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RETHINK THE SKIES

Airlander feasibility study for the

HIGHLANDS & ISLANDS OF SCOTLAND

September 2023

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Working Group participants:

Highlands & Islands Airports Limited (HIAL)
Hybrid Air Vehicles Limited (HAV)
Orkney Islands Council (OIC)
Highlands & Islands Transport Partnership (HITRANS)
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AECOM
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SATE
SUSTAINABLE AVIATION TEST ENVIRONMENT

HYBRID Air Vehicles

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Introduction

The Highlands and Islands of Scotland have a unique set of challenges in maintaining efficient, cost-effective and flexible means of transport of all kinds. With many outlying islands and some of the most difficult weather in the world for all forms of transport, delivering reliable connections always has a high priority in the region. Delivering a safe, efficient, cost-effective and sustainable multi-mode transport system for the benefit of the people of the Highlands and Islands is therefore a perennial objective.

The public transport market in the Highlands and Islands is complex, combining both sea transport and air services to provide the connectivity to local communities in the region. Services are coordinated by local agencies which include Highlands & Islands Transport Partnership (HiTrans) and the local councils providing subsidies and grants required to operate many of the Public Service Obligation (PSO) services.

The needs for both sea transport and air transport to serve the Highlands and Islands are diverse. These include social connectivity e.g., friends and relatives visiting, hospital visits and appointments, education requirements for both teachers and students, as well as tourism. In addition, there is a significant requirement for the movement of freight and livestock. Transport services make the livelihoods of the local communities sustainable and gives them the necessary lifelines to maintain competitiveness and quality of life.

Today's transport networks globally rely on fast but relatively expensive and small aircraft on the one hand and much slower, though lower-cost surface transport on the other. The gap between the speed and cost of air services and surface services is often large: air freight can deliver worldwide in a day, whereas the same journey over the surface takes many weeks. Air freight commands a premium therefore, and accordingly takes only a small fraction of the global freight market. Surface transport accounts for the bulk of the volume, at lower cost and subject to substantial time delays.

These dynamics are evident across the Highlands and Islands of Scotland. Air transport relies on small aircraft which deliver passengers (whose journeys are usually time-sensitive) and a small volume of freight into the existing airfield infrastructure (Table 1). The bulk of cargo meanwhile travels over the water to the port infrastructure of the islands (Table 2), with a small number of passengers travelling alongside. Both forms of transport are subject to disruption and delay, both contribute significantly to the CO_2 emissions footprint of Scotland and the UK and both are recognised as difficult sectors to decarbonise.

Furthermore, to deliver growth, air services need sufficient high-value markets to pay the air transport premium and are currently limited by the size of the airfield infrastructure on the islands. Expansion of waterborne transport on the other hand requires expensive infrastructure upgrades and/or capital expenditure on new vessels.

	Air passengers, ('000):		Air freight, (tonnes):		
Airport	**2018**	**2019**	**2019**	**2020**	**2021**
Barra	15	15	13	12	6
Benbecula	35	35	390	375	544
Campbeltown	8	8	-	-	-
Dundee	21	21	-	-	-
Inverness	893	938	2,946	3,191	3,726
Islay	33	35	364	397	231
Kirkwall	170	162	1,101	1,104	1,250
Lerwick	4	3	-	-	-
Scatsta	175	109	275	-	-
Stornoway	133	130	1,294	1,364	1,523
Sumburgh	246	267	1,199	1,113	1,270
Tiree	12	12	60	52	55
Wick	17	13	-	-	-
Total Highland and Islands	**1762**	**1748**	**7642**	**7608**	**8605**

Source: UK Civil Aviation Authority

Table 1 – Air service volume in the Highlands and Islands of Scotland

Sea freight			
Port ('000 tonnes)	**2018**	**2019**	**2021**
Orkney Islands	3,470	3,050	2,778
Lerwick (Shetland)	513	548	559
Inverness	672	645	767

Ferry passengers			
Passengers carried ('000)	**2018**	**2019**	**2021**
Orkney Ferries	339	336	235
Caldonian	5,253	5,686	3,950
Argyll and Bute	139	141	152
Western Ferries	1,373	1,320	1,063

Source: Department for Transport, Maritime Statistics

Table 2 – Maritime service volume in the Highlands and Islands of Scotland

A proposed Airlander 10 network: Potential benefits

Airlander is designed to be the world's most efficient family of large aircraft. Capable of carrying large payloads with ultra-low or zero emissions, it is a new category of transport providing a new option between today's air, sea and surface transport choices. A truly flexible aircraft, Airlander 10 combines many potential capabilities in a single, civil-certified platform capable of providing 100+ seats, 10 tonnes of payload, or combinations of them both. Airlander 10 can operate from any reasonably flat surface, including on water, and has short take-off and landing capability, opening up new possibilities for connections to and away from the current airfield portfolio in the region. The services provided can include ‘sub-regional’ passenger, PSO and freight logistic services. A larger version, the Airlander 50 is also planned and is likely to be optimised for cargo work.

Airlander 10 has the potential to complement and enhance the Highlands and Islands transport network, improving the much-needed support to local communities and contributing to decarbonising the network. It could complement ferry and air services both provided on a subsidy and a commercial basis. Due to the capabilities of the aircraft to carry larger and heavier payloads into existing airfield infrastructure, it may open up new opportunities for the Highlands and Islands, linking regions and locations not currently served by air services and increasing air capacity to others. This would mean air journeys for passengers of similar time and cost to today’s air services, but with much lower emissions, and a much enhanced air freight capacity for the region based around the already existing airfield estate. It would also mean introducing a premium service of higher speed and reliability for time-sensitive freight that can currently only be transported over the sea.

Airlander 10’s many capabilities, low operating costs and ultra-low (and ultimately zero) carbon emissions characteristics have the potential to offer the local community an enhanced, reliable and regular passenger and freight service which is fit for the decarbonised aspirations of the 21st century.

Airlander 10 prototype in flight

Objective of study

This study is intended to test the hypothesis that Airlander 10 can complement the region's transport system and provide sustainable economic growth so local communities can flourish now and into a zero-emissions future.

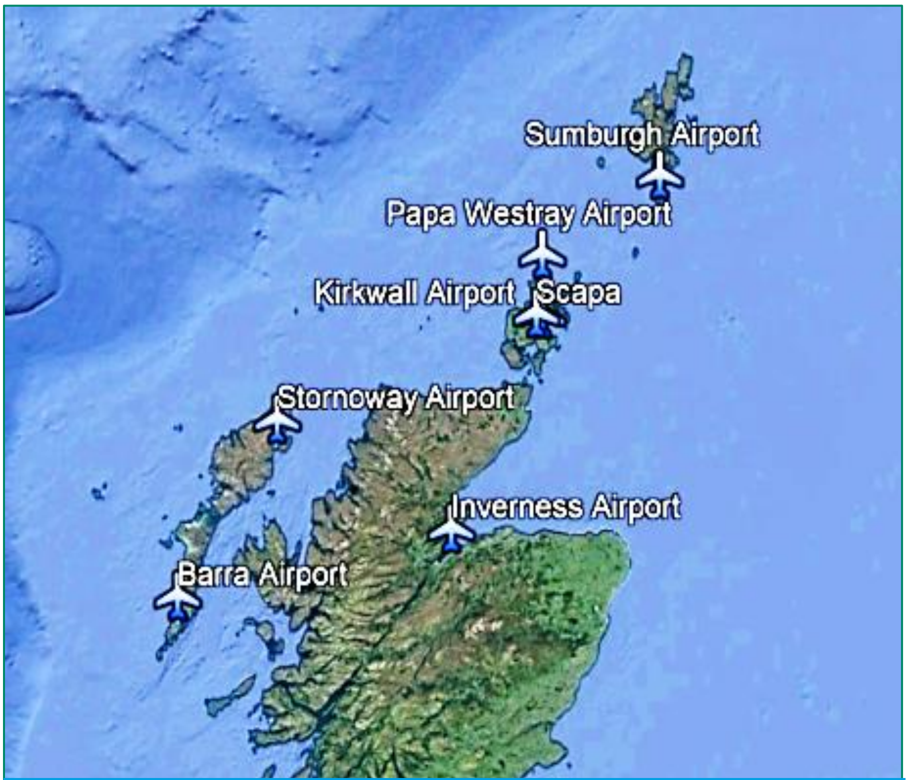
The objectives of this study are:

- To identify the operational benefits of using Airlander 10 within the Highlands and Islands and draw conclusions as to how the aircraft can complement the current fleet of aircraft and sea-borne vessels.
- To understand the potential reliability of Airlander 10 services throughout the year and in all weathers across the region.
- To identify the extent to which infrastructure needs to be adapted or created in order to enable Airlander 10 services, and to develop indicative costs for any work required.
- To verify that the services which can be provided are economical and affordable in the context of current transport options in the region.
- To highlight and if possible, to evaluate the potential environmental benefit of Airlander 10 operations across the region.
- To identify future opportunities for the Highlands and Islands of Scotland to benefit from the planned family of Airlander aircraft, including the Airlander 50.
- To draw wider conclusions about the potential benefits of Airlander 10 in similar geographies across the UK and worldwide.

