Anumá Aerospace, LLC – vacuum airships

Peter Lobner, 11 February 2022

1. Introduction

Anumá Aerospace, LLC was founded in 2018 in Raleigh, North Carolina by Diana and James Little and incorporated in Delaware on 26 May 2021. The firm's mission is to "dramatically lower the carbon footprint of the cargo industry by developing solar-electric cargo aircraft capable of providing global, point-to-point, VTOL cargo delivery with zero emissions, and operating independently of underlying infrastructure, such as highways, bridges, rail lines, ports, etc." The company's website is here: https://www.anumaaerospace.com

Anumá's cargo aircraft concept is a novel vacuum airship in which aerostatic lift is generated by lifting cells containing air at a partial vacuum. These vacuum lifting cells can hold air at a very low pressure, with a density that is comparable to the densities of helium or hydrogen at standard temperature and pressure (STP).

It turns out that STP is less "S" (standard) than you might suspect, so for this article, I chose the Federal Aviation Administration (FAA) definition of STP, with T = 15ºC (59ºF) and P = 101.3 kPa (1 atmosphere, 760 mm mercury). The following table summarizes the lift at sea level available from helium and hydrogen at STP and air at partial vacuums of 0.1 and 0.01 atmosphere.

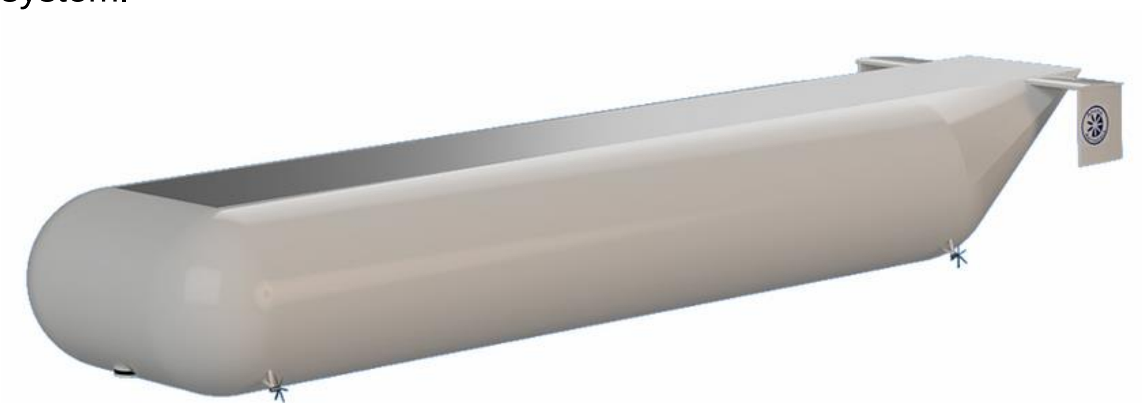
Gas	**Condition**	**Density (kg/m^3)**	**Lift (kg/ m^3) ***
Dry air	STP	1.22	0
Helium	STP	0.166	1.054
Hydrogen	STP	0.0841	1.136
Dry air	0.1 atm, 15ºC	0.129	1.091
Dry air	0.01 atm, 15ºC	0.013	1.207
-	Perfect vacuum	0	1.22

** Lift based on 1 m^3 of gas at STP or air at partial vacuum replacing 1 m^3 of air at STP.*

At sea level, air at a partial vacuum of 0.1 atmosphere can generate about the same amount of lift as helium or hydrogen, both of which can be contained aboard an airship in lightweight, gas-impermeable cells at atmospheric pressure. In contrast, the partial vacuum will be contained in a solid, rigid structure designed to maintain constant volume regardless of the variable internal vacuum condition. A key challenge for a vacuum airship is to have vacuum lifting cells that are light enough to maintain the desired vacuum conditions and still be able to generate usable lift. The best chance for meeting this challenge is at lower altitudes.

In 2019, researchers A. Akhmeteli & A.*V. Gavrilin* concluded "a lighter-than-air rigid vacuum balloon can theoretically be built using commercially available material ….A prototype vacuum balloon would also become the first ever lighter-than-air solid."

