Nautilus Elettra Twin Flyers (ETF)

Peter Lobner, Updated 3 April 2021

1. Introduction

In 2002, the Italian firm Nautilus S.p.A and Politecnico di Torino developed a concept for a twin-hull, optionally-piloted, hybrid airship with thrust vectoring propulsion for a range of possible missions, including reconnaissance, communications and advertising.

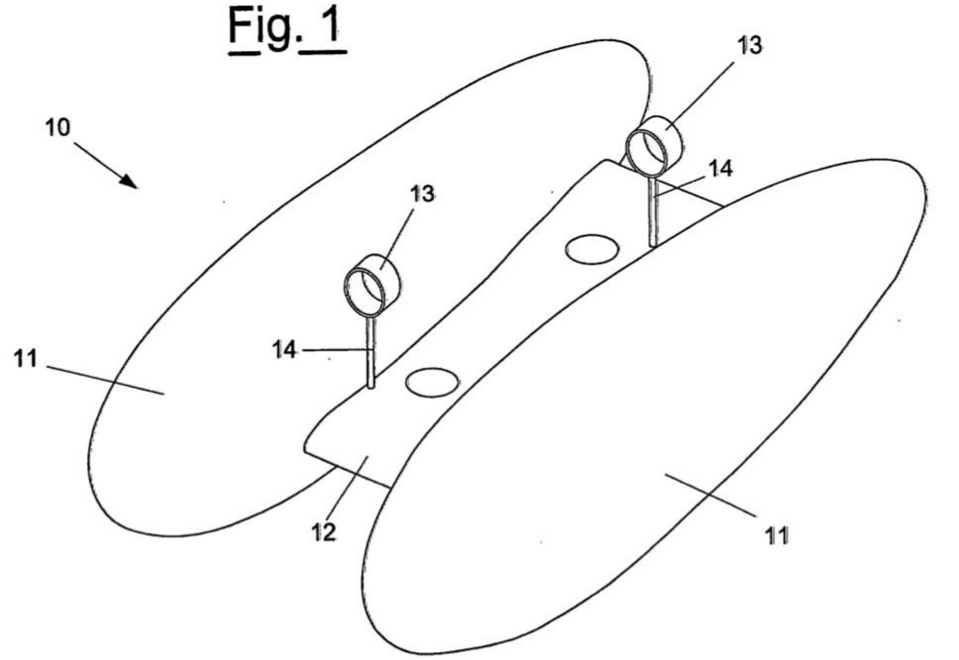
2. Twin hull airship patents

This airship design is described in European patent EP 1,551,706 B1, "Dual Hull Airship Controlled by Thrust Vectoring," which was submitted in 2003 and published on 13 August 2005. You can read this patent here:

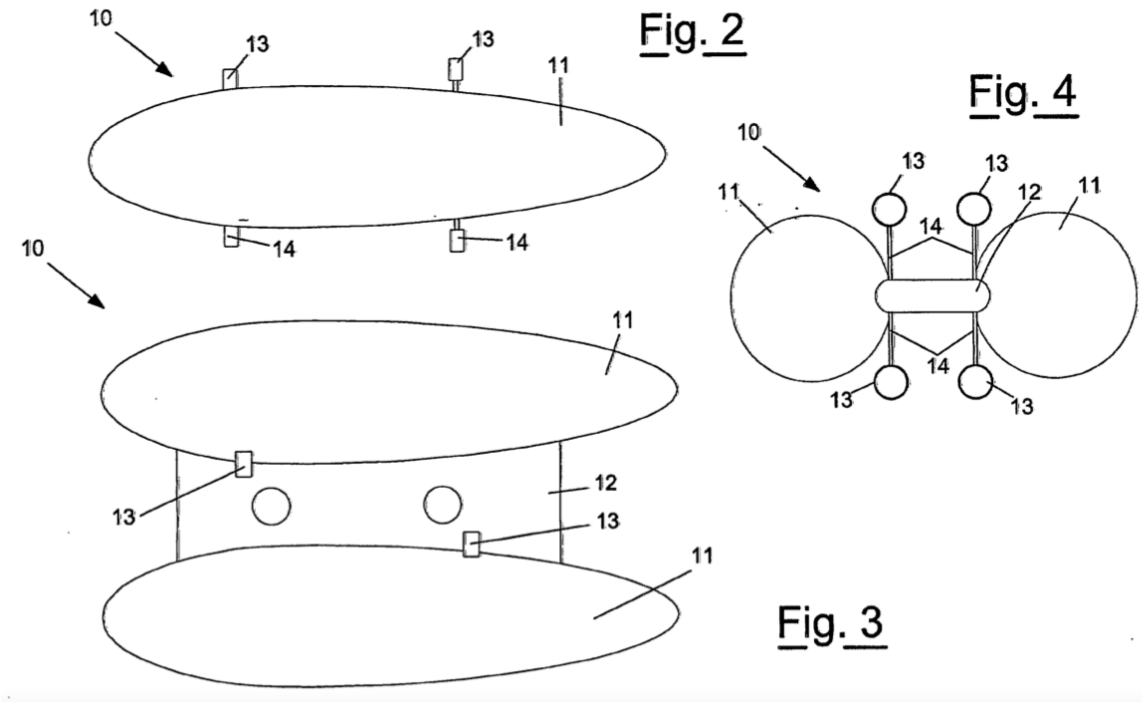
https://patents.google.com/patent/EP1551706B1/en?oq=EP+1%2c551%2c706+B1%2c+

The general arrangement of the twin-hull airship is shown in the following figures from patent EP 1,551,706 B1:

Fig. 1



The preceding isometric drawing of the twin-hull airship (10), shows the two hull components (11), the central structural member (12), which houses two flush-mounted fixed vertical thrusters and 360° vectorable thrusters (13), which are mounted on asymmetrical rotating arms (14). There are two vectorable thrusters above the central structure and two more below that structure.



Three-view drawing of the twin-hull airship.

3. Developing the design of the Nautilus twin-hull airship

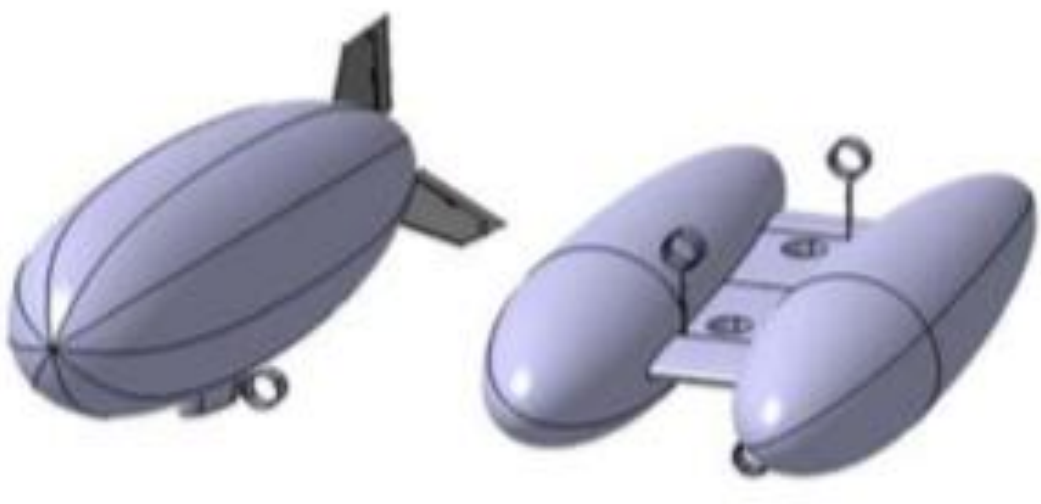
In the 2004 paper, “Peculiar Performance of a New Lighter-Than-Air Platform for Monitoring,” authors Battipede, Lando, Gili & Vercesi describe the unique features of the Nautilus airship as follows:

> “The main characteristic that makes this vehicle unconventional is the lack of either fixed or moving aerodynamic surfaces: the complete control around the three axes is obtained through four thrust-vectoring propellers. This unique command system provides the Nautilus airship with the uncommon capability of hovering with any heading, even in adverse weather conditions.”

