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Design of a 150-Seat, 2000 km-Range LH-Fuelled Jetliner †

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Abstract

The use of hydrogen to power aircraft is considered as a promising direction for the future of air travel, as it enables CO_2-free operation and supports long-term climate goals. This study considers the feasibility of developing an aircraft with a gas turbine power plant fuelled by liquid hydrogen. The aircraft is designed to carry 150 passengers over a distance of 2000 km, taking into account design features, technological challenges and operational advantages.

Keywords: hydrogen; passenger aircraft; environmentally friendly aviation; requirements; option; performance

1. Introduction

As part of the Environmentally Friendly Aviation for All Classes of Aircraft (EFACA) project and to meet international sustainability goals, including those set out in Flightpath 2050 [1,2], the concept of a regional passenger aircraft with next-generation, low-emission propulsion technologies is being developed.

The transition to hydrogen-powered aircraft requires the development of a dedicated aircraft concept, including an aerodynamic and structural layout, the integration of cryogenic fuel tanks and a compatible fuel system, and safety considerations related to liquid hydrogen storage [3–6].

2. Requirements for Aircraft

The requirements for the aircraft are shown in Table 1.

Table 1. Aircraft design and operational requirements.

Maximum series production rate of aircraft	≥30 units per year
Estimated total production	≥300 units
Estimated catalogue value of a production aircraft	120 million USD
Number of passengers	≥150
Maximum commercial load	18 t
Maximum flight altitude	12,000 m;
Estimated weight of a passenger with baggage	105 kg;
Design cruising speed	820 km/h
Design range	2000 km

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Table 1. *Cont.*

Type certificate	CS 25 (FAR-25)
Noise in the passenger cabin	≤75 dBA
Certified flight altitude	≤12,000 m (40,000 ft)
Airfields of operation	Code ≥ 3C
After-sales support	24/7, all year round
Service life	≥30 years

The subsequent analysis is based on predefined mission profile that reflects the expected operational conditions of the aircraft. A typical flight profile is shown in Figure 1.

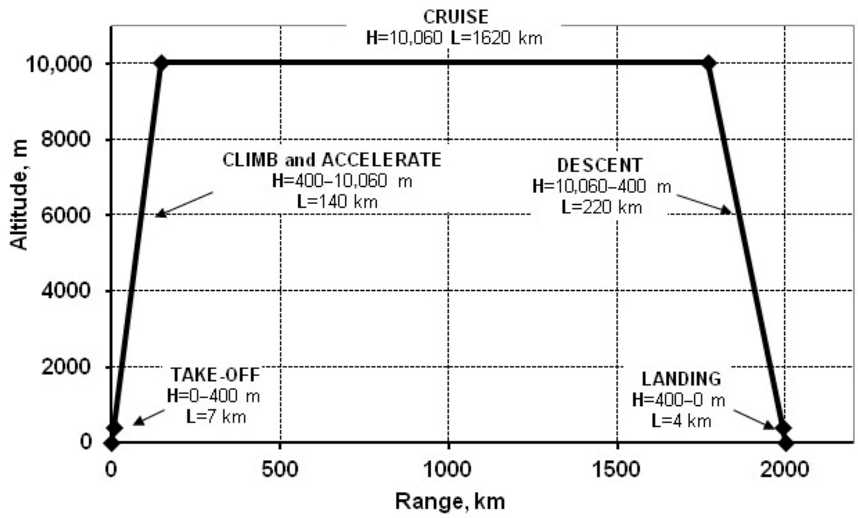


Figure 1. Typical flight profile.

3. Preliminary Design of a Passenger Aircraft with Hydrogen-Fuelled Propulsion System

3.1. Aircraft Configuration

Six alternative configurations (Figure 2) of the regional hydrogen-powered aircraft were generated to explore possible design directions. These options differ in terms of their aerodynamic layout, cabin arrangement, and approach to integrating liquid hydrogen tanks [3,7]. The concepts also vary in terms of the number of cryogenic tanks and their placement, including underfloor installation, wing nacelles or a dedicated rear fuselage section.

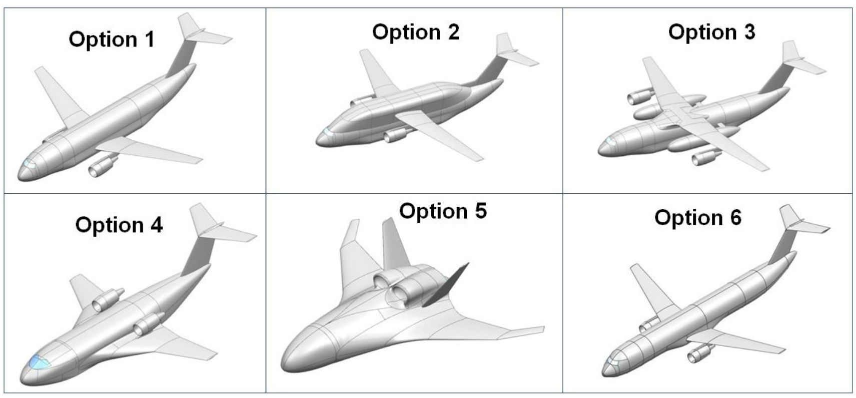


Figure 2. Options of aircraft.

