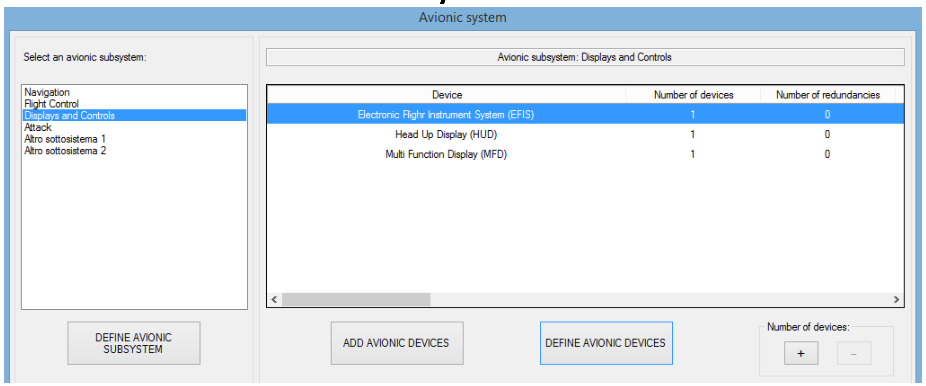
Aircraft **mission profiles** designed to take into account the on-board systems utilization



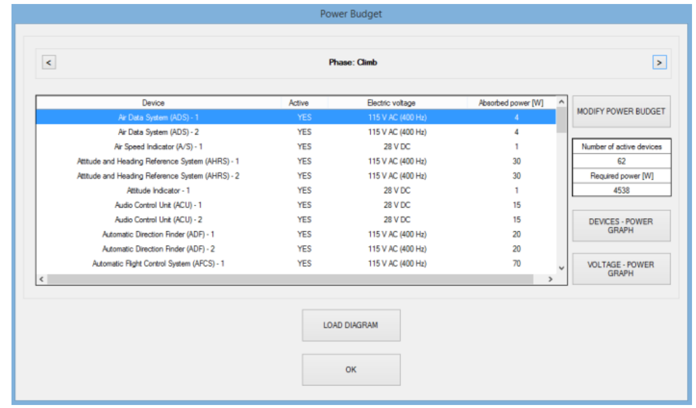
Aircraft geometry. Needed for subsystems design (e.g. distance between fuel tanks and engines etc.)



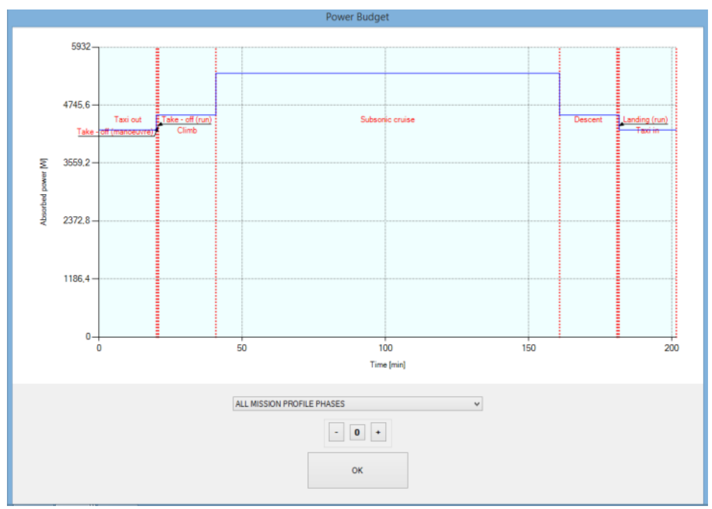
Selection of avionic equipment starting from functional analysis



Equipment utilization within mission profile phases

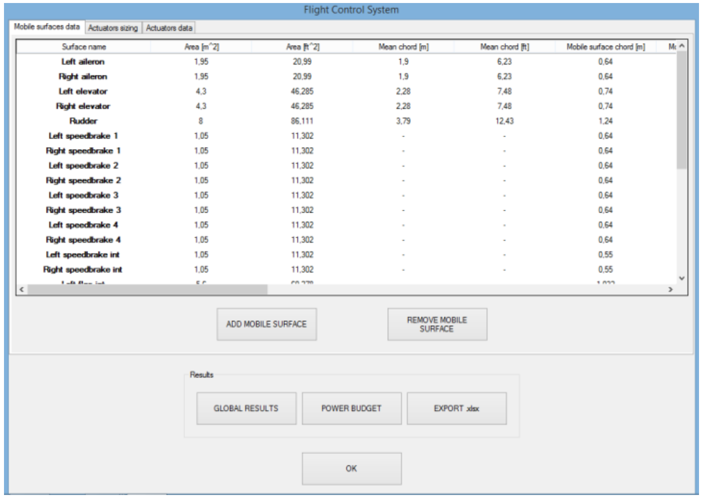


Power budget

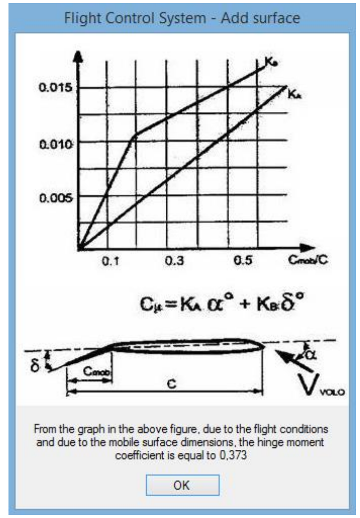


Second approach (for FCS, LND, Brakes, ECS, Fuel, anti-ice…)

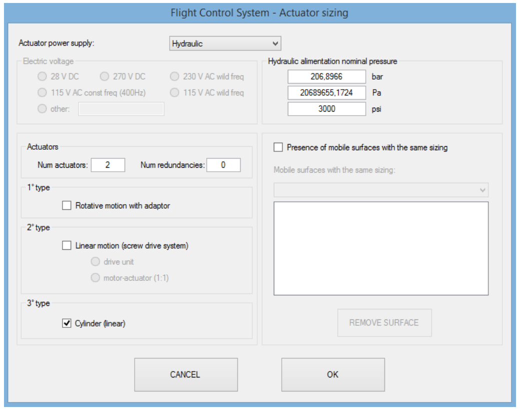
Users (flight control surfaces) definition



