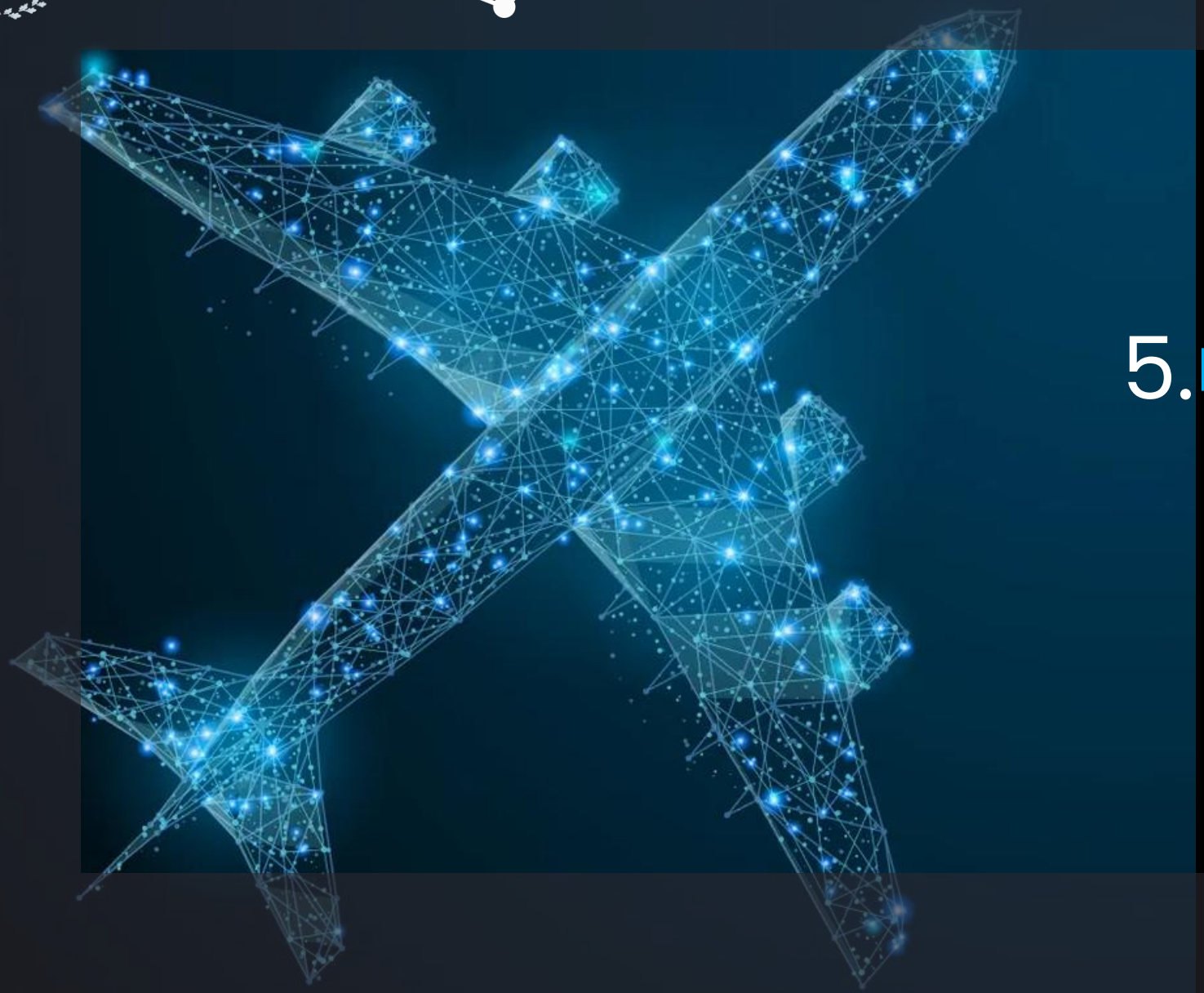

Progettazione di veicoli aerospaziali (AA-LZ)

E1. Conceptual Design of subsonic commercial aircraft

5. Fuselage Design

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Aircraft Components

To define the aircraft configuration, it is worth starting from the identification of the major **components** and their design alternatives. Some ideas are reported in the following table.

Table 3.2 Aircraft major components with design alternatives

No.	Component	Configuration alternatives
1	Fuselage	Geometry: lofting, cross-section Seating arrangement What to accommodate (e.g., fuel, engine, and landing gear)?
2	Wing	Type: swept, tapered, dihedral Installation: fixed, moving, adjustable Location: low wing, mid-wing, high wing, parasol
3	Horizontal tail	Type: conventional, T-tail, H-tail, V-tail, inverted V Location: aft tail, canard, three surfaces
4	Vertical tail	Single, twin, three VT, V-tail
5	Engine	Type: turbofan, turbojet, turboprop, piston-prop, rocket Location: (e.g., under fuselage, under wing, beside fuselage) Number of engines
6	Landing gear	Type: fixed, retractable, partially retractable Location: (e.g., nose, tail, multi)
7	Control surfaces	Separate vs. all moving tail, reversible vs. irreversible, conventional vs. non-conventional (e.g., elevon, ruddervator)

Fuselage: functions and features

To properly define the **fuselage configuration**, it is worth starting from the identification of the identification of major **functions and features.**

Fuselage: functions and features

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Fuselage: functions and features

To properly define the **fuselage configuration**, it is worth starting from the identification of the identification of major **functions and features.**

No.	Functions and features	Description
1	Primary function	Accommodate the payload
2	Secondary functions	Accommodate crew members Accommodate flight attendants and other technical personnel Provide space for landing gear (if retracted inside fuselage) Provide space for engine (if inside fuselage) Provide space for fuel tanks (if inside fuselage) Provide sufficient room for systems (electric, hydraulic, mechanical, radio, etc.) Provide structural arm for empennage Keep the integrity of the aircraft structure (e.g., hold the wing)
3	Desired features and expectations	Generate the lowest drag Contribute positively to the lift generation Low weight Provide passenger/pilot/crew comfort Carry structural flight loads External symmetry Loading and unloading effectiveness Safe against environmental hazards (e.g., lightning) Low wetted area

Which functions and features are more interesting for our case study?

Fuselage: functions and features

To properly define the **fuselage configuration**, it is worth starting from the identification of the identification of major **functions and features.**