Basic operating characteristics of a Nautilus airship include:

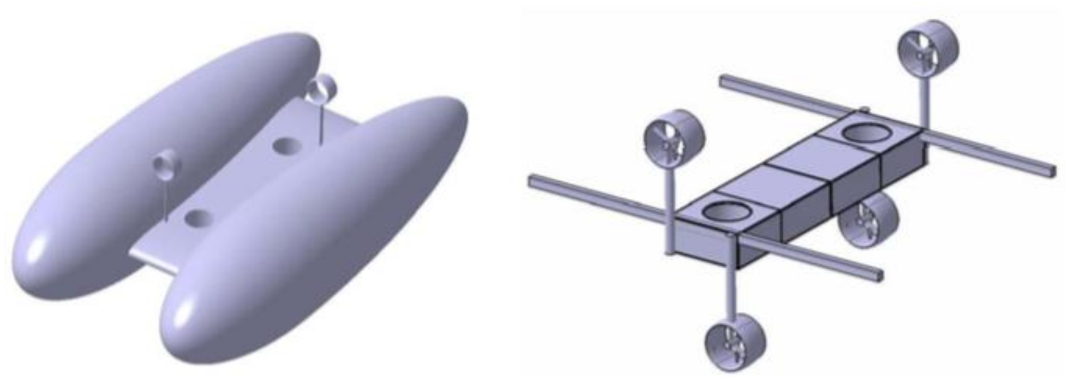
- In hovering, total lift is the combination of aerostatic lift from helium buoyancy and propulsive lift from two fixed, ducted propellers in the central structure connecting the two hulls.
- Capable of hovering in head winds of up to 46 knots (85 kph) and side winds of 19 knots (35 kph).
- In forward flight, total lift is the combination of aerostatic lift, propulsive lift and aerodynamic lift from the hull.
- The two fixed vertical axis propellers in the central structure enable steep, rapid climbs and descents.
- The central structure connecting the two hulls can be used to house a voluminous payload.
- The airship has two ballonet systems, one for each hull, but interconnected and controlled by a common pneumatic system. The ballonets allow altitude variations by changing the helium volume without helium loss or shifting the center of buoyancy.
- All propulsors are electrically powered.

The twin-hull airship has less lateral surface area than a conventional airship with a comparable gas volume and lifting capacity. Hence, the twin-hull design is less sensitive to lateral gusts.



Comparison of single and twin-hull airships with comparable gas volumes. Source: Battipede, Lando, Gili & Vercesi, 2004

The basic structure of the semi-rigid, twin-hull design is quite simple. The central structural houses the batteries, avionics and communications systems, two fixed vertical thrusters, the attachments and controls for the four vectorable thrusters, and the spars for attaching the two hulls



Nautilus twin-hull airship and rigid frame counterpart.
Source: Battipede, Lando, Gili & Vercesi, 2004

The flight control system is fully automatic, fly-by-wire, with an autopilot feature to maintain steady-state flight conditions and follow a specific flight path. Due to the intrinsic instability of the hull, a stability augmentation system was designed to achieve the desired flight characteristics, which enable the airship to be piloted using a classic helicopter-type command architecture, with a throttle lever, a stick and a group control device. The means for implementing speed, pitch, roll and yaw controls using the four vectorable thrusters are shown in the following diagrams.

In their 2004 conclusions, Battipede, Lando, Gili & Vercesi report:

> "All the tests on the flight simulator confirm the maneuvering capabilities and the remarkable performance foreseen during design phase of the Nautilus vehicle."

Longitudinal control determines airship forward thrust from all four propellers (two top & two bottom). Pitch is controlled by the differential thrust of the upper set relative to the lower set of propellers.

