# ESA / Lindstrand - High-Altitude Long Endurance (HALE) airship

Peter Lobner, updated 10 March 2022

## 1. Introduction

Per Lindstrand founded Lindstrand Balloons Ltd (LBL) in December 1991, based in Oswestry, Shropshire, England. The firm has since been renamed Lindstrand Technologies Ltd (LTL) to reflect its broader business capabilities, which include designing, manufacturing and repairing airships, aerostats and gas balloons, passenger carrying aerostats and a whole host of leading-edge fabric engineering products.

The European Space Agency (ESA) has long been interested in developing solar-powered high altitude platforms for a variety of roles, including local and regional telecommunication services, Earth observation services, atmospheric science and astronomical observations. In 1999, ESA contracted with Lindstrand Balloons Ltd. to conduct a design study for a high altitude airship. Lindstrand Balloons Ltd., founded by Per Lindstrand, has a well-established business designing and supplying airship envelopes and related technologies. In March 2000, ESA announced:

> "The European Space Agency, together with Daimler Chrysler Aerospace of Germany (now Astrium GmbH), Lindstrand Balloons Ltd. of the United Kingdom and the Technical University of Delft in the Netherlands, have completed a first assessment of a concept for a High-Altitude Long-Endurance (HALE) aerostatic craft, positioned in the stratosphere at about 20 km (65,600 ft) altitude - in a region of space where no aircraft or satellites fly - and with an operational lifetime ranging from months to years."

As a result of this project, and having more than 20 years' experience of lighter-than-air technology, Per Lindstrand was awarded the German-based Körber Prize for engineering excellence.

*HALE stratospheric airship. Source:  ESA*

## 2.  The ESA / Lindstrand HALE airship

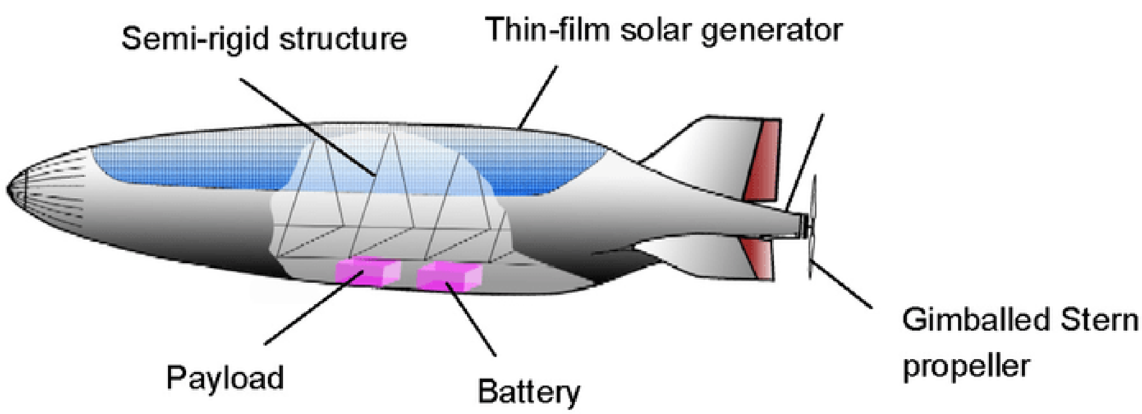
The result of the ESA's assessment was a conceptual design of a semi-rigid airship propelled by a single large diameter propeller mounted at the tail.  Power was provided by a hybrid solar electric / regenerative fuel cell system.

*Source: RAND TR-423 (2005)*

ESA described this airship as:

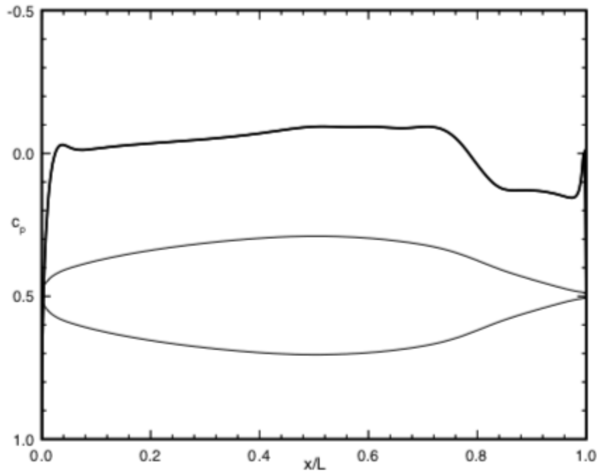
> “…..an aerodynamic "cigar" shape about 220 m (722 ft) in length and 55 m (180.4 ft) in diameter, carrying payloads of up to 1,000 kg (1 metric ton, 2,200 lb) or so. Unlike Zeppelins, which they closely resemble from the outside, HALEs do not need a rigid overall internal structure. With modern flexible hull materials, helium-tight and UV-resistant, their design can rely on pressurization to impart the necessary stiffness to the airship body. Only local rigid reinforcements for the engine and payload attachment are necessary.”
>
> “HALEs are equipped with an engine for mobility and stable positioning against stratospheric winds. The altitude of 20 km (65,600 ft) is high enough to give local or regional coverage of about 100 km (62 miles) in diameter and also offers the advantage of minimum wind speeds. Solar cells covering the upper, sun-oriented parts of the airship skin gather energy at daytime to power a high-efficiency electric engine, which drives a large propeller, and feed energy into a storage and conversion system, from which it is drawn for nighttime propulsion and operation of the vehicle.”

The semi-rigid design of the ESA / Lindstrand HALE airship is shown in the following diagram.




*Source: ESA*

The unusual profile shape of the HALE airship resembles the shape of a hull optimized for laminar flow.  An example of such optimization is described by Lutz and Wanger (Fig. 8, 1997).




"This relatively slender body is characterized by its far aft position of the maximum thickness point and by moderate, almost constant acceleration upstream of this point. This slightly favorable pressure gradient is sufficient to keep the boundary layer laminar up to 75% of the body length… "

> "Downsteam of transition the body shows a steep pressure rise. This corresponds to a reduction in diameter and a reduction of the wetted surface area in the region of high turbulent skin friction values. The resulting drag curve for the optimized body is shown in (the accompanying figure). Very low drag coefficients for the whole design regime can be observed."

In 2005, RAND examined the ESA / Lindstrand HALE airship as part of a study on high-altitude airships for the US Army. RAND reported:

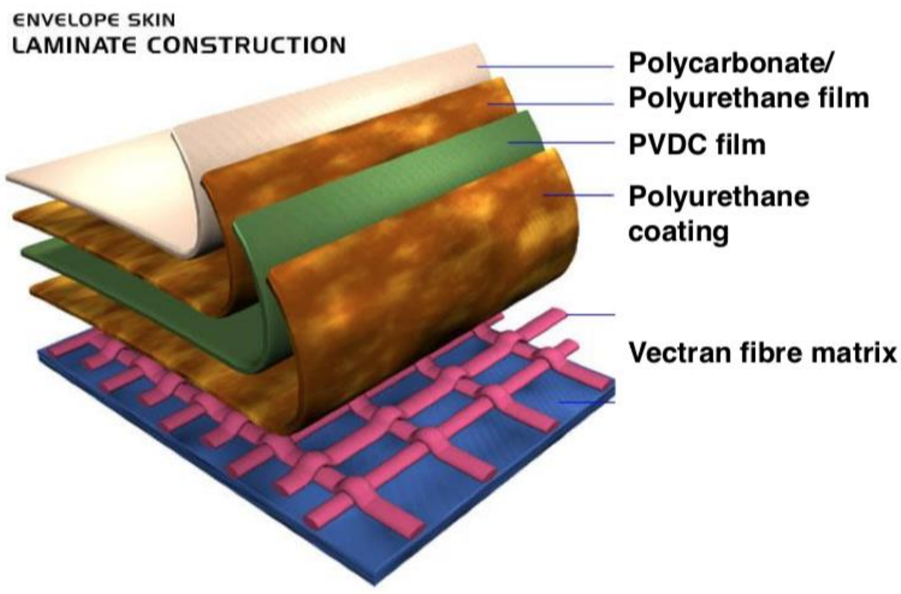
> "The European Space Agency (ESA) is developing a solar-powered airship being built by Lindstrand Balloons. The airship will have a single 8-meter diameter propeller. Fuel cells will store the sun's energy during the day and produce (an average power of) 90 kW at night to drive the propeller and provide (an average power of) 15 kW to power a communications base station payload. The fuel cells have a mass of 1.1 tons as compared to 16 tons for batteries of equivalent energy storage. At the present level of fuel cell efficiency, 8 percent, the Lindstrand airship will have enough daylight sunshine in the winter to provide yearlong coverage only between 45° latitude north and south. This limitation precludes its use in the London area during winter until fuel cells improve but will be useful in areas like Rome and countries surrounding the Mediterranean Sea".

