DESIGN TRENDS AND GLOBAL DEVELOPMENTS IN MODERN LTA VEHICLES

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Abstract

Designs trends of modern LTA vehicles, which are being developed around the world, are presented. These include: semi-rigid structure with conventional aerodynamic shaping, as well as twin hull structure; propulsion using marine diesel engines and gas turbines, coupled with vectorable propellers\fans for cruise/lift augmentation; bow and stern thrusters for low speed maneuverability; FBW\fiber optic control paths and automatic control systems; composite materials which enhance strength-to-weight ratio to improve performance and safety.

The paper describes four significant developments around the world which include: heavy lift cargo transporter being developed by CargoLifter in Germany; tethered aerostat for on-station surveillance being developed by Lockheed-Martin in United States; a hybrid vehicle which uses both buoyant and aerodynamic lift and air cushion landing gear being developed by SkyCat Technologies of United States; and solar powered stratospheric LTA platform for communication being developed in Japan.

Highlights of these design trends and ongoing vehicle developments are presented in the paper with available technical details and results.

1 Introduction

During last 30 years, LTA vehicles have been used primarily for surveillance and advertisement. However, the application of the state-of-art technologies could bring them back to the transportation market. Nowadays, several companies and national agencies around the world are performing research in order to find an optimum market for airships. And also, the economical viability of airships is being inspected. As an example, Ref.[1] concludes that more attention needs to be given early in the airship design phase to those engineering factors that can lead to reduce the life cycle cost. These include low speed maneuverability, fuel economy, manning requirements, and environmental friendliness. The following describes ongoing global developments in this regard.

2 Vehicles

2.1 CargoLifter CL-160, Heavy Lift Cargo Transporter

The CargoLifter CL 160 is a semi-rigid airship being developed by CargoLifter AG, a German company that plans to build airships capable of carrying enormous loads for the bulk airfreight market. Heavy loads, for example large turbine casings, can be carried directly from the factory to their intended operations location, without the airship touching the ground and almost independently of local infrastructure. The CL 160 will be able to carry payloads weighing up to 160 t, with a volume of up to 3,200 m³, to a range of up to 10,000 km, without the need for airfields or extensive road systems. The CL 160 could also be used in transporting humanitarian and emergency aid – one CL 160 could transport food for 25,750 people for 14 days in a relief program

Fig. 1. CargoLifter CL-160

This vehicle is intended to fill the niche of heavy indivisible cargo transport, especially for transportation of large industrial plants. However, it has a wide range of operational possibilities, which range from on/off-shore operations, to deployment of humanitarian aid. The designers describe it as a “flying crane”, and with a payload of 160 tones, only a few aircrafts, as the Russian An-225, have ever exceeded this cargo capability.

Table 1. Physical characteristics of CargoLifter CL-160

EXTERNAL DIMENSIONS	
Length (m)	260.00
Max Diameter (m)	65.00
Fineness ratio - FR	4.00
Height overall (m)	78.00
Propeller diameter (m)	6.50
INTERNAL DIMENSIONS	
Envelope Volume (m^3)	550000.00
Payload Module Dimensions:	
Length (m)	50.00
Width (m)	8.00
Depth (m)	8.00
Volume (m^3)	3200.00

The structural concept is a semi-rigid keel airship. It is a compromise design between low weight nonrigid blimps and heavy rigid airships. Thus, the semi-rigid configuration has greater strength than non-rigid to withstand higher payload stresses, because of the rigid keel. Moreover, semi-rigid airships are lighter than rigid airships, which allow them to carry a bigger payload.

Table 2. Performance characteristics of CargoLifter CL-160

Max level speed (km/h)	134.00
Cruise Speed (km/h)	105.00
Flight altitude (m)	2000.00
Payload (tonnes)	160.00
Max range (km)	10000.00

Low speed maneuver is a critical point in airship’s performance. And the CargoLifter has to hover up to 100 meter from the ground in order to load/unload the cargo multibox. In order to accomplish this task, the CL-160 has 10 thrusters. It has two-bow/stern lateral propellers that give yawing control at low speed. Moreover, the 6 main propellers are vectorable, in order to get powered lift for STOL capability. It has also a stern mounted propeller, which increases the propeller efficiency with the consequent reduction in required power. A comparison between stern-isolated propeller efficiencies, from a study performed by the University of Stuttgart Ref [2], has a result of η= 1.5 for stern propeller and η= 0.8 for isolated propeller, for fully laminar blades.

2.2 SkyCat™, a hybrid airship

The second concept is the SkyCat. It is being developed in USA by SkyCat Technologies, a subsidiary of the U.K. based company Advanced Technologies Group (ATG), one of the leaders in airship development. This is a hybrid vehicle that uses both lifting gas and aerodynamic lift. It is not lighter-than-air, but has a heaviness of 35 %. That means vehicle has to use powered lift to fly.