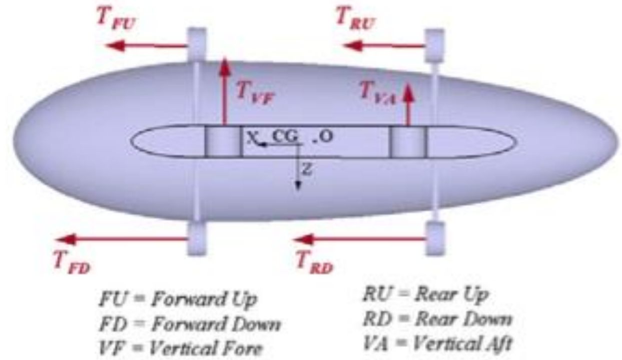


Figure 3: The longitudinal control law.

Roll is controlled by the cross differential rotation of the two upper thrust vectoring propellers relative to the two bottom propellers.

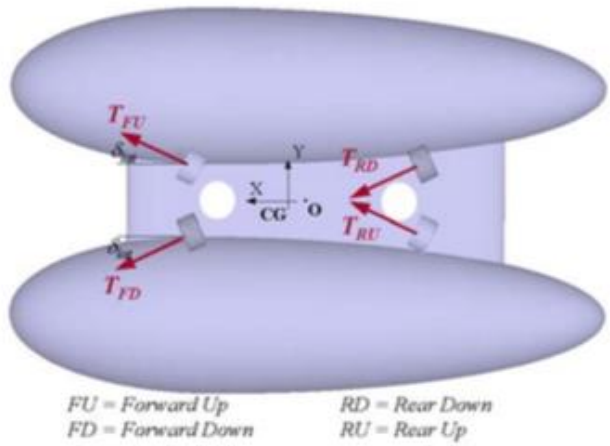


Figure 4: The lateral control law.

Yaw is controlled by the differential rotation of the front propellers (one top, one bottom) relative to the rear propellers (one top, one bottom)

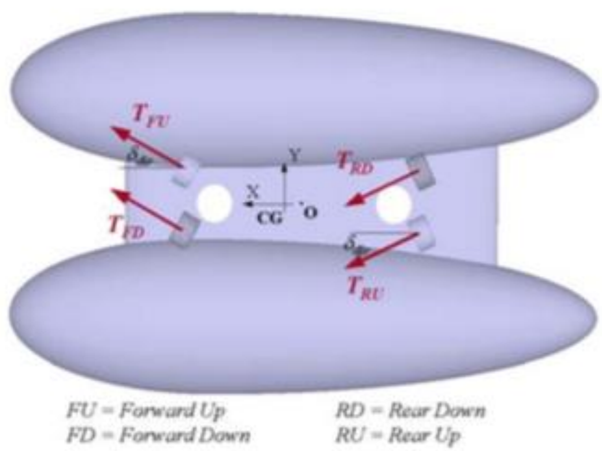
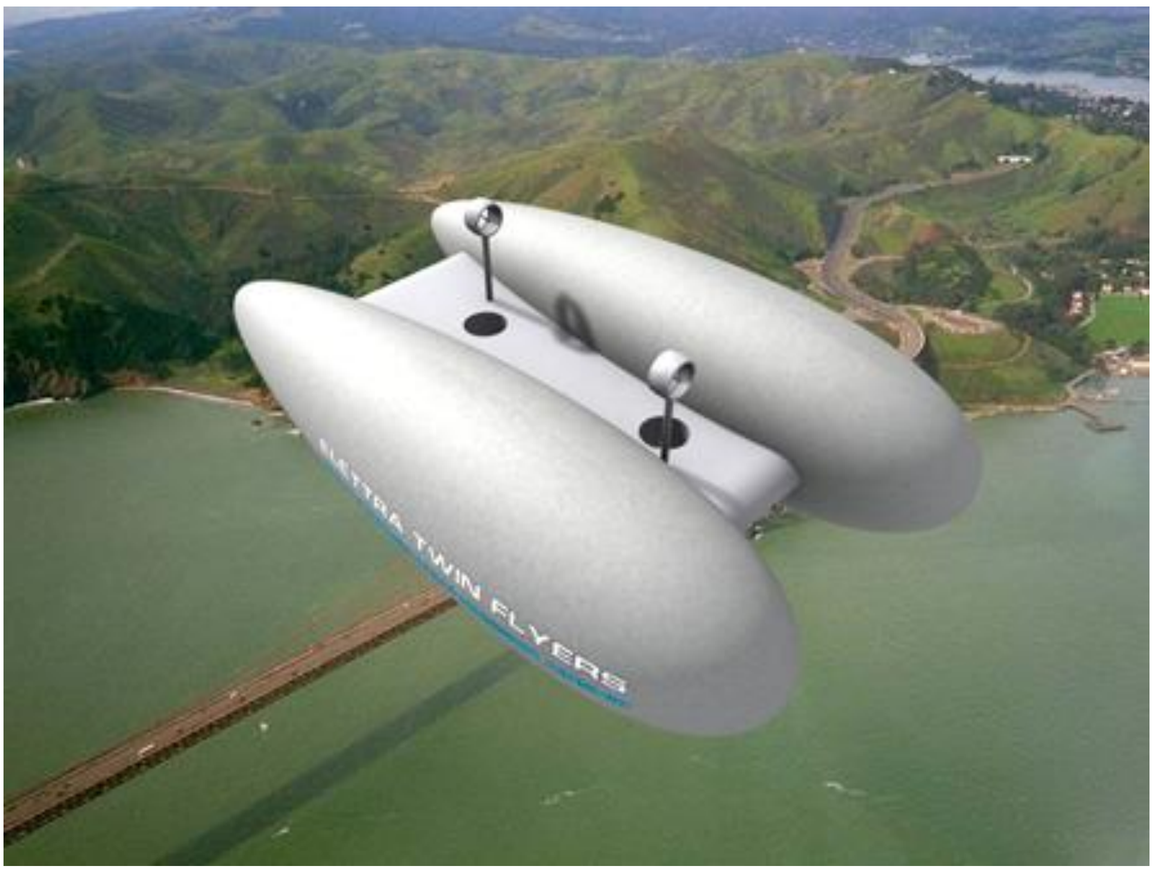


