FlyWin SA – autonomous hydrogen lift gas cargo airships

Peter Lobner, 11 February 2022

1. Introduction

FlyWin SA is a small, privately-held firm founded in Liège, Belgium in 2013 by Laurent Minguet with the goal of developing a practical remotely-piloted cargo airship that uses hydrogen lifting gas and can transport 20 metric ton (22 ton) standard (intermodal) shipping containers while operating with zero carbon emissions. The firm was funded from 2016 to 2019 by venture capital, with an initial investment of 1,000,000 €, largely financed by the Walloon Region. The first step was to use this initial investment to develop and fly a subscale demonstrator airship to validate the basic design and materials planned for the larger operational cargo airship.

The demonstration airship project was a collaboration among the following organizations:

- FlyWin: Project coordinator
- GDTech (https://www.gdtech.eu): Structural design
- Deltatec (https://www.deltatec.be): Control laws, intelligent software
- Université catholique de Louvain (https://uclouvain.be/en/index.html): Aerodynamic model
- UCL Université Libre de Bruxelles (https://www.ulb.be/en): Hydrogen gas management

The FlyWin LinkedIn site includes a short video (in French) on their airship, at the following link:
https://www.linkedin.com/company/flywin/videos/

I am grateful to FlyWin SA for their thoughtful input for this article.

2. The subscale demonstrator

The subscale demonstrator is a remotely piloted rigid airship that is designed for vertical takeoff and landing (VTOL), stationary flight and cruising flight. The airship has a 15.7 m (51.5 ft) long exoskeleton hull assembled from small diameter carbon fiber tubes. The longitudinal structure is comprised of nine segmented tubes that terminate in rigid nose and tail caps. The transverse structure is comprised of eight rings that intersect the longitudinal structural tubes at 3-D printed nodes, where they connect to form a lightweight, rigid structure that is maintained in tension by cross-sectional wires.

The wire supports for the hull structure create three internal volumes, or compartments, for locating the hydrogen lifting gas cells. The lifting gas cell shape conforms closely to the shape formed by the tubular hull structural members. The central lift gas cell is the largest, with smaller lift gas cells at the bow and stern. There are no ballonets.

The lifting gas cells were made from an aluminized packaging film named EVAL™, which is an ethylene vinyl alcohol copolymer (EVOH) resin that has superior gas barrier properties. EVAL™ film product information on is available here:
https://www.kuraray.com/products/eval

A large, sensor-operated pressure relief valve (PRV) provides overpressure protection for the lift gas cells. Another, more precise, remotely-controlled PRV, with a smaller mass flow rate, is used to control altitude and land the airship. The valves and overpressure sensor are 3-D printed.

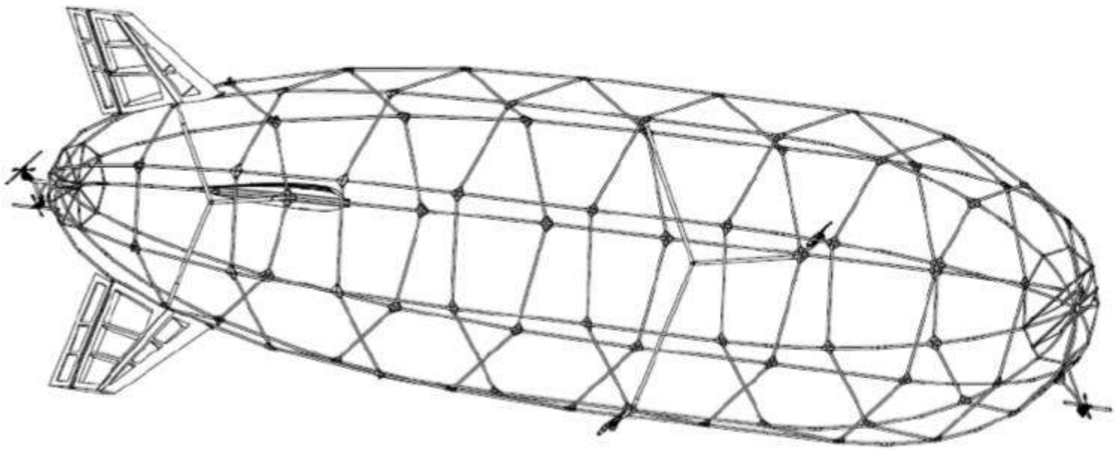
Five electric motors provide propulsion and control. There are two flank propellers for propulsion. Flight control is provided by one vectoring bow propeller and two stern propellers (one vectoring up/down for pitch control and for propulsion, the other is fixed for lateral control). Batteries are the power source for the demonstrator airship.