Fig. 2. SkyKitten 1, 1/7th scale model of SkyCat™ 20.

Instead of the typical single hull, this vehicle has a tri-lobe structure, as can be seen in fig. 2. This configuration is lifting body that generates the aerodynamic lift needed to overcome the heaviness.

There is a growing interest in LTA industry on diesel engines. This is because it appears to have some advantages for long range, high payload missions. From Ref [3], it is seen that fuel weight is a greater driving parameter for high endurance mission than engine weight. Therefore, the low fuel consumptions of diesel engines can give more room for payload over the same range. Moreover, diesel engines require a considerably lower air/fuel ratio than do turbofans, what produces a greater amount of water when condensing the exhaust gases, for ballast or another use.

Thus, the selection for the propulsion system was four 600 hp diesel engines, two being mounted on each side of the forward hull and two at the aft end of the envelope (two stern mounted propellers). All four engines are configured in ducts with blown vanes to allow vectored thrust for take off/landing/ground handling operation.

Table 3. Physical characteristics of SkyCat^{TM} 20

EXTERNAL DIMENSIONS	
Length (m)	81.30
Width (m)	41.00
Height (m)	23.90
Fineness ratio - FR	2
INTERNAL DIMENSIONS	
Envelope Volume (m^3)	32,000.00
Payload Deck Space:	
Length (m)	22.30
Width (m)	3.10
Height (m)	2.00
Volume (m^3)	138.26

Table 4. Performance characteristics of SkyCat^{TM} 20

Flight altitude (m)	2740.00
Max level speed (KTAS)	80.00
Cruise speed (KTAS)	70.00
Payload (tonnes)	20.00
Max range (km)	7410.00

In order to minimize ground crew requirements for take-off and landing, designers of this vehicle have come up with an innovative idea. An air cushion system has been mounted on the bottom of the envelope. It consists of two longitudinal inflatable air-bags located on each side of the payload module. This system not only reduces the crew required, but it also allows the vehicle to land in almost any kind of terrain, from grass to sand, and even over the water. The system is deflated when in-flight for a clean profile and enhanced all-around visibility.

2.3 Lockheed Martin NE&SS- Akron 420K Tethered Aerostat

Tethered aerostats are blimps that are anchored to the ground by a tether. These are airships built for station keeping and are widely used for surveillance missions. The tether can be used for electrical supply and control signal transmission. Modern tethered aerostats have proven to be safe and reliable platforms for mounting of radar and various other electronics payloads. New applications include military surveillance and mounting of telescopes on high altitude aerostats for enhanced viewing above the effects of the atmosphere. Standard models range in length from 25 to 71 meters with corresponding volumes of 25000 ft^3 to 600,000 ft^3.

For instance, Lockheed Martin Naval Electronics & Surveillance Systems- Akron offers a full line of tethered aerostats: the 56K, 275K, 420K, and 595K (number designates envelope volume in thousands of cubic feet). The 420K, with the Lockheed Martin L-88A radar, is the baseline system for the U.S. southern border Tethered Aerostat Radar System (TARS). Operating at up to 15,000 ft (4570 m), a 420K aerostat radar platform detects objects up to 200 nautical miles (370 km) and stays on station in full accordance with U.S. Air Force operational requirements.

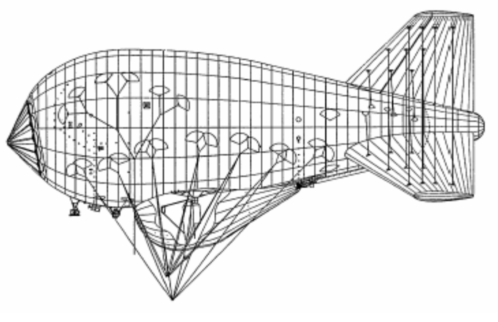

Fig.3. Lockheed Martin NE&SS-Akron 420K tethered aerostat.

The envelope fabric has always been a primarily concern in LTA systems. It has to accomplish several diverse tasks. First, it has to withstand the stresses generated by both the suspended weight and the difference in pressure over the envelope. Secondly, it has to avoid the leakage of helium. And last, but not least, it has to suffer natural extremes such as, ice, wind, snow, a wide range of operating temperatures (from –50° C to 50° C), and UV radiation.