Figure 5: The directional control law.

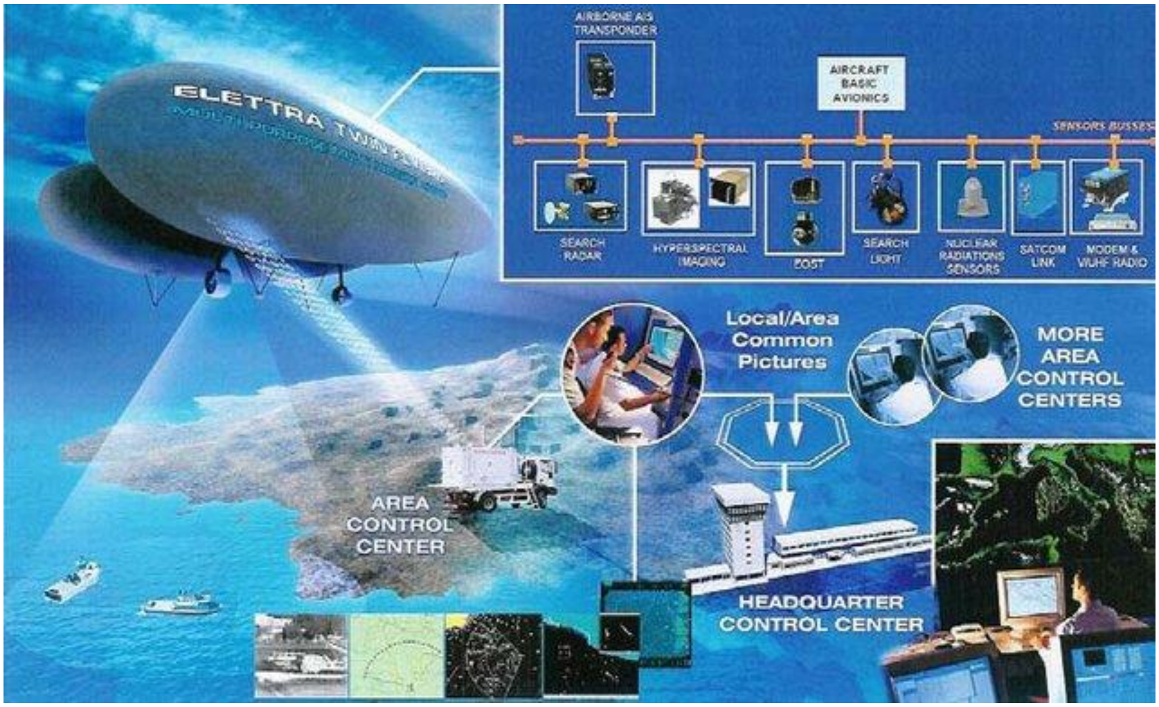
Controlling the Nautilus twin-hull airship with thrust vectoring.
Source: Battipede, Lando, Gili & Vercesi, 2004