Methodology

Hybrid Air Vehicles Ltd (HAV), working with its partners have prepared this feasibility study document (CONOPS) which considers the concept for operating the Airlander 10 in the Highlands & Islands environment.

The report assumes a network of services connecting five Highlands and Islands Airports Limited (HIAL) airports, with the addition of water operations at Scapa and on the Orkney Island of Papa Westray. This network is real but also representative of what can be achieved from other similar airports / sites in the region.



Survey locations

The methodology included assessment of the following:

- Desktop and physical assessments of suitability of selected airports and operating sites for Airlander 10 operations
- Assessment of the effect on Airlander 10 services of average and extreme meteorological conditions experienced across a typical year in the region
- Implications for and requirements placed on existing airport infrastructure
- Cost estimates for additional infrastructure requirements
- Economic analysis of Airlander 10 operations
- Consideration of environmental benefits of an Airlander 10 operation

Desktop assessments were conducted by HAV. Physical surveys of airports and operating sites were undertaken by AECOM with support from HAV, HIAL and Orkney Islands Council (OIC).

Physical surveys were undertaken following initial desktop analysis by HAV using open-source topographical information and the anticipated key performance parameters of the Airlander 10 aircraft.

Physical surveys focused on the following key aspects:

- Topography
- Identification of mooring (parking) positions for the aircraft including availability of space for mooring aircraft
- Availability and limitations of aircraft operational area including take-off and landing runs
- Potential effects on existing facilities, infrastructure and operations

Economic, environmental and meteorological analyses were conducted by HAV as desktop assessments based on open-source data and the anticipated key performance parameters of the Airlander 10 aircraft. Conclusions have been drawn supporting the economic viability and reliability of Airlander services in the weathers encountered in the HIAL region. The study has identified Airlander's suitability for unique operations incorporating both passenger and freight services. Therefore like-for-like cost and availability comparators between Airlander and existing transport modes have not been performed and may form suitable scope for further study.

Suitability of selected airports and operating sites for Airlander operations

Survey rationale

Airlander has differing requirements of an operating site to existing aircraft. In particular, Airlander 10 always takes-off and lands into the direction of the prevailing wind, meaning it cannot be restricted to operating on a runway of one fixed direction. It travels over the ground on inflatable "skids" rather than on wheels. When held on the ground, it is moored at the nose, and the tail of the aircraft is free to swing around the mooring point, rather like a boat at anchor or on a mooring buoy. [1] The purpose of the on-site and desktop inspection work was therefore to understand:

- The feasibility of operating Airlander 10 from five existing airfields and two water-based sites[2]
- The cost and practicality of adapting existing airfield facilities for Airlander use
- The forecast despatch reliability of Airlander 10 at each site given historical weather patterns and the aircraft's performance
- What (if any) restrictions on take-off and landing direction and payload might accompany operations from any given site

The survey methodology focussed on gaining the necessary information on site to assess:

- Topography
- Mooring circles (the parking positions) for the aircraft
- Operational area (take-off and landing runs)
- Effect on existing facilities

1 Refer to Appendix 2 for an overview of the Airlander 10 aircraft, and Appendix 3 for a summary of its operations.
2 Barra and Scapa Bay sites are considered purely as water-based operating sites (although technically the aircraft can operate at Barra on the beach with the tide out) while the remaining 5 sites are land-based. If desired, four of the five land-based sites could add water-based operations nearby.

Summary outcomes

Sumburgh Airport

Table 3 shows the key survey results. Airlander 10 can deliver a minimum 10,000kg payload capacity to all seven locations, and Inverness, Kirkwall and Stornoway can accommodate Airlander 10 operations with an enhanced 12,000kg payload. In all cases sufficient fuel and reserves for nine hours of flight would be carried. Normal Airlander operations would not therefore require refuelling during the day. Fuel could be provided at any Airlander operating site (to include hydrogen assuming that aspirations were to operate electric versions of the aircraft), but the ability to operate without fuel at some locations may be advantageous.

Available take-off and landing directions are shown, the optimum being 360°, denoting that take-off and landing in any direction should be possible. A lower number denotes that some take-off and landing directions are unavailable. This has an effect on the weather despatch reliability figures shown later.

Place	Desktop survey	On-site survey
	direction/payload (kg)	direction/payload (kg)
Kirkwall	*360°/12,000*	**360°/12,000**
Papa Westray*	*315°/8,000*	**360°/10,000**
Stornoway	*360°/12,000*	**360°/12,000**
Barra**	*360°/6,000*	**360°/10,000**
Inverness	*360°/12,000*	**360°/12,000**
Sumburgh	*360°/12,000*	**360°/10,000**
Scapa Bay**	*360°/10,000*	**360°/10,000**

* Annexation of adjacent field
** Denotes water-based operation as standard

Table 3– Key survey outcomes

The surveys therefore concluded that Airlander 10 is capable of operating from all seven locations and that the forecast take-off, landing and payload performance at each location will enable viable transport services.

Barra Beach

Scapa – potential water operations site

Site surveys at Barra identified that a larger area of the Barra sands and bay area could be used for Airlander operations than had been assumed in the original desktop analysis. This yields a significant performance improvement from the standpoint of weather dispatch reliability (i.e., Airlander's capability to operate into or out of a site purely due to the year-round wind levels). This arises because of the amphibious capability of Airlander. Current aircraft may only operate with minimal surface water on the beach.

At Papa Westray, site surveys identified that annexation of an adjacent field into the operating area for Airlander, which appears prima facie feasible, would enable take-off and landing from all points of the compass, overcoming a restriction that was originally assumed in the desktop analysis.

At Sumburgh the on-site survey identified more airfield equipment, facilities, and no-go site areas than had been noted in the desktop surveys. This restricts the maximum payload for Airlander 10 operations to the standard 10,000kg rather than an enhanced 12,000kg which had appeared possible from the desktop work.

Effect of meteorological conditions on Airlander operations

The local weather is a preoccupation to all transport operators, and ability to operate a service reliably in spite of the prevailing conditions is absolutely key.

Airlander will be certified to the same standards of safety as other large passenger aircraft and is designed for all-weather operations over the range of temperatures found worldwide. This implies that the aircraft can safely manage extreme events such as lightning strikes.

All aircraft have weather-related limitations, for example a 30kt manufacturer's crosswind limit is typical for current aircraft operated in the Highlands and Islands (lower limits may be placed for operations from some airfields). However, Airlander operates at relatively slow speeds by comparison with other large aircraft and always takes-off and lands into the direction of the prevailing wind. This introduces different considerations to some fixed wind and rotary aircraft:

1. The prevailing wind strength / direction is capable of restricting operations if it exceeds 30-35 knots, which is the upper limitation expected for take-off and landing of the production Airlander 10.
2. If a take-off and landing direction is unavailable, this may restrict operations if the prevailing wind is in that direction, assuming a straight take-off or landing run is required.
3. Flight planning requires that ground speeds rather than air speeds are used. The effect of prevailing winds on journey time must therefore be considered.
4. The aircraft has a 70kt limit when 'parked' on mast. If wind in excess of that figure (by definition hurricane force) are expected, the aircraft must be relocated to a calmer area.

Effect of wind on aircraft despatch

Analysis of the effect of typical annual wind conditions on Airlander 10 operations was undertaken based on a review of over 13 years of METAR weather data, which is overlaid on the operating site characteristics for each of the surveyed locations. METAR data is meteorological data collected and supplied to the aviation community in a standardised manner and is gathered at weather stations situated at most airports. Combining this with the key take-off and landing limitations of the aircraft identifies the percentage of time in the average year in which Airlander 10 operations would be available at each site.

Place	Desktop survey	On-site survey
	weather dispatch %	weather dispatch %
Kirkwall	*97.2%*	**97.2%**
Papa Westray	*41.5%*	**85.1%**
Stornoway	*97.3%*	**97.3%**
Barra	*79.3%*	**79.3%**
Inverness	*99.1%*	**99.1%**
Sumburgh	*96.3%*	**96.3%**
Scapa Bay	*97.2%*	**97.2%**

Table 4 – Forecast service reliability in local year-round meteorological conditions

Additional analysis of the historic METAR data for Kirkwall (as an example) was undertaken to explore the potential to improve on the average year-round figures.

