POTENTIALS OF LIGHTER-THAN-AIR TECHNOLOGY IN FUTURE MARKETS – AN EVALUATION

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Abstract

The history of the Lighter-Than-Air (LTA) Technology dates back to the mid eighteen hundreds, where first aviation pioneers tried to create ships for the sky. During that time until the beginning of the Second World War airships all around the world were successfully in constant operation, both in civilian and military applications. Since then airships have never reached their former utilization. For the last few decades these air vehicles have been serving only diminutive specialized niche markets. Till today airships were not being able to reach lucrative markets in order to gain more market share within the steady growing field of aviation. Recently, a few companies and universities are trying to develop new kinds of airships for specialized missions, which they hope will bring the breakthrough for Lighter-Than-Air vehicles, e.g. hybrid airships. This paper gives a short overview of former fields of applications, critically enumerates chances and potentials for LTA technology and evaluates neutrally identified markets, e.g. luxury cruises.

1 Introduction

The Montgolfière brothers have been the first applying the 'lighter-than-air' principle when their balloon took off in 1783. The same principle was defined 2000 years ago by the Greek philosopher Archimedes. That principle states that "a body immersed in a fluid is buoyed up by a force equal to the weight of the displaced fluid." This principle applies to both floating and submerged bodies and to all fluids, for example liquids and gases. In airship design three different construction methods need to be differentiated. The differences can be seen mainly on airship structures and their lifting gas management systems. These aircraft are being separated into blimps, semi-rigid and rigid airships.

2 Types of airships

2.1 Blimp

Blimps do not have an internal support structure as the other airship types. Stability is being achieved by a slight over pressure of the lifting gas within the hull of about 0.05 to 0.1 bar. The gondola, engines and other subsystems are being fixed at the hull through catenary wires. Those non-rigid airships are often being called blimps. These aircraft have the big disadvantage that they are subject to size constraints due to stability problems.

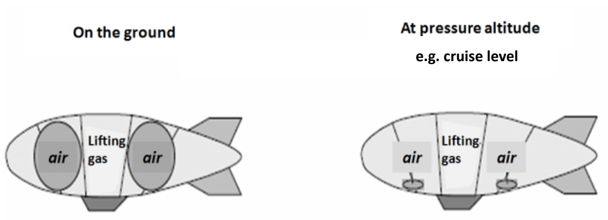

Fig. 1: blimb [1]

2.2 Semi-rigid airship

Semi-rigid airships combine the construction methods of blimps and rigid airships. This type consists of a lifting gas hull, which is fixed at an inside or outside keel. Exactly as blimps, semi-rigid airships are being stabilized through the ballonet-technique. A huge advantage of this particular construction method is the solid fixation of gondola, engines and control surfaces. As today, this design represents the most common construction method for new airships. The most prominent exponents are the Zeppelin NT and the never built Cargolifter CL 160.

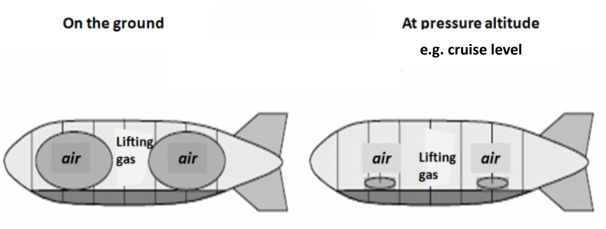

Fig. 2: semi-rigid airship [1]

2.3 Rigid airship

This specific type of airship has a rigid structure, which dictates the external shape of the aircraft. This frame contains gas cells, which expand with increasing altitude and are enclosed by an outer hull. The space in between is filled with air. Due to a very high rigidity of that structure, gondolas, control surfaces, engines and other systems can be attached quasi arbitrarily on that framework. The widely known Graf Zeppelin or Hindenburg aircraft were rigid airships. Besides all of those conventional airship designs a few hybrid solutions have been identified since the 1970s.