The demonstrator was built in a hangar at a military airfield in Louvain-la-Neuve, a village in Wallonia located 30 km (18.6 miles) southeast of Brussels.

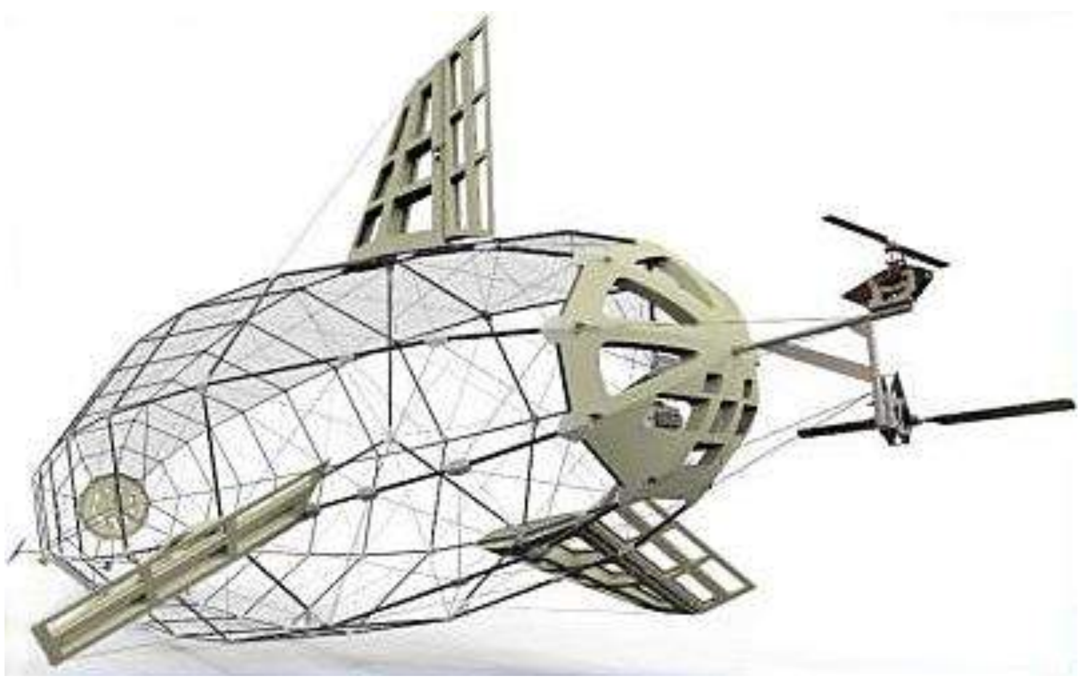
FlyWin subscale demonstrator airship during construction. Note the nose and tail caps attached to the carbon composite tubular rigid airframe. Source: RTBF - Erik Dagonnier (8 March 2018)