- The METAR weather data demonstrates a probability of being able to operate round the clock at Kirkwall of 97.2% in the average year. However, services are likely to only be required between the hours of 6am and 10pm. Analysis verifies that this does not affect the 97.2% delivery level.
- The impact of adverse weather on any service ranges from delays to cancellations. Taking a one- to two-hour delay as typical, 98.3% of services could be offered with up to a one-hour delay, and 98.7% of services could operate with up to a two-hour delay. It may be anticipated that the remaining 1.3% of services could be subject to cancellation in a typical year.

Airlander 10 operations could also be disrupted if the aircraft needed to be moved out of the area for a period of time due to windspeeds that exceed its ability to be safely secured on the ground. However, only one day of operations over 13 years of data reviewed would have been adversely affected in this way at Kirkwall.

Weather-related despatch reliability data for the other aircraft types currently operating from the surveyed locations was not available for comparison. However, we expect that based on the analysis above Airlander will result in services with similar or better weather-related reliability than other modes of transport in the region.

En-route considerations

Once airborne, the effect of wind on anticipated journey times is limited by the fact that each flight sector is short. Additionally, in a typical operating day, time lost due to headwinds on one sector will to a reasonable extent be mitigated through tailwinds on the return flight. For the purpose of this study, a simple analysis of 50th, 75th and 95th percentile windspeeds on journey times for five representative Highlands and Islands sectors has been undertaken. Further probabilistic analysis could be undertaken once network parameters and anticipated flight schedules have been developed.

Twelve years of METAR data was used in the analysis. An altitude multiplier was used because surface winds, as measured by METAR, are typically lower than winds aloft for which data is unavailable.

The table below shows the impact on the flight time for five example/typical routes (black text is the outbound headwind/flight time while the blue text is return headwind/flight time) taking into account a selection of percentile levels of prevailing wind speed and direction. Negative wind values indicate that a tailwind component prevails (increasing Ground Speeds (GS) and reducing flight time).

In still winds Indicated Air Speeds (IAS) and GS of 60 knots are assumed. Note that we assume that throttle setting is increased where possible to improve flight time in the event of a headwind (up to the maximum flight speed of 70 knots if required). This technique consumes a little more fuel but mitigates the schedule impact of the headwind.

Sector	**Distance** (nautical miles)	**Still air flight time** (mins)	**Impact of 50th percentile headwind on flight time** (in mins delay)	**Impact of 75th percentile headwind on flight time** (in mins delay)	**Impact of 95th percentile headwind on flight time** (in mins delay)
A) Inverness – Stornoway	83	83	0	0	+4
B) Stornoway – Barra	79	79	+1	+10	+30
C) Kirkwall – Sumburgh	74	74	0	+4	+18
D) Kirkwall – North Ronaldsay	29	29	0	+2	+6
E) Inverness – Kirkwall	92	92	0	+2	+14

Table 5 – Flight times for example network sectors with impact of headwinds

Implications for existing airfield infrastructure

Airlander 10 requires a reasonably flat surface to operate from, and unlike fixed-wing aircraft it is not (and cannot be) restricted to using a single runway orientated towards one particular point of the compass. In general, operating from existing airfields would require some modification of the infrastructure.

Barra – Nominal Airlander take-off/landing area

Taxiways and runways typically have lights that protrude upwards from the tarmac or grass surface. For areas where Airlander 10 operate, these will need to be replaced with lights that are flush with the surface rather than protruding above it. They also typically have signs that stand upright. Where these are in areas of Airlander 10 operation, they need to be fitted with a simple mechanism allowing them temporarily to be retracted flat to the surface.

Typical airport sign

Airlander 10 takes off and clears a 50ft obstacle in 600m in still air conditions. As noted above, site surveys considered opportunities to add to existing airfield land where required in order to maximise the availability of the aircraft for operations.

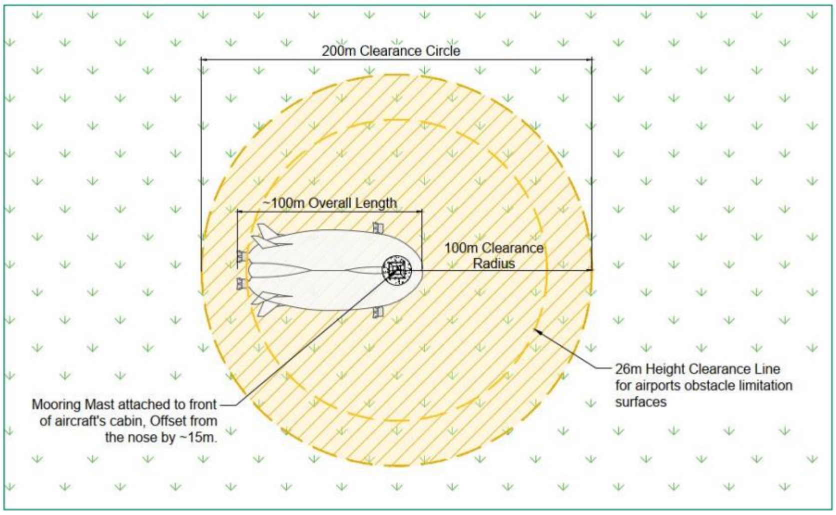
At Inverness there is a need for approximately 500m of drainage canal to be overlaid with reinforced concrete panelling to allow Airlander to operate over it, maintaining functionality of the drainage system.

Airlander 10 does not require a hangar for operations or for maintenance so consideration of sites and costs for hangars was excluded from the survey.

No further significant infrastructure upgrade requirements were identified in the surveys.

An indicative cost analysis has been undertaken for all the works identified to be necessary to enable Airlander 10 operations from the existing airfields surveyed. Excluding possible water landing opportunities, the average cost of modifying the six airfields surveyed was circa £287k per site, with the largest cost at Inverness (circa £671k). This compares with costs cited in the public domain of more than £2m for upgrades to even minor harbours in Orkney.

Aircraft mooring while not in service



When Airlander 10 is not in operation it is moored to a mobile mast (provided with the aircraft) which provides ground services such as power and which holds it on the ground in up to 70 knots of surface wind speed. Mooring requires a 200m circle (which can form part of the take-off and landing area where a mobile mast is used). The mast requires connection to ground anchors to provide this capability. All airfields except Barra and Sumburgh do not have enough space to moor Airlander without it interfering with other users of the airport, meaning that at those locations Airlander could not be stationed overnight. The aircraft route network will need to be designed to accommodate this by completing each day's operation at a field capable of mooring the aircraft overnight.

Fire and rescue provision

It was not possible to accurately assess the additional cost (if any) of airport fire services to cater for Airlander operation in this study. The reason for this omission is that the novelty of Airlander means that it has not yet been classified for the purposes of aerodrome firefighting category. However, a reasonable planning assumption at present is that an Airlander 10 aircraft operating with 50% passenger and 50% freight would be in aerodrome category 4 – the same as required by an ATR-42 aircraft.

Opportunities for locating aircraft maintenance, servicing and repair services in the region

Three of the airports surveyed (Inverness, Kirkwall, and Stornoway) appear to offer good opportunities for supporting land-based maintenance, servicing and repair of Airlander. They all had the space necessary to allow the aircraft to be moored for these tasks to be undertaken without interruption of the airports operational capability to handle arrival and departure of airplanes, helicopters or other Airlander aircraft.

Papa Westray Airport

The full AECOM feasibility study underpinning this section is available in Appendix 4 of the study.

Airlander 10 economics in the Highlands & Islands

Service characteristics and anticipated demand

Potential demand for passenger and freight services as a result of the introduction of the Airlander aircraft need to be subject to a further study, beyond the scope of this document. However, tables 1 and 2 indicate substantial air and surface traffic volumes across the Highlands and Islands transport network. A suitably sized Airlander 10 fleet with appropriately priced services has the potential to increase capacity by tonne-km and seat-km, up-scale and decarbonise existing air passenger and freight services and provide premium services complementing existing surface transport via the extant ferry services. The question of potential economic viability is examined in this section through assessing the anticipated cost of services delivered by Airlander 10.

A key part of the feedback from local groups during the infrastructure site inspection visits was that a 'combi' type version of Airlander carrying in the order of 30 to 40 passengers and 6,000kg+ of freight might make for the most powerful of services, increasing capacity for islanders to move between islands and to provide a more regular supply of freight (fuel oil, foodstuff, household goods etc.) than the ferries currently provide.