Anumá Aerospace has taken on this challenge and patented their approach for building a rigid vacuum airship, which will contain many relatively small vacuum lifting cells that are connected via a vacuum control system to function as a variable buoyancy, fixed volume system.



General arrangement of the vacuum airship.
Source: Anumá Aerospace

This vacuum airship will have the following primary features:

- **Controllable vacuum lift**: Inherently self-ballasting by precisely adjusting the level of vacuum. This eliminates the need for lifting gas, air ballonets, engine exhaust gas water recovery systems, ballast and more.

- **Vertical takeoff and landing (VTOL):** Capable of operating from nearly any large open space.
- **Zero carbon emissions:** Powered by a hybrid solar photovoltaic (PV) system, with a large, thin-film PV array on the hull for power generation and batteries or regenerative fuel cells for energy storage to support operations at night.
- **Long range and endurance:** Able to travel non-stop to nearly anywhere on the globe.
- **Large cargo bay:** Designed with bulk item transfer in mind, with the ability to move large items, such as mining and construction equipment, rocket and aircraft parts, military equipment and wind turbine components, in and out of remote areas.
- **Simplicity:** All-electric. No engine fuel systems, hydraulic systems, or auxiliary power units.
- **Low direct operating costs:** No fossil fuel cost, no expensive, non-renewable lifting gas (helium), low maintenance cost.

2. The vacuum lifting cell patent

On 7 April 2020, Anumá Aerospace filed patent application US2021/0309337A1, “System for the structure, control, and energy management of low-pressure cells for aerostatic lift,” with Anumá’s Chief Technology Officer, James Little, identified as the inventor. The basic invention is described in the patent application as follows:

> “A structural system for lifting cells, constructed of modular, lightweight framing supporting thin, lightweight, single-ply or laminated, air-impermeable membranes, that maintain near constant-volume under low pressure for aerostatic lift in lighter-than-air aircraft; a system for controlling that aerostatic lift in a single or a plurality of such lifting cells, using electrically-powered vacuum pumps and valves; and a system for recovering electrical energy expended during ascent by using the inflow of air into the lifting cells during descent to generate electricity.”

Constant-volume, variable-buoyancy lifting cells

This patent describes a very lightweight, constant-volume, variable-buoyancy lifting cell consisting of a nearly spherical (icosahedral, 20 triangular sides), modular geodesic frame that supports an air-impermeable membrane. When filled with air at ambient conditions, the lifting cell is heavier-than-air. When partially evacuated of air, the gross weight of the lifting cell decreases and the cell can become buoyant.

The icosahedral geodesic frame (13) shown in patent Figure 4 is assembled from arched struts (14), each reinforced by cable tendons (15), and connected to 5- and 6-point hubs (11, 12). The arched struts are manufactured with an arch that matches the desired diameter of the lifting cell.