General characteristics of the FlyWin sub-scale demonstrator airship

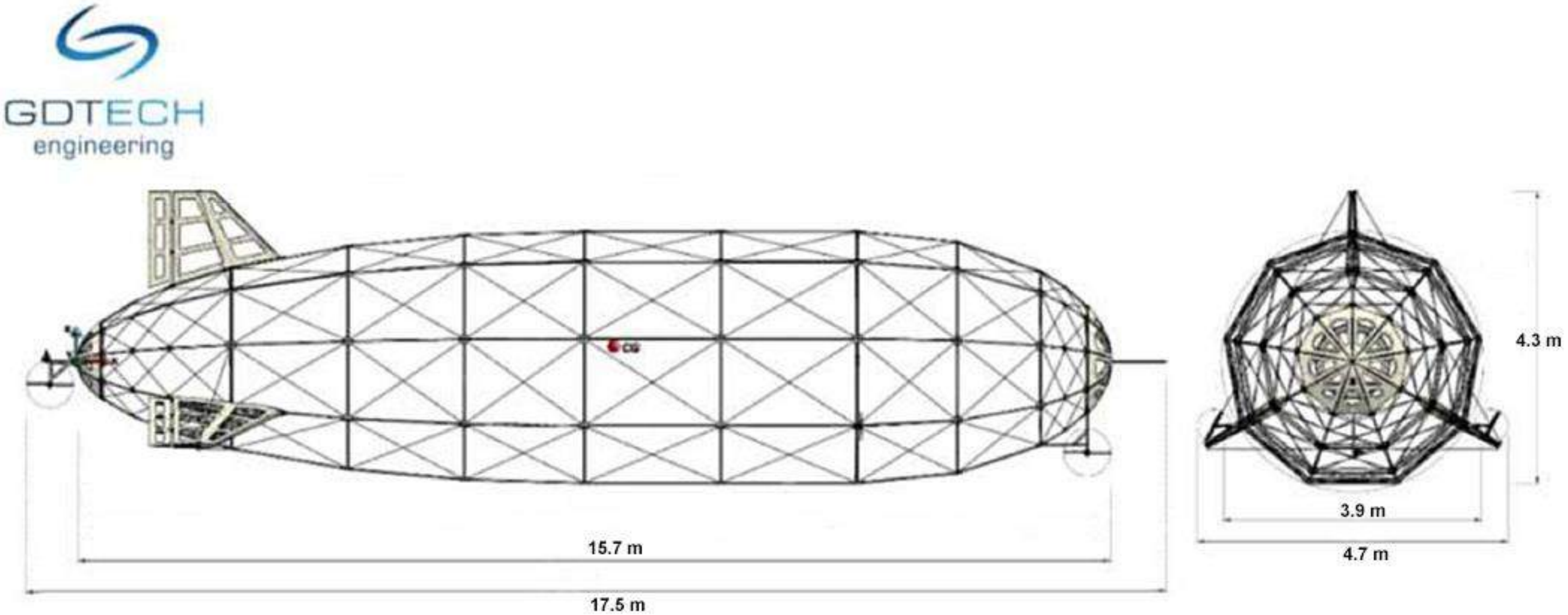
Parameter	FlyWin subscale demonstrator airship
Length, envelope	15.7 m (51.5 ft)
Length, overall	17.5 m (57.4 ft)
Diameter, envelope	3.9 m (12.8 ft)
Width, overall	4.7 m (15.4 ft)
Height, overall	4.3 m (14.1 ft)
Lifting gas volume	123.5 m^3 (4,361 ft^3) in three lift gas cells
Lifting gas	Hydrogen
Structural weight	About 125 kg (275.6 lb)
Propulsion & dynamic flight control	5 electric motors, each driving a 2-bladed propeller: • 1 x vectoring bow propeller • 2 x vectoring flank propellers • 2 x stern propellers (1 for propulsion and vectoring up/down for pitch control, 1 fixed lateral thruster)
Aerodynamic flight controls	Inverted-Y tail fins with movable control surfaces



FlyWin demonstrator airship oblique view showing the carbon composite tubular structure of the rigid airframe. Note the additional inverted Y-shaped support structures for the two flank-mounted propellers and the tail conrol surfaces.
Source: DOI: 10.13009/EUCASS2017-382