In 2005, Battipede, Gili and Lando reported on the development of a sub-scale twin-body prototype in their paper, "Prototype Assembling of the Nautilus Remotely-Piloted Lighter-Than-Air Platform." I have not been able to find any evidence that this prototype ever flew.

By 2005 the design had evolved into a low-speed, low-altitude advanced unmanned platform, now named Elettra Twin Flyers (ETF), which was intended for reconnaissance, monitoring and telecommunication mission for military and civilian users. The full-scale airship was to be 26 m (85 feet) long, 16 m (52.5 feet) wide and 9 m (30 feet) high.



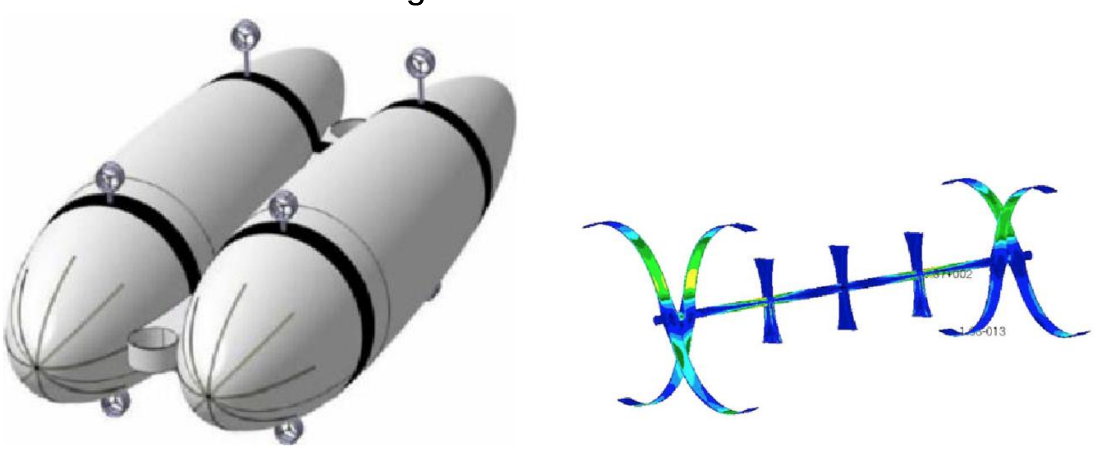
Rendering of an Elettra Twin Flyers (ETF) in flight. Source: Aeronautical and Space Department, Politecnico di Torino, 2005



Elettra Twin Flyers (ETF) ground station. Source: Aeronautical and Space Department, Politecnico di Torino, 2005

4. Further evolution of the Elettra Twin Flyers design

In 2009, the design team developed an alternate closely-spaced twin hull design and mono-hull configurations formed by drawing together and uniting the two hulls and replacing the central structure with an exoskeletal, load-bearing structure. In all cases, the relative positions and function of the vectoring and fixed thrusters was retained.

