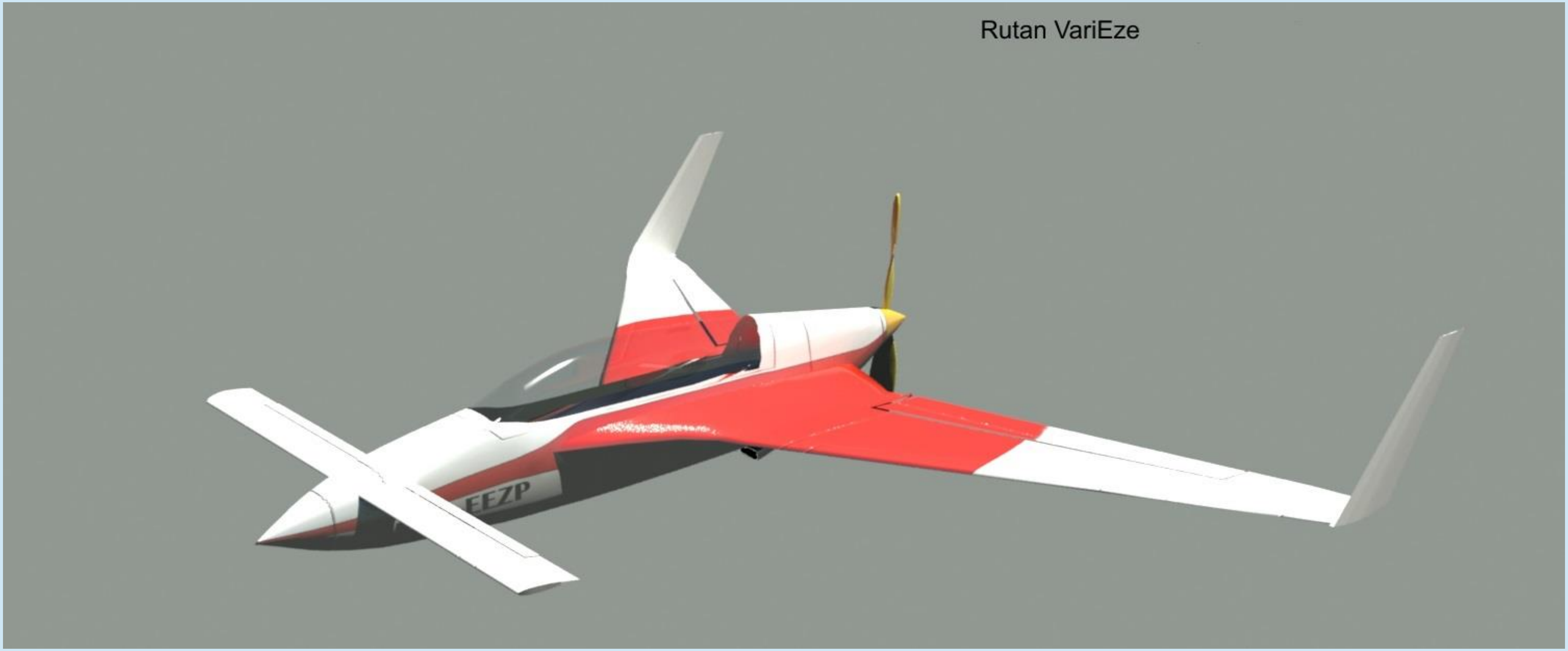
Ultralight airplane Design



Ultralight airplane definitions:

Airworthiness authorities define aircraft as vehicles that can rise or move in the air and enforce strict regulations and requirements for all such machines.

Ultralight airplanes (ULMs) are low cost fliers that can operate outside the sophisticated regulatory systems designed for heavier aircraft. Airworthiness authorities have defined four different classes of ULM:

- Class 1 (Powered paraglider): A powered paraglider (or paramotor) consists of a motorized frame suspended from a flexible parachute-like sail. It meets the following technical requirements:
  - The maximum continuous power is lower than or equal to 45KW for single-seat aircraft and 60KW for two-seat aircraft;
  - The maximum mass is lower than or equal to 300 kg for a single-seat aircraft and 450kg for two-seat aircraft.
- Class 2 (Ultralight trike): An ultralight trike is a motorized card suspended from rigid sail. It is effectively a powered hang glider.
- **Class 3** (Airplane): An Ultralight airplane is an aircraft featuring a fixed wing. In France, ULM airplanes are known as 'Multi-axes'. ULM airplanes and trikes meet the following technical requirements:
  - The maximum continuous power is lower than or equal to 45KW for single-seat aircraft and 60KW for two-seat aircraft;
  - The maximum mass is lower than or equal to 300 kg for single-seat aircraft and 450kg for two-seat aircraft. These masses can be increased by 5% if the ULM has a parachute or a floatation system;
  - Stall speed (VSO) is lower than or equal to 65 km/h, or the wing loading at the maximum weight is lower than 30 kg/m².
- Class 4 (Autogyro): An ultralight autogyro (also known as gyroplane) is supported by an unpowered rotor and must meet the following technical requirements:
  - The maximum continuous power is lower than or equal to 60 KW for single-seat aircraft and 80 KW for two-seat aircraft;
  - The maximum mass is lower than or equal to 300 kg for single-seat aircraft and 450kg for two-seat aircraft;
  - Rotor loading at maximum mass is between 4.5 and 12 kg per square meter
- Class 5 (Hot air balloon)

Zenair CH 601 (Ultralight airplane)

Specifications:

Empty weight: 283 kg
Gross weight: 450 kg
Fuel capacity: 60 + 2 X 55 L
Wing Loading: 36 kg/m²
Limit Load Factors: +4G -2G
Never Exceed speed (VNE): 224 km/h
Cruise Speed: 201 km/h
Stall speed: 73 km/h (version without flaps)
Power Output: 80 hp
Wing Span: 8.23m
Length: 6,1m

Chickinox Kot Kot (1985) (Ultralight airplane) (Dynali Belgium)

Specifications:

Empty weight: 190 kg
Gross weight: 368 kg
Fuel capacity: 30 L
Wing Loading: 27.5 kg/m²
Limit Load Factors: +4G -2G (elastic), +6G -3G (ultimate)
Never Exceed speed (VNE): 130 km/h
Cruise Speed: 100 km/h
Stall speed: 70 km/h
Power Output: 30 hp
Wing Span: 11 m
Length: 6.1m

VariEze
(Burt Rutan United States)

Specifications:

Empty weight: 320 kg
Gross weight: 476 kg
Fuel capacity: 95 L
Limit Load Factors: ?
Never Exceed speed (VNE): 340 km/h
Cruise Speed: 291 km/h
Stall speed: 95 km/h
Power Output: 100 hp (Lycoming O-235)
Wing Span: 6.8m
Canard Span: 3.1m
Length: 4.32m

Aericks 200 (Switzerland)

Specifications:

Empty weight: 400 kg
Gross weight: 650 kg
Fuel capacity: 110 L
Never Exceed speed (VNE): 370 km/h
Cruise Speed: 259 km/h
Stall speed: 120 km/h (without flap), 107 km/h (with flaps)
Power Output: 105 hp
Wing Span: 8 m
Canard Span: 2 m
Length: 6.5m

IBIS
(Junka France)

Specifications:

Empty weight: 260 kg
Gross weight: 470 kg
Fuel capacity: 120 L
Never Exceed speed (VNE): 260 km/h
Cruise Speed: 200 km/h
Stall speed: 95 km/h
Wing Loading: 72 kg/m^2
Power Output: 60-80 hp (Volkswagen)
Limit Load Factors: +4.5G -3G
Wing Span: 6.3 m
Canard Span: ?
Length: 5.1 m

Falconar Golden Hawk (Ultralight airplane)
(Falconar avia Canada)

Specifications:

Empty weight: 227 kg
Gross weight: 449 kg
Fuel capacity: 34 L
Never Exceed speed (VNE): 209 km/h
Cruise Speed: 161 km/h
Stall speed: 64 km/h
Wing Loading: 28.7 kg/m^2
Power Output: 55 hp (Hirth 2703 Bi-Cylindre, moteur avion 2T)
Wing Span: 10.26 m
Canard Span: ?
Length: 4.27 m

Flying Electron

Flying Electron

Flying Electron

Flying Electron

VL3 (Ultralight airplane) (Belgium)

Specifications:

Empty weight: 300 kg
Gross weight: 472.5 kg
Fuel capacity: 90-120 L
Never Exceed speed (VNE): 305 km/h
Cruise Speed: 265 km/h
Stall speed: 55 km/h
Wing Loading: 46 kg/m^2
Limit Load Factors: +6G -3G
Power Output: 100 hp (Rotax 912 ULS)
Wing Span: 8.44 m
Length: 6.24 m

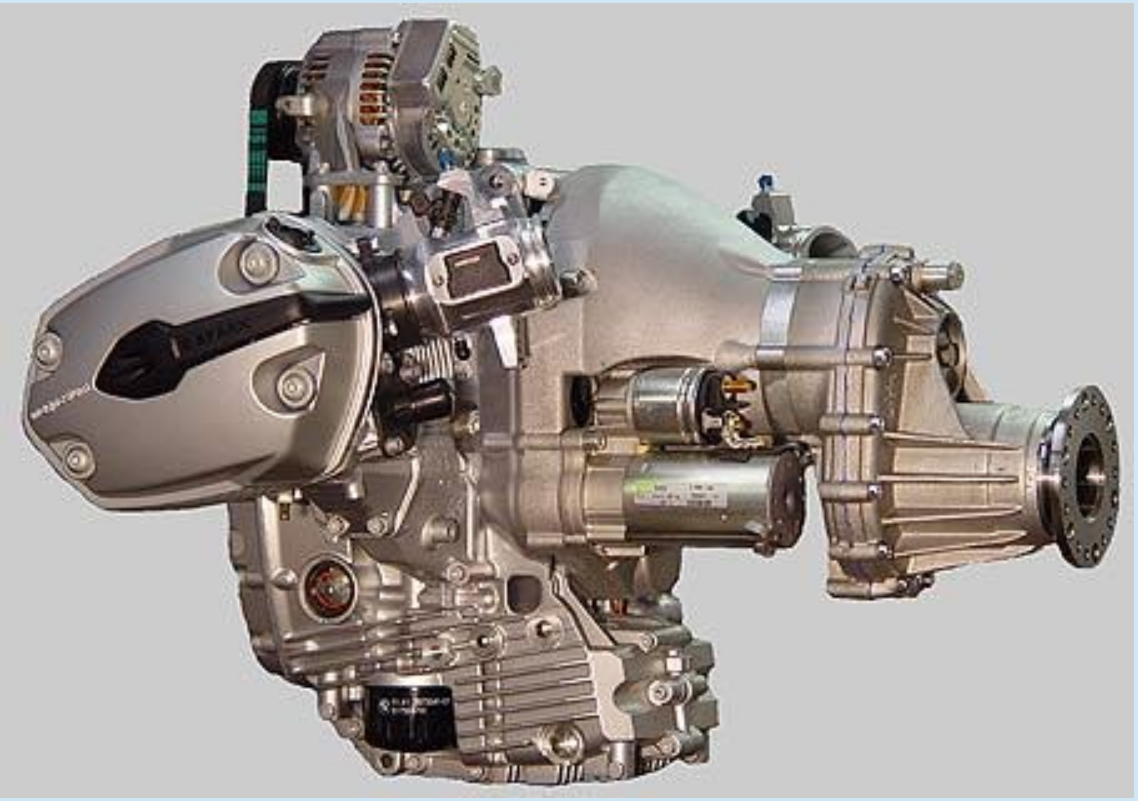
Project vision :
The wings

Engine:
Rotax 912 UL

Engine Data/Performance:

Bore: 79.5 mm
Stroke: 61 mm
Volume: 1211.2 cm3
Power: 59.6 KW (80 hp) at 5800 1/min
Torque: 103 Nm at 4800 1/min
Max RPM: 5800 1/min
Weight:
- Engine with propeller speed reduction unit i = 2.27 (opt. i = 2.43): 55.4 kg
- Overload clutch: 1.7 kg
- Exhaust system: 4.0 kg
- External alternator: 3.0 kg

Engine
BMW R 1200 S



Engine Data/Performance:

Bore: 101 mm
Stroke: 73 mm
Volume: 1170 cm3
Power: 84 hp) at 5500 1/min
Torque: 110 Nm at 6200 1/min
Max RPM: 6500 1/min
Propeller: 3-blade DUC, REF FC type R WINDSPOON reference 01-01-003 diameter 1727 mm
Weight:
- Engine: 50.3 kg
- Propeller speed reduction unit i = 2.76: 9.5 kg
- Accessories: 2.08 kg
- Exhaust system: 4.5 kg
- External alternator: 2.5 kg

Propeler
3-blade DUC

Weight: ± 3100 g
Size: 1727mm
Reference: 01-01-003

Canard (foreplane): Advantages

- Canards are almost always lifting surfaces. In contrast, classical horizontal tails create downforce when the centre of gravity lies in front of the wing's aerodynamic centre.
- If the canard's lift if significant, the main wing can afford to be smaller. This again depends on the relative positions of the wing's and canard's aerodynamic centres and of the centre of gravity.
- A well-designed canard protects again stall. The canard stalls first, then the aircraft pitches nose-down avoiding main wing stall.
- ULMs with canards usually do not have a classical fin in order to shorten the fuselage as much as possible. Fuselage drag and weight are reduced. Yaw stability and control is ensured by winglets on the wingtips. The large winglets reduce induced drag.
- The canard configuration allows a wide range of centre of gravity locations with an important restriction: beyond a forward limit, the canard can stall too early at low speed.
- The use of a canard combined with elevons located on the wing can increase the pitch angular velocity and hence the maneuverability.

Canard (foreplane): Drawbacks

- Longitudinal stability requires a larger loading increment on front surfaces than on rear surfaces (ratio about 1.6 to 2 for 1) for an increase of the angle of attack.
- The canard stalls first, which means that the wing can never reach its maximum lift angle. This problem can be solved with all-moveable canards, which can allow very high angles of attack.
- The downwash of the canard reduces the effective angle of attack of the inboard main wing, thus reducing lift. Again, all-moveable canards can overcome this problem.
- Extending the flaps causes a pitching nose down moment. With a canard configuration, there is no extra supply of lift sufficient to compensate this moment. There are three possible solutions:
  - All-movable canards
  - Canards with variable geometry (e.g. Beechcraft Starship, a model not pursued by the manufacturer)
  - No flaps
- Propulsion (single engine)
  - The propeller being generally at the back, the air flow on the wing is not increased: loss of lift at take off.
  - The rear propeller (small diameter due to the limitation of ground clearance) works in the disturbed wake of to canard, wing, landing gear and fuselage. Propulsive efficiency is affected (about 0.72 to 0.76 instead of 0.80 to 0.85), which reduces takeoff thrust.
  - All these factors make takeoff and landing longer than for conventional aircraft, as higher airspeeds are required.

Canard (foreplane): Drawbacks (2)

- In order to ensure winglet effectiveness in finless configurations, the main wing features significant sweepback. This reduces lift and increases construction costs.
- Freeplay in all-moveable canard bearings and actuators is crucial. Construction and service costs increase in order to reduce freeplay.
- Longitudinal balance can be sensitive to rain: the low chord of the canard and a choice of a "laminar flow" airfoil can cause early separation of the flow when the suction side is wet and reduce lift. As the rain affects less the main wing, the aircraft can pitch nose-down. One remedy is to install vortex generators on the canard; another remedy is to return to a classic airfoil: on the Rutan Long-EZ, the GU-25 airfoil was replaced by a Roncz 1145MS.

Targeted characteristics

- Performances:

  Empty weight: 200-220 kg
  Fuel capacity: 100-150 liters (50L in each wing, 50L in the fuselage),
  Load factor : +8g -5g (Elastic Limit)
  Continuous power output: 80 Hp (two engines to be considered: Rotax 912 and BMW 1100)

- Dimensions and speed:

  Never Exceed Speed (VNE) : ?
  Cruise: 200-250 km/h
  Stall speed: lower than 65 km/h
  Wing Span: ?
  Length: ± 5m

- Each group should study a different configuration (all three configurations must be studied):

  Canard and aft engine (Flaps ? All-moveable canard?)
  Aft empennage and frontward engine
  Aft empennage and aft engine

- Manufacturing:

  Composite skin with carbon or glass fiber

- Reinforcements made of aluminum alloy (7071), sheet metal laser cut (DXF) / composite materials

- Pyrotechnic parachute