> "Photovoltaics that have a specific power of over 1,400 watts per kilogram have been successfully produced by DayStar Technologies. A power demand of 90 kW, published for the Lindstrand airship, would result in a weight of 64.3 kg for the solar array."

General characteristics of the ESA / Lindstrand HALE airship are summarized below:

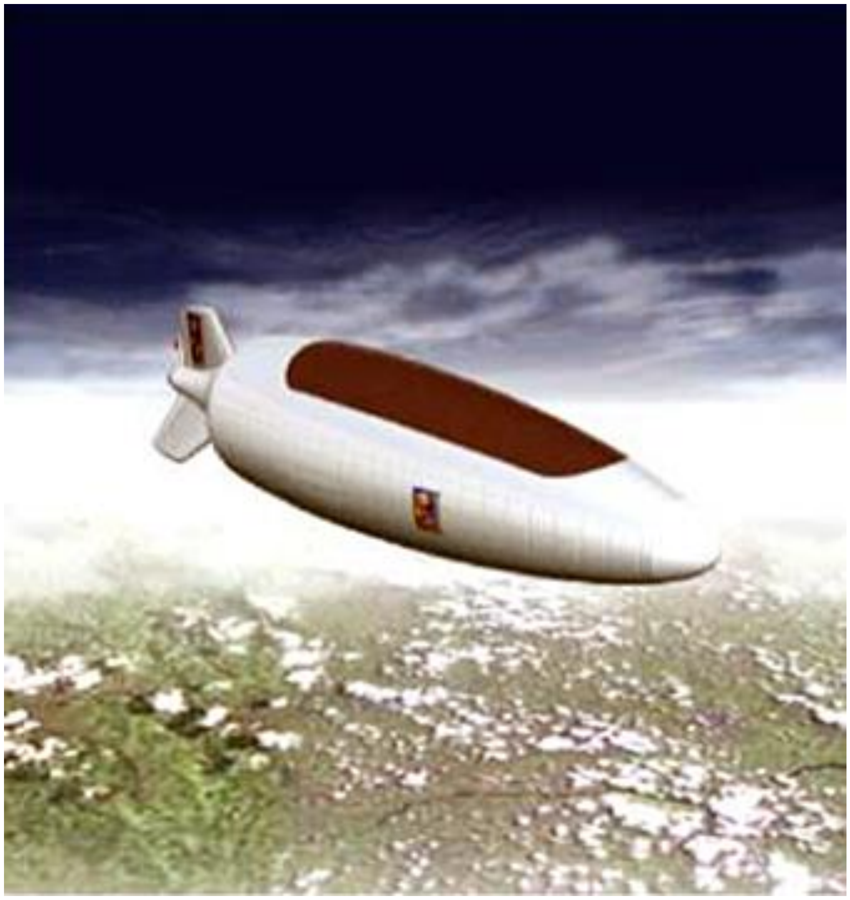
- Length: 220 m (722 ft)
- Maximum diameter: 55 m (180.4 ft)
- Operating altitude: 20 km (65,600 ft)
- Payload: 1,000 kg (2,200 lb)
- Power: thin film solar array generating up to 105 kW to supply loads & charge a regenerative fuel cell for operation at night.
- Propulsion: single, electric motor driven 8-meter (26.2-ft) diameter propeller
- Platform mission duration: months to years

The envelope skin for the ESA / Lindstrand HALE airship is a multi-layer laminate as shown in the following diagram.




*Source: Lindstrand*

The ESA / Lindstrand HALE airship was not built.



*Source: Fresen (2007)*

**3. The ESA / Lindstrand communications network concept**

Regarding business prospects for the ESA / Lindstrand HALE, ESA noted:

> "Considerable effort is currently being put into assessing HALE's business potential and market access while additional companies and institutions are considering to join the team and discussing their possible roles in the development and commercial exploitation. This initiative must be seen in the context of similar efforts in Japan (Sky-Net) and the US (Sky Station Int'l), in which also European Space (Agency) and balloon-manufacturing companies are participating."

A specific telecommunications package has not been attributed to the ESA / Lindstrand HALE airship.  However, the desired telecommunications functionality likely would have been similar to contemporary systems being developed in other countries in the 1999 – 2000 time frame. An interesting clue to potentially unique functionality (for the time) on the ESA / Lindstrand HALE airship is shown in the following graphic, which appears to depict laser-based free space optical communications links between the HALE airship and an orbiting satellite.

