C.N.R.S. Pégase – lenticular stratospheric airship

Peter Lobner, 24 August 2021

1. Introduction

The Pégase high-altitude, lenticular, rigid airship design concept was developed under a 1969 – 1975 French study entitled, “Stationary Geophysical and Astronomical Study Platform,” which focused initially on the development of a large, unmanned, long-endurance stratospheric airship with onboard remotely-controlled observatories. The astronomical observatory would exploit the excellent optical viewing conditions while the geophysical observatory would exploit its geo-stationary high-altitude vantage point to deliver persistent surveillance over a large observable land area. The stratospheric platform also could host active telecommunication relays and airborne radars.

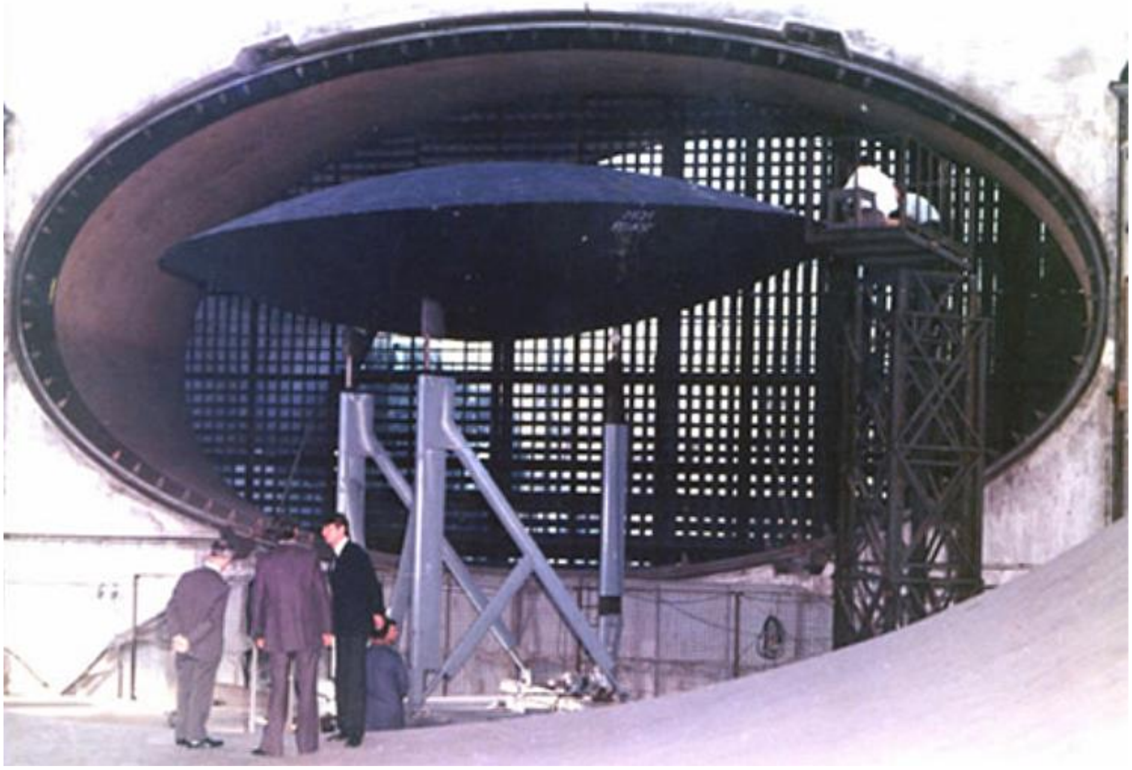
The study was led by Pierre Balaskovic of the Space Technology Department of the C.N.R.S. (Scientific Research National Center). This project was presented in October 1969 and began in June 1970 with 10 million francs in funding from several sources:

- I.N.A.G (National Institute of Geophysics)
- C.N.E.S. (National Center for Space Studies)
- C.N.E.T. (National Center for Telecommunications Studies)
- O.R.T.F. (Radio and Television of France)
- D.A.T.A.R. (Regional Planning Delegation).