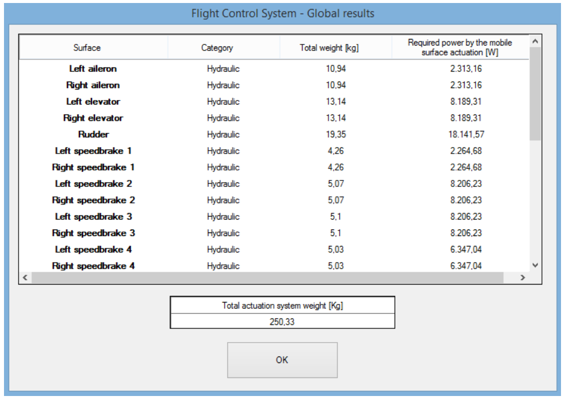
Estimation of the key design factors



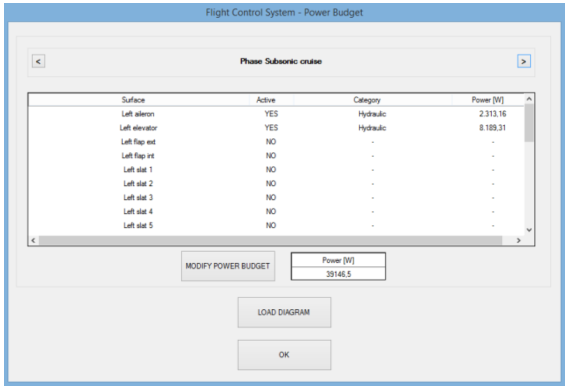
Selection of technology (electrical, hydraulic…)



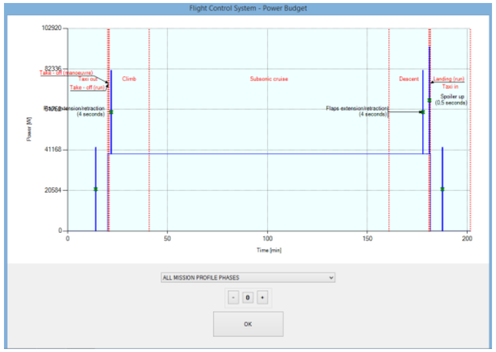
Power required and dimensions estimation



Utilization within the mission profile phases

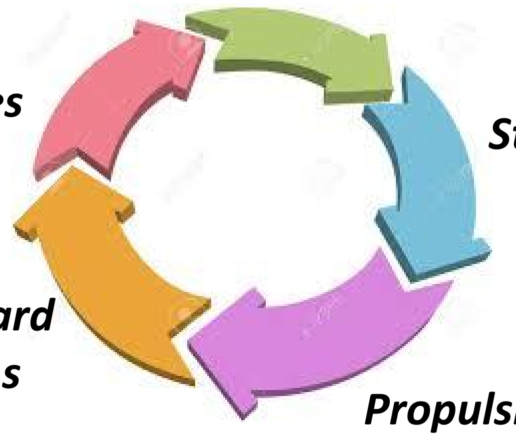


System power budget



After this design step, students' team should redesign the aircraft

Be familiar with the impact of each discipline on the other should be a primary task within Aircraft MDO optimization

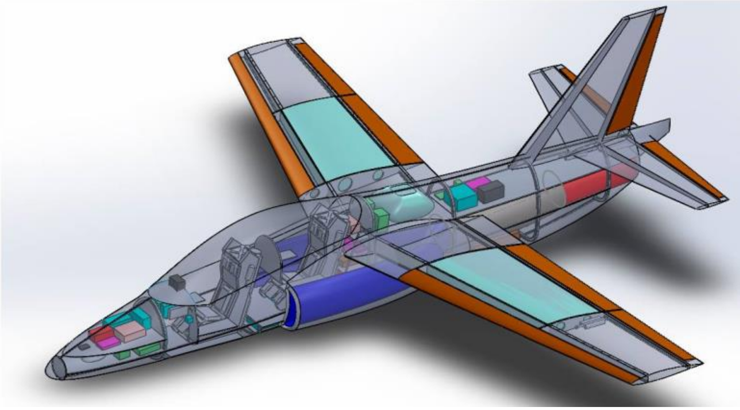


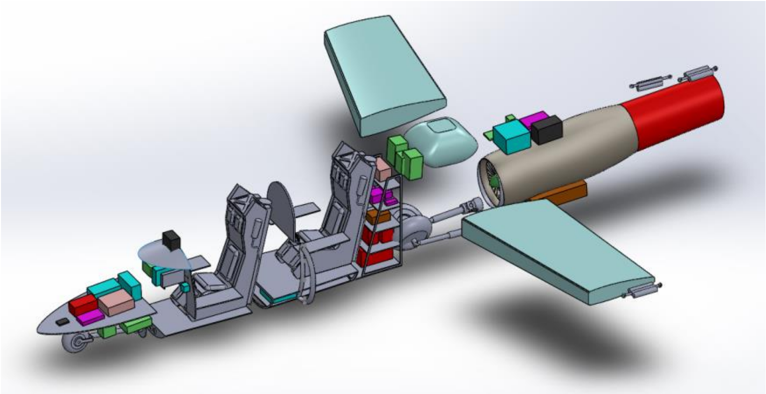
ATA 21	AIR CONDITIONING AND PRESSURIZATION
ATA 22	AUTO FLIGHT
ATA 23	COMMUNICATIONS
ATA 24	ELECTRICAL POWER
ATA 25	EQUIPMENT/FURNISHINGS
ATA 26	FIRE PROTECTION
ATA 27	FLIGHT CONTROLS
ATA 28	FUEL
ATA 29	HYDRAULIC POWER
ATA 30	ICE AND RAIN PROTECTION
ATA 31	INDICATING / RECORDING SYSTEM
ATA 32	LANDING GEAR
ATA 33	LIGHTS
ATA 34	NAVIGATION
ATA 35	OXYGEN
ATA 36	PNEUMATIC
ATA 37	VACUUM
ATA 38	WATER/WASTE
ATA 39	ELECTRICAL - ELECTRONIC PANELS AND MULTIPURPOSE COMPONENTS
ATA 40	MULTISYSTEM
ATA 41	WATER BALLAST
ATA 42	INTEGRATED MODULAR AVIONICS
ATA 44	CABIN SYSTEMS
ATA 45	DIAGNOSTIC AND MAINTENANCE SYSTEM
ATA 46	INFORMATION SYSTEMS
ATA 47	NITROGEN GENERATION SYSTEM
ATA 48	IN FLIGHT FUEL DISPENSING
ATA 49	AIRBORNE AUXILIARY POWER
ATA 50	CARGO AND ACCESSORY COMPARTMENTS