HAV has therefore completed an outline economic study of Airlander 10 services to assist customers and understand their potential costs.

Airlander economic study

The study assumed a three aircraft operating fleet with an average utilisation of 3,445 hours per annum per aircraft flying a generic flight schedule in the Highlands and Islands region.

The combined annual capacity of this route network and three aircraft utilisation is 37.2 million pax-km and 5.6 million tonne-km for the year[3].

Assuming an average passenger load-factor of 75% this is a demand of 219,000 passenger per year, representing approximately 12.5% of the air passenger capacity on the network excluding Edinburgh, Glasgow and Aberdeen in 2019 (being the most recent year for which data is available and not disrupted by the covid pandemic) and a fraction of the 6.3 million passengers carried on ferry services within Scotland in 2021.

Freight capacity provided on the selected routes at six tonnes per sector would be 43,800 tonnes per annum which is a 79% increase in the 2021 air freight capacity of the current network and only 0.25% of total domestic sea freight loaded and unloaded at Scottish ports in 2021.

The volume comparison appears to support the hypothesis that an Airlander 10 fleet (in this case of three aircraft) could serve the air network, providing additional passenger capacity (or an opportunity to decarbonise existing passenger operations), and significantly upscale air freight capacity and by providing a premium service for a high-value fraction of the freight that is currently transported over the surface.

[3] Assumes average route sector length of 127km, average ground speed 55 knots and 7,300 sectors flown per year.

Airlander cost parameters

The tables below provide the summary cost calculations for a three aircraft Airlander 10 fleet providing these services. These are presented as Cost per Available Seat KM (CASK) and Cost per Available Tonne KM (CATK).

For the average sector length in the network, this analysis implies a one-way cost of approximately £35 per available passenger journey (this is the cost of operation, not the ticket price for the end user). These economics have been shown to be cost-competitive when compared to 100-seat regional jet aviation on similar sector lengths elsewhere in the world.

The balance of freight costs against the cost of current alternatives needs further analysis in the context of the demand across the Highlands and Islands network, but at £2.74 per tonne-km across passenger and freight combined, this is expected to sit between the current underlying costs of surface and air transport. These indicative costs therefore support the proposition that a low-emissions, reliable, premium service for fast and outsize air freight and for low- or zero-emissions passenger services is economically viable in the region.

Sector	**US$ per sector**	**GBP per sector**	**Sector** (km)
Inverness – Kirkwall	5994.43	4720.02	172
Inverness – Stornoway	5414.33	4263.25	156
Stornoway – Barra	5156.50	4060.24	148
Kirkwall – Sumburgh	4769.76	3755.72	137
Stornoway - Benbecula	3609.55	2842.17	104

All pax (100 seat)	£0.27	Per ASK
All freight (10 tonnes)	£2.74	Per ATK

Combi variant*	**Operating cost split**	
40 passengers (seats)	£1096.18	per 100 km
6 tonnes of freight	£1644.26	per 100 km
Total sector cost	**£2740.44**	**per 100 km**

* Combination of passenger and freight payload

Assumption:
Exchange rate: £1 – US$ 1.27

Fleet: Three Airlander 10 aircraft
Utilisation: Average 287 hours per month per aircraft

Operating costs:
Fixed: Leasing, flight and cabin crew, insurance
Variable: Maintenance, airport charges, fuel

Table 6 - Key economic parameters for Airlander 10 fleet of three aircraft providing combination passenger and freight services across a representative Highlands and Islands transport network. All costs are indicative.

Notes on the calculations:

Included in these derived CASK and CATK numbers are aircraft leasing costs, maintenance costs (including maintenance reserves), aircraft insurance, manufacturer's support costs, flight crew costs, cabin crew costs and airport charges (including landing fees, parking fees, handling charges and Air Traffic Control charges).

Excluded from the CASK and CATK numbers are any costs associated with managing passengers (including ticketing, commission, passenger insurance, passenger taxes, catering, airport passenger charges) and any overhead absorption costs normally allocated by airlines to their operating cost.

Further opportunities

There is the potential for these economics to be further improved over time.

In the route network assumed, the range and operating altitude of Airlander 10 can be reduced, to enable it to accommodate up to 130 passengers or a combination of passengers and freight up to a maximum of 13 tonnes. Subject to additional demand, achieving these load factors would reduce the cost per passenger or per tonne of freight.

Additional savings may be found in the maintenance of Airlander 10 as operators familiarise themselves with the aircraft and optimise its operation. Airlander 10 has few of the complicated systems of fixed wing aircraft of similar payload and very few life-limited parts, which has the added benefit of imposing little cost penalty on the number of flight cycles completed. This is extremely beneficial on island-hopping services where multiple cycles per day are achieved and make flying a more conventional fixed wing aircraft very expensive.

Airlander has a low-risk path to decarbonisation capable of delivering hybrid or all-electric variants of Airlander 10 in this decade, improving on the already very high fuel economy and low CO_2 impact of the kerosene-powered version. These will significantly reduce the requirement for kerosene and increase the use of hydrogen rather than carbon-based fuel, which will alter the fuel economics of flying. In light of expected taxation, mandates or emissions charges in pursuit of net zero goals, this is likely to further enhance Airlander's cost competitiveness against other modes of transport.

In summary, Airlander 10 offers an economically viable proposition to enhance air passenger and freight services while increasing timeliness and delivery reliability of high-value freight that can currently only use surface services via road and ferry. The benefits include:

- Ultra-low fuel costs due to Airlander's low net weight
- Low maintenance costs due to simplicity
- Well-matched aircraft to high frequency and short sectors
- Significant savings on infrastructure costs – ability to operate into a variety of sites only suitable for small fixed-wing aircraft with minimal infrastructure modification
- Low operational complexity

Airlander and the environment

HAV aims to accelerate aviation's transformation into a low carbon industry.

In aviation, meaningful progress in lowering carbon demands bold thinking, and radical change

The International Air Transport Association (IATA) recently committed to net-zero carbon emissions by 2050, in line with Paris Agreement targets. Meanwhile the International Civil Aviation Organisation (ICAO) and IATA forecast a 4.5% compound average annual growth rate (CAGR[4]) in global demand for air travel and air freight between now and 2050.

Only with a bold and innovative mindset can these targets be reached. The necessary technological changes may demand adaptation of transport networks allowing existing services to be replaced and new services grown, while severing the growth / emissions relationship.

Highly targeted and rapidly deployed innovation can help meet sector emission reduction goals. Improvements in conventional airframe, propulsion and sustainable fuel technologies can then be optimised for those applications and sectors that cannot feasibly be addressed in other, less energy-intensive ways.

However, radical change does not mean the end of air travel. Aviation is critical to our society and economy. It promotes trade, creates millions of jobs, and connects people and cultures. Radical change in this context means transport solutions which augment aviation's benefits, without the associated impacts.

Airlander 10 over island network

4 https://www.icao.int/environmental-protection/Documents/EnvironmentalReports/2019/ENVReport2019_pg17-23.pdf

Aviation must therefore look beyond conventional incremental innovation. Low-carbon aviation (or zero-carbon emissions in flight) demands a rethink of how and where conventional aircraft operate, and what alternative aircraft configurations and networks could deliver beyond today's air transport system.

For example, hybrid aircraft with hovering or short take-off and landing capabilities can fulfil roles including sub-regional air transport, long-haul logistics, and special air services. These aircraft produce up to 10 times less harmful emissions than fixed-wing alternatives performing hovering manoeuvres. These new aviation categories offer opportunities ranging from rapid decarbonisation of domestic air travel markets to enabling low-emissions air freight and the transport of outsize equipment such as sustainable energy-generation infrastructure, like wind turbine blades, to remote places, with less impact.

New category, new possibilities - Transforming logistics and air travel

By creating more energy-efficient lift, hybrid aircraft can fly more slowly, using much less energy per km than conventional aircraft.

Many air services can deliver economic benefits without high-speed flight. In regional aviation flying time is often a fraction of overall journey time. Hybrid aircraft can offer more convenient connections and less lost time in security, airport protocols, and handling services, delivering near-equivalent journey times at a tenth of the carbon footprint. Compared to options such as sea or road, hybrid aircraft can fulfil rapid deliveries and short journey times, cost-effectively, and with far lower emissions.

The pandemic revealed the global supply chain's vulnerability. Supplementing conventional systems with low-emissions aircraft, independent of fixed infrastructure for their operation, could not only boost overall supply chain resilience but reduce carbon emissions. And, in removing the need for runways, reduce soil artificialisation thereby improving biodiversity[5].