3.2. Comparative Assessment of the Options

Six conceptual configurations were evaluated to identify the most promising option. The comparative analysis methodology follows established aircraft conceptual design principles and incorporates hydrogen–aircraft integration challenges reported in recent studies [3–8].

The comparative analysis methodology follows established preliminary aircraft design practices. These include classical weight build-up methods, mission fuel fraction estimation and semi-empirical aerodynamic correlations, which are typically used at the conceptual design level [3,7,8]. All performance-related parameters were evaluated under the assumption of consistent design points and mission profiles across all configurations.

A consolidated summary of the advantages, disadvantages and aerodynamic implications for each configuration is provided in Table 2.

Table 2. Comparison of options.

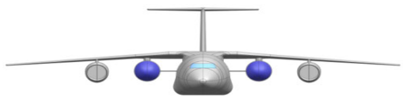
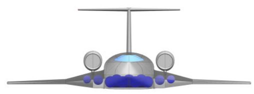
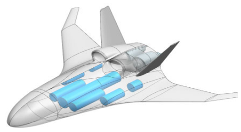
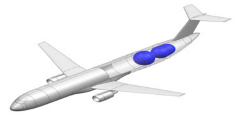
Option 1	Option 2
	
Advantages: • High fuel efficiency; • Easy to maintain.	Advantages: • High fuel efficiency; • Large volumes for additional cargo.
Disadvantages: • Small volumes for additional cargo; • Fuel tank protection is required in case of emergency belly landing.	Disadvantages: • Difficulties in maintenance; • Difficult evacuation in case of ditching.
Aerodynamic considerations: • Cy = 0.5; • L/D = 17.1; • M = 0.76.	Aerodynamic considerations: • Cy = 0.5; • L/D = 15.7; • M = 0.76.
Option 3	Option 4
	
Advantages: • Promising layout for number of passengers > 400 (significant wing volumes for fuel tanks appear).	Advantages: • High fuel efficiency; • Large volumes for additional cargo.
Disadvantages: • Low fuel efficiency; • Increased aircraft price (due to high take-off weight and more powerful engines).	Disadvantages: • Difficulties in maintenance; • Difficult evacuation in case of ditching.
Aerodynamic considerations: • Cy = 0.5; • L/D = 14.2; • M = 0.76.	Aerodynamic considerations: • Cy = 0.31; • L/D = 13.8; • M = 0.76.

Table 2. *Cont.*

Option 5	Option 6
	
Advantages: • Useful for practising the design of 'long range aircraft'.	Advantages: • High passenger safety; • Simplified fuel system—two fuel tanks; • Large volumes for additional cargo.
Disadvantages: • Low fuel efficiency; • High pitch trim losses; • Oversized wing.	Disadvantages: • Limited possibilities for concept development; • Difficulties in fuel tank maintenance and replacement.
Aerodynamic considerations: • Cy = 0.32; • L/D = 13.5; • M = 0.76.	Aerodynamic considerations: • Cy = 0.5; • L/D = 17.0; • M = 0.76.

3.3. Take-Off and Landing Performance Comparison

Figure 3 compares the balanced take-off and required landing distances for all six options under ISA sea-level conditions. Performance characteristics were evaluated using conventional aerodynamic methods together with insights from recent LH_2 feasibility studies [3,6–9].

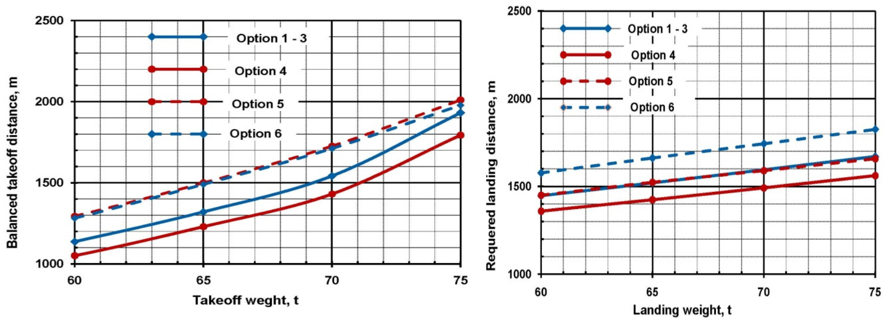


Figure 3. Take-off and landing field length.