Aircraft On-board systems represent:

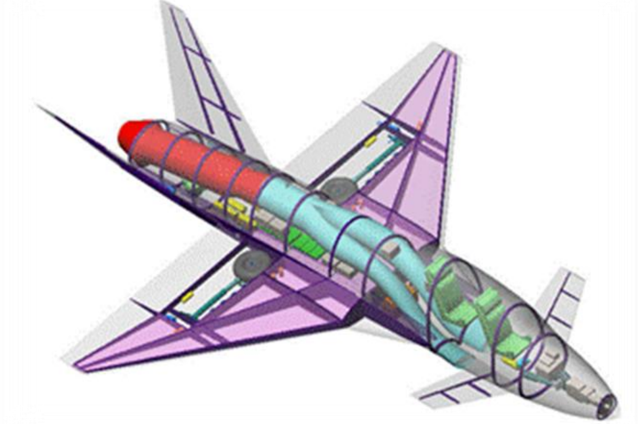
- 15% (liner) ÷ 30% (fighter) of aircraft empty weight
- 30% ÷ 50% of aircraft cost

Some examples of the impact of on-board systems on the other design disciplines :



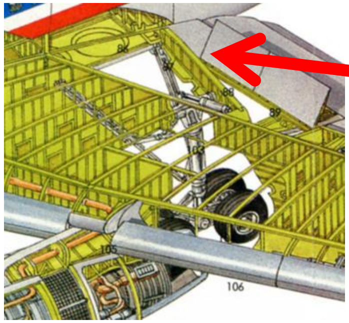


- **On-board systems integration**:
  - Impact on aircraft stability (influence on aircraft C.G.)
  - Position constraint and volume allocations (e.g. fuel tank for liner, landing gear, flight control actuator, radar etc.)
  - Reduction of power / thrust available
  - Handling qualities (moment of inertia)
  - RAMS
  - Cost (Development, Production and Operating)



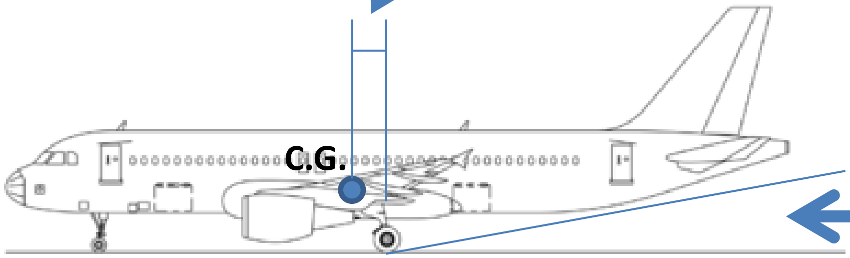
- **Landing gear integration**
  - Influence on wing or fuselage geometry
  - Aerodynamics (external vane)
  - Take-off / landing performance
  - A/C stability on ground

Landing gear fairing



Structure arrangement

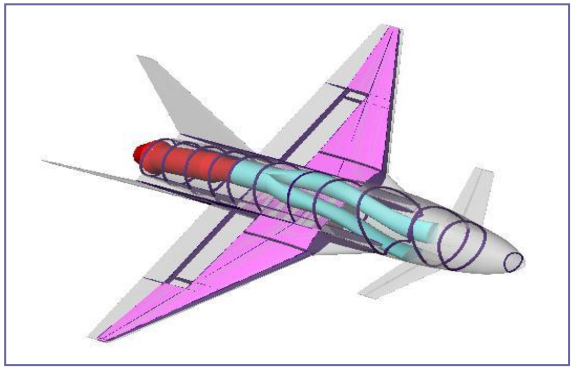
This distance affects pitch moment during rotation



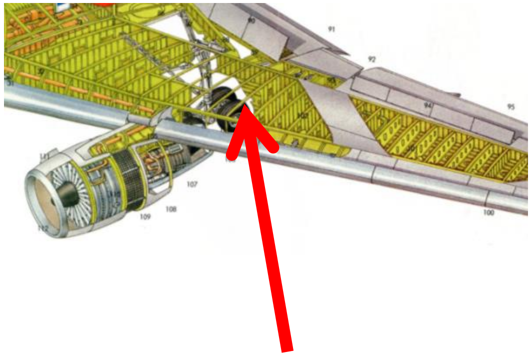
Landing gear length affects tail shape (tail clearance)

Impact of on-board system on Aircraft design optimization
AGILE Research Program

Some example of the impact of on-board system on the other design disciplines :

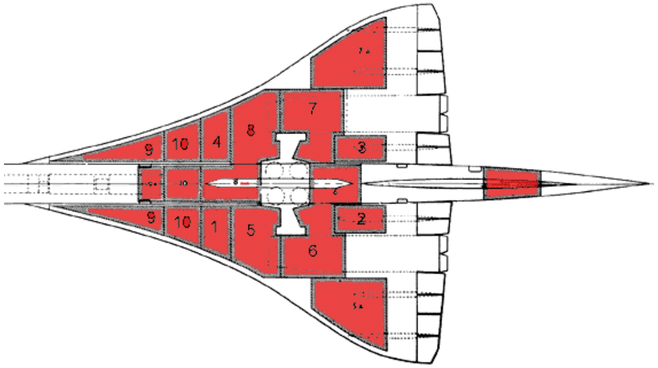


External fuel tanks



- Distance between spares
- ribs geometry

- **Fuel system integration**:
  - Impact on fuselage and wing geometry
  - Aircraft performance range / endurance (quantity of fue storable)
  - Aerodynamics (when external fuel tanks are needed)
  - Influence on aircraft stability



Some example of the impact of on-board system on the other design disciplines :

- **Avionic system integration**:
  - Aerodynamics (Air intakes, antennas, external POD)
  - Wing / fuselage geometry
  - Airframe material (radome, EM transparent material)