Hybrid aircraft could provide extra capacity and flexibility, avoiding reliance on roads and ports and significantly increasing aviation's capacity to deliver goods.

They can also reinvent point-to-point logistics alongside services and energy infrastructure by unlocking new opportunities in remote areas less accessible to conventional transport. Hybrid aircraft, which can load and unload while hovering, can reach new territories and remote communities by minimising the need to access expensive airport infrastructure. By helping expand access to goods and produce, these aircraft can also help promote global equality, enabling those in isolated places to access the global marketplace.

This capacity to reach landlocked areas makes hybrid aircraft key to the UN's Sustainable Development Goals:

SDG7: Affordable and clean energy – for example, by supporting the complex logistical operation needed to install wind turbines and the creation of high voltage electricity networks.

SDG8: Decent work and economic growth – by unlocking whole regions of the planet.

SDG13: Climate action – by proposing a low-carbon means of transportation.

Efficiency, energy sources and green benefits

Hybrid aircraft offer helicopter-speed air transport with vast efficiency improvements, bringing new possibilities for both sustainability and energy efficiency.

Whether using conventional fuel, sustainable aviation fuel or hydrogen, the energy source is used efficiently, preserving limited energy and emissions budgets for other aviation sectors such as long-haul aviation, which currently lacks alternative technologies.

5 https://youmatter.world/en/soil-artificialization-erosion-ecosystem-biodiversity/

Inherently efficient, hybrid aircraft combine buoyant lift with aerodynamic lift and vectored thrust. The lifting gas offsets the aircraft's weight, requiring less energy to fly, allowing the aircraft to carry substantial cargo with far greater efficiency than conventional fixed and rotary wing aircraft. This means hybrid aircraft typically require <25% of the energy of alternate aircraft performing the same task. Adoption of hydrogen-electric technology to deliver most of this energy leads to an expected 90% emission reduction per revenue km in most roles at service entry in 2028[6].

This has huge implications. For example, 50% of air freight, and the 12% shortest-sector air travel, are together forecast to generate 639 million tonnes of CO_2 annually by 2050.[7] Hybrid aircraft can minimise these emissions without restricting growth in these sectors.

6 Based on HAV analysis of Airlander's CO_2 production on a pax.km or tonnes payload.km basis vs the UK Gov CO_2 creation figures for airplanes.

7 Based on HAV analysis of predicted freight demand, total passenger operation figures and the proportion of that number committed to short haul.

Operational infrastructure

Compared to conventional fixed wing and rotary wing aircraft Airlander needs very little specialised infrastructure or facilities to sustain operations. Airlander 10 was designed from the outset to be easy to maintain with all normal maintenance expected to be done with the aircraft attached to the mast without the need for being inside a hangar. The following section outlines example facility and site infrastructure requirements for Airlander operations.

Airlander 10 flight operations do not require large-paved runways. Although it requires a short take-off and landing run, its operation is more comparable to that of a light/small aeroplane.

The absence of the requirement for a large-paved runway makes Airlander operation possible from an almost endless range of locations including small islands, atolls as well as from water and ice surfaces.

Infrastructure – land and water

This should provide similar facilities to a conventional airport but tailored to lower levels of security screening and a more 'turn up and go' approach. This facility could be set up in an existing building or in a series of temporary buildings (allowing flexibility/season operational costs to be minimised) and providing easy access to the short transfer by bus and boat to the aircraft. Aircraft cleaning, catering and refuelling (kerosene or hydrogen) services can be provided by conventional vans/bowsers on land and via a small, dedicated service boat for water operations.

Land operation

Airlander taxis under its own power and attaches to a fixed mast at the edge of the operating area.

Once moored passengers can access the aircraft in two ways depending on the ground equipment at the specific site. Either the forward cabin doors can be opened and their integral stairs deployed or a ground-based access carousel (allowing ramps to be raised to interface with the forward cabin doors) can be provided.

Regardless of the forward cabin access, passengers would walk from the front cabin doors (down the steps or carousel ramp) a distance of circa 30m to the area ahead of the Airlander and its mast where they would board a conventional bus or coach which would take them to the terminal building.

The rear/ventral access to Airlander can be used during ground operations and in the absence of the carousel described above, limited mobility passengers can enter/exit the aircraft via the rear from a dedicated small mobility van/coach.

As in waterborne operation, the ventral ramp can provide cleaning/galley/luggage access during ground-based operations.

A more permanent Airlander facility could be provided where there is no requirement for a coach transfer and a more traditional 'airport' style layout is offered. A holding lounge under the mast would be provided with both stair and lift access to the surface and a carousel and ramp arrangement would allow everyone to board via the forward aircraft doors.

Water operations

Airlander taxis under its own power and docks to a mooring mast. Airlander weathervanes (at a maximum of a few degrees per second) to remain facing into the wind whilst loading/unloading/cleaning etc. are carried out.

Passengers then disembark onto a carousel moving with the aircraft (which can be provided with both sun and rain protection) and from there join a boat via an access ramp.

Airlander can take off and land in waters up to a World Meteorological Organisation (WMO) Sea State of Three. Sea state is the general condition of the free surface on a large body of water—with respect to wind waves and swell—at a certain location and moment. A sea state is characterised by statistics, including the wave height, period, and spectrum. The sea state varies with time, as the wind and swell conditions change. The WMO sea state code largely adopts the 'wind sea' definition of the Douglas Sea Scale, a sea state of three is a wave height of up to 1.25m.

Airlander 10 – Operation from unprepared surfaces

Conclusion

Airlander 10 is a revolutionary new aircraft. This document is the first in depth study of the aircraft in a commercial operational context to be made publicly available, and it has addressed for the first time some of the key aspects of the aircraft's operation which will bear on its practicality and cost in the context of the Highlands and Islands of Scotland.

The Highlands and Islands of Scotland are characterised, from an air transport point of view, by relatively small, simple airports with low operating costs and short runways. With the exception of Inverness and Kirkwall in this study, this restricts the aircraft types that can be used to aircraft such as the Britten Norman Islander (pictured, right). Whilst these aircraft are rugged and well-adapted, they are small.

Britten Norman Islander in Orkney

Airlander is well-suited to deliver a new network offering to the Highlands and Islands of Scotland

This report breaks new ground in substantiating the performance of Airlander 10 in the regional air transport role, with key conclusions as follows:

This study demonstrates that Airlander 10 allows operation, with minimal and inexpensive airfield modifications, of a 10 or more tonne payload aircraft from the same set of airfields to which much smaller aircraft are currently operated, allowing a significant expansion of air services. It has the potential to supplement the existing ferry fleet by providing significantly more cargo capacity and the ability to move larger, heavier items by air.

Airlander will deliver good availability in weather conditions

Airlander is a low-speed aircraft and (as with all aircraft) has limitations on windspeed and direction for take-off and landing. A key part of the study demonstrated high despatch availability from the sites studied, considering historic wind speeds and directions and the availability of take-off and landing direction at the sites studied, all with minimal impact on journey times.

Airfield adaptations for Airlander are simple and inexpensive

Many of the studied operating locations are currently suited only to the operation of small aircraft. This study demonstrates that, because of the excellent airfield performance and slow take-off and landing speeds of Airlander 10, adaptations needed for its operation are limited, and as a result, inexpensive. The average cost of modifying the six airfields surveyed was circa £287k per site, compared to costs cited in the public domain of more than £2m for upgrades to even minor harbours in Orkney. The aircraft can also operate at full payload at the majority of the surveyed sites.

Airlander provides a capability for net zero Scottish regional air transport by 2040

In this context and in aviation generally, two main influencing factors are present at the end of the first quarter of the 21st century.

The continuing desire of governments and the population for higher quality of life and for access to transport at prices which are progressively less expensive as a proportion of real income. The aviation industry has successfully delivered this progress since the end of the second world war. In the context of the Highlands and islands of Scotland, progressive improvement in air and sea transport is critical since many communities cannot be reached by road. Failures of transport have a disproportionate effect in such communities, but at the same time success clearly has the potential to have a large positive multiplier effect on quality of life and the economy.

The realisation that failure to decarbonise the economy could cause extremely adverse consequences through continued global warming, some foreseeable, some unforeseeable, and a near universal push to policies which will allow net carbon emissions to be reduced or brought to zero. The physics of aviation mean that its carbon emissions tend to be high – it is costly in energy to achieve speed by lifting mass into the air.