The take-off and landing distance were estimated using classical balanced field length formulations with assumed high-lift device characteristics and maximum lift coefficients consistent with comparable CS-25 class aircraft (Table 3).

Table 3. Take-off and landing field length.

Option	**1**	**2**	**3**	**4**	**5**	**6**
MTOW, t	72.2	73.0	73.4	75.2	73.0	73.4
Wing area, m^2	135	135	135	200	200	135
Cl max	2.4	2.4	2.4	1.5	0.9	2.4
TOFL, m	1700	1780	1800	1830	1900	1920 (1820 2-sl. F. flap)
LFL, m	1600	1610	1620	1530	1600	1770

3.4. Quantitative Comparison of Layout Options

Quantitative comparison of layout options is carried out using the integral quality method: all comparison criteria are normalised, added up for each layout option (integral quality), and then the integral quality values of all layout options are compared. The importance of a particular criterion (price, fuel efficiency, etc.) can be strengthened or weakened by means of weighting coefficients; the sum of the weighting coefficients is always equal to 1.

Table 4 shows the initial data and results of integral quality calculation when the weight coefficients of the criteria of aircraft price, fuel efficiency and passenger safety are the same and equal 0.3, and the weight coefficient of development possibility is 0.1.

Table 4. Initial data and results of integral quality calculation.

	Quality Factor								Integral Index (Quality Factor)
	Cost of Aircraft, M$		Fuel Efficiency, MJ/p-km		Safety		Possibility of Developing		
Weight Factor	**0.30**		**0.30**		**0.30**		**0.10**		
	abs.	**norm.**	**abs.**	**norm.**	**abs.**	**norm**	**abs.**	**norm.**	
Option 1	117.5	1	0.936	1	0.6	0.60	0.9	0.90	0.863
Option 2	117.7	0.98	1.056	0.87	0.7	0.70	0.9	0.90	0.854
Option 3	118.2	0.97	1.145	0.78	0.8	1	0.9	0.90	0.855
Option 4	126.1	0.90	1.132	0.79	0.6	0.60	1	1	0.788
Option 5	126.0	0.90	1.089	0.84	0.6	0.6	1	1	0.802
Option 6	115.0	1	0.95	0.99	1	1	0.7	0.8	0.966

3.5. Best Option Selection

After comparative assessment—considering performance, structural mass, safety, passenger comfort, environmental impact and system integration feasibility—Option 6 was selected for further development due to its clear advantages.

The comparison with two conventional reference aircraft A320 and CS300 (Airbus, Leiden, The Netherlands) [3,8–10] is also used to verify the consistency of the adopted sizing and performance estimation methods at conceptual design level (Table 5).

Table 5. Flight characteristics.

		Option 6	**A320**	**CS300**
Engines	-Type -Take-off thrust, tf Cr max. Cruising (M = 0.75, H = 11 km), kg/kgf h	TurbofanPW1431G 2 × 13.3 0.522 (on kerosene)	CFM56-5A (B) 2 × 12.25 0.62	PW1521G 2 × 9965 0.565
MTOW, t		73.60	77.0	67.6
OEW, t		53.30	43.6	38.9
Maximum Payload, t		18	20.8	20.8
Passenger weight with baggage, t		15.75	16.9	16.9
Additional Payload, t		2.25	3.9	1.73
Maximum fuel weight (LH_2 γ = 0.071 kg/dm^3; kerosene γ = 0.81 kg/dm^3), t		3.43 (9.35 kerosene)	18.8	18.1
Wing area, m^2		135	122	112

Table 5. *Cont.*

		Option 6	A320	CS300
Wing span, m		35.0	34.0	35.1
Wing aspect ratio		9.1	10.5	11.0
Wing sweep at ¼ chord, deg.		23	25	25
Fuselage cross-section, length x width, m		4.62 × 4.62	4.16 × 3.95	3.7
Fuselage length, m		45.3	37.5	38.7
Number of LH_2 fuel tanks		2	—	—
Passengers	Single class Two class	164 150	164 150	140 132
OEW/seat (two class), kg		355	291	295
Aisle width in economy class, inch (cm)		20.5 (52)	19 (48)	20
Seat width in economy class, inch (cm)		18 (46)	18 (46)	18 (46)
Cruising altitude, km		10.6–12.0	10.6–12.0	10.6–12.0
Cruising speed, km/h		820	840	840
Fuel efficiency (150 pas.), MJ/p-km		0.955	0.770	0.800
Runway length (ISA, SL), m	For take-off For landing	1920 (1820 2-sl. F. flap) 1770	2200 1530	2500 1500

Option 6, comprising a layout with fuel tanks located behind the passenger cabin in the tail section, has a number of disadvantages along with safety advantages:

- The extended fuselage limits the pitch angle at take-off, which increases the requirements for wing mechanisation;
- Placement of the fuel tanks far behind the centre of gravity (CG) of an empty aircraft leads to a significant expansion of the range of operational alignment, which, in turn, requires an increase in the area of the horizontal plumage;
- The large size of the fuel tank creates obvious difficulties in its maintenance and replacement. For this reason, for Option 6, the trailing edge mechanisation is in the form of a double-slotted Fowler flap (in addition to the full-wing span wing flap). This mechanisation option ensures that the aircraft breaks away on take-off with a pitch angle of only 6.9°. In this case, the breakaway speed VLOF = 262 km/h, CL = 1.64.
- The three-dimensional visualisation of the Option 6 aircraft are shown in Figure 4.
- The main geometric characteristics of the Option 6 aircraft are shown in Figure 5.