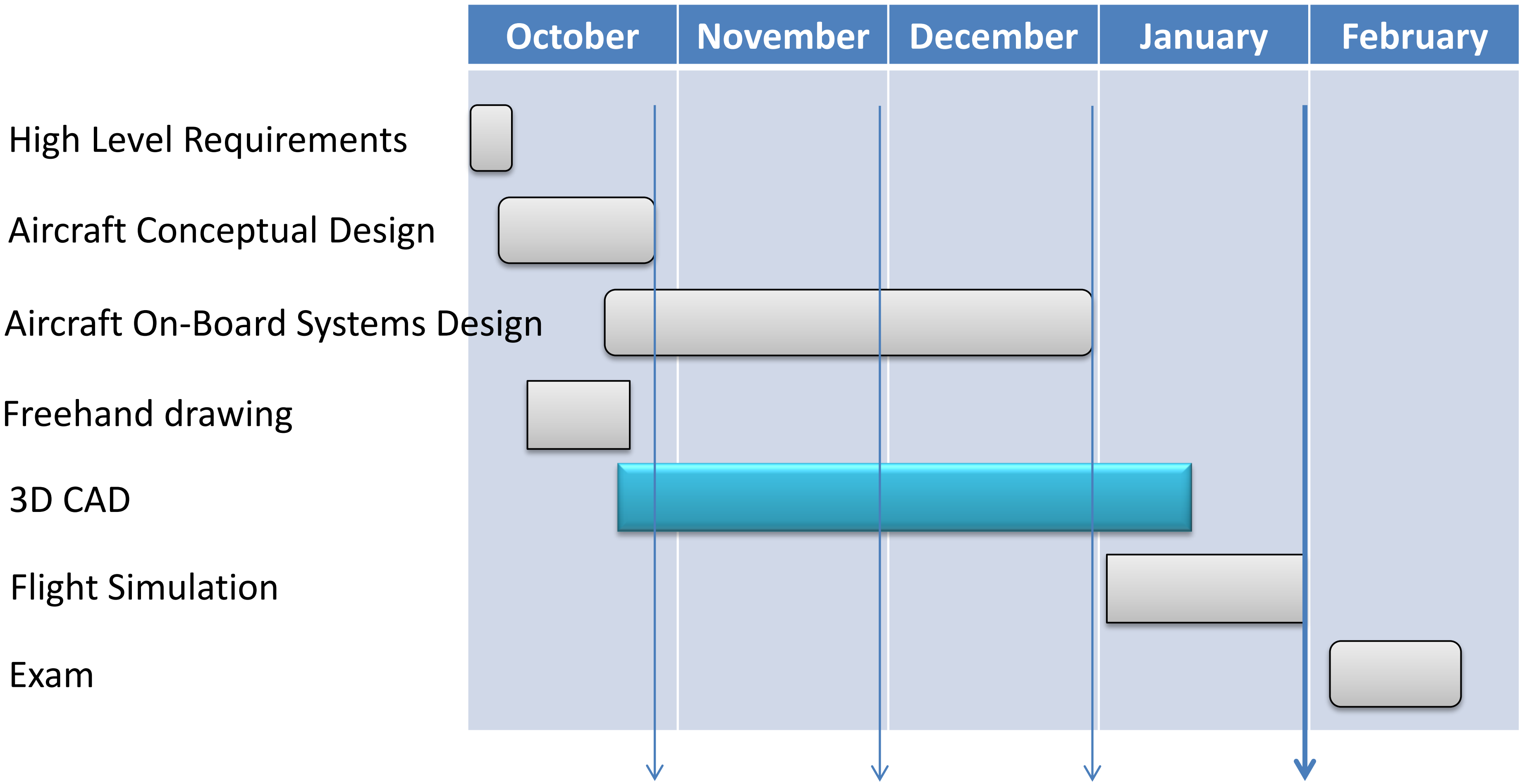
Fuselage enlargement needed to store satcom antenna

Avionics POD

Flap fairings

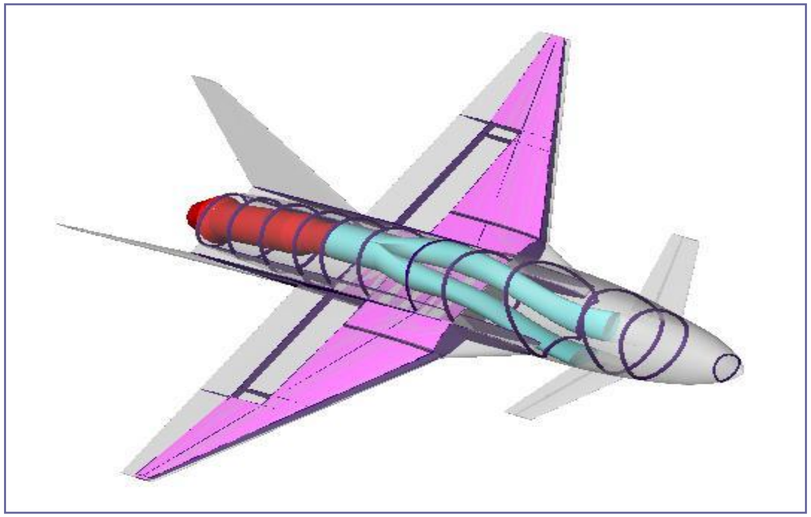
- **Flight control system** (e.g. actuator speed, actuator dimensions, etc.)
  - Influence on aircraft handling qualities
  - Wing aerodynamic drag