Aviation currently brings these objectives into conflict, at least in the short to medium term. There is a lack of credible technical avenues for the decarbonisation of most large passenger aircraft. Retaining existing aircraft types but switching to sustainable fuels is superficially credible, except that such fuels are likely to remain costly and scarce in the lifetimes of those reading this report. Carbon offsets have potential but are subject to similar capacity and price constraints. Such steps have the potential to make a small difference but are not a substitute for either technical progress or (in the worst case for the objectives above), reduction of journeys taken so as to reduce carbon output, with consequent drop in economic output.

Airlander 10 delivers significant reductions in carbon-impact versus aircraft of similar payload in its baseline kerosene-powered version, but more importantly offers a low-risk path to a hydrogen fuel cell-powered variant this decade. Whilst this aircraft will have much shorter range than the baseline aircraft, its range is more than sufficient for the applications studied here.

Airlander is economical to own and operate relative to aircraft of similar payload and is likely to become more so with government interventions

Airlander 10 delivers broadly the same or better economics as 100 seat regional aircraft. This is an important reference point, and one over which Airlander 10's advantage is likely to grow over time. At present, there are few 'sanctions' on aviation with the objective of delivering net zero. Jet fuel is untaxed. Emission trading schemes are really the only new method to drive the aviation industry towards a lower-carbon state. However, pressure from governments and the public is only likely to increase. Measures such as bans on inefficient air travel where alternatives exist are likely to spread. Therefore, apart from direct benefits of lower carbon emissions, Airlander 10 is likely to become progressively cheaper to own and operate in relation to current types and may ultimately be one of a restricted number of aircraft types allowed to operate on some routes.

Airlander has growth and tourism potential

Airlander 10 is intended to be the first in a line of products from HAV – a British company – exploiting the same hybrid technology. The aircraft's very large cabin unlocks potential for Airlander 10 capacity to also be employed for dedicated tourism purposes. Large windows and a spacious cabin allow an environment of luxury.

The later-planned Airlander 50 variant, which is focussed on logistics and outsize payloads, offers significant utility to (for example) the wind power industry.

HAV looks forward to working further with the contributors to this study to explore and develop the potential for the aircraft type in Scotland.

Airlander 10 – 100 seat cabin

Appendix 1 – Consortium Partners

Hybrid Air Vehicles Limited

Hybrid Air Vehicles Limited (HAV) is the company behind Airlander technology. Its first production aircraft, Airlander 10, will deliver up to a 90% reduction in carbon emissions compared to other aircraft in its various roles, before attaining zero emissions operations through providing an all-electric variant to the market from 2030. The company's vision is to be the future of zero-carbon aviation. It expects Airlander to be the first large scale aircraft (capable of carrying up to 100 passengers or 10 tonnes) to achieve zero-emissions flight. This capability, combined with the performance of the aircraft and its ability to use relatively small and unprepared airfields or water for landing and take-off is at the core of the prima facie case for Airlander's deployment in the Highlands and Islands.

AECOM

AECOM is the world's trusted infrastructure consulting firm, partnering with clients to solve the world's most complex challenges and build legacies for generations to come.

AECOM Aviation is a global provider of technical services to airport owners, investors, airlines and aviation clients — leading and supporting programs for airports of all sizes and forms. AECOM's expertise spans a broad range of facilities, including passenger and cargo terminals, runways, taxiways and aprons, aircraft hangars, infrastructure, and support facilities.

AECOM's services are demonstrated through the success of airport terminal, airfield and airside and landside infrastructure projects around the world. Building on their global network of expertise and local knowledge, their multidisciplinary, skilled professionals are experienced in delivering integrated, collaborative aviation solutions across projects and continents, from finance and analysis to design, master planning, program management, and construction services.

AECOM's specific scope and input is centred around the aerodrome infrastructure required for both land and sea operations as well as surface access and obstacle restrictions. Further detail is provided later in the study however for clarity AECOM's scope includes the assessment of cost in respect to changes/additions/interventions at each of the locations, in respect to supporting the Airlander to operate safely and efficiently.

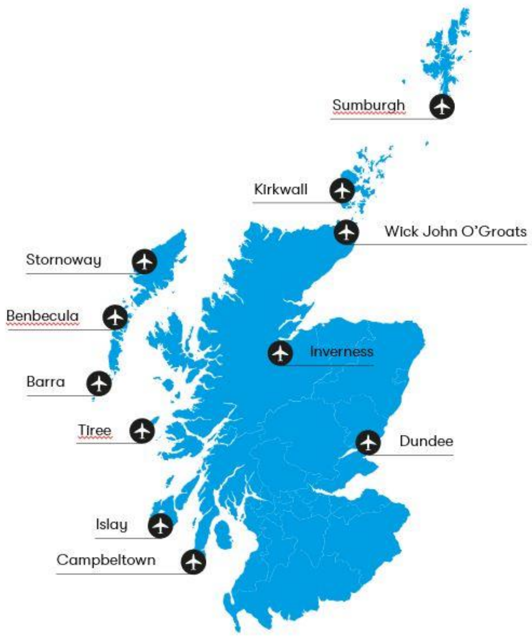
The assessment is to focus on a list of seven locations and builds upon work that has already been carried out by HAV in respect to initial airfield performance analysis for the Airlander 10 aircraft.

Highland and Islands Airports Limited

Highlands and Islands Airports Limited (HIAL) is a private limited company wholly owned by the Scottish Ministers and responsible for the management and operation of 11 regional airports located at: Barra, Benbecula, Campbeltown, Dundee, Inverness, Islay, Kirkwall, Stornoway, Sumburgh, Tiree and Wick John O'Groats.

Working with our stakeholders, we are committed to supporting the essential socio-economic role of aviation in Scotland by maintaining and developing our airports and the connections they provide for some of our country's more remote communities.

HIAL's airports enable lifeline and emergency services and act as regional travel hubs for their communities. Our airports connect the communities we serve to the UK and International destinations via Amsterdam, London, Edinburgh, Glasgow, and Manchester.



As a private limited company wholly owned by the Scottish Ministers, HIAL receives subsidies from the Scottish Government in accordance with section 34 of the Civil Aviation Act 1982 and is sponsored by Transport Scotland – Aviation, Maritime, Freight and Canals Directorate.

Kirkwall Airport is particularly suited to acting as a test environment location as it offers a variety of short routes, connecting Orkney's island communities through short hops to inter-island airfields. For example, the connection to Westray - best known for being one of the two airports joined by the shortest scheduled flight in the world and operated by Orkney Islands Council.

For more information visit: Highlands and Islands Airports Limited (hial.co.uk)

Orkney Islands Council

Orkney Islands Council is the local authority for the islands of Orkney, a key geography for the study. Orkney Islands Council has six island airfields situated on the beautiful islands of Eday, North Ronaldsay, Papa Westray Sanday, Stronsay, and Westray. Ideally located for visitors to the Northern Isles in uncontrolled airspace with some of the most breath-taking scenery in Scotland, the airfields are situated some 14 to 28 nm (nautical miles) North of Kirkwall Airport. Loganair operate scheduled flights from Kirkwall Airport to all six north isle airports.

HIAL has embarked on a multi-million pound project to develop a sustainable aviation programme that could transform short flight travel between remote communities. Part funded by UK Research and Innovation (UKRI) through the Industrial Strategy Challenge Fund, the SATE project is creating the UK's first operationally based, low-carbon aviation test centre at HIAL's Kirkwall Airport in the Orkney Islands.

Launched as part of UKRI's Future Flight Challenge which supports the development of greener ways to fly. Different types of low-carbon aircraft will be tested to identify the next generation of air services as well as the operational airport infrastructure necessary to support sustainable aviation, including Airlander. Addressing the challenge to improve UK regional air connectivity and helping to decarbonise the Highlands and Islands region, the innovative project will stimulate job creation and use local renewable energy, supporting Orkney's net zero ambitions.

Highlands and Islands Transport Partnership

The Highlands and Islands Transport Partnership (HITRANS) is the statutory regional transport partnership for Na h-Eileanan Siar, Highland, Moray, Orkney Islands and Argyll and Bute. It was created by Transport Scotland under the Transport (Scotland) Act 2005, along with six similar groups covering other areas of Scotland. HITRANS covers the largest area of any such partnership in Scotland, covering over 50% of the country's total landmass.

Its main functions are to determine and deliver better transport, both locally and nationally, and to act as a catalyst for regeneration of the region's economy.

HITRANS makes plans through its Regional Strategy, which was first approved by the Scottish Government in 2008. It was later refreshed in 2017.