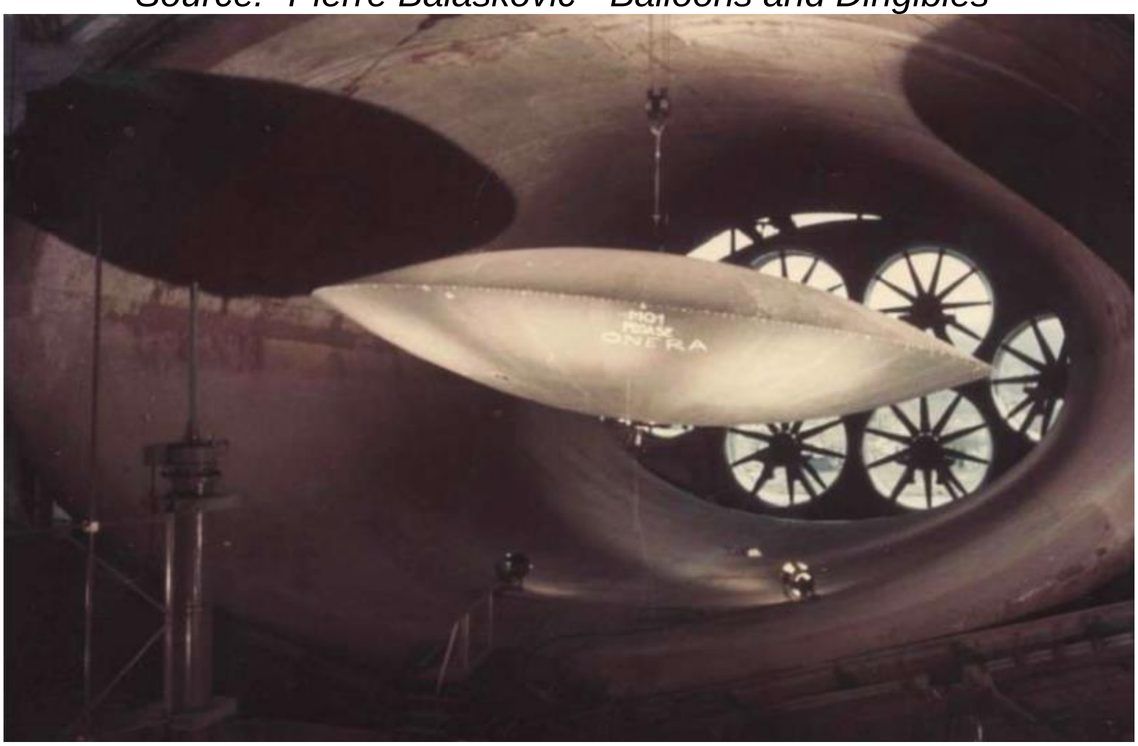
O.N.E.R.A. (National Office for Aerospace Studies and Research) was the prime contractor.