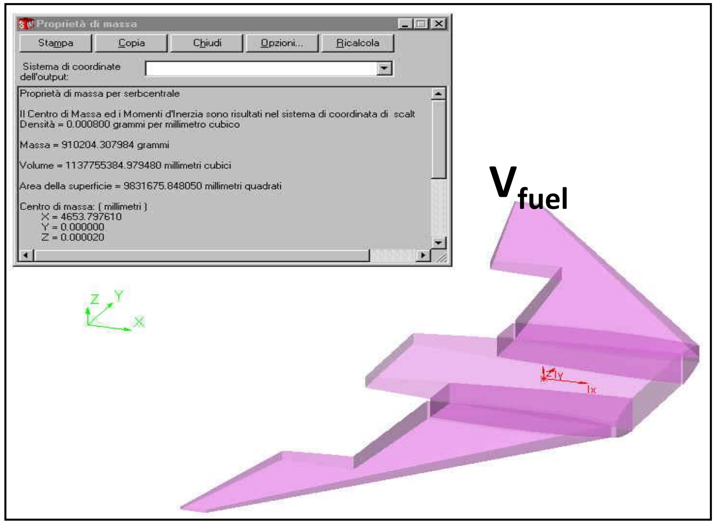
Design process – 3d CAD

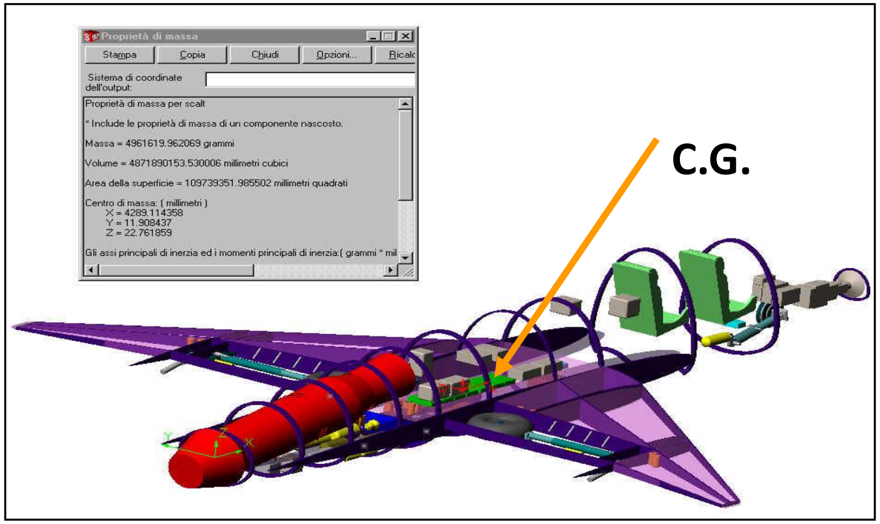


Presentation to teachers and other teams
(the chairman of final presentation is the director of Alenia Aermacchi preliminary design office)

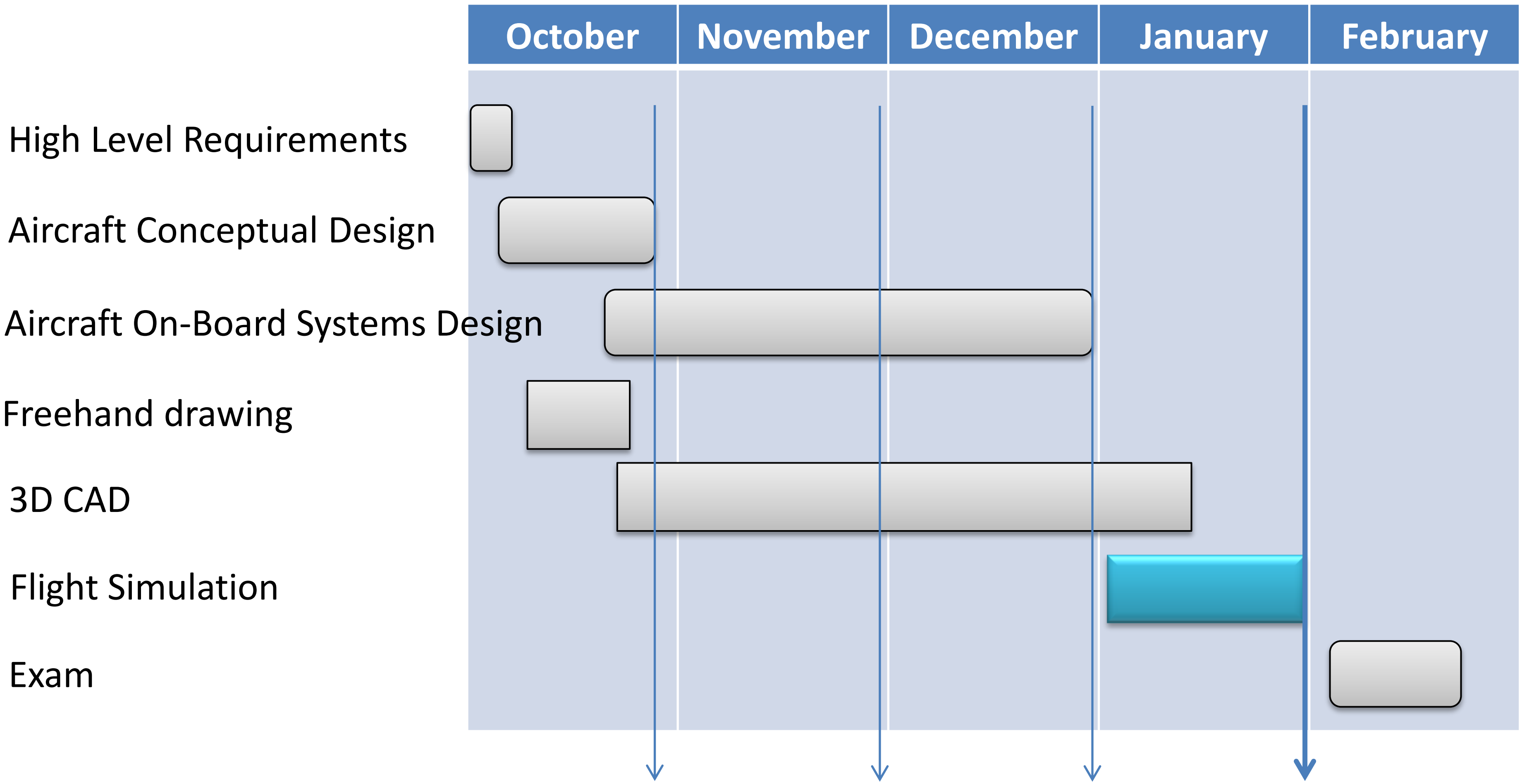
- Physical aircraft components integration
- Verification of fuel storable
- C.G. position
- Aircraft wet area