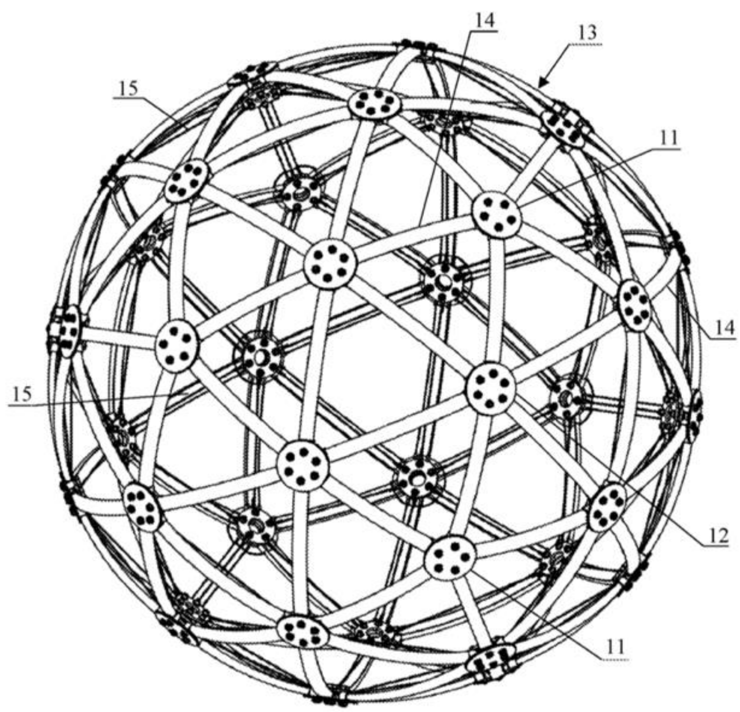


Fig. 4

Source: Patent US20210309337A1, Fig. 4

The geodesic frame is sealed within with an air-impermeable membrane (10), which is held to the frame by a sealing gasket and a cover plate fastened to each frame hub (11, 12). This spherical assembly is the lifting cell (8) shown in patent Figure 3.

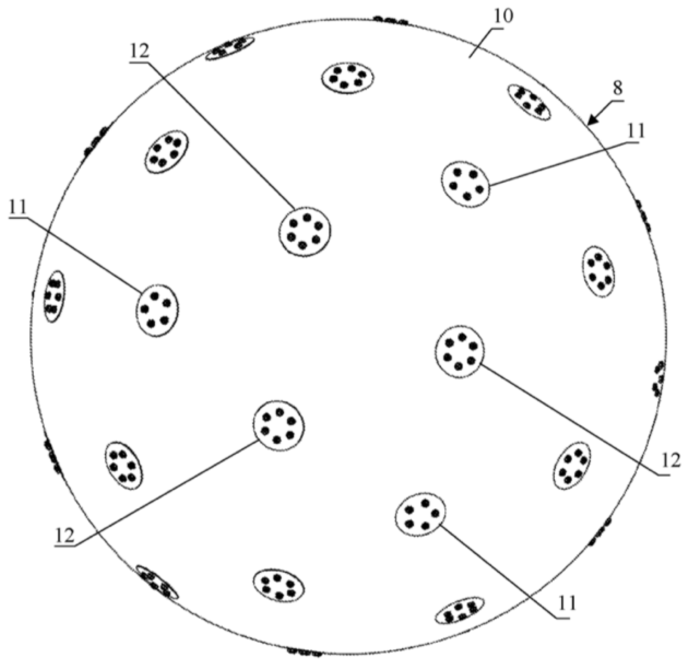


Fig. 3

Exterior view of a variable-buoyancy lifting cell.
Source: Patent US20210309337A1, Fig. 3

An air-filled lifting cell is a heavier-than-air object. When a cell is partially evacuated, creating a partial vacuum with a low enough gas density on the inside, it will become lighter-than-air. An airship will have many lifting cells secured within its hull, interconnected via a vacuum control system.

Buoyancy control system

An external buoyancy control system connected to each lifting cell in an airship can partially evacuate air from the lifting cells, making each cell lighter-than-air, enabling the entire airship to take off vertically and ascend to cruise altitude. The external system also can introduce ambient air into buoyant lifting cells, decreasing their collective buoyancy, enabling an airship descend, land, and self-ballast to be heavier-than-air for stability on the ground. In flight, differential control of lifting cells will allow the pilot to adjust the trim and roll angles of the airship.

A. Ascent control

Patent Figure 1 shows a scroll compressor (6, a vacuum pump) taking a suction on a lifting cell (8) to draw a partial vacuum in the cell and discharge to the atmosphere via an open outflow control valve (7). The left-hand side of the diagram shows the photovoltaic / battery electric power system that supplies the motor-generator (5) that drives the scroll compressor.