2. Wind tunnel models

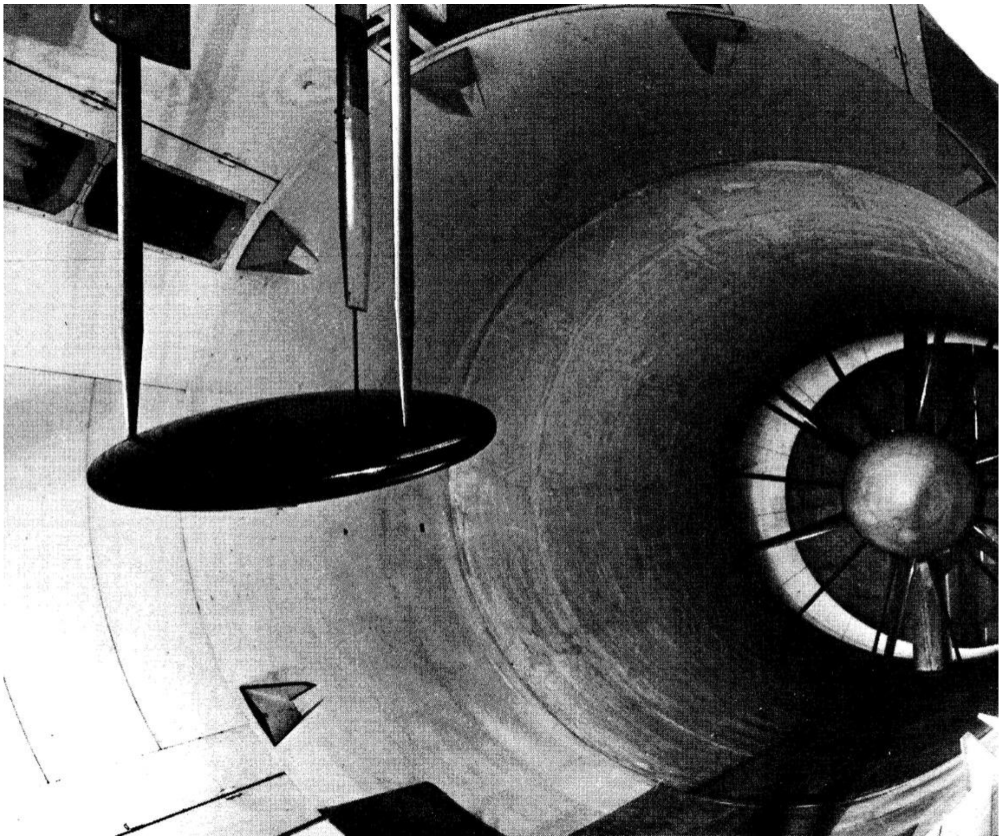
At the end of 1972, the first tests of an 8-meter (26.2-ft) model of Pégase were conducted in the large wind tunnel of Chalais-Meudon (La Grande Soufflerie, aka “The Great Wind Tunnel”).



A Pégase wind tunnel model. Note sharp edge lenticular shape. Source: "Pierre Balaskovic - Balloons and Dirigibles"



Testing a 1/40 scale model of Pégase in the S1Ch wind tunnel in Chalais-Meudon*. Source: "A Half Century of Aeronautics in France"*



A blunt edge scale model of Pégase in an ONERA wind tunnel.
Source: "Les ballons du futur" (1983)

The wind tunnel tests determined that the lenticular hull had good aerodynamic properties.

3. Description of the Pégase

Aerodynamic studies led to the choice of a circular (lenticular) hull shape with a parabolic-elliptical profile and a rigid structure based on either an array of hexagonal, geodesic cells or a star beam network. The hexagonal, geodesic cell structure was selected. The hull consists of a frame of composite material beams with a stretched fabric outer skin.

During the six years of the Pégase program, the airship's design changed significantly, evolving from a sharp-edge lenticular shape to a blunt edge shape of substantially greater diameter and with significant changes to the proposed propulsion system. The following table summarizes design characteristics of two version.