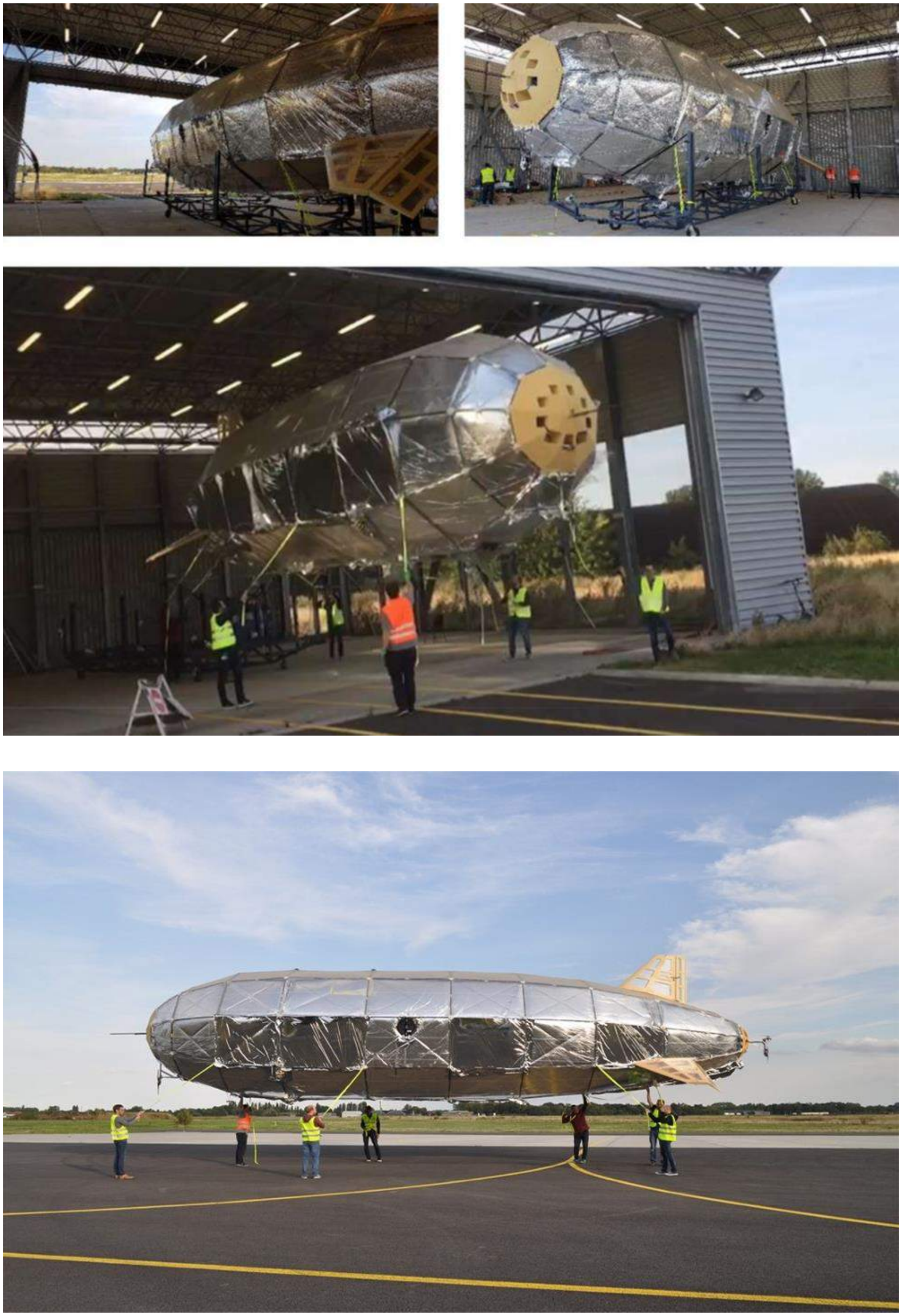
FlyWin demonstrator airship stern quarter view showing details of the aerodynamic fins and stern-mounted propellers: one vectoring up/down, the other fixed for lateral control.
Source: Pascal Pluvinage via LinkedIn



FlyWin demonstrator airship rigid structure, profile and bow views.
The airship's center of gravity is at the red dot in the profile view.
Source: adapted from M. Bruyneel, et al. (2019)

FlyWin project leader Nicholas Caeymaex reported that the team conducted several float (buoyancy) tests with hydrogen lifting gas, first inside the hangar and then outdoors on the taxiway. During these successful tests, the airship exhibited good behavior and lift while under the control of a ground crew at all times. Free flight was not attempted after the subsystem and float testing programs revealed a number of technical issues with motors, vibrations, controls, membranes and hydrogen leakage, all of which can be corrected.

FlyWin subscale demonstrator airship indoor float test.
Source, both photos: FlyWin SA