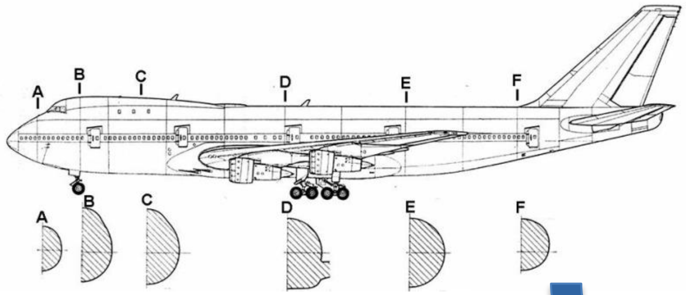
Design process – Flight simulator

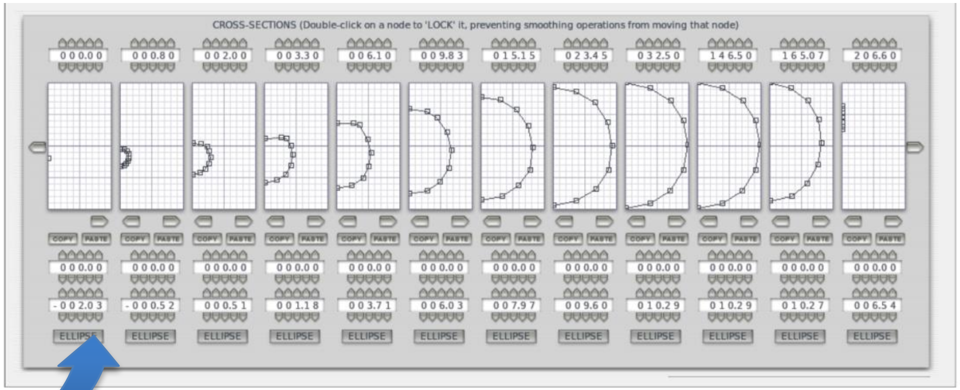


Presentation to teachers and other teams
(the chairman of final presentation is the director of Alenia Aermacchi preliminary design office)

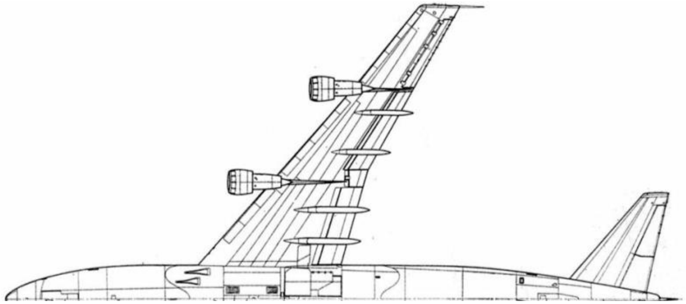
Use of X-Planes simulator to validate aircraft conceptual design