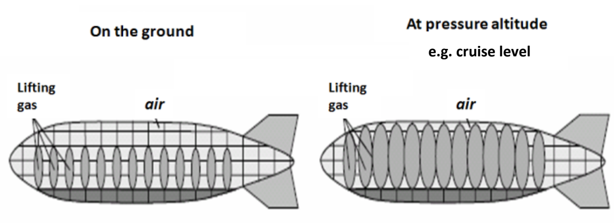

Fig. 3: rigid-airship [1]

2.4 Hybrid airship

An aircraft concept combining the features of a helicopter or a fixed wing airplane with those of an airship is being called a hybrid airship. Experts define a concept as a hybrid airship when more than 40% of the weight is being carried by dynamic lift. But such an airship does not represent a proven alternative to today's air transport systems. Airship manufacturers wish for new application scenarios for those concepts in the future. Due to higher cruising speeds, this flying body has quite stable flight characteristics and better maneuverability compared to regular airships. Therefore its dependability on weather, in particular heavy winds and gusts is lower. Furthermore the usual ground infrastructure as used for conventional airships is not needed anymore. This is due to Heavier-Than-Air (HTA) features of that aircraft, which has the ability to take off and land similar to an airplane. Santos Dumont was the first, who had the idea of such a hybrid airship concept in 1905. Since the 1970s various variants have been designed and built as figures 4 and 5 illustrate.

Fig. 4: example of already built and planned hybrid airships

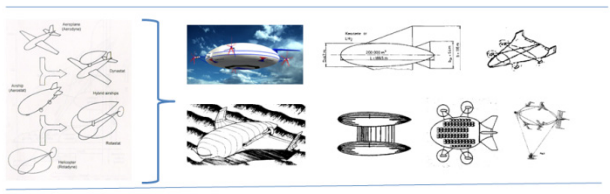

Fig. 5: theoretical hybrid airship concepts

Figure 6 shows the terminology of the flight system aircraft.

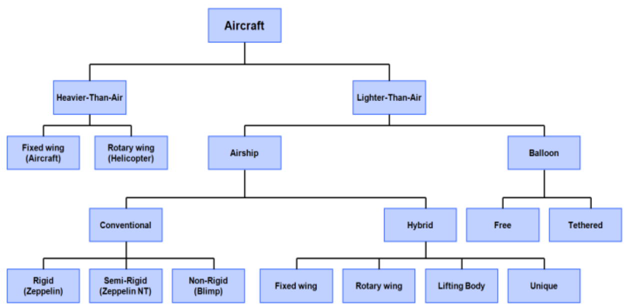

Fig. 6: terminology of the aircraft system [2]

3 Chronology and former application

3.1 History of airship technology

Airships and the Lighter-Than-Air technology in general have a long history behind them. The man's dream of being able to fly was realized by the Montgolfière brother in 1783.

The idea not to fly in a balloon, but to lift off in an airship came from General J. Meusnier in the year 1795. Figure 7 shows his concept, which already had a great similarity to airships, designed 100 years later. Unfortunately his construction has never been realized. The airship development has been pushed quite rapidly since the 19th century. Size, payload and speed rose constantly during the years, see figure 8 and 9. The size of the spheres in figure 9 describes the respective payload capacity.

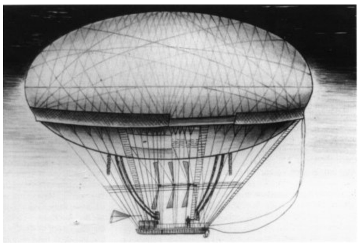

Fig. 7: airship design of J. Meusnier, 1795 [3]

#	type	Year	speed (km/h)	payload (kg)	built
1	LZ 1	1900	28	1400	yes
2	LZ 6	1910	56	4400	yes
3	LZ 36	1915	85	11000	yes
4	LZ 120	1920	127	96000	yes
5	LZ 129	1936	137	96000	yes
6	WDL 1B	1988	105	800	yes
7	American Blimp A-150	1997	95	628	yes
8	Skyship 600	1998	120	1900	yes
9	Spirit of Goodyear GZ 20A	2000	80	650	yes
10	Zeppelin NT	2000	125	1900	yes
11	Cargolifter CL 160	2005	125	160000	no
12	Aeros 40 D	2006	82	980	yes
13	Skycat 20	2008	157	20000	no
14	Aeroscraft ML16	2009	220	5400	no
15	Dynalifter PSC-1	2009	185	86200	no
16	RA-180 /Airship Holland	2009	148	30000	no