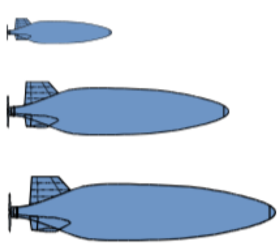
*Free space optical communications links between an ESA / Lindstrand HALE stratospheric airship and an orbiting communications satellite. Source: F. Fidler, Dissertation (2007)*

## 4. Continuing development under the French Pégase initiative

The Pégase initiative is an industrial collaboration to build a dirigible industry in France. Within that collaboration is an effort to build a stratospheric airship capability and develop a platform that can maintain station keeping for a year at an altitude of 20 to 25 km. Thales Alenia Space, Astrium, Zodiac, CNES, ONERA are the major space companies supporting this effort. The Thales Alenia Space Stratobus is one stratospheric airship program supported by Pégase. Another may be an airship based on the ESA / Lindstrand HALE design, as suggested by the following graphic.

*Source: Pole Pégase presentation (14 Dec 2011)*

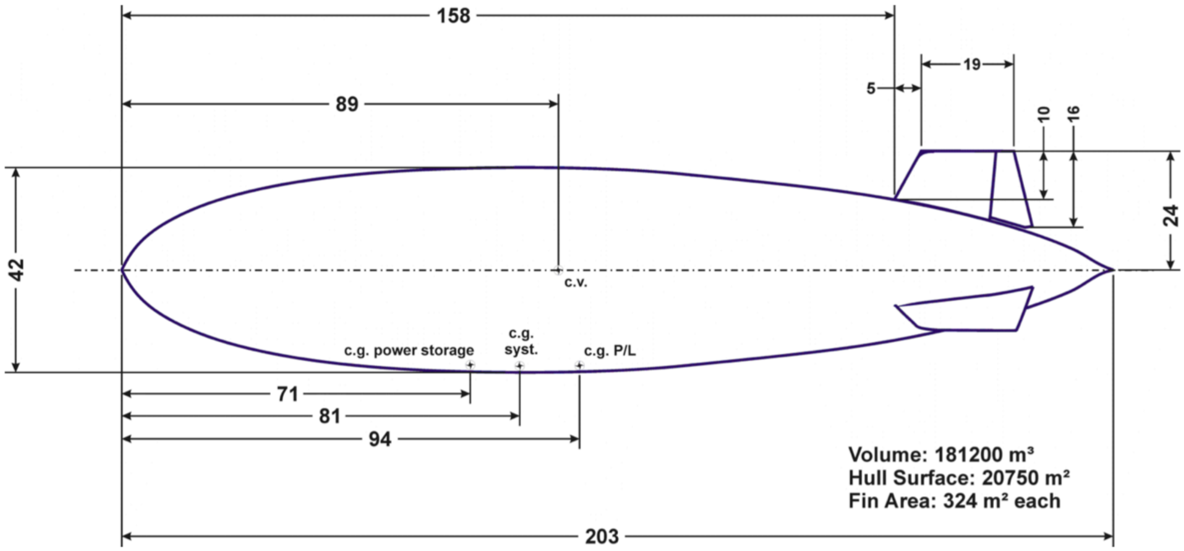
Lindstrand Technologies has defined the following three HALE models. In this table, $mass_{sys}$ is the overall vehicle mass, and $mass_{pl}$ is the payload mass.