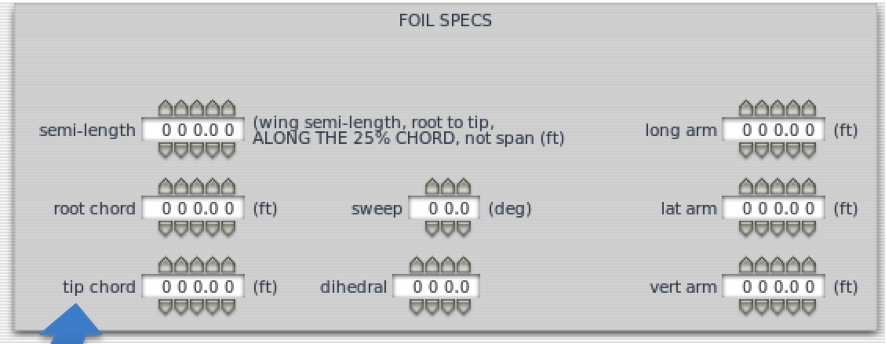
Fuselage layout





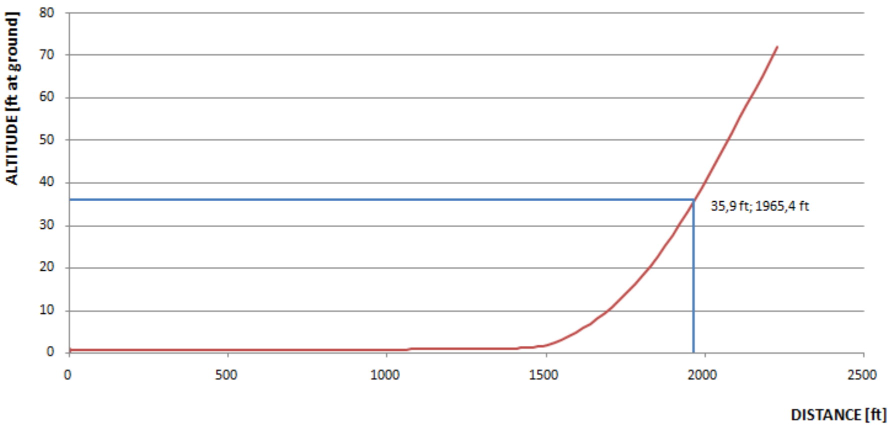
Wing layout



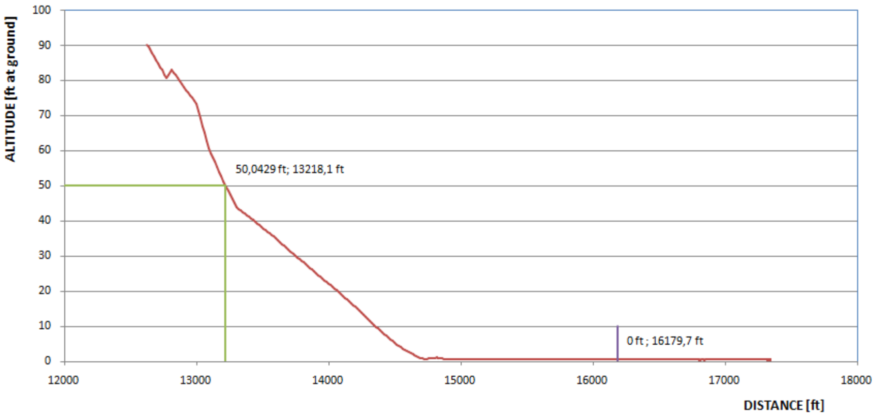


Some example of concept validation

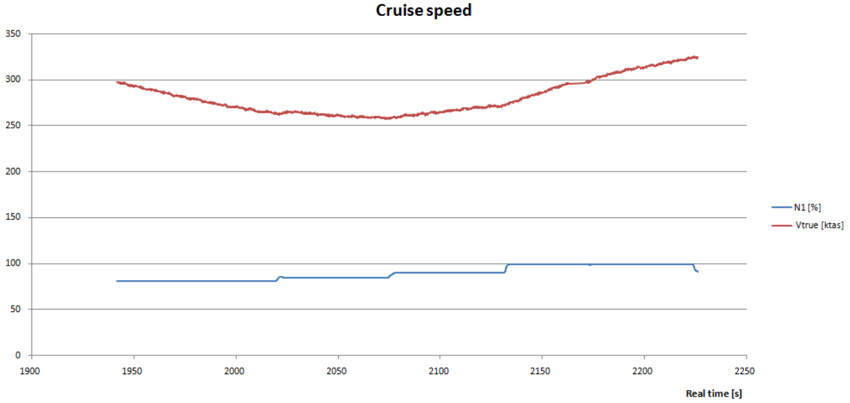
TAKE OFF RUNWAY LENGTH 1965,4 ft = 598 m