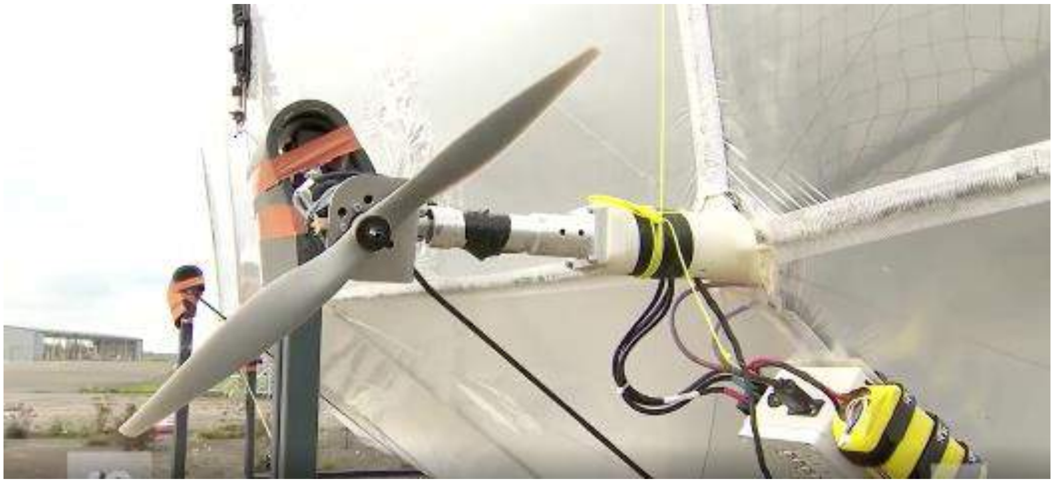


FlyWin subscale demonstrator airship moving out of its hangar and conducting the outdoor float test.
Source: Colin Delfosse photos via detours (12 April 2019)

After the float tests, the subscale demonstrator was placed in outdoor storage while FlyWin SA seeks additional funding for the next phase of their hydrogen lifting gas airship development program.

FlyWin demonstrator in its cradle, bow quarter view, with bow propeller removed. Source: FlyWin SA

FlyWin demonstrator stern view, with stern propellers removed. Source: Screenshot from FlyWin LinkedIn video



FlyWin demonstrator flank propeller, supported from a node in the rigid composite frame. Source: Screenshot from LinkedIn video

3. Hydrogen safety case

FlyWin and their safety partner, Star Engineering Toulouse, prepared a strong safety case document for their planned use of hydrogen lifting gas in an unmanned cargo airship. The safety case document includes full details on the airship technical design, risk mitigation measures, and airship deployment plans. After presenting the safety case to Belgian authorities, FlyWin obtained a Permit to Fly, which will enable them to deploy their airship RPAS / UAV (remotely piloted aerial system / unmanned aerial vehicle) in the future.

Nicholas Caeymaex commented on this milestone: “As you can imagine, it’s was tricky to defend a full H2 UAV but it was a success to have these authorizations.”

4. The next step

As of December 2021, FlyWin was seeking 1,000,000 € in a second round of funding to develop and fly a second sub-scale demonstrator airship with the following goals:

- Correct the technical issues identified during the test program for the first sub-scale demonstrator
- Introduce a fuel cell power system
- Conduct free flights and develop a Conduct of Operations (ConOps) for future operational flights

Rendering of a FlyWin demonstrator in free flight.
Source: DOI: 10.13009/EUCASS2017-382

5. The longer-term goals

FlyWin’s longer-term plan is to develop a full-scale hydrogen airship prototype that can be certified by the European Union Aviation Safety Agency (EASA) and the US Federal Aviation Administration (FAA) for serial production.

An initial target market could be North Atlantic cargo transport, with airships operating autonomously and navigating a worldwide cargo transportation network without an on-board pilot. FlyWin expects that the cost of cargo transportation by a hydrogen airship will be one-third the cost of current fixed-wing air cargo transportation.

In 2018, the performance goals for the first operational hydrogen airships were to transport a standard 20 metric ton (22 ton) shipping container a distance of 6,500 kilometers (4,039 miles) at a speed of about 100 to 120 kph (62 to 74.5 mph). The airship would be about 80 m (262 ft) long. Development time with adequate funding was expected to be about eight years.

The design and performance goals are being further developed and, in 2021, the cargo target is to carry two 40 ft (12.2 m) standard (intermodal) shipping containers.

6. For more information

- Milova Praskovia, et al., "FlyWin, a H_2-lifting gas airship demonstrator," 7th European Conference for Aeronautics and Space Sciences (EUCASS), DOI: 10.13009/EUCASS2017-382, 2017: https://www.eucass.eu/doi/EUCASS2017-382.pdf
- Erik Dagonnier, "Liège-based company FlyWin is developing an airship prototype for air freight," (in French), rtbf.com, 8 March 2018: https://www.rtbf.be/info/regions/liege/detail_le-liegeois-flywin-developpe-un-prototype-de-ballon-dirigeable-pour-le-fret-aerien?id=9860561
- "A view of the Flywin #airship demonstrator," Ballonics, Twitter, 9 June 2018: https://twitter.com/ballonics/status/1005373129508696064
- M. Bruyneel, et al., "Design and sizing of an airship supported by CAE," NAFEMS World Congress, June 17-20, 2019, Québec City, Canada: https://orbi.uliege.be/bitstream/2268/242017/1/Bruyneel_C146.pdf

<u>Other *Modern Airships* articles</u>

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