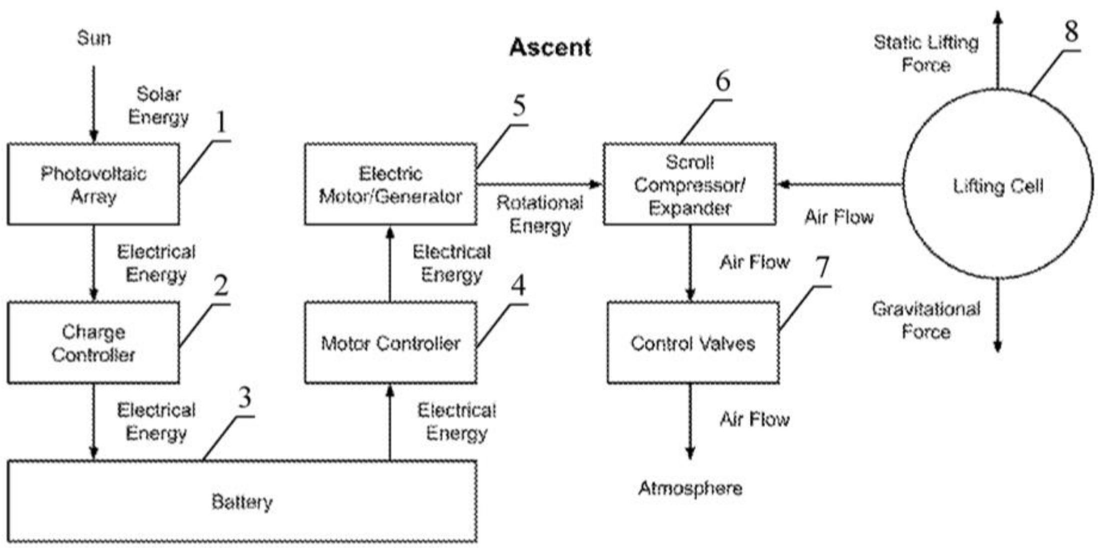


Fig. 1

Airship systems required for variable buoyancy control during ascent.
Source: Patent US20210309337A1, Fig. 1

When the lifting cell is at the desired partial vacuum, and the airship is at the desired overall buoyancy for ascent, the scroll compressor is turned off and the outflow control valve is closed. The airship will rise to an altitude where it is at neutral buoyancy.

As altitude increases and ambient air density decreases, a vacuum lifting cell is able to generate less usable lift. A higher altitude can be reached by increasing the vacuum (decreasing the air density) in the lifting cell, up to the mechanical design limits of the system. This will be a "vacuum altitude" that is analogous to the maximum "pressure altitude" that a helium airship can reach.

B. Descent control

Patent Figure 2 shows ambient air being supplied to a lifting cell via inflow control valve (7) and the scroll compressor (6), which is few-wheeling in the incoming pressure-driven airflow and is driving the motor generator (5). The left-hand side of the diagram shows the electric power system recovering energy from the motor-generator and using it to recharge the battery (3).