Fig. 8: speed and payload development of airships

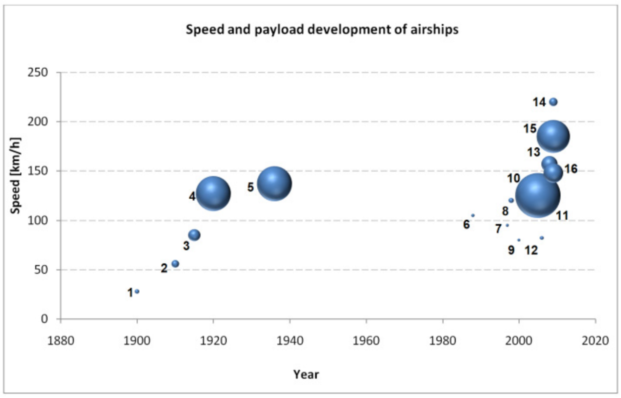

Fig. 9: speed and payload development of airships

Figure 10 shows the airship LZ 127 Graf Zeppelin, which circled the earth in 20 days (12 ½ pure driving time). This example should just emphasize the enormous performances those former airships.

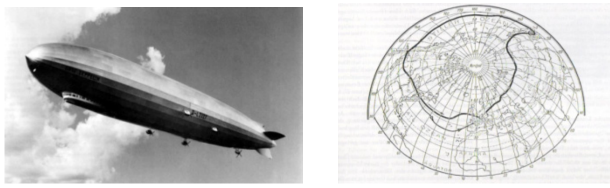

Fig. 10: LZ 127 and its world tour 1929 [4],

3.2 The end of an airship era

At the beginning of the Second World War, big airships lost importance. The German military did not find any use and dismantled LZ 127 and LZ130 whereas the US Navy used small blimps for surveillance purposes. Very quickly fixed wing aircraft ruled the skies and became the preferred air transportation system.

Interesting is the aspect that it took about 50 to 60 years since LTA technology could celebrate its revival; however thought for completely different application areas. Since the founding of the Luft Hansa AG in 1926 passenger volume could show a growth of over 338% within the first 12 years. This meant an increase from 56,000 to over 255,000 people within that time span.

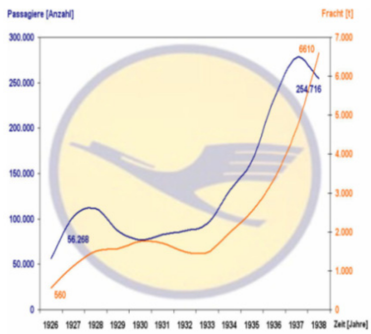

Fig. 11: development of air travel [1]

Within the same timeframe air cargo grew over 1,080%, an increase from 560 tons to 7,000 tons in 1938. Figure 11 shows the constant increase in passenger and cargo transportation by fixed wing aircraft. Zeppelin airships instead carried only 18,000 passengers in 28 years (1919 to 1937). This number almost vanishes in comparison to the 255,000 passengers carried by Luft Hansa in 1937 alone [1]. These numbers clearly show that airships did not have a chance in the emerging mass air transport market, which fixed wing aircraft have been ruling since then.

5 Potential future application areas

5.1 Luxury air cruises

Bauhaus Luftfahrt is pursuing the application of airships for luxury cruises. This particular market has not been looked into quite deeply and could provide a future niche market for Lighter-Than-Air technology. The required aircraft needs to operate very quietly, with almost no vibration, and it needs to provide a very high level of comfort. It also should be able to hover above a particular point of interest. Furthermore it should offer enough room for the passengers on board to feel at ease any time.
Most of those requirements could be satisfied solely by an airship. Such cruises are unique in the way that private cabins are being offered to the passenger, who has the possibility to spend a couple of nights onboard – while airborne.