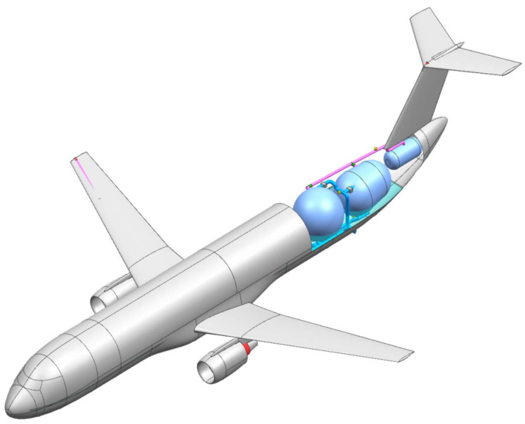


Figure 4. Visualisation of the Option 6.

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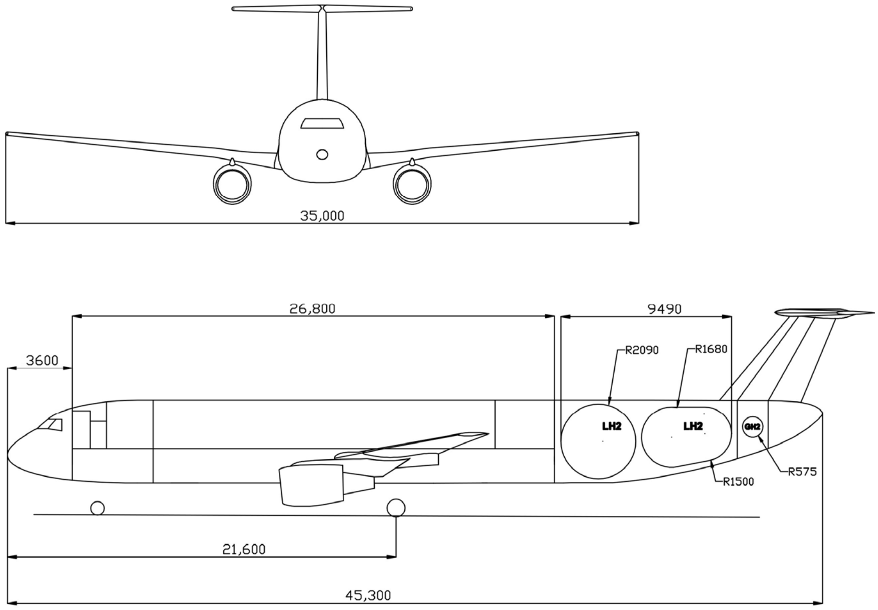

Figure 5. Geometric characteristics.

4. Conclusions

This study examined the feasibility of a 150-seat, 2000 km-range, LH-fuelled passenger aircraft, assessing multiple aerodynamic and structural configurations to identify the most promising concept for further development.

The presented results are based on preliminary-level methods calibrated against existing narrow-body aircraft and therefore provide a consistent basis for comparative assessment rather than detailed performance prediction.

A quantitative and qualitative comparison of these configurations was performed, taking into account aerodynamic efficiency, take-off and landing performance, estimated structural mass, CG compatibility, safety considerations, and system integration complexity. The integral quality assessment using weighted criteria confirmed that Option 6 has the best balance between fuel system integration, aerodynamic performance and operational feasibility.

The results demonstrate the technical feasibility of a 150-seat, hydrogen-powered regional aircraft with a range of 2000 km using structural materials, aerodynamic technologies, and fuel cell systems expected to be available by 2035. Future research will focus on refining the fuel system's architecture, optimising tank geometry and placement, enhancing aerodynamic efficiency, and conducting thorough thermal management and safety analyses to ensure compatibility with airport hydrogen infrastructure.

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Conflicts of Interest: The authors are employed by the ANTONOV Company. All authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Abbreviations

The following abbreviations are used in this manuscript:

CG	Centre of gravity
OEW	Operating Empty Weight
MTOW	Maximum Take-Off Weight
FC	Fuel Cell
TOFL	Take-Off Field Length
LFL	Landing Field Length
LH	Liquid Hydrogen
VLOF	Lift-off Speed

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