General characteristics of two versions of Pégase

Parameter	Version 1	Version 2
Airship type	Lenticular, rigid airship	Lenticular, rigid airship
Diameter	188 m (617 ft) *	252 m (827 ft) *
Height	54 m (177 ft) *	61 m (200 ft) *
Lift gas	Helium	Helium
Lift gas cells	108	
Envelope volume	900,000 m^3 (31,783,000 ft^3)	1,600,000 m^3 (56,503,500 ft^3)
Weight, empty		102 metric tons (110 tons)
Payload	5 metric tons (5.5 tons)	49 metric tons (53.9 tons)
Weight, maximum		151 metric tons (166 tons)
Weight compensation	Water ballast	
Propulsion system	• 10 x hydrogen-powered turboprops @ 11,200 kW for high wind conditions • 8 x DC electric motors @ 620 kW powered by hydrogen-air fuel cells for light winds	4 x DC electric motor-driven propellers powered by a hybrid solar electric system with hydrogen-air fuel cells, particularly for winter months
Fuel	16 metric tons (16.6 tons) of liquid hydrogen (LH_2)	LH_2
Speed, max. air speed	172 kph (107 mph)	60 m/sec (216 kph, 134 mph)
Altitude, operating	18,000 m (59,055 ft)	18,000 m (59,055 ft)
Altitude, maximum		21,000 m (69,000 ft)
Mission endurance	1 to 4 months depending on the winds	1 year with 1 to 2 rotations for refueling & maintenance
Vehicle lifetime		10 years
Source	Balaskovic, *"Les ballons du futur,"* 1983	Aerall, http://aerall.org/Principaux-Projets-depuis1975.htm
* Two sources (Mowforth & Weber) describe *Pégase* as having a 300 m (984 ft) diameter lenticular disk with an 80 m (262.5 ft) maximum thickness.		

The stratospheric airship was expected to be able to reach a maximum altitude of 21,000 m (69,000 ft) and operate closer to 18,000 m (59,055 ft). At the time *Pégase* was designed, in the early 1970s, there was almost no operational experience on getting a large, rigid airship into the stratosphere. The seasonal winds at the operating altitude were expected to reach 250 kph (155 mph), but this

maximum would be aerodynamically equivalent to a sea level airspeed of only about 20 kph (13 mph).
Piloting was to be provided by a computer that could operate autonomously or be controlled remotely from a ground station, the latter being used during challenging periods, such as takeoff and landing and crossing areas of turbulence during ascent or descent. Static longitudinal instability of the lenticular airship was to be managed with active controls.

Edwin Mowforth described the operation of Pégase's propulsion system as follows:

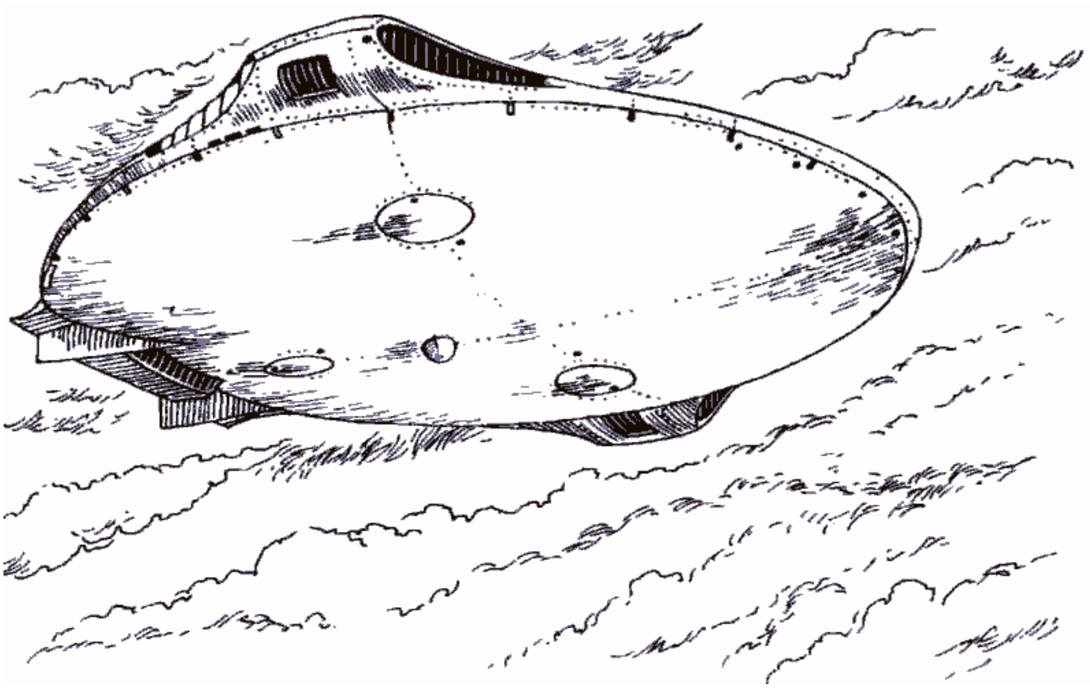
> "….this was to be driven by vectoring propellers powered by hydrogen (fuel) cells and DC electric motors. It was intended that appropriate variations of propeller thrust and direction should render aerodynamic control surfaces unnecessary – a control technique sometimes referred to as "live thrust." The relatively gentle gust regime anticipated at the working altitude of 21,000 m (69,000 ft) might well have conferred validity both upon the live thrust system and upon the very light structural design necessary to achieve such heights…"