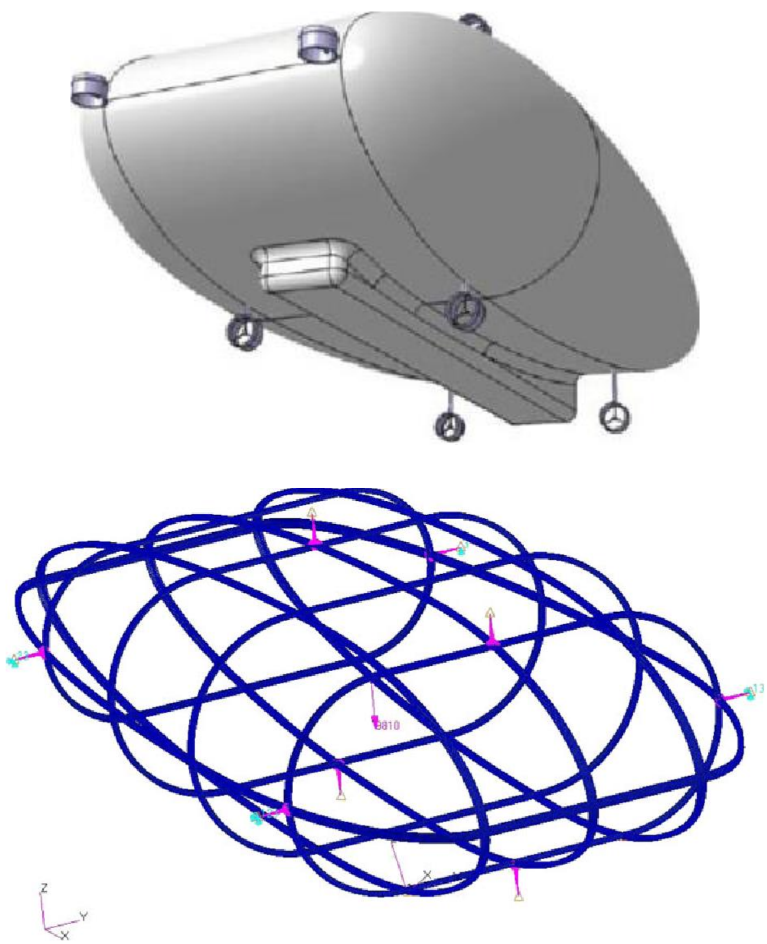


Elettra Twin Flyers closely spaced twin hull airship (left) and exoskeleton (right). Source: Cappadona, Lecca, Vazzola, Gili, Farina & Surace, 2009

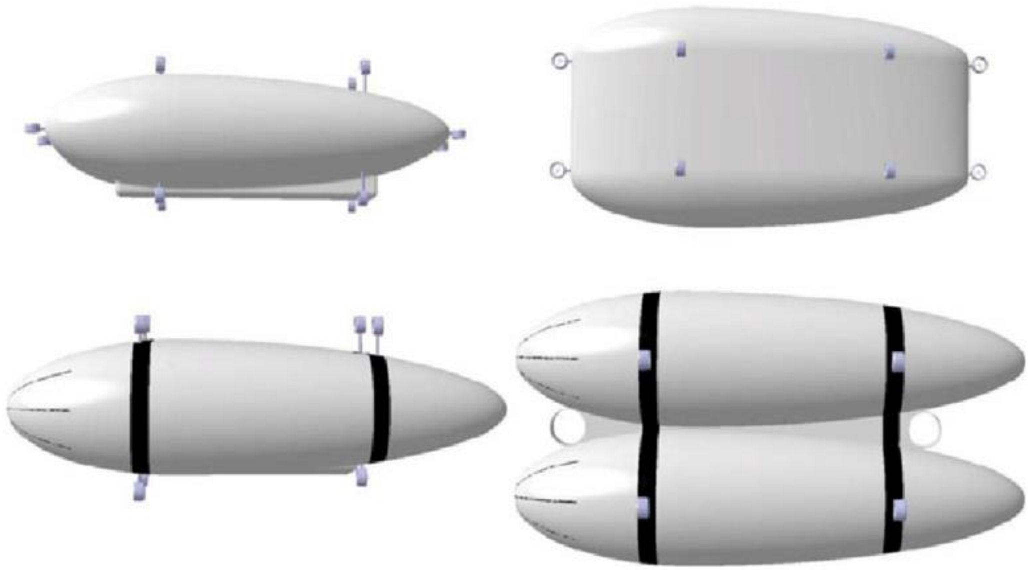
The principal advantage of the monohull exoskeletal design was that, for an equivalent vehicle size, the helium volume increased by about 20%. This translated to a payload increase or a decrease in the size of the airship needed for a particular mission payload.