Highland and Islands Enterprise

The Economic and Community Development Agency for the North and West of Scotland. Highlands and Islands Enterprise (HIE) is the development agency for the Highlands and Islands of Scotland. It is an executive non-departmental public body of the Scottish Government. Its role is to "help build a prosperous, sustainable and inclusive economy across the Highlands and Islands, attracting more people to live, work, study, invest and visit.

Loganair

Loganair is a Scottish regional airline based at Glasgow Airport, Scotland. It is the largest regional airline in the UK by passenger numbers and fleet size.

The operator of the majority of existing Scottish air services and all but one PSO contract.

In addition to its main base at Glasgow, it has hubs at Aberdeen, Edinburgh, Inverness and Newcastle airports. It holds a United Kingdom Civil Aviation

Authority Type A Operating Licence, permitting it to carry passengers, cargo and mail on aircraft with 20 or more seats.

Due to the structure and financing of Highlands and Islands air services Loganair have joined the consortium to advise on airline operations for the region and have invaluable experience in this area of expertise.

Sustainable Aviation Test Environment

The Sustainable Aviation Test Environment (SATE) is the UK's first low-carbon aviation test centre embedded at a commercial airport, Kirkwall Airport on Orkney.

SATE brings together an international consortium of industry partners, public sector bodies and academia who will work with a range of regional businesses and stakeholders to apply state-of-the-art aviation technology to deliver targeted economic growth.

The Highlands and Islands represents an ideal "living laboratory" for emergent aviation technologies, demonstrating their practical applications in addressing connectivity challenges, as well as creating an emerging new sector with significant job creation potential. SATE is at the forefront in progressing both the UK and Scottish government's aviation aspirations and has already delivered new airport infrastructure and demonstrated hybrid-electric aircraft and autonomous logistics.

The SATE programme aspires to become the UK Centre of Excellence for Sustainable Regional Aviation Systems.

While the SATE facilities are based at Kirkwall Airport, Phase 2 involves plans to work with other Highlands and Islands communities and will match the new technology with practical use cases to benefit communities in the Highlands and Islands.

SATE and its partners aim to:

• Establish a UAV hub-and-spoke delivery network

• First hydrogen-propelled (19 seat) regional-aircraft flight

• Drone demonstration flight from Scotland to Norway

• Impact and policy - including geospatial analysis and socio-economic modelling for the future Highlands and Islands route network

Use cases developed in SATE have been, and will continue to be, supported by Orkney, Shetland, Western Isles and Highland councils. Use case projects from the initial phase include serving the NHS, NatureScot, Orkney Food and Drink, Streamline Shipping and Royal Mail.

For more information visit: https://www.hial.co.uk/homepage/21/sustainable-aviation-test-environment

UK Research and Innovation

UK Research and Innovation (UKRI) is the largest public funder of research and innovation in the UK, with a budget of around £8bn. It is composed of seven disciplinary research councils, Innovate UK, and Research England.

We operate across the whole country and work with our many partners in higher education, research organisations businesses, government, and charities.

UKRI's vision is for an outstanding research and innovation system in the UK that gives everyone the opportunity to contribute and to benefit, enriching lives locally, nationally and internationally.

UKRI's mission is to convene, catalyse and invest in close collaboration with others to build a thriving, inclusive research and innovation system that connects discovery to prosperity and public good.

For more information visit: UKRI – UK Research and Innovation

The consortium and the study

This study is a collaborative piece of work led by HAV, HIAL and AECOM with significant contributions from OIC, HITRANS, and Loganair.

The study is part funded by the SATE project, which is a consortium of companies promoting sustainable aviation, led by HIAL. SATE is funded directly by the UK government, through UKRI funding.

We would like to pay tribute to the local communities at each of the locations described herein, whose wholehearted engagement with the project provided the consortium with so much local knowledge crucial to the compilation of this study.

Appendix 2 - Airlander technical

Market-ready green mobility

Airlander is a new type of aircraft, with technology designed from the ground up to maximise efficiency, improve the flying experience and enable new use cases. It does not compete directly with traditional aircraft, but instead establishes entirely new possibilities. It brings together the buoyancy of an airship (through use of inert helium) with the aerodynamic lift of an aeroplane, as well as vectored thrust that provides control and the capability to take-off and land with minimal infrastructure.

HAV is developing a pathway to adopt and drive demand for key net zero technologies, such as hydrogen fuel cells and electric motors. HAV anticipates Airlander will enter service from 2027, taking UK R&D through to large-scale UK manufacture.

The result is a truly unique aircraft capable of delivering 90% fewer emissions compared to traditional aviation undertaking the same roles, and an improved passenger experience with less noise, more space, more windows and natural light, and no requirement for a pressurised cabin.

Aircraft certification

HAV has pursued its goal by collaborating on the development of industry-specific regulations, working closely with the European Union Aviation Safety Agency (EASA) to produce the certification basis for airship-based aircraft designs. EASA is the first aviation authority to have published a complete set of dedicated certification specifications in a document called Special Condition "SC Gas" Airships[8]. The aircraft will be certified with CAA, EASA and FAA. The primary certification authority will be UK CAA, but HAV will work with other regulatory bodies in parallel to ensure near simultaneous certification in the three jurisdictions. Certification is planned for 2027.

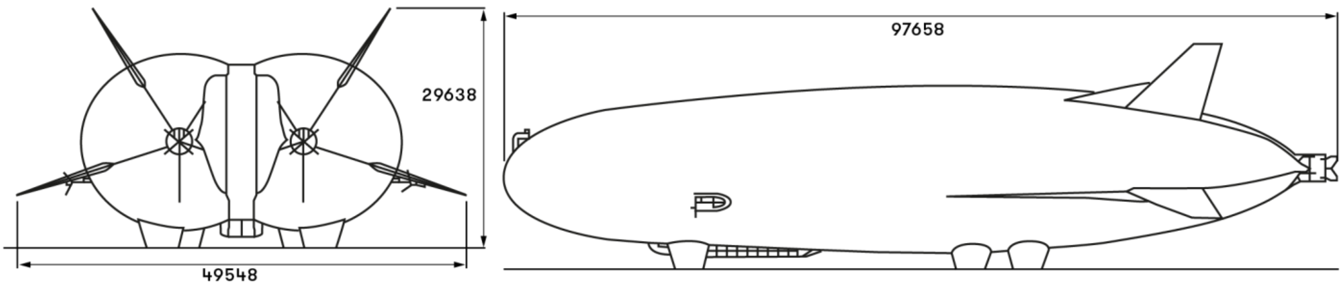
General characteristics - Airlander 10

The aircraft dimensions make Airlander 10 a very recognisable aircraft from the air and due to the innovative hybrid design the aircraft is extremely manoeuvrable at low altitudes. During the landing/take off phases of flight the aircraft is very manoeuvrable and is designed with a Short Take Off and Landing (STOL) capability, the aircraft does not require a runway and can operate from water.

Aircraft exterior dimensions:

Length: 320ft (98m)
Height: 98ft (30m)
Width: 164ft (50m)

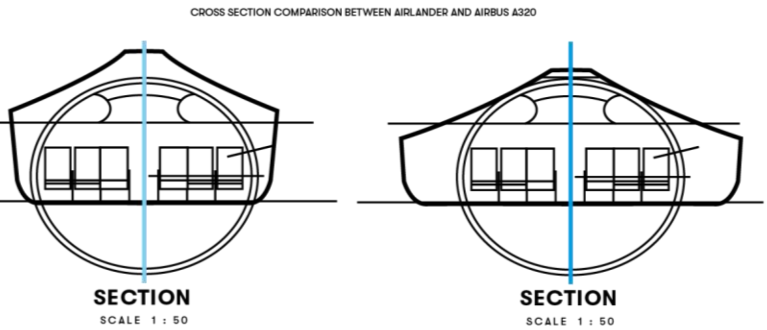
8 https://www.easa.europa.eu/downloads/134946/en



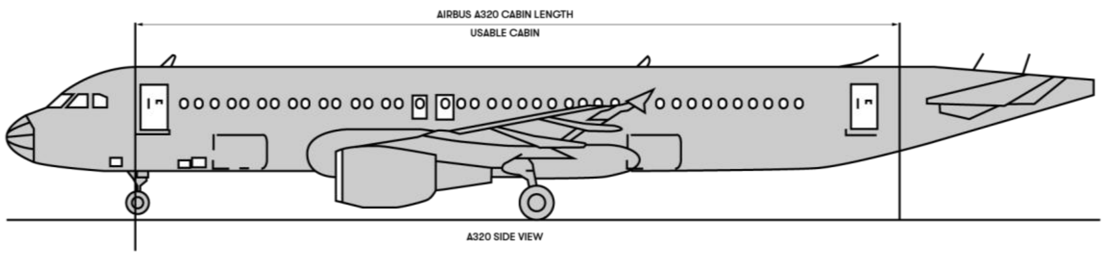
Passenger cabin for mobility variant dimensions (approx.):