Fuselage: functions and features

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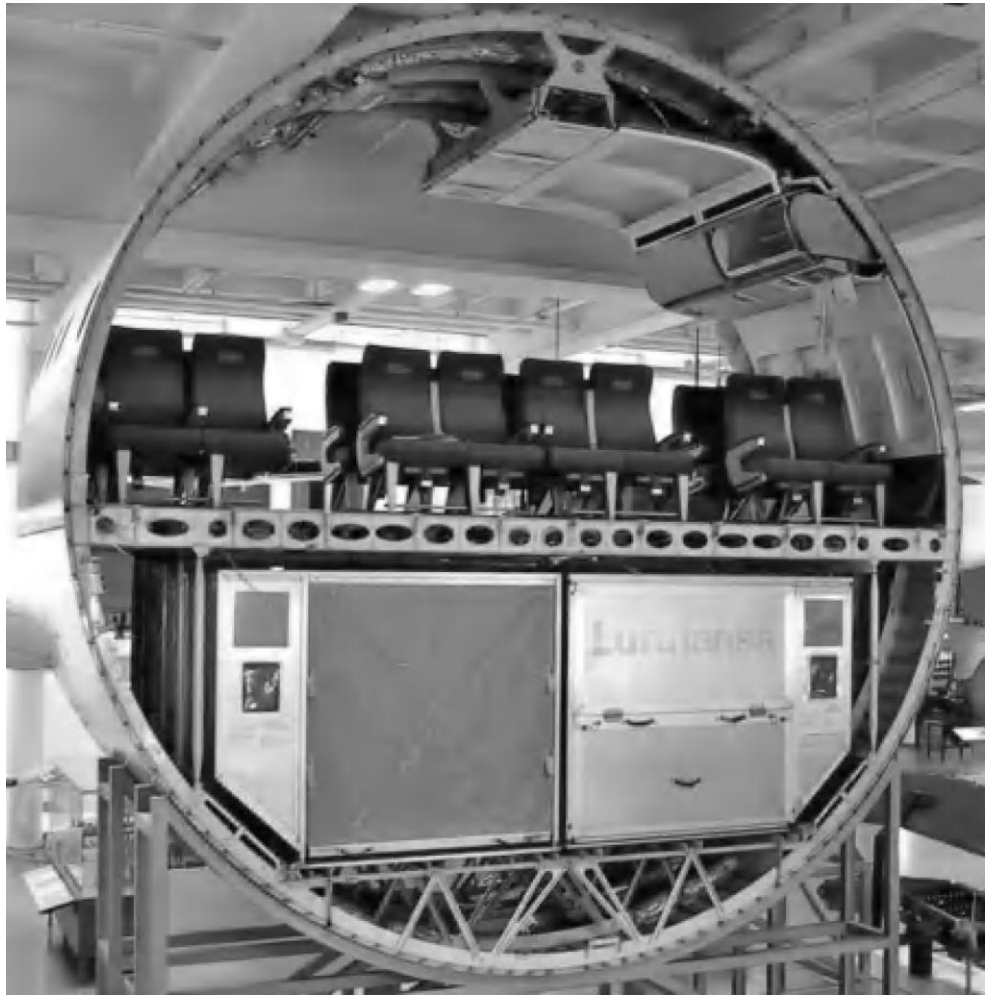
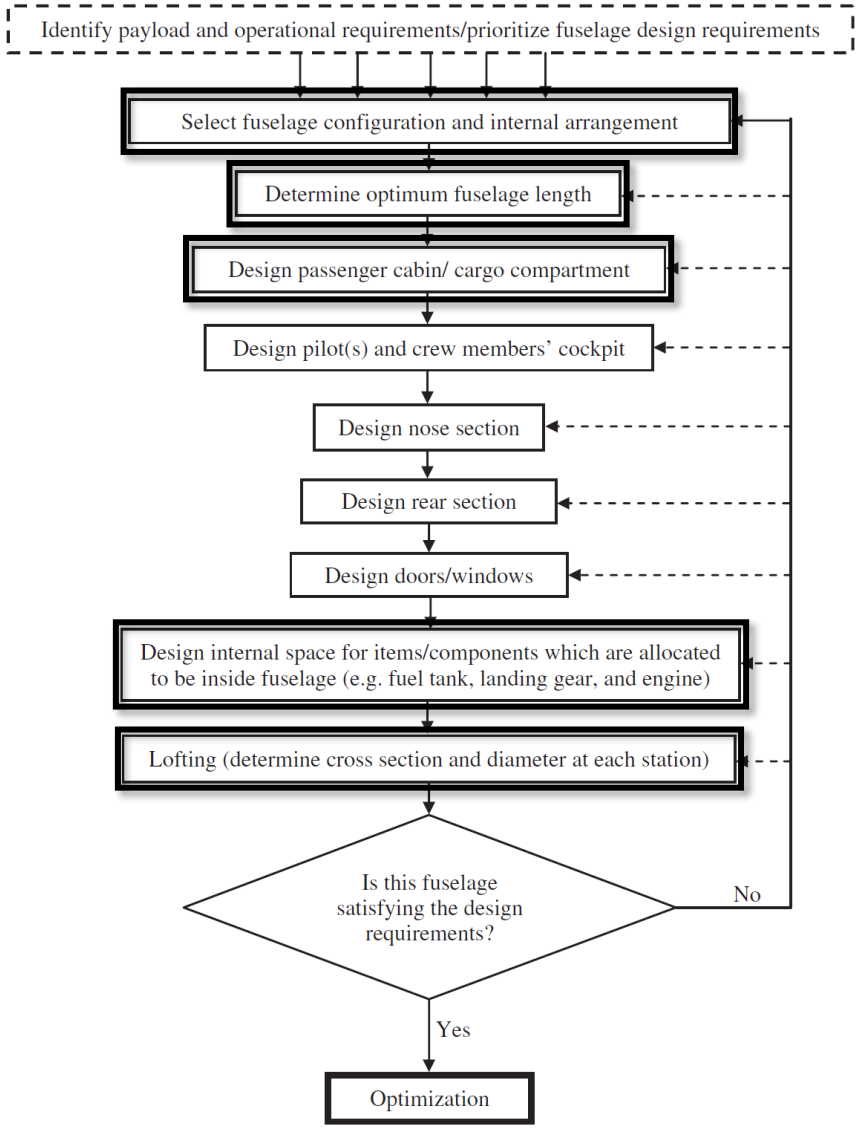


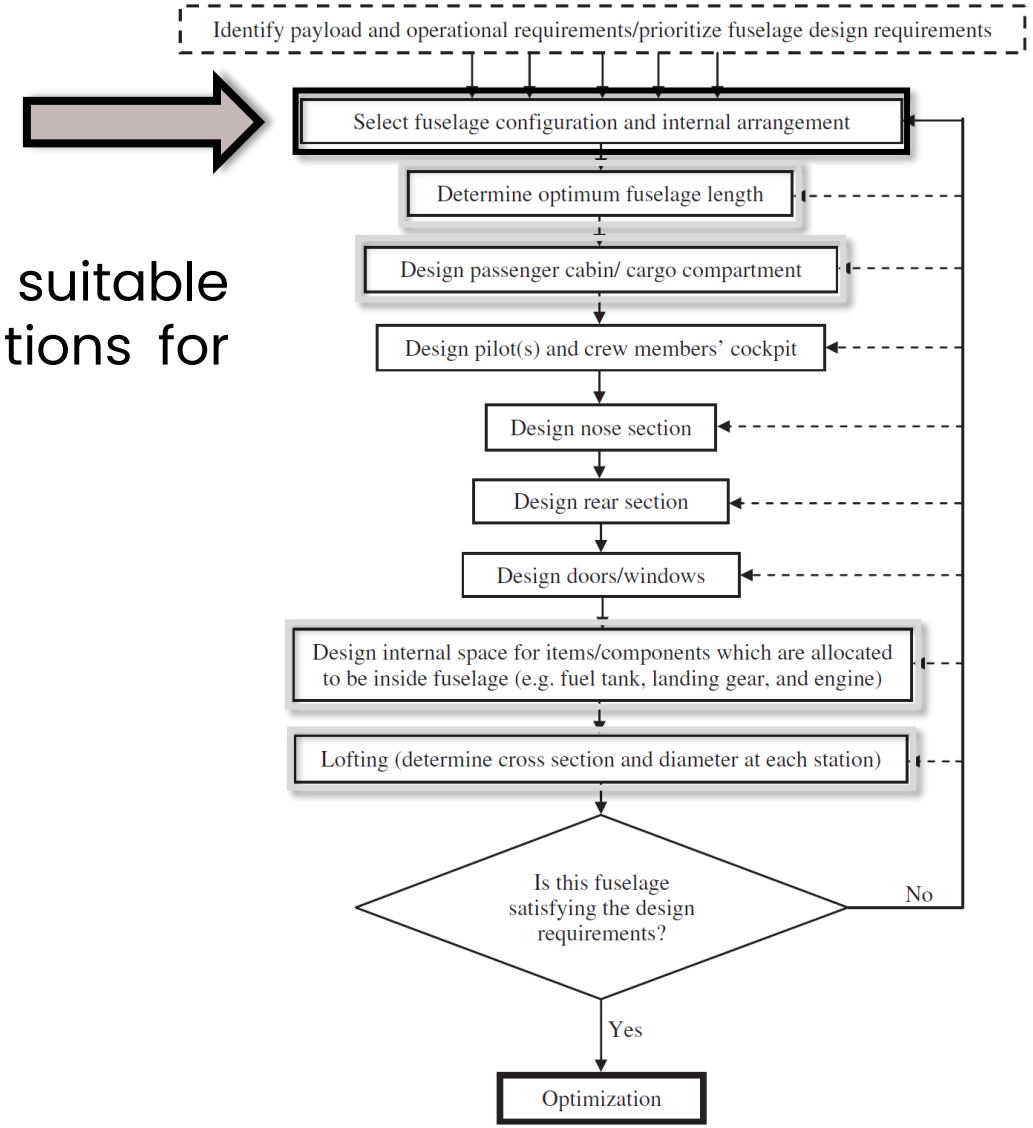
Fuselage conceptual design

Which functions and features are more interesting for our case study?



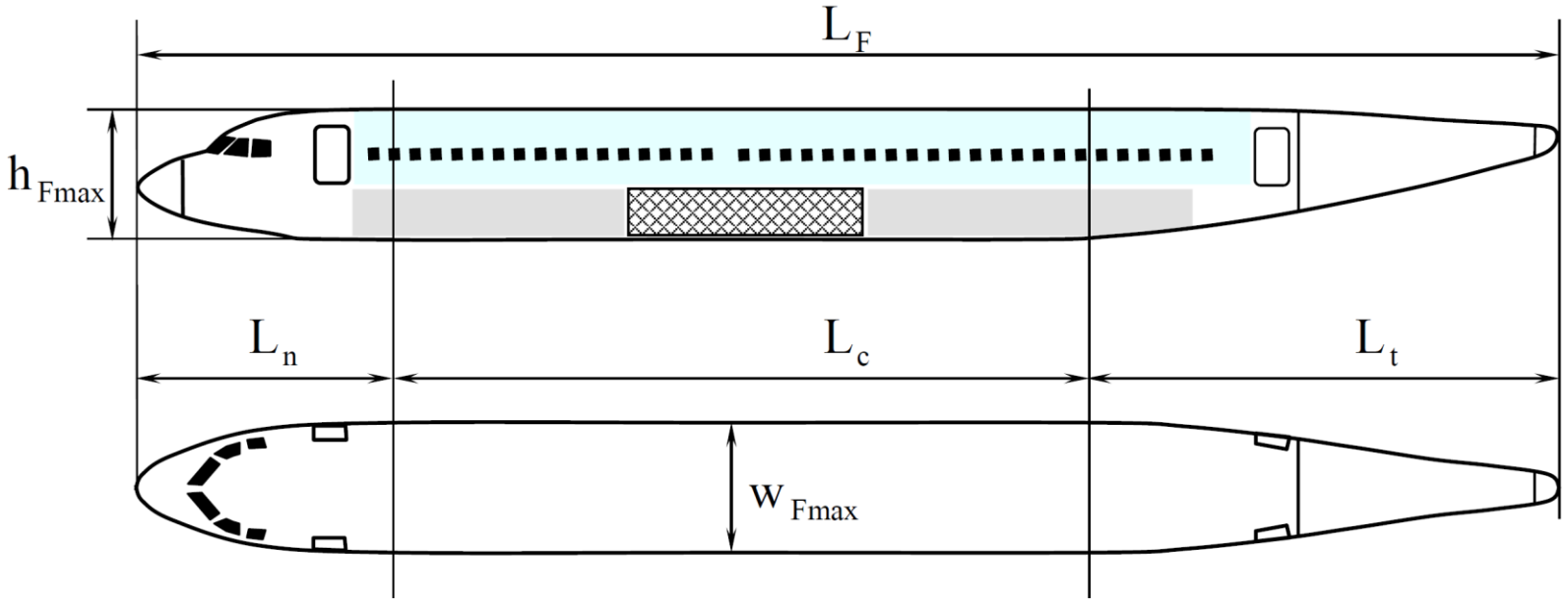
Fuselage: cabin arrangement

Which are the most suitable cabin internal configurations for our case study?



Fuselage: cabin arrangement

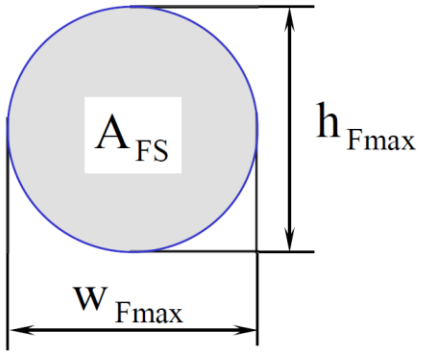
General main dimensions of a fuselage



$$D_{Feq} = \sqrt{\frac{4}{\pi} A_{FS}}$$

$$L_n = (1.5 \div 2.5) \cdot D_{Feq}$$

$$L_t = (2.5 \div 3.5) \cdot D_{Feq}$$



Fuselage: cabin arrangement

General main dimensions of a passengers' cabin

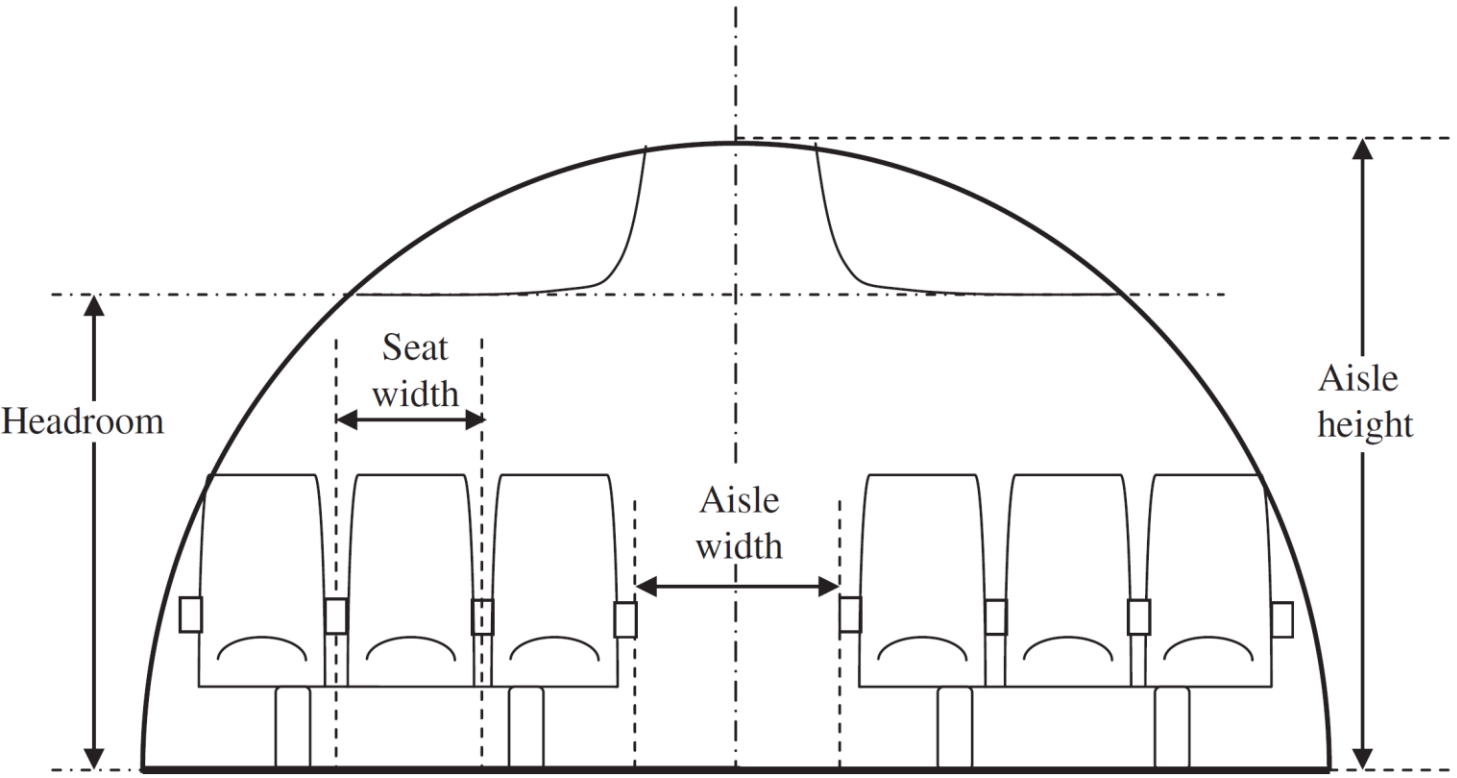
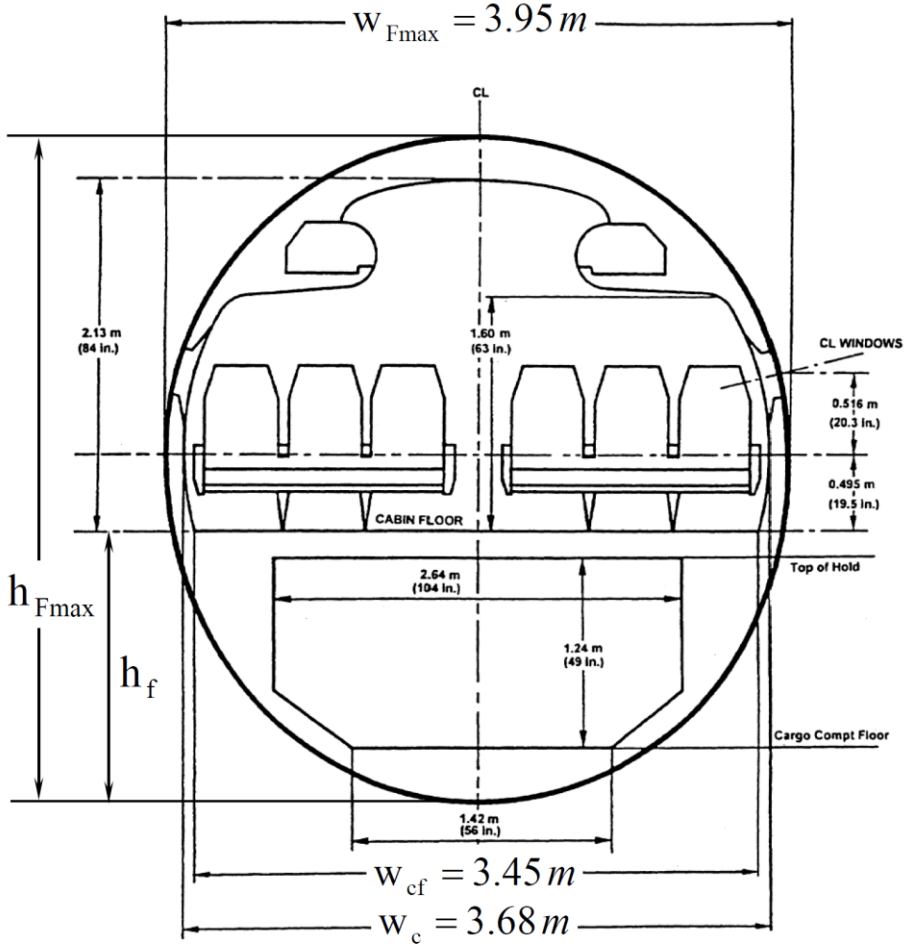


Table 7.4 Recommended cabin data (in centimeters)

No.	Cabin parameter	GA aircraft	Transport aircraft		
			Economy		First class
			High density	Tourist	
1	Seat width (W_S)	38–43	42–46	48–55	60–75
2	Seat pitch (P_S)	55–65	65–72	75–86	92–104
3	Headroom	120–130	150–160	160–170	170–185
4	Aisle width (W_A)	35–40	40–50	43–53	60–70
5	Seatback angle (deg)	10–13	13–17	15–20	20–30

Fuselage: cabin arrangement

General main dimensions of a fuselage: internal cabin layout - narrow body



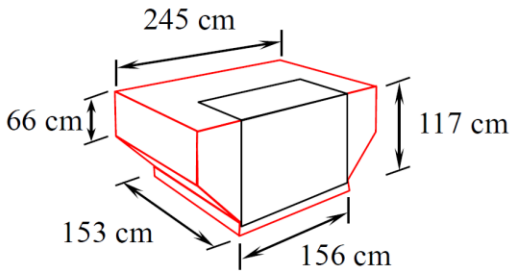
Airbus A318 - A321

$h_{Fmax} = 4.14\,m$

$h_f = 0.38 \cdot h_{Fmax}$

$w_c = 0.93 \cdot w_{Fmax}$ $\quad w_c = 0.87 \cdot w_{Fmax}$

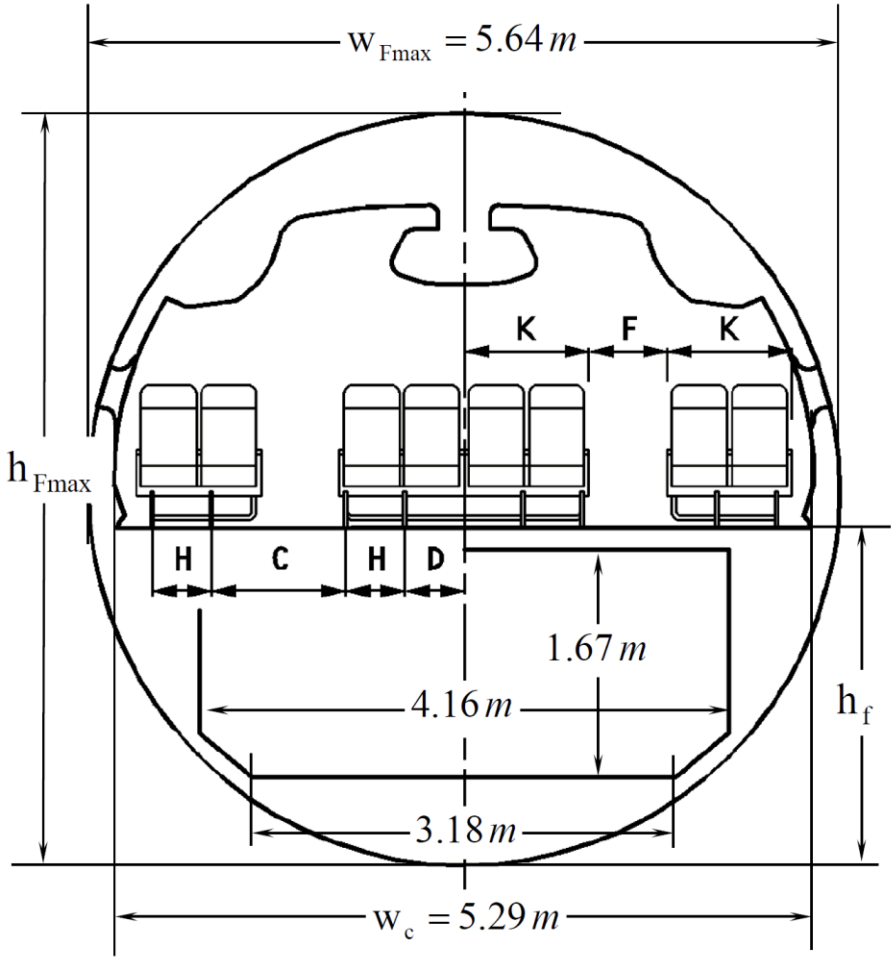
Container LD3/46(W)



Tara	= 90	kg
Max peso netto	= 1045	kg
Max peso lordo	= 1135	kg
Volume interno	= 3.68	m^3

Fuselage: cabin arrangement

General main dimensions of a fuselage: internal cabin layout - wide body



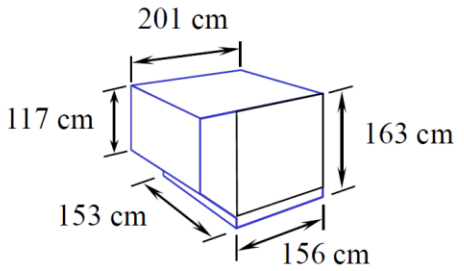
Airbus A300 A310 A330 A340

$$h_{Fmax} = w_{Fmax}$$

$$h_f = 0.46 \cdot h_{Fmax}$$

$$w_c = 0.94 \cdot w_{Fmax}$$

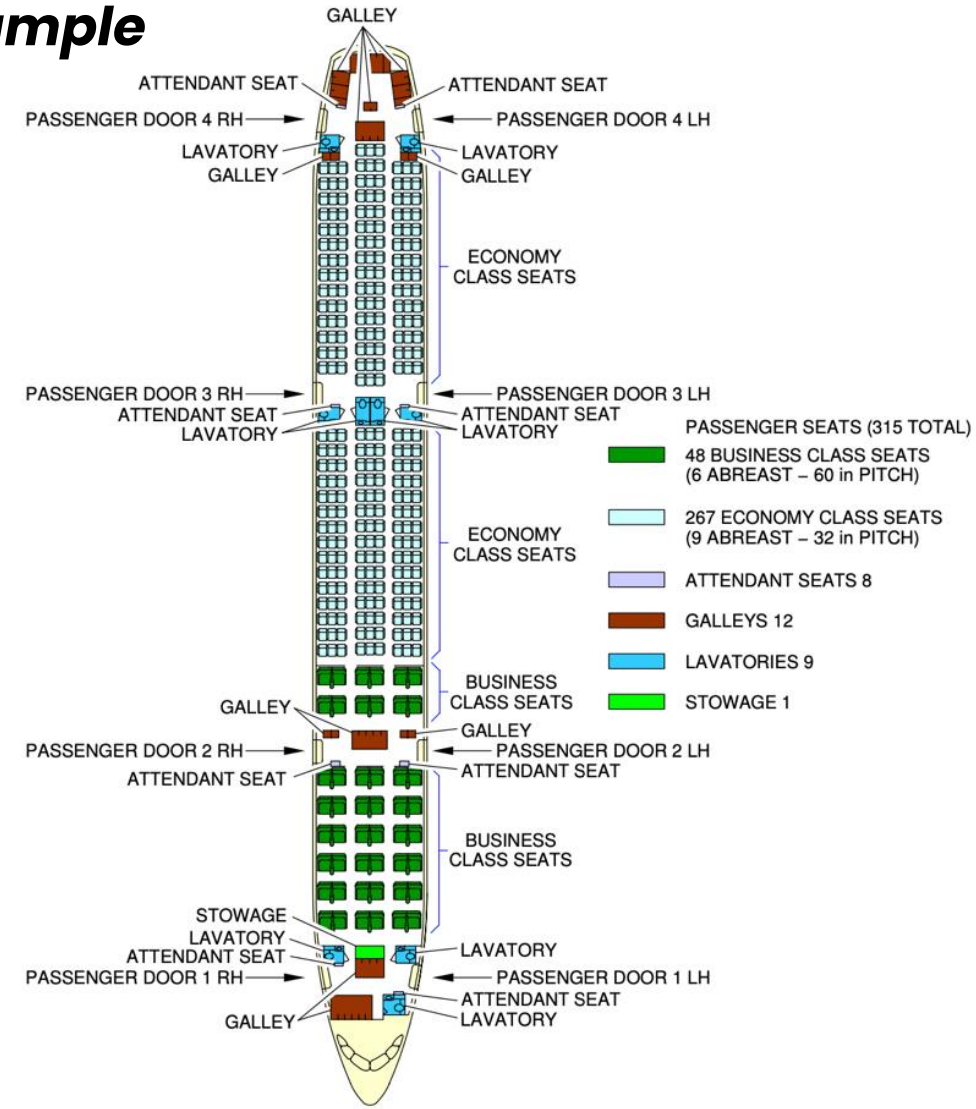
Container LD3



Tara	= 98	kg
Max peso netto	= 1490	kg
Max peso lordo	= 1588	kg
Volume interno	= 4.13	m^3

Fuselage: cabin arrangement

A350 Example



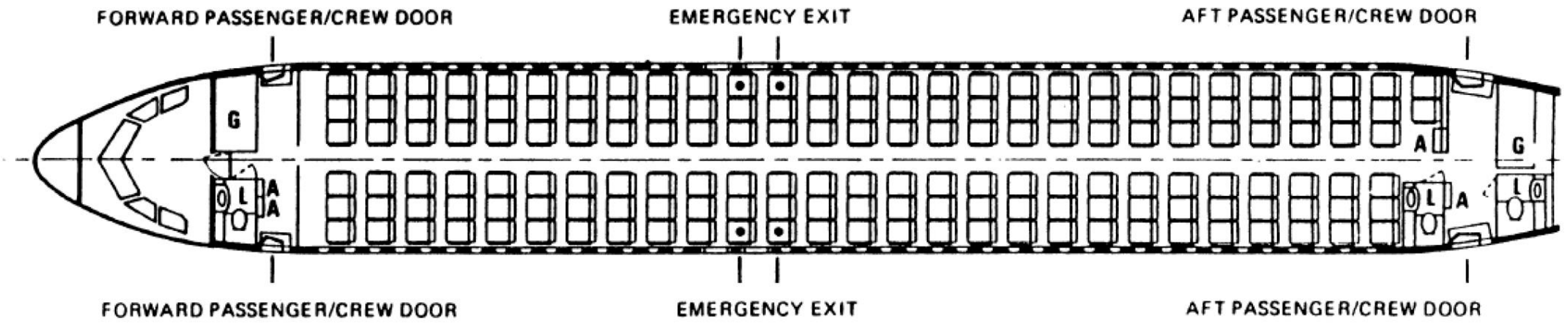
AEA Requirements

Remember that the actual internal layout is then defined together with airlines!

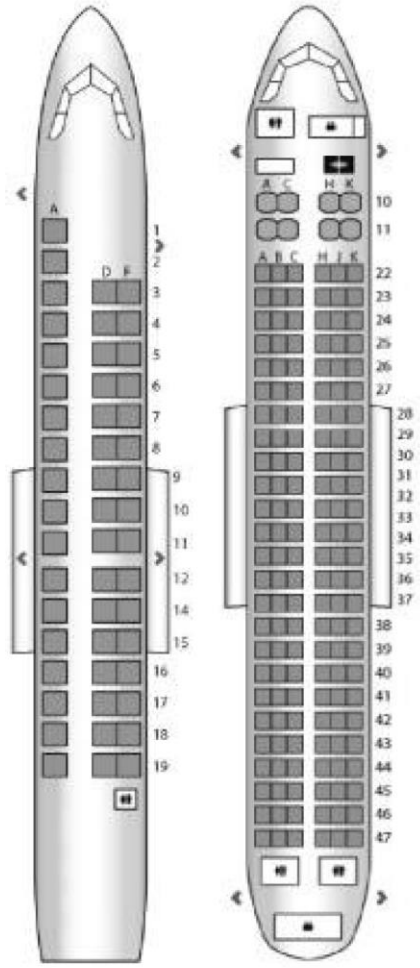
Therefore, requirements related to specific comfort standards have a high impact on the definition of the internal aircraft layout.

However, this is an example of results we want to achieve.

Fuselage: cabin arrangement

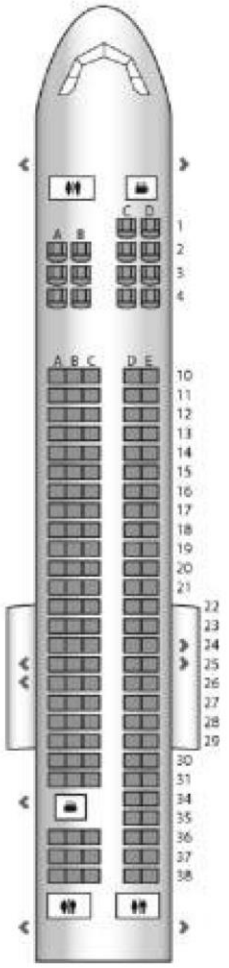


Fuselage: cabin arrangement

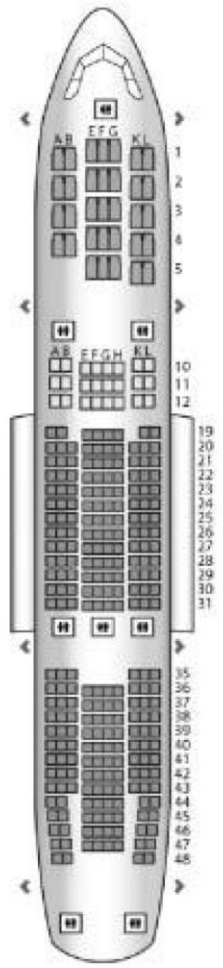


EMB-145
G:Galley,
L: Lavatory,
C: Closet

A-320-200
First two rows: First class

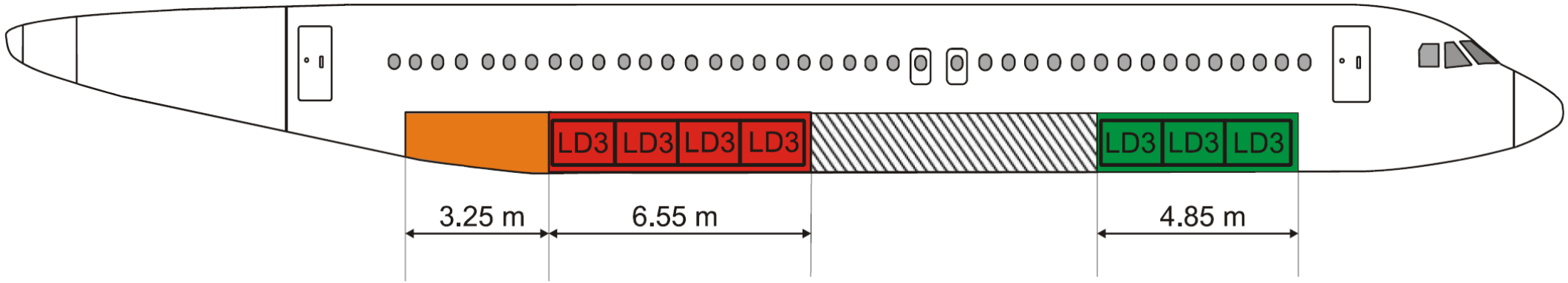


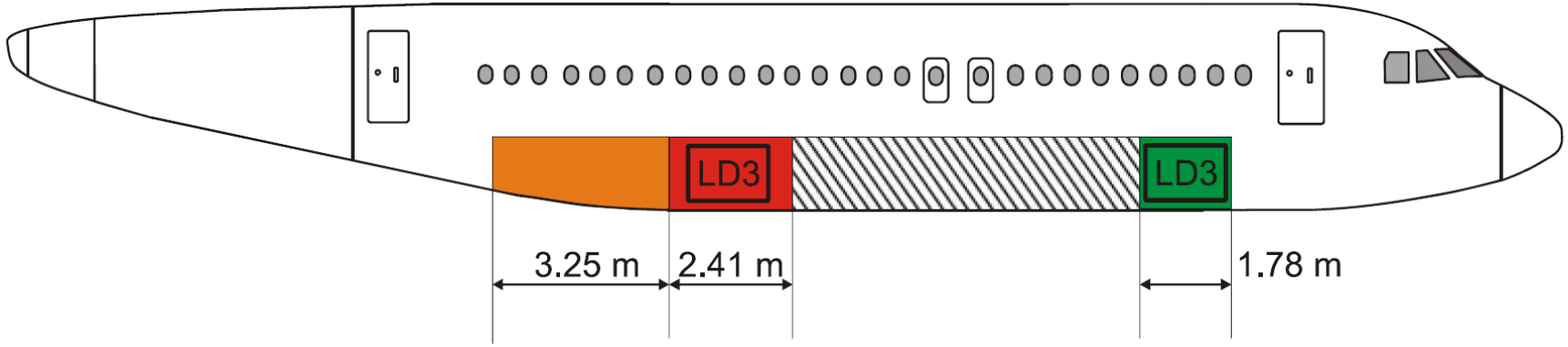
MD-88
First four rows: First class



B-777-200ER
First five rows: First class

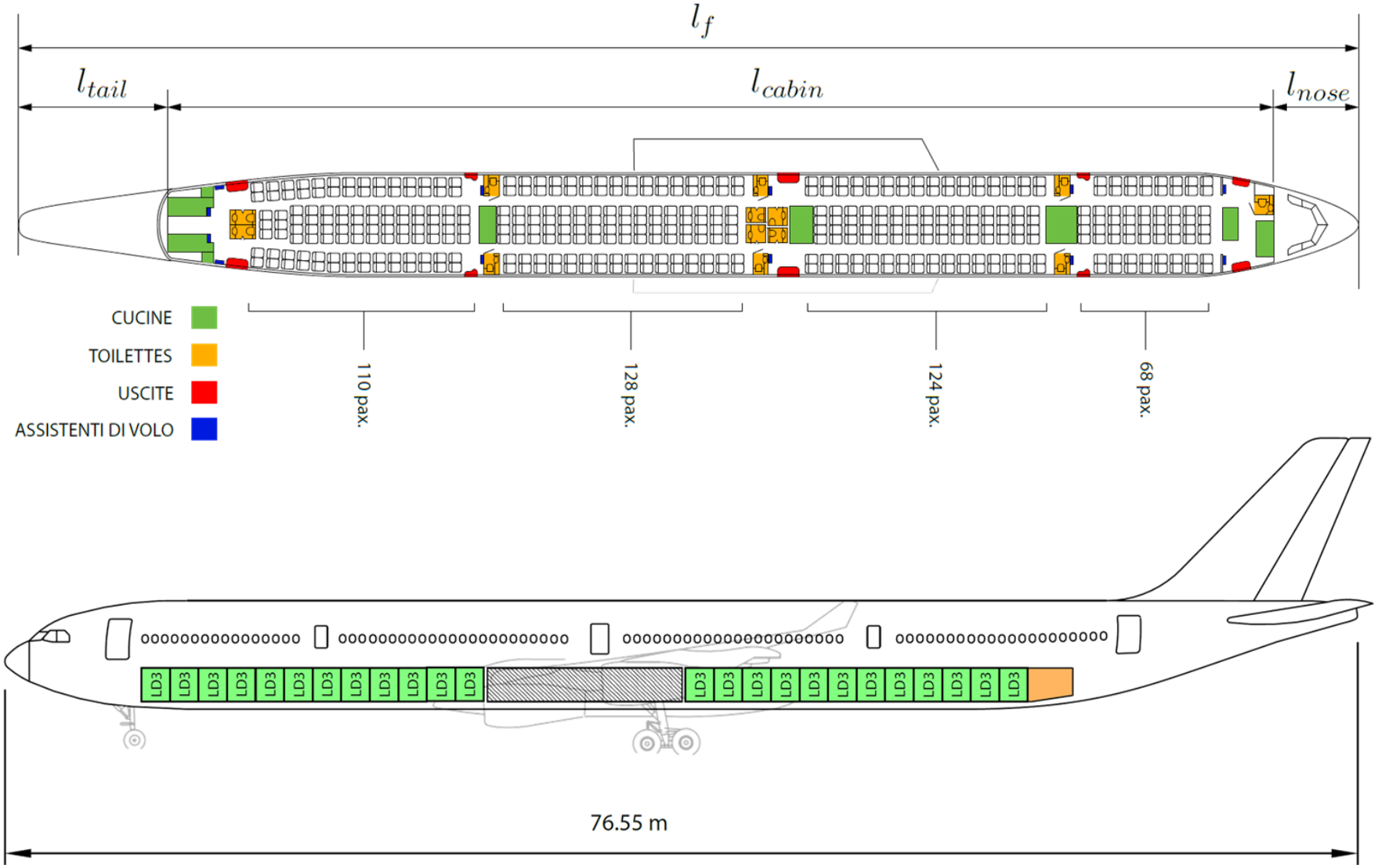
Fuselage: cargo hold arrangement





Drafting the cargo arrangement allows to compute: number and volume of containers, volume of bulk hold, and consequently the number of baggage allowed, extra possible payload (e.g. goods). Baggage volume: 0,113 m^3 per passenger. Bulk cargo density: 160 kg/m^3

Fuselage: example of results



Fuselage: slenderness ratio

Two of the main fuselage design parameters are the **fuselage length (l_f)** and the **maximum diameter (d_f)**. These two fuselage parameters produce the **fuselage volume, wetted area, and weight**. The fuselage optimum length-to-diameter ratio (or slenderness ratio) may be determined based on a number of design requirements. The design objectives may be to determine the fuselage length-to-diameter ratio such that it:

1. lowest zero-lift drag;
2. lowest wetted area;
3. lightest fuselage;
4. maximum internal volume;
5. lowest mass moment of inertia;
6. contributes the most to aircraft stability;
7. requires the lowest cost to fabricate.

8. ...
9. ...

No.	Aircraft	Type	Engine	Take-off mass (kg)	L_t/D_t
1	Reims F337F Super Skymaster	Utility	Twin piston	2 000	3.2
2	Cessna 208	Light GA	Piston	3 645	6.8
3	Cessna Citation III	GA light transport	Twin turbofan	9 979	8
4	Pilatus PC-7	Trainer	Turboprop	2 700	7
5	BAE ATP	Transport	Twin turboprop	12 430	9.6
6	STEMME S10	Motor glider	Piston	850	8.4
7	ATR 52C	Cargo	Twin turboprop	22 000	9
8	Firecracker	Trainer	Turboprop	1 830	7.2
9	Embraer Tucano	Trainer	Turboprop	2 250	7.5
10	Dornier 328	Transport	Twin turboprop	11 000	7.5
11	Fairchild Metro VI	Transport	Twin turbofan	7 711	10.7
12	Fokker 100	Airliner	Twin turbofan	23 090	9.85
13	Boeing 737-200	Airliner	Twin turbofan	52 400	8.2
14	Boeing 747-400	Airliner	Four turbofan	394 625	10.5
15	Boeing 757-200	Airliner	Twin turbofan	133 395	12
16	Boeing E-3 Sentry	Relay-communication	Twin turbofan	147 417	11.6
17	Airbus A-330	Airliner	Twin-jet	230 000	11.4
18	Sukhoi SU-27	Fighter	Twin turbofan	25 000	10.3
19	F-16 Fighting Falcon	Fighter	Twin turbofan	27 000	9.5
20	Concorde	Supersonic transport	Four turbojet	141 200	23

Fuselage: slenderness ratio

- Fuselage parasite drag coefficient

$$C_{D0}^{Fus} = Q\, C_f\, FF\, \frac{S_{fus}}{S_{ref}}$$

$$FF_F = 1 + \frac{60}{f^3} + \frac{f}{400}$$

$$f = \frac{l}{d} = \frac{l}{\sqrt{(4/\pi) A_{max}}}$$

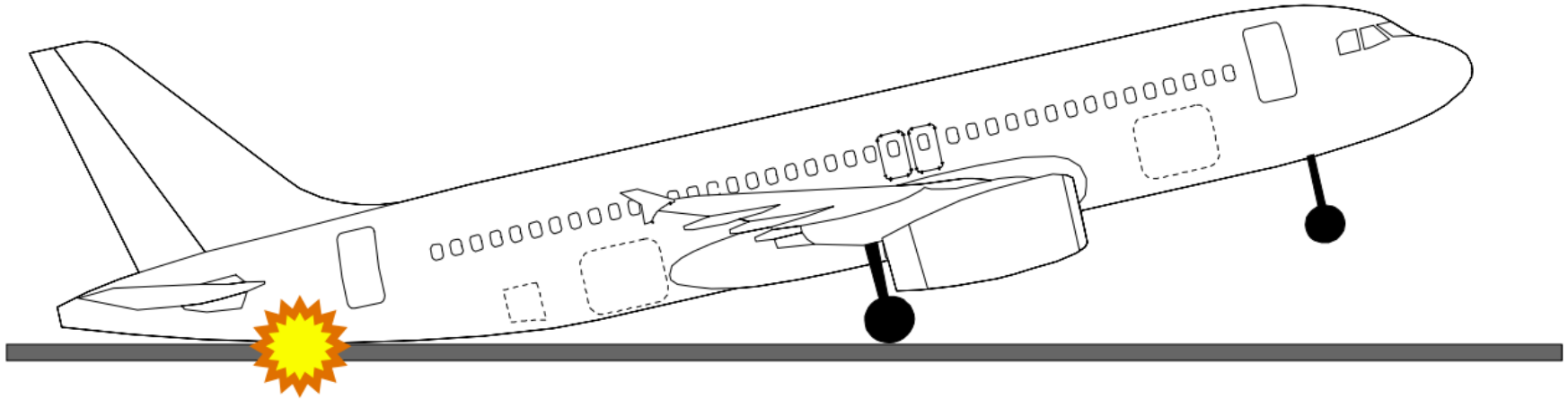
Lunghezza (indicates l)

Area massima della sezione (indicates A_{max})

- Fuselage weight

$$W_{Fus} = 1.35 \times (l \times d)^{1.28}$$

Fuselage: tail cone



Task 5.1

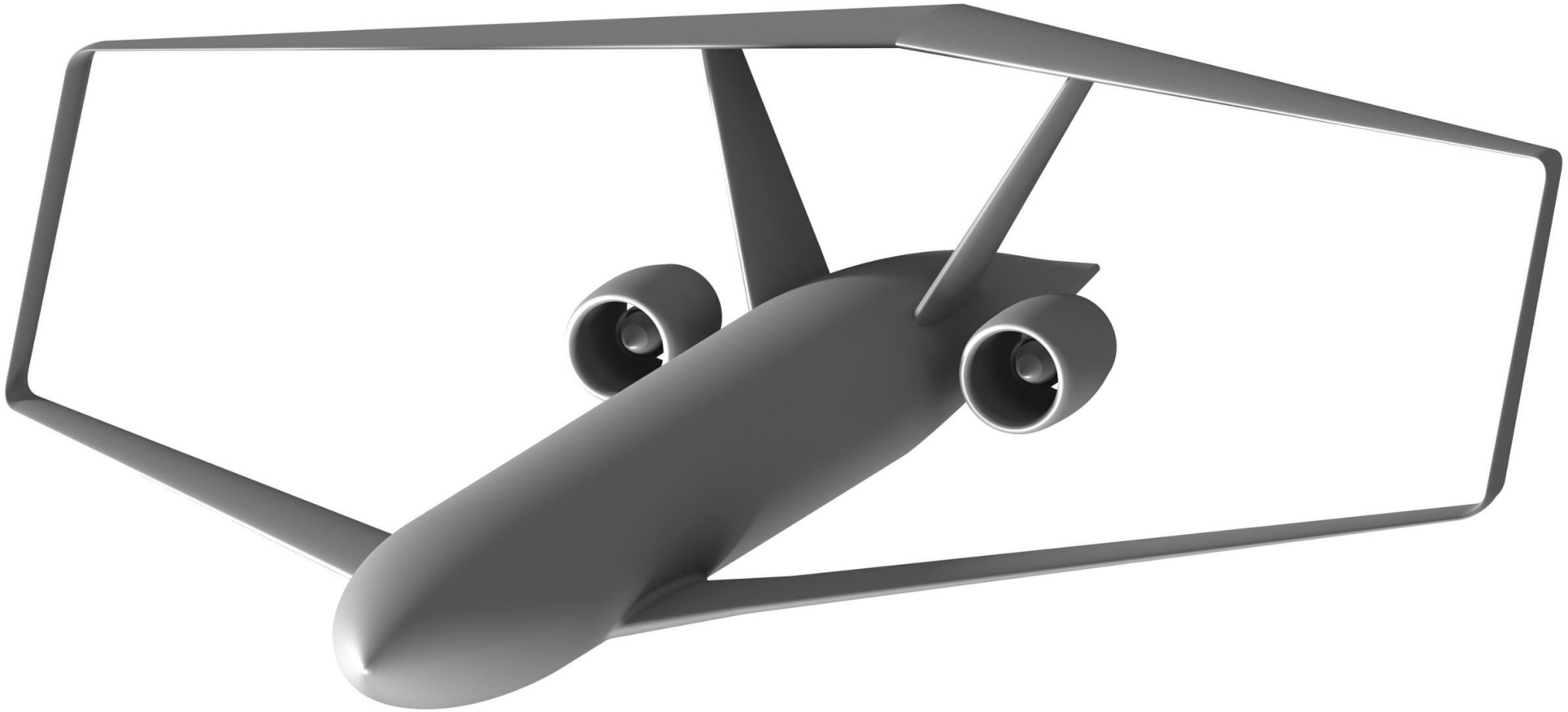
- **Design your fuselage following the suggested information**

Back-up and discussion

A practical study-case

Box-Wing aircraft

Back-up and discussion

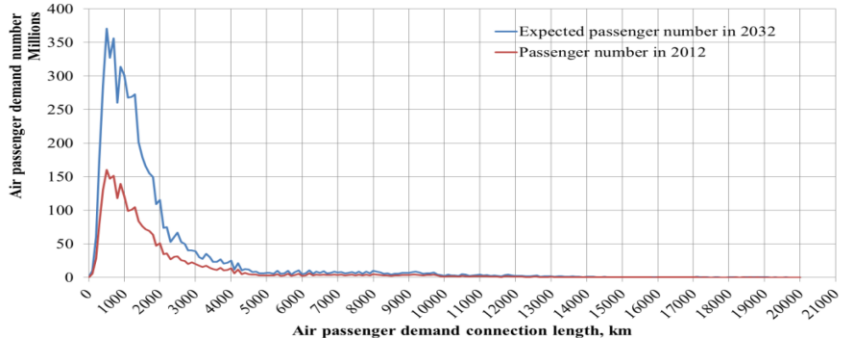


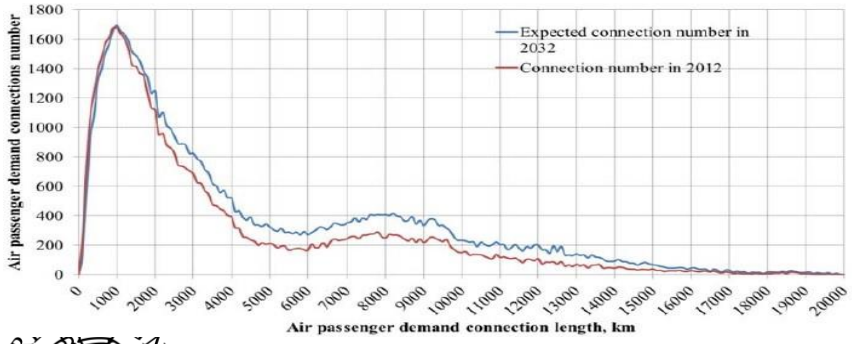
Aircraft design process

Top Level Aircraft Requirements	Conceptual Design	Configuration Development	Performance Evaluation	Conventional aircraft comparison

Aircraft design process

Top Level Aircraft Requirements → Conceptual Design → Configuration Development → Performance Evaluation → Conventional aircraft comparison

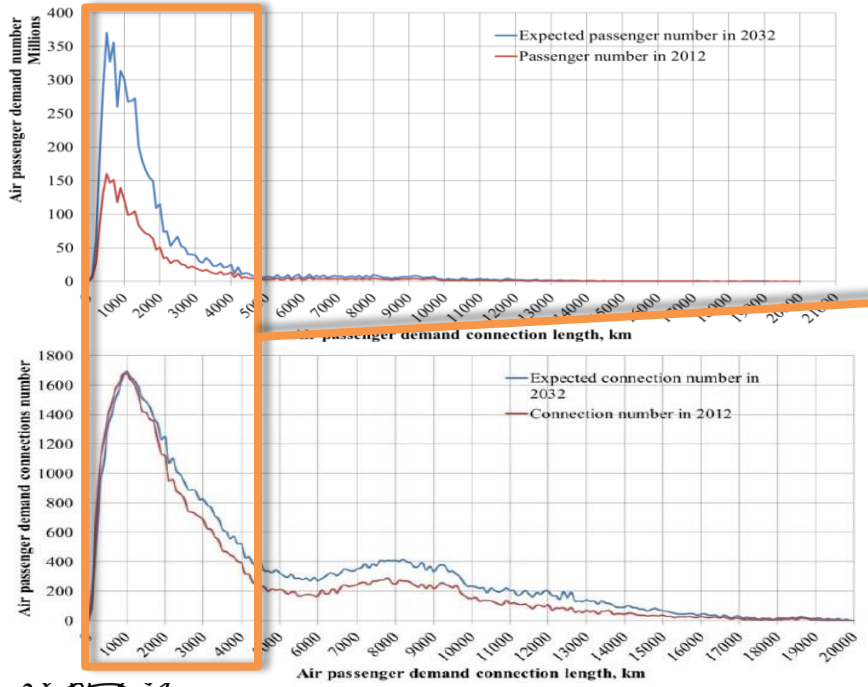




Top Level Aircraft Requirements	
> 300	Passenger number
5000 km	Harmonic Range
0.79	Cruise Mach
4C (w.span ≤ 36m)	ICAO Aerodrome Code

Aircraft design process

Top Level Aircraft Requirements → Conceptual Design → Configuration Development → Performance Evaluation → Conventional aircraft comparison



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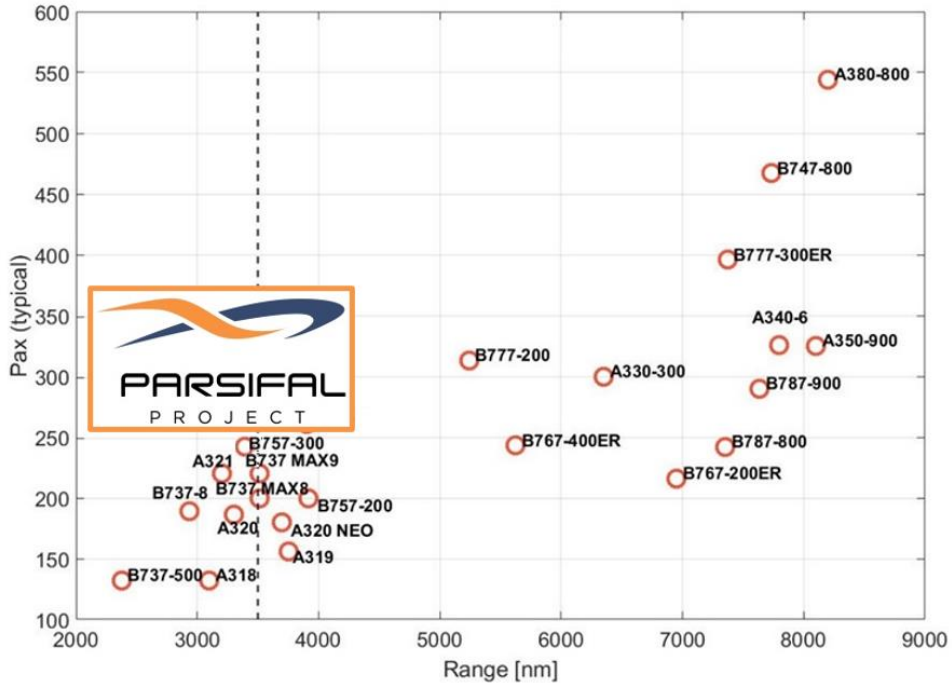


Aircraft design process

Top Level Aircraft Requirements | **Conceptual Design** | Configuration Development | Performance Evaluation | Conventional aircraft comparison

Fuselage Design

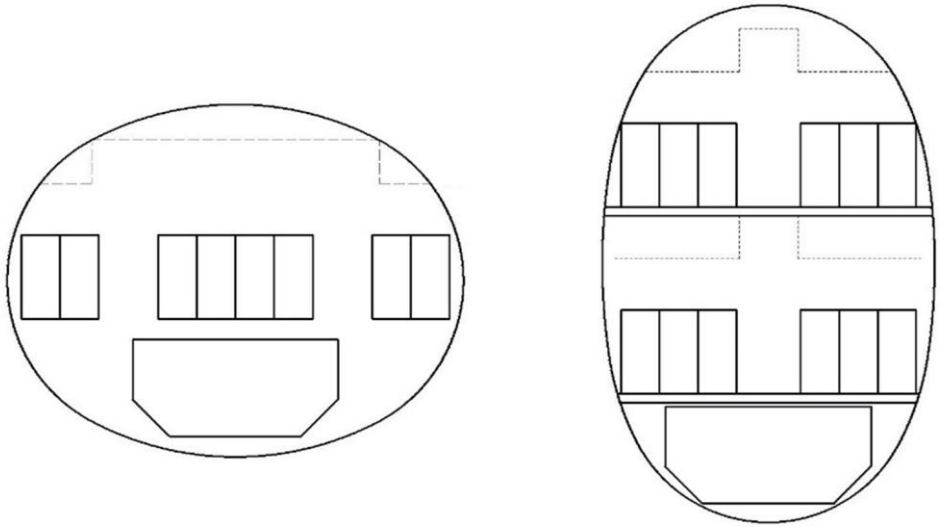
Requirements:

- Passengers capacity > 300
- Turnaround time equal to competitors
- Airport compatibility

Aircraft design process

Top Level Aircraft Requirements | **Conceptual Design** | Configuration Development | Performance Evaluation | Conventional aircraft comparison

Fuselage Design



'napkin sketch'

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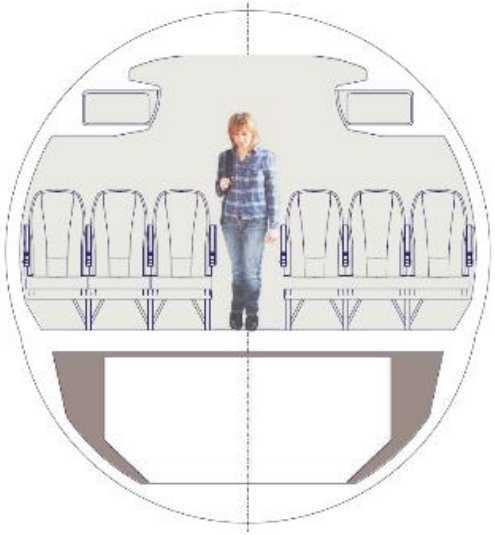
Aircraft design process

Top Level Aircraft Requirements | **Conceptual Design** | Configuration Development | Performance Evaluation | Conventional aircraft comparison

Fuselage Design



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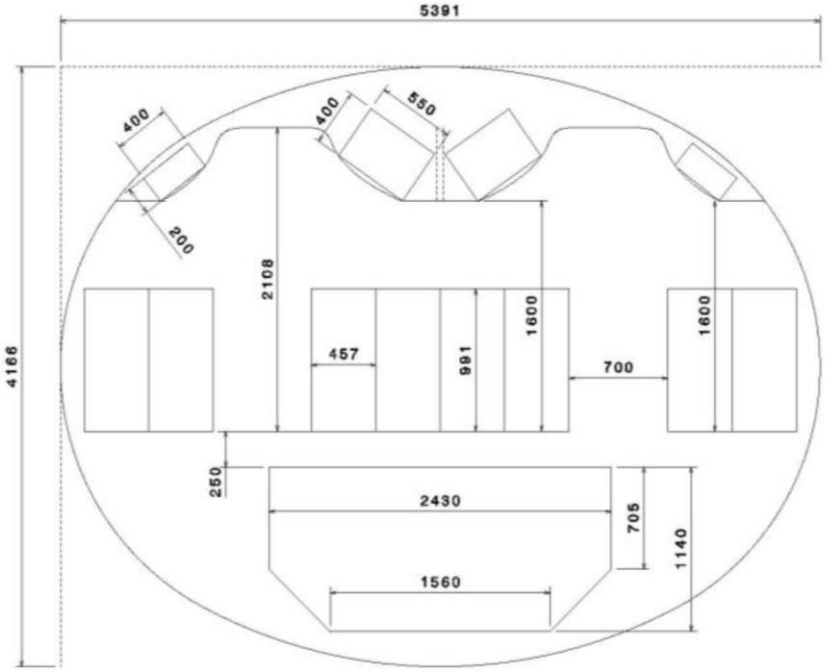

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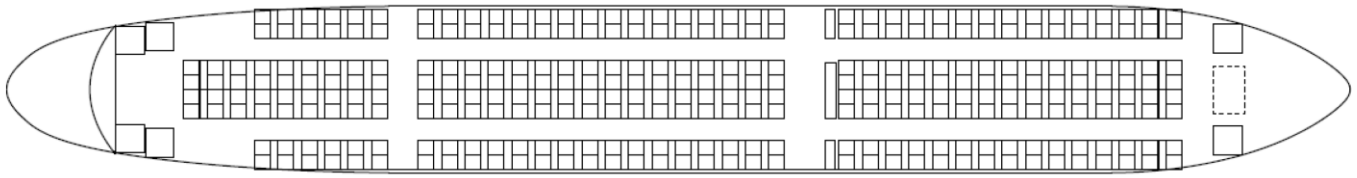

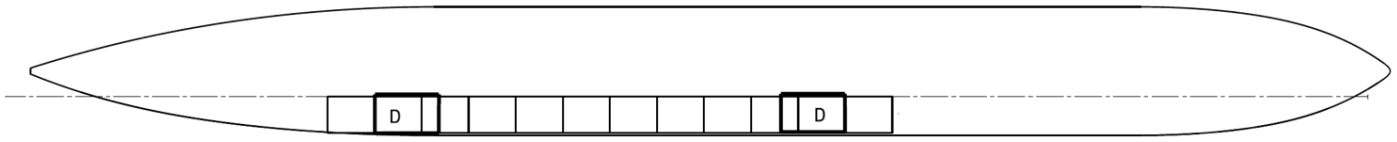

D = Cargo Door

Requirements:

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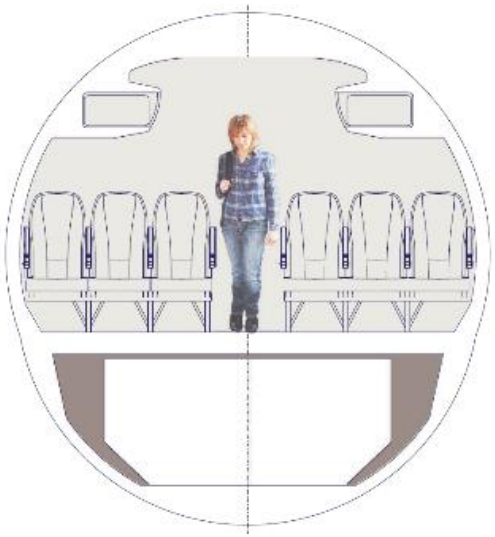

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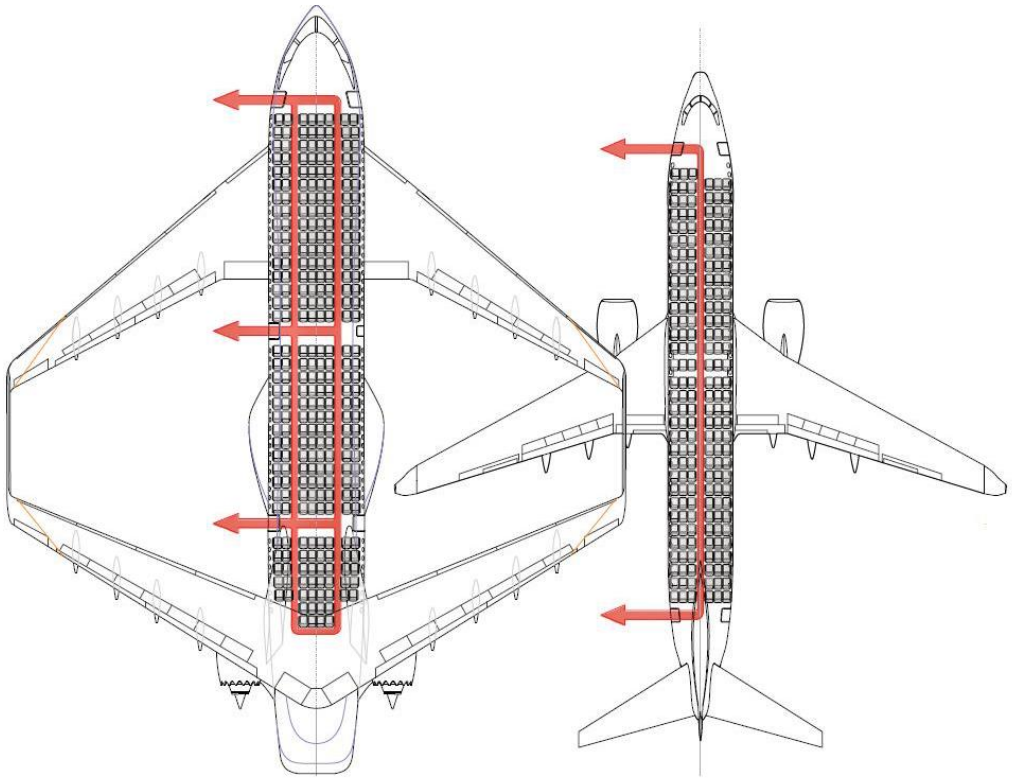

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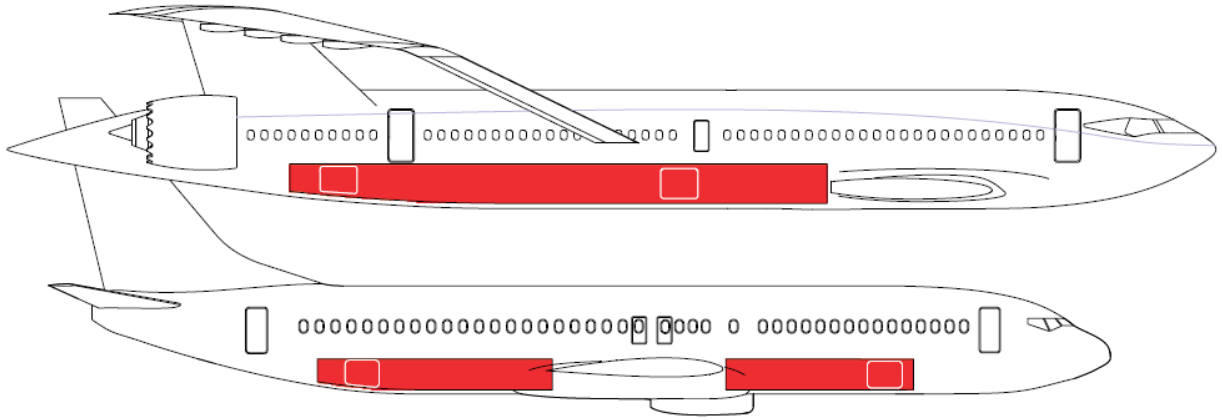

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