This interesting design evolution is described in two papers: “Innovative Unmanned Airship Structural Analysis: Dual-Hull and Exoskeletal Configurations” (2009) and “Structural and Aerodynamics Analysis on Different Architectures for the Elettra Twin Flyer Prototype” (2013).

The first iteration of the monohull Elettra Twin Flyers had a complex exoskeleton, with two fixed vertical thrusters at the bow and two more at the stern, as shown below.



Elettra Twin Flyers monohull (the “second design”) and revised exoskeleton. Source: Battipede, Gili & Vazzola, 2009



Comparison of two Elettra Twin Flyers configurations: monohull (top) and closely spaced twin hull (bottom). Source: Battipede, Gili & Vazzola, 2013

The final iteration had a simpler exoskeleton and preserved the original number and positioning of the fixed vertical thrusters and vectoring propulsors.

Elettra Twin Flyers monohull (the "third design") showing details of the exoskeleton. Source: Cappadona, Lecca, Vazzola, Gili, Farina & Surace, 2009

The authors report:

> "In summary, the cost function reveals that the structural and financial advantages of the dual-hull design are roughly balanced by the aerodynamic benefits of the exoskeletal

design. As such, a third design (shown above), is in the development stage, which will unite the aerodynamic advantages of the exoskeletal design with the construction benefits of the dual-hull: Illustrated are the internal cables (for structural loads) and supports (to maintain the position and form of the membrane) together with the load-bay (for the avionics, power systems, payload etc.). A robust longitudinal keel has been introduced, this being the sole rigid structural element, on which act all the loads in the system, including propulsive and aerodynamic forces and buoyancy. The command and control systems are to remain unchanged."

Since 2013, it appears that there has been no further development of the Elettra Twin Flyers.

5. For additional information

- M. Battipede & P. Vercesi, "Design Characteristics of a Non Conventional Thrust Vectored Airship," Semantic Scholar, June 2003: https://pdfs.semanticscholar.org/d1fc/f0d76c911a7ca2280135ffcca7d89bc50ac1.pdf
- M. Battipede, M. Lando, P. Gili & P. Vercesi, "Peculiar Performance of a New Lighter-Than-Air Platform for Monitoring," AIAA 4th Aviation Technology, Integration and Operations (ATIO) Forum, September 2004: https://www.researchgate.net/publication/268571619_Peculiar_Performance_of_a_New_Lighter-Than-Air_Platform_for_Monitoring
- M. Battipede, P. Gili and M. Lando, "Prototype Assembling of the Nautilus Remotely-Piloted Lighter-Than-Air Platform," AIAA 5th ATIO and16th Lighter-Than-Air Sys Tech. and Balloon Systems Conferences, September 2005: https://www.researchgate.net/publication/268571369_Prototype_Assembling_of_the_Nautilus_Remotely-Piloted_Lighter-Than-Air_Platform
- A. Cappadona, R. Lecca, M. Vazzola, P. Gili, P. Farina, and C. Surace, "Innovative Unmanned Airship Structural Analysis: Dual-Hull and Exoskeletal Configurations," Journal of Physics Conference Series 181(1):012097, August 2009:

https://www.researchgate.net/publication/231107344_Innovative_Unmanned_Airship_Structural_Analysis_Dual-Hull_and_Exoskeletal_Configurations

- M. Battipede, P. Gili, M. Vazzola, “Structural and Aerodynamics Analysis on Different Architectures for the Elettra Twin Flyer Prototype,” Journal of Intelligent & Robotic Systems, DOI:10.1007/s10846-013-9823-9, 2013: https://iris.polito.it/retrieve/handle/11583/2514901/60676/Structural%20and%20Aerodynamics%20Analysis%20on%20Different.pdf

6. Additional patents

- US7350746B2, “Dual hull airship controlled by thrust vectoring,” filed 11 August 2003, granted 1 April 2008, assigned to Nautilus SpA, Politechnico di Torino: https://patents.google.com/patent/US7350746B2/en?oq=7350746