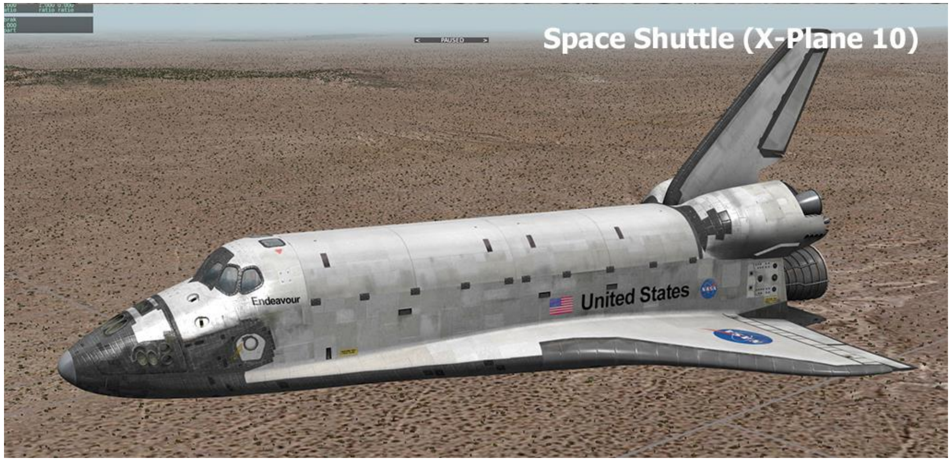
LANDING RUNWAY LENGTH: 2962 ft = 903 m

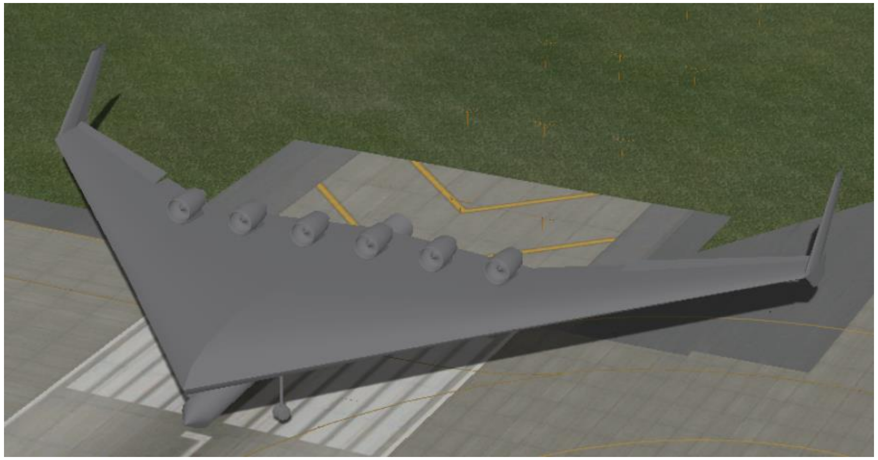


Cruise speed

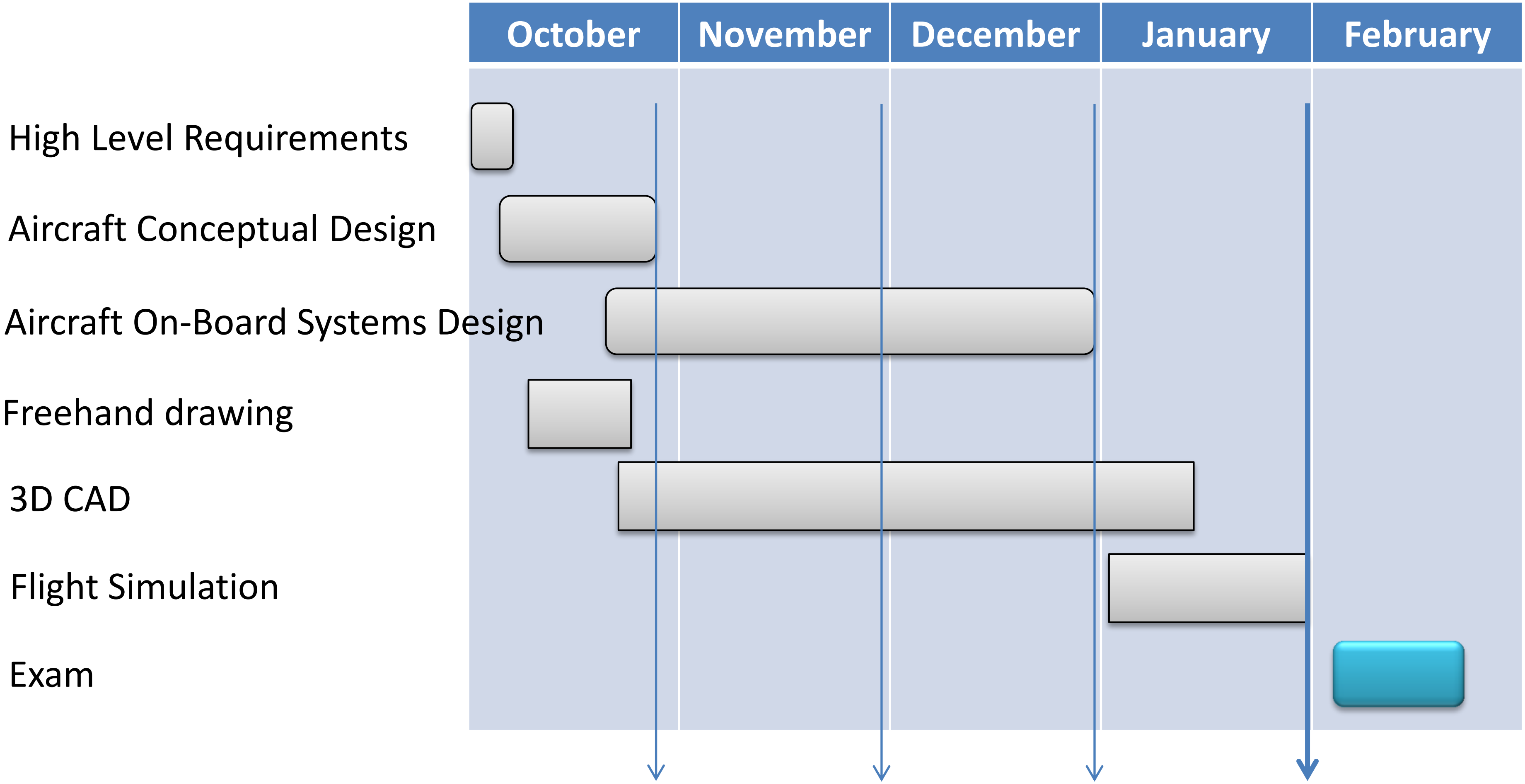


Examples of software's capabilities



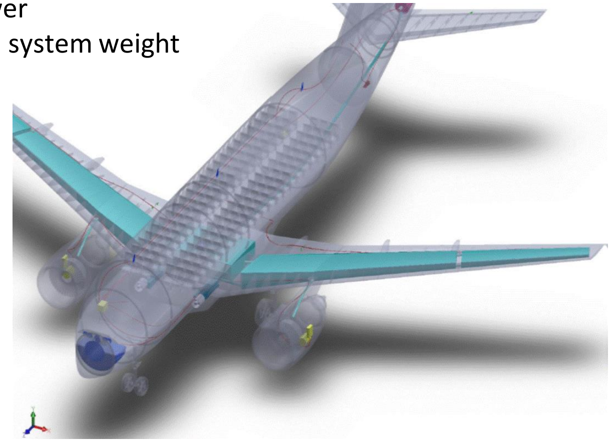


Design process – Final report



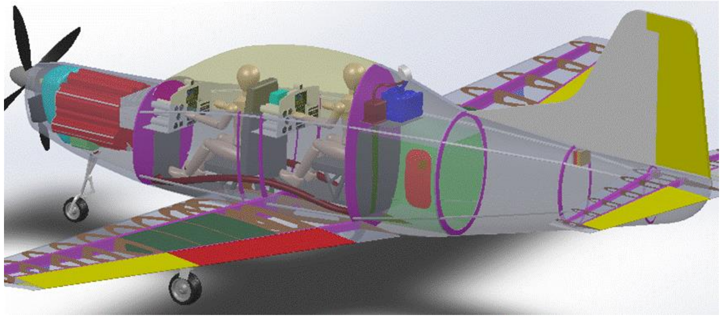
Presentation to teachers and other teams
(the chairman of final presentation is the director of Alenia Aermacchi preliminary design office)

1st Team: Conventional jet-liner with innovative on-board systems
- Bleedless engine
- 270 V DC primary power
- Reduction in on-board system weight

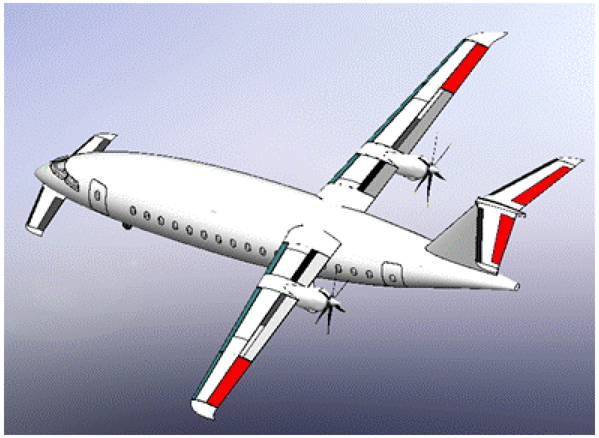


2nd Team: General aviation long range
- Diesel engine to improve fuel efficiency
- Electric de-icing
- High voltage electric system

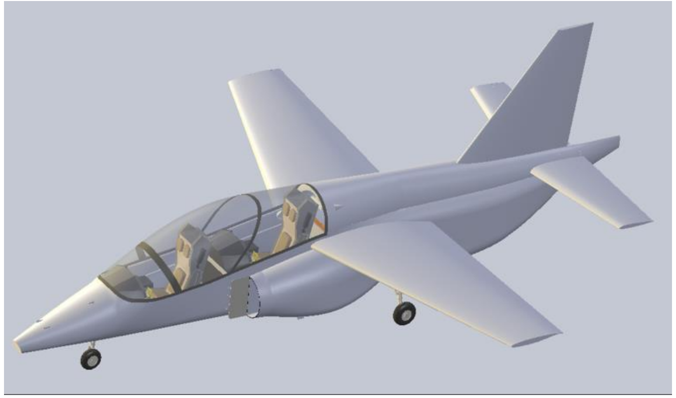
3rd Team: acrobatic general aviation / Screener
- Hybrid propulsion
- 270 V DC electric system, electric motor and batteries for propulsion



4th Team: Regional turboprop advanced architecture
- All-electric on-board system
- Uneven passenger's seats disposition



5th Team: Light jet-trainer
- Difficulty of comply with takeoff requirement
- Engine selection, fuel efficiency limited by engine installation and available volume



6th Team: MALE UAV civil missions
- Diesel engines to obtain endurance required
- New (TMEDS) de-icing system to reduce electric consumption

7th Team: BeePlane
- Difficulty of achieving required cruise speed and altitude