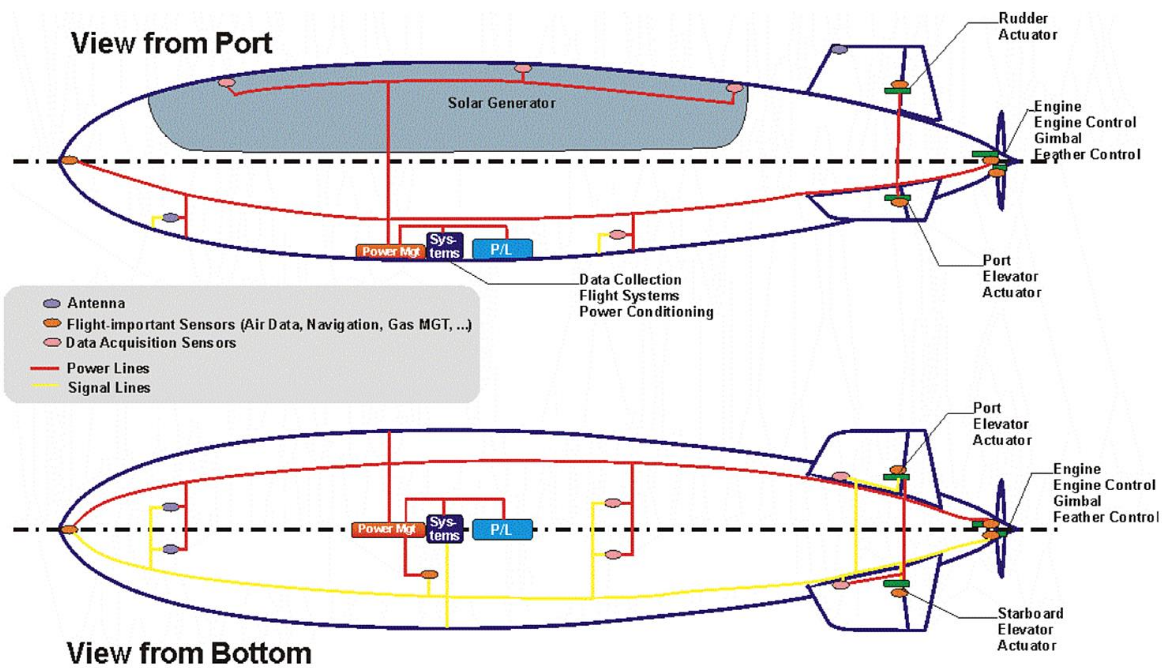
| | volume | length | $mass_{sys}$ | $mass_{pl}$ |
|---|---|---|---|---|
| D15 | 16.000 m³ | 80 m | 2.700 kg | 100 kg |
| D20 | 180.000 m³ | 180 m | 12.600 kg | 500 kg |
| PS &series | 320.000 m³ | 220 m | 20.800 kg | 1.000 kg |

*Source : Lindstrand Technologies (2015)*

The PS series airship is the size of the former ESA / Lindstrand HALE stratospheric airship (circa 1999 – 2007). The smaller D-20 airship has adopted a new envelope design, as shown below.




*HALE D-20 dimensions (above), internal arrangement (below). Source, all graphics: Lindstrand Technologies (2015)*



## 5. For more information


- T. Lutz & S. Wagner, “Drag Reduction and Shape Optimization for Airship Bodies,” Institute for Aerodynamics and Gas Dynamics, University of Stuttgart, Germany, published by American Institute of Aeronautics 1 and Astronautics,1997: https://pdfs.semanticscholar.org/6523/9efd20583090d4a383bd0dacf5a4960de09f.pdf
- European Space Agency, N° 19–2000: Airships to complement satellite and terrestrial systems, 17 March 2000: https://www.esa.int/Newsroom/Press_Releases/Airships_to_complement_satellite_and_terrestrial_systems
- L. Jamison, G. Sommer & I. Porche III, “High Altitude Airships for the Future Force Army,” Technical Report TR-423, ISBN 0-8330-375905, pp. 11, RAND Corporation, 2005: https://www.rand.org/content/dam/rand/pubs/technical_reports/2005/RAND_TR423.pdf
- T. Tozer & D. Grace, “USE-HAAS, WP2, 1st Deliverable - Analysis of works and underway programmes,” Section 3.7, Creative Technologies Israel Ltd., 27 July 2005: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.607.291&rep=rep1&type=pdf
- R. Fesen, “High altitude station keeping astronomical platform,” Department of Physics & Astronomy, Dartmouth College, 2007: https://spacegrant.colorado.edu/COSGC_Projects/space/fall_2007/downloads/airship_spie.pdf
- Franz Fidler, “Dissertation – Optical Communications from High-Altitude Platforms,” Technical University of Vienna, September 2007: https://publik.tuwien.ac.at/files/PubDat_112010.pdf
- “High Altitude Long Endurance Aerostatic Platforms: The European Approach,” Lindstrand Technologies, ESA & CargoLifter, 2015: https://ftfsweden.se/wp-content/uploads/2015/11/Bevingat_2013-4_Luftskepp.pdf


**Other *Modern Airships* articles**

- *Modern Airships - Part 1*: https://lynceans.org/all-posts/modern-airships-part-1/

    - Lindstrand Technologies - GA-42 & GA-22 blimps
- *Modern Airships - Part 2*: https://lynceans.org/all-posts/modern-airships-part-2/
    - EU CAPANINA
- *Modern Airships - Part 3*: https://lynceans.org/all-posts/modern-airships-part-3/