Thus, nowadays, envelope fabric is a laminate, made up of multiple layers of fabric and adhesive or composite films. The 420K fabric is a good example of the new generation laminate. A fragment from Ref. [4] describing the fabric is reproduced here for greater detail: "The next-generation inflatable structure will probably utilize a material similar to that used on NE&SS- Akron's 420K aerostat. It consists of an outer layer of Tedlar material bonded to a woven polyester cloth, bonded to an inner layer of Mylar. The lightweight Tedlar layer provides UV protection and weather resistance. The woven polyester cloth adds strength in both the wrap and fill direction. Mylar provides biaxial strength and helium resistance."

2.4 Stratospheric Station-Keeping Non-Rigid LTA Platform

The National Institute of Advance Industrial Science and Technology (AIST), from Japan, is performing research on the feasibility of stratospheric long-endurance LTA platforms. Static airships being on-station in the stratosphere could be a cheaper alternative to LEO broadcast communication satellites. It is so for a number of reasons. On one hand, since LTA platforms do not need expensive boosters in order to reach operational altitude/orbit, they are cheaper and environmentally friendly. And, on the other hand, they are reusable vehicles, unlike most satellites, what increases the operational life of the platform. It also avoids a growing problem as the on-orbit debris acumulation.

These LTA stratospheric platforms can be powered by either solar power or ground-to-air transmitted microwave power. The solar power was selected because it is the most environmentally friendly, although it has a weight penalty because secondary batteries are needed for night time propulsion.

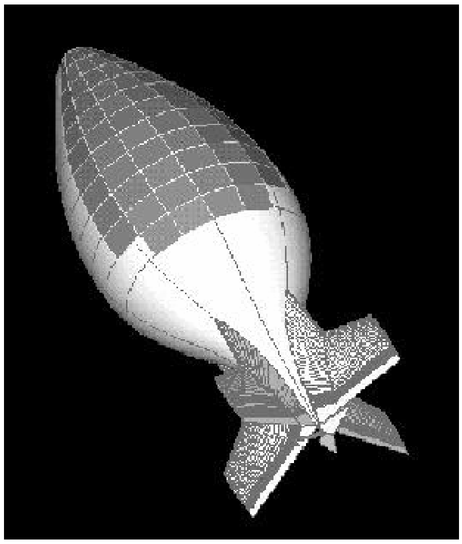

Fig. 4. A design example for a stratospheric LTA platform.

A report on this concept was presented Ref. [5] at the 14th AIAA LTA Technology Conference. In this paper, results of a feasibility study on a simulated model are shown, with maximum cruising airspeed 40 m/s and the maximum vehicle length 300 m, which yields 1.5 million cubic meters as the vehicle hull volume. The results of the study show that the modeled platform can support a 2 t payload and supply 20 kW power for the mission equipment.

One of the critical points in order to achieve an autonomous solar powered platform is the solar cell efficiency. Solar cells are quite inefficient devices that convert into electrical energy less than one forth of the solar radiation. In this case, a photo-voltaic conversion efficiency was set to be 21 %, which is almost the highest value attainable today, for off-the-shelf mono-crystal silicon solar cells.

Table 5. Physical characteristics of sample design of stratospheric LTA platform

Length (m)	300.00
Max Hull Diameter (m)	117.00
Fineness ratio - FR	2.60
Envelope Volume (m^3)	1,450,000.00

Table 6. Performance characteristics of sample design of stratospheric LTA platform

Flight altitude (m)	22,000.00
Max cruising speed (m/s)	40.00
Endurance (months)	6.00
Payload (tonnes)	2.00

3 Concluding Remarks

A small scale (1:8) experimental airship known as "Joey" has already been built and had its maiden flight in October 18, 1999. The full scale CargoLifter development is taking place at the dock in Briesen-Brand near Berlin, where the production hangar (360 m long, 210 m wide and 107 m high) is the world's largest freestanding hangar.

A 1/7th scale model of SkyCat™ 20, named SkyKitten 1, was built on the 4th of July 2000. It has carried out over 30 flights, the last being on the 23rd of November 2001. It has been a complete success, and all expectations were overcome. Some quantitative results, taken out from Ref [6], are: "SkyKitten 1 comfortably takes off in four hull lengths at a maximum attitude of 12 degrees. The full power climb rate is 400 feet per minute with a maximum level speed of 27 kts. Power off, zero forward airspeed descent rate is 5 feet per second. All the above figures apply to the model at 32 to 38 % heaviness." The full scale SkyCat™ 20 is expected to be built before the end of the current year.

The NE&SS- Akron's 420K aerostat is the only vehicle, among the four concepts, that is completely operational right now. As mentioned before, it is on duty for the TARS program of the U. S. Air Force.

Since the AIST study was a success, the agency has decided to going on with the project. A demostrator model has being built in order to achieve further knowledge about the concept. Then, the design process is in the flight testing phase.

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