Length:	**128ft (39m)**
Height:	**7ft (2.1m) average**
Width:	**16ft (5m) average**
Floor area:	**2,050ft^2 (195m^2)**
Volume:	**13,760ft^3 (390m^3)**
Luggage storage area:	**425ft^3 (12m^3)**

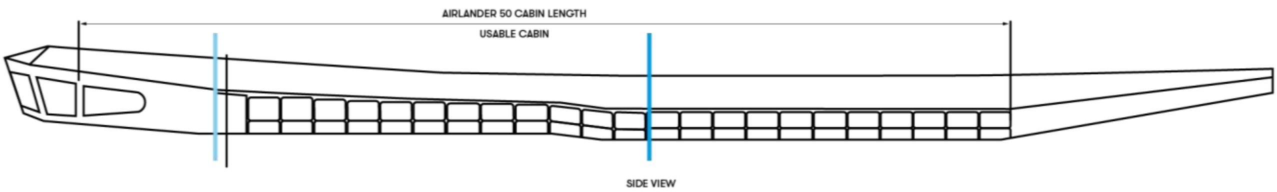
With extensive cabin space the Airlander offers our customers the scope to adapt the interior space to their concept of operations and to the product and clientele they desire. Two lengths of cabin are available, the longer of the two being depicted below.



Passenger Cabin for the A320:
Length: 90ft 3in (27.5m)
Height: 7ft 4in (2.2m)
Width: 12ft 1in (3.7m)



Passenger Cabin for the Airlander (approx.):
Length: 128ft (39m)
Height: (average) 7ft (2.1m)
Width: (average) fwd cabin 15ft (4.5m) aft cabin 18ft (5.5m)

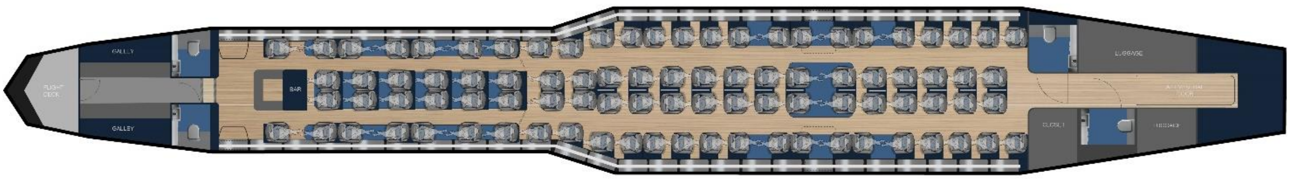


Provides 4.3/6.0m x 36.8m of useable floor space (194.5 sq. m) far exceeding that of an Airbus A320 (see diagram above) **All passenger (mobility) concept (100 passenger configuration)**

Mobility cabin concept

The diagram below is the 100-seat cabin layout, which gives a high level of space and scenic views for the passenger.

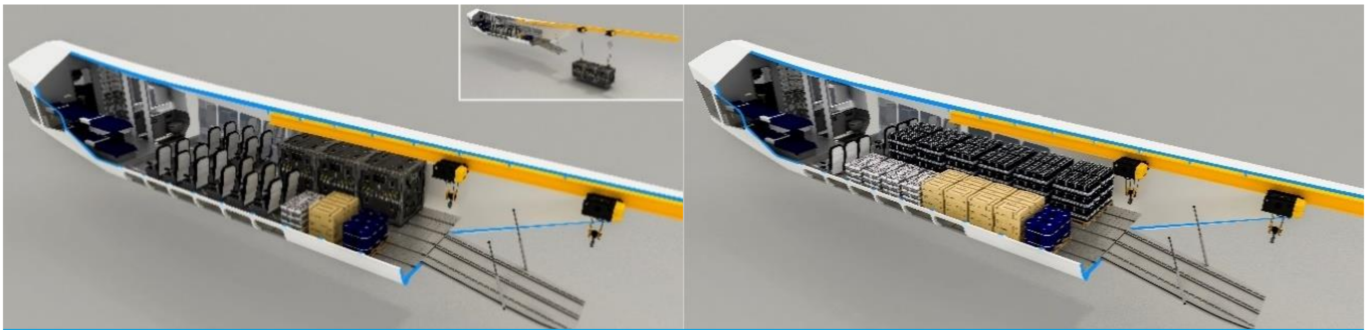
Average seat pitching = 1.1m (43½")



The mobility variant gives all passengers a comfortable cabin experience and scenic views, which could even encourage tourism for a more comfortable way of experiencing the islands. Due to the ability of high frequency and "bus-stop" style service this could be very appealing to tourists on day trips to different islands. It will also give local connectivity to the local community and provide accessibility to the islands.

Utility cabin concept (combi layout of passengers and freight, with rear loading ramp for freight)

The utility module can be a short cabin or long cabin variant. Below is the short cabin variant - with the long cabin variant there is double the space and therefore double the seats and freight area. There is minimal impact on performance of the aircraft.



Freight and 'combi' configurations

The upside is more volume of freight and high pax number with the longer cabin, the downside of the extended cabin is the loss of the self-loading mechanism, but the rear loading ramp is still available allowing easy access of freight.

100 seat interior

Appendix 3 - Airlander operations

Aircraft operation

Fuel used and fuel capacity: The aircraft uses Jet A1 fuel – this is the standard fuel used in aircraft gas turbine engines. For the all-kerosene models there are four tanks, total fuel capacity is of the order of 10,000Kg. For the hybrid model (with two kerosene engines and two electric motors), the two forward kerosene tanks are replaced by cylinders containing hydrogen.

Weights & balance: The aircraft is designed to carry 10 tonnes over 2000nm.

Passenger boarding and disembarking and baggage/cargo loading and unloading: Passengers embark the aircraft through a pair of forward or ventral (rear) doors, using steps or built-in airstair. In respect of luggage there are two options – either it can be self-loaded (as in a train), or the cabin can be configured to allow for baggage to be sequestered at check-in and loaded by staff. The example layouts are based upon self-loading.

Take-off and landing distances on ground and water: In zero wind conditions in still air (the worst case), the aircraft requires 600m of available space.

Vertical take-off & landing capability: Airlander is not a conventional airship, and it relies partially on aerodynamic lift. As wind speeds rise the aircraft will have a very short landing or take off roll and very low ground speed (especially at low weights).

Climb and approach gradients: The aircraft is capable of a standard 3-degree landing approach. More varied approaches are possible according to local arrangements, especially if the aircraft is not utilising standard airfields.

Banking and turning manoeuvring: In the take-off and landing phase, manoeuvrability is enhanced by vectored thrust from the two forward engines. The aircraft otherwise makes use of aerodynamic control surfaces in the same manner as fixed wing aircraft. Trimming is performed using air-filled ballonets contained within the envelope of the aircraft.

Cruising and descent considerations: The aircraft cruises below 10,000 feet. In many cases it will cruise well below controlled airspace, especially in uncongested areas. It has no special characteristics with respect to descent, when compared to fixed wing aircraft of similar speed.

Severe weather capability

Turbulence: Due to the Airlander's low speeds and relatively large size / mass, the impact of turbulence is minimal.

Strong winds: There are no in-flight operational wind speed constraints and Airlander's top speed is 70 knots. Airlander can take off and land in surface winds of up to 35 knots. Crosswinds are not a consideration since Airlander does not normally utilise a runway and always takes off and lands into wind. When the aircraft is powered down it requires a mooring mast, HAV will provide a mobile mooring mast – a tracked vehicle with an integral mast used to secure Airlander in winds of up to 70 knots.

Lightning/hail: Airlander will be certified against the same lightning and High Intensity Radiate Fields requirements as other large aircraft.

Aircraft maintenance

In summary, there will be daily, weekly and annual maintenance requirements designed to ensure an average of up to 14 hours per day operation of the aircraft, six days a week, with two weeks per annum downtime for more complex maintenance. Depending upon the country in which the aircraft is registered, it will be for the relevant country of registration to approve the operator's maintenance programme for the aircraft.

Appendix 4 - Operational infrastructure and airfield survey

Redacted from public document – Included in version for NDA partners.

HYBRID Air Vehicles

AIRLANDER
RETHINK THE SKIES

Airlander is designed and built by
Hybrid Air Vehicles Ltd.

Hybrid Air Vehicles Limited

239 Ampthill Road
Bedford
MK42 9QG

info@hybridairvehicles.net