Fig. 12: various cruise airship concepts [6],[7],[1]

Figure 12 shows just a few concepts of different companies, some more mature than others. But all have the same idea: taking a cruise up in the skies in order to create a never forgettable experience. All those companies and universities have plans to design airships for 250 up to 450 passengers. The resulting dimensions of such an aircraft could drastically reduce the chances for realization in the near future. Mr. Thorbeck of the Technical University of Berlin emphasized in January 2000 that a cruise airship must have a minimum capacity of 200 passengers in order to operate in an economically advantageous regime [8]. In order to prove that fact an independent market analysis needs to be performed. But Bauhaus Luftfahrt sees the potential of such an air cruise within the luxury segment for the upper class.

The idea here is to offer a cruise for a maximum of 20 passengers; providing a journey with wellness character.

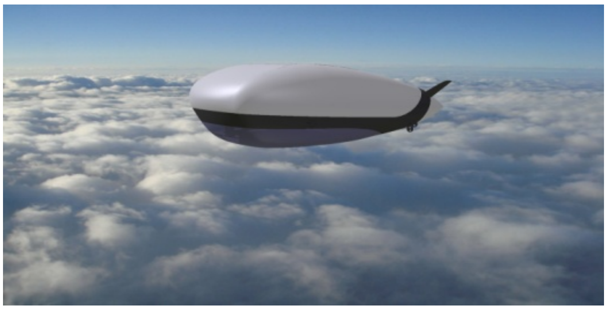

Fig. 13: Bauhaus Luftfahrt luxury cruiser design study

Bauhaus Luftfahrt has worked on a design study (Fig.13) and has set following preliminary requirements:

requirements:	technical data:
passengers: 18 + 8 crew	hull volume: 45.000 m³
cruise speed: 70-100 Km/h	total weight: 45.000 Kg
lifting gas: helium	length: 85 m width: 42 m
propulsion: e.g. fuel cells + electric engines and solar modules	height: 22 m

Table 1: preliminary requirements for a luxury air cruiser

The idea of luxury in that particular concept should be defined in a completely new way. That means that in an actual interior design, luxury could be re-discovered through entirely new solutions, e.g. an exclusive foam bath rather than a heavy swimming pool. Additional equipment like casino, bar or sauna requires to be designed for minimum weight. Comfort here means using exclusive offers only available on board that luxury cruise vehicle. This specialized airship could fly to any destination and perform various missions, e.g. city sightseeing, safari flights or rainforest cruises.

Fig. 14: Bauhaus Luftfahrt interior design study

In 2007 Bauhaus Luftfahrt took a survey concerning the future of civil aviation. During five days at the Hannover convention more than 470 people had taken that survey and answered questions regarding luxury air cruises. The results (Fig. 15 to Fig. 18) show that the majority of people generally favor the idea of luxury air cruises.

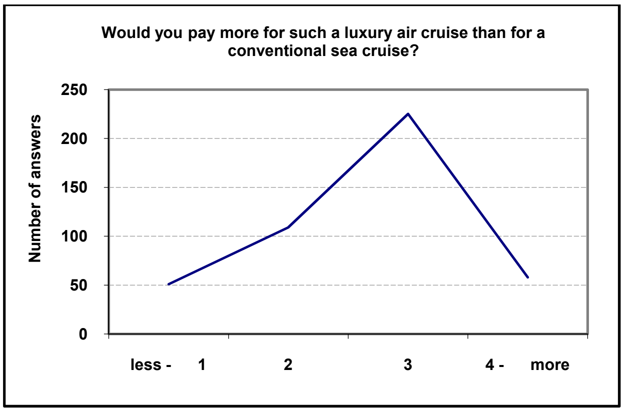

Fig. 15: Hannover convention 07 survey – price estimation