The stratospheric airship would be at its geostationary position for at least 9 months of the year. The necessary energy would be supplied by a solar photovoltaic system with energy storage for continuous operation at night. During the three winter months, another source must provide additional energy required to operate the airship 24/7. Alternatives considered included (hydrogen) fuel cells and stored liquid hydrogen. The operational goal for the stratospheric platform was for one year of autonomous operation with one or two short returns to base for refueling and maintenance. Vehicle operating life was expected to be about 10 years.

4. Pégase as a stratospheric telecommunications platform

While initially designed as a scientific observation platform, *Pégase* was studied for use as a geostationary, stratospheric telecommunications relay, remaining at an altitude of 18 - 21 km precisely above one spot on the Earth's surface for a year, with a maximum of 9 hours of service interruptions per year.

The lenticular hull shape provides large surface areas to install very high-aperture antennas, including phased arrays, on the bottom surface and a large and well-oriented solar photovoltaic array on the top surface. The symmetry of the hull shape makes it relatively insensitive to changes in wind direction.



Automatic Pégase platform serving as a telecommunications relay. Source: "Les ballons du futur" (1983)

In 1972, studies carried out by the ORTF and the CNET determined that about 10 Pégase airships could provide radio coverage for all of France, and around 20 airships would be needed to deliver nation-wide TV service.

A fleet of stratospheric telecommunications airships costs much less to build and operate that a geostationary satellite. One performance advantage compared to a geostationary telecommunications satellite at 36,000 km (22,300 miles) is that the airship requires much less energy per channel and has greater throughput for telecommunications services. The airship also can be periodically recalled to base for refueling, updates and repairs that can’t be accomplished on satellites in orbit.

Pierre Balaskovic's Pégase stratospheric airship design concept was not developed into a working airship.

5. Flipper

A sub-scale, proof-of-concept, single-place, lenticular vehicle known as "Flipper" was designed by Balaskovic and constructed in 1978, after the end of the Pégase project. Flipper was intended to provide in-flight data for lenticular airship design, but it was damaged beyond repair before its first flight.

Possibly the sub-scale "Flipper" constructed in 1978. The general shape bears a resemblance to the Pégase wind tunnel models tested in the early 1970s. Source: E. Pinto & J. Barata, 2012

6. For more information

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- Anthony J. Dolman, "Current and Possible Future Developments in Lighter-Than-Air (LTA) System Technology," Section 4.4, "France," United Nations Industrial Development Organization (UNIDO), 1983: https://open.unido.org/api/documents/4793600/download/CURRENT%20AND%20POSSIBLE%20FUTURE%20DEVELOPMENTS%20IN%20LIGHTER-THAN-AIR%20
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- Charles Luffman, "Lenticular Airships – An Exposition," Section 4.1, "Pégase 1969," LTA Solutions, 7 May 2015 (amended): https://docplayer.net/64482432-Lta-solutions-a-lighter-than-air-aircraft-design-engineering-practice-page-1-of-16-lenticular-airships-an-exposition.html

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