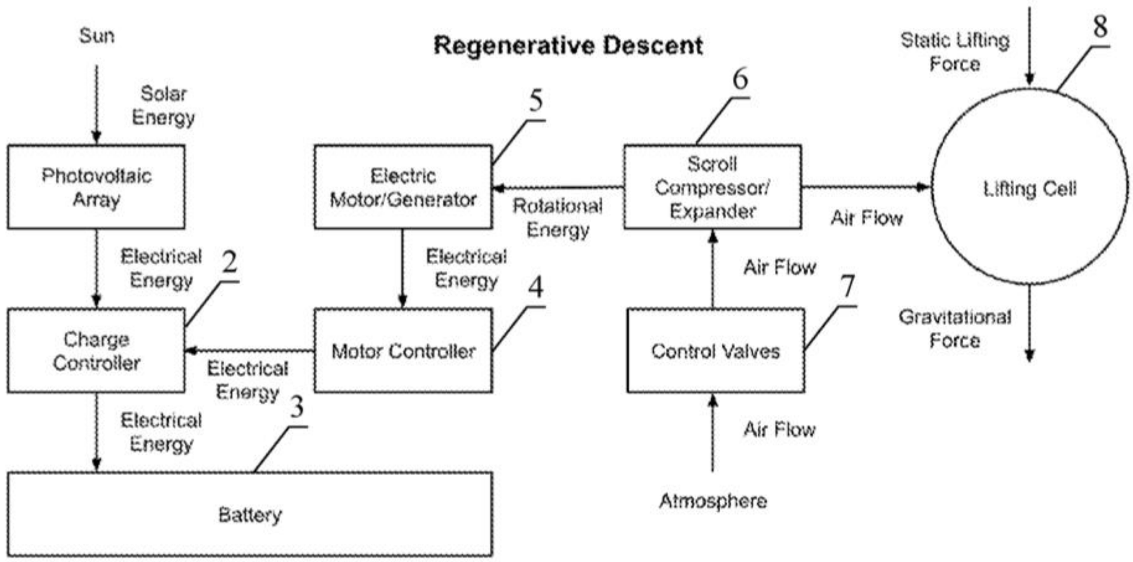


Fig. 2

When the lifting cell is at the desired partial vacuum, and the airship is at the desired overall buoyancy for descent, the inflow control valve is closed. The aircraft would descend under the influence of gravity until it again is at neutral buoyancy or lands on the ground.

The descent can be fine-tuned by repeated cycling of the variable buoyancy control system. Final descent during a vertical landing likely will require dynamic thrust from propulsors to precisely control the geo-position of the airship and its orientation in the local wind conditions.

On the ground, the lifting cells can be vented to the atmosphere, resulting in zero aerostatic lift and making ground operations safer, easier, and less costly.

3. Applications

Anumá's vacuum airship is being developed as a long-range heavy lift cargo airship that can directly deliver large items / volumes from point-to-point, bypassing inter-modal transshipment points in traditional supply chains, and thereby improving the overall reliability and timeliness of the supply chains.

Key applications envisioned for Anumá's vacuum airship include:

- Global shipping, linking factories and major distribution centers directly to end-users with zero carbon footprint.
- Rural and remote area service, linking remote, underserved communities with the rest of the world, particularly where other transportation infrastructure does not exist.
- Long-endurance communications and surveillance support for the military and civilian federal, state and local agencies.
- Humanitarian aid, capable of rapidly delivering large volumes of emergency supplies and field facilities, and serving as a temporary solar-powered field generating station.
- Oversized item transport for the mining, aerospace, construction and energy industries, avoiding the difficulties of wide-load shipping on the ground, and expanding the siting opportunities for some very large items (i.e., wind turbines).
- Airborne fulfillment center (AFC), similar in concept to the autonomous flying warehouses proposed by Amazon and Walmart.

4. The future

Anumá has not announced a development schedule for their vacuum airship.

Their plans likely will include a sub-scale, proof-of-concept demonstrator. Regardless of its scale, it will be an important milestone when a lighter-than-air solid object floats in the air by itself.

5. For more information

- Philip Ball, “Could vacuum airships go from steampunk fantasy to 21st century skies?” New Scientist, 18 December 2019: https://www.newscientist.com/article/mg24432611-000-could-vacuum-airships-go-from-steampunk-fantasy-to-21st-century-skies/
- “Vacuum Airships: Reality or Steampunk Fantasy?” Airship Flamel, 23 July 2021: https://airshipflamel.com/2021/07/23/vacuum-airships-reality-or-steampunk-fantasy/
- B.E. Jenett, C.E. Gregg & K.C. Cheung, " Discrete Lattice Material Vacuum Airship,” Massachusetts Institute of Technology & NASA Ames Research Center: http://cba.mit.edu/docs/papers/19.01.vacuum.pdf
- A. Akhmeteli & A.V. Gavrilin, ” Vacuum Balloon – a 350-Year-Old Dream,” LTASolid, Inc. & National High Magnetic Field Laboratory, 2019: https://arxiv.org/pdf/1903.05171.pdf

Patent

- US2021/0309337A1, “System for the structure, control, and energy management of low-pressure cells for aerostatic lift;” Inventor: James Little; Filed: 7 April 2020; Status: pending; Assigned to: Anumá Aerospace, LLC: https://patents.google.com/patent/US20210309337A1/en?q=Anumá+Aerospace&oq=Anumá+Aerospace

Other *Modern Airships* articles

- *Modern Airships - Part 1*: https://lynceans.org/all-posts/modern-airships-part-1/
- *Modern Airships - Part 2:* https://lynceans.org/all-posts/modern-airships-part-2/
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