URBAN AIR MOBILITY

Aerospace Design – Group 1
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INTRODUCTION

Constraints

- Payload of 600kg;
- Cruise speed of 100-200 kts;
- Operational radius of 300 km;
- Altitude ceiling < 3,000m;
- Cruise altitude of 1,500 m (AGL).

Objective

- To design an innovative hybrid-electric VTOL UAM.

General & Design Requirements

- MTOW < 3000 kg;
- 20 min of reserve energy;
- All-electric or hybrid-electric propulsion.

DATA GATHERING

	De Havilland DHC-3	Bell Long Ranger 206L3	Joby Aviation's Aircraft	Lilium Jet	Aurora Boeing Personal Air Vehicle	Airbus CityAirbus
MTOW	3629 kg	1882 kg	-	-	800 kg	2200 kg
Cruise Speed	120 kt	104 kt	170 kts	160kts	97 kts	65 kts
Range	1540 km	515 km	240 Km	300km	80 km	<30 km
Passengers	11	5	4	4	2	4
Energy sources	-	-	Electric	Eletric	All Electric	All Electric
Development Status	-	-	Expected launch 2023	Expected launch 2025	Expected launch 2024	Expected launch 2023

De Havilland DHC-3


Lilium Jet


Bell Long Ranger 206L3


Aurora Boeing Personal Air Vehicle


Joby Aviation's Aircraft

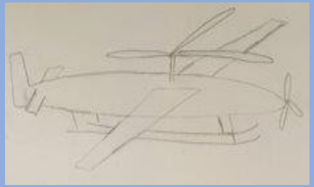

Airbus CityAirbus

CONCEPT GENERATION – First Sketches

Number 1:

✓ Mechanically easy concept;

X Drag and lateral drift.



Number 2:

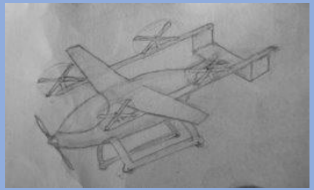
✓ Good VTOL and cruise performance;

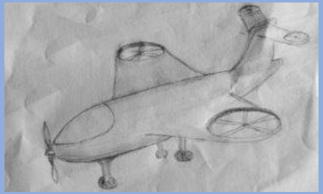
X Expensive and rotating elements.

Number 3:

✓ No rotating elements and VTOL stability;

X Noise and drag.





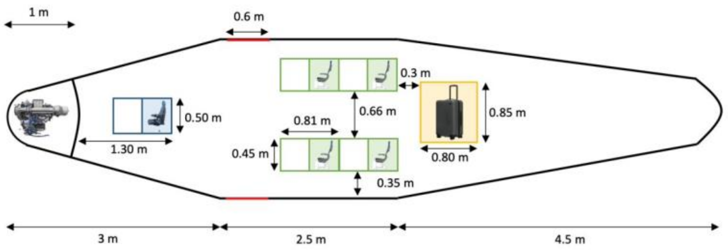
Number 4:

✓ Aesthetically pleasing and futuristic;

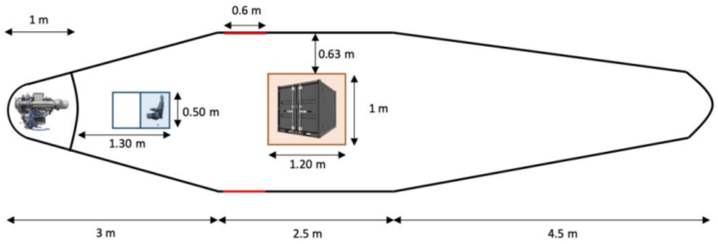
X Wing holes.

CONCEPT GENERATION – Configurations

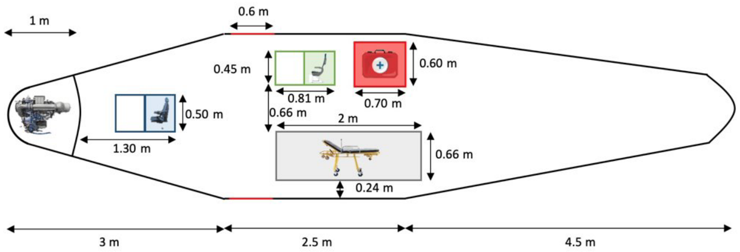
Airtaxi mode



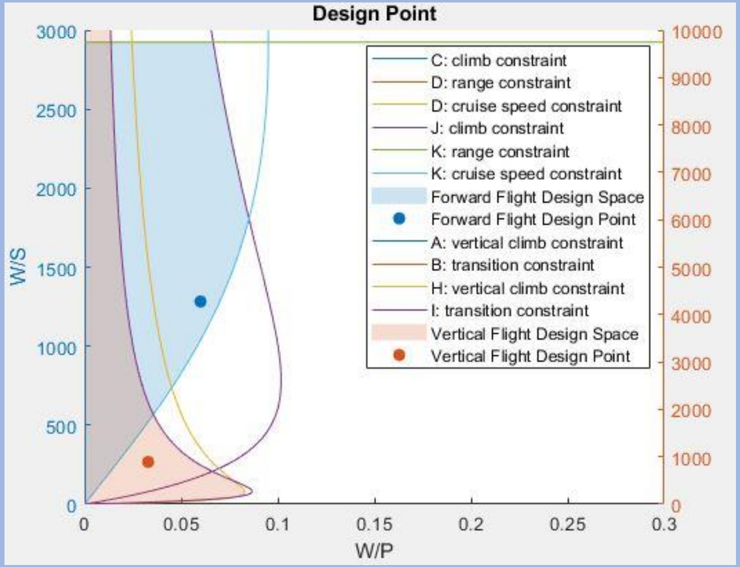
Cargo mode

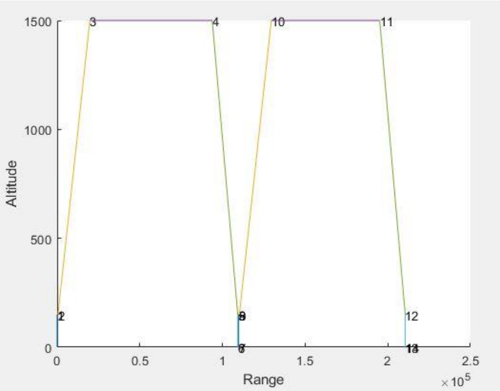


Ambulance mode



AIRCRAFT SIZING – MTOW and Design Point





MTOW = 2282 kg

W/S = 1282 N/m²
S = 17.45 m²

W/P$_{horiz}$ = 0.060 N/W
P$_{horiz}$ = 373 kW

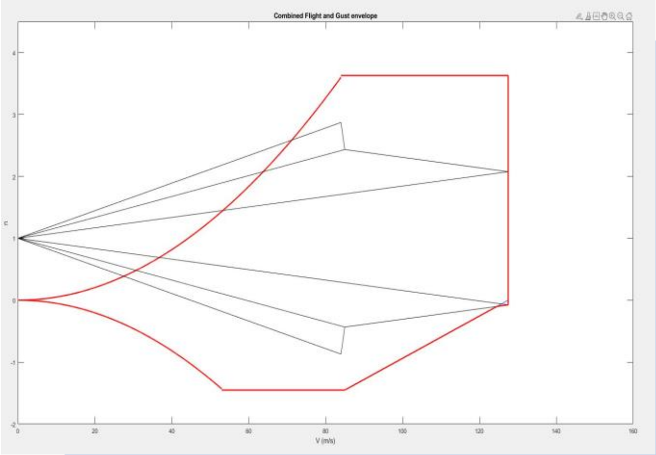
W/A = 890 N/m²
A = 25.12 m²

W/P$_{vert}$ = 0.03292 N/W
P$_{vert}$ = 680 kW

AIRCRAFT SIZING – Methodology

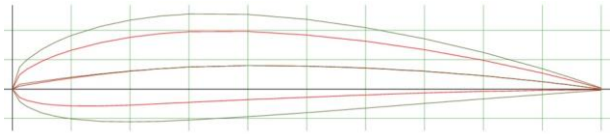
General design objective:

- Low cruise speed;
- Simple and efficient forward propulsion;
- Capable of landing and taking off twice until next recharge;
- Low MTOW.



1. **Cruise velocity**: The higher it is, the more forward propulsion will be needed;
2. **Vertical take off velocity**: A faster take off will needed more powerful engines but will take less time and may reduce MTOW;
3. **Aspect ratio**: The higher it is, the higher L/D will be but a large wing will have to support higher loads and will have higher mass;
4. **Transition altitude**: Affects the battery mass and thus the range.

AERODYNAMICS – Airfoil Selection and Wing Design

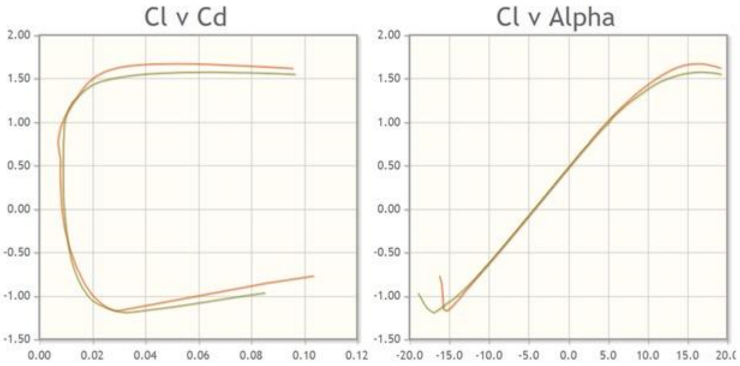


Design objectives:

- Low stall speed;
- Low cruise speed;
- Low transition speed.

- NACA 4412 airfoil:
  - Max thickness 12% at 30% chord;
  - Max camber 4% at 40% chord.

- NACA 4418 airfoil:
  - Max thickness 18% at 30% chord;
  - Max camber 4% at 40% chord.



Choosing NACA 4412:

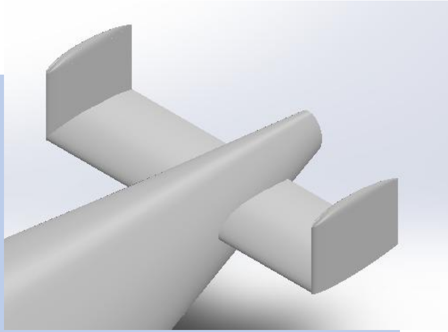
- S = 17.45 m^2
- AR = 8.3
- b = 12.03m
- c = 1.45 m

AERODYNAMICS – Tail Design

Design objectives:

- Good control at low speed;
- High C_{L_α};
- Large range of usable α.

Chosen airfoil: NACA 0012



Vertical stabilizer:

- H-tail;
- S_{VT} = 1.68 m^2;
- $\bar{c}_{VT}$ = 0.98 m.

Horizontal stabilizer:

- S_{HT} = 3.37 m^2;
- $\bar{c}_{HT}$ = 1.12 m;
- b_{HT} = 3 m;
- AR = 2.67

AERODYNAMICS – Drag Calculations

For the wing:

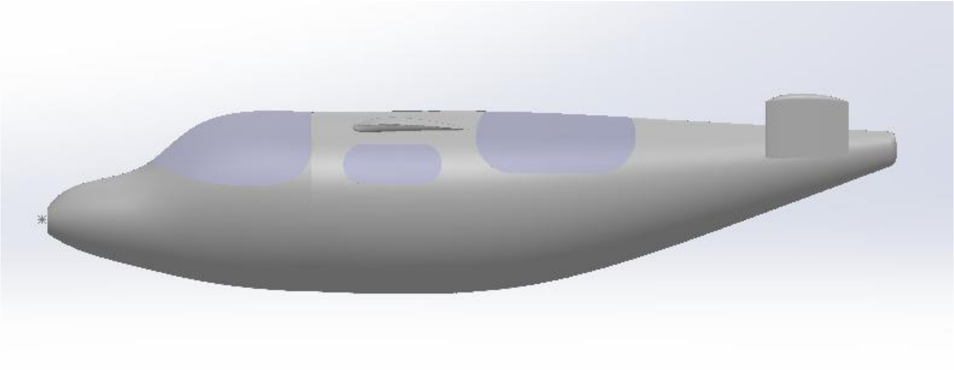
- C_{D_0} = 0.0085;
- C_{D_i} = 0.0057;
- L/D = 23.

For the fuselage:

- C_{D_0} = 0.0197.

For the aircraft:

- $D_{aircraft}$ = 2201 N;
- L/D = 10.17



PROPULSION – Engine Selection

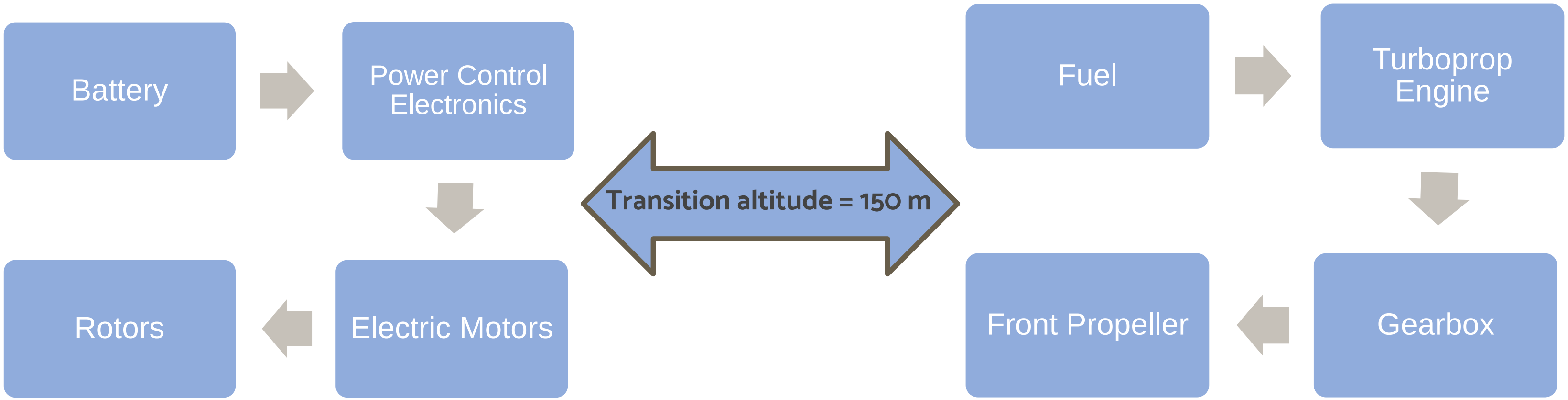
	Rolls-Royce M250-C28B	TP100 (x2)	Vedeneyev M14P	Rolls-Royce RR500
Continuous Power	373 kW	160 kW	268 kW	280 kW
Dry Weight	103.9 kg	61.6 kg	214 kg	102 kg
Diameter	846 mm	398 mm	985 mm	590 mm
Length	1219 mm	891 mm	924 mm	1090 mm
Specific Fuel Consumption	0.369 kg/kWh	0.525 kg/kWh	0.282 kg/kWh	0.412 kg/kWh

	MagniX magniDrive	EMRAX 348	Siemens SP260D	MAGiDRIVE 300
Continuous Power	170 kW	210 kW	261 kW	240 kW
Weight	12 kg	42 kg	50 kg	45 kg
Diameter	562 mm	348 mm	418 mm	482 mm
Length	74 mm	105 mm	300 mm	200 mm

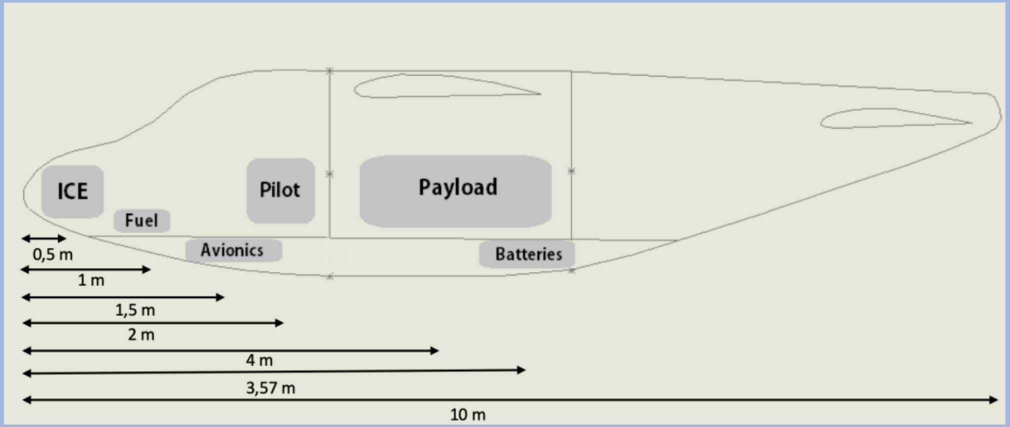
PROPULSION – Hybrid-Electric Propulsion System Design

From the Design Point:

- Disk loading = 890 N/m^2
- MTOW = 2282 kg
- Total Rotor Area = 25.12 m^2



STABILITY – Longitudinal Static Stability



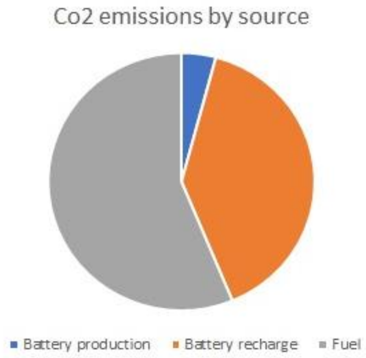
Component Masses (kg)			
Fuselage	600	Rotors	160
Main Wing	215	Fuel Tank	25.12
HT	60	Landing Gear	60
VT	40	Payload	500
Batteries	152.2	Cabin/Interior	283
ICE	103.9	Gearbox	5
Propeller	10	Avionics	65
Motors	48	Crew	100

MTOW = 2282 kg

x_{CG} = 4.08 m

- Static Margin = 10.0%
- CM_α = -1.02

EMISSIONS - Noise and Pollutant Emissions Estimation

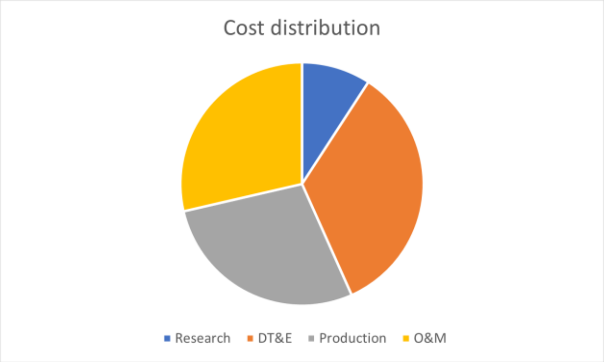


Total CO_2 emissions: 34.55 ton per 714 cycles.

# blades	# rotors	c_{blade} (cm)	r_{rotor} (m)	M_{tip}	$SPL_{hover,500ft}$ (dB)
6	8	5.24	1	0.4	74.160

Concluding Remarks and Remaining Tasks

Estimated Total Cost: 382M US$



Remaining Tasks:

- Further study of the drag on the fuselage;
- Lateral/directional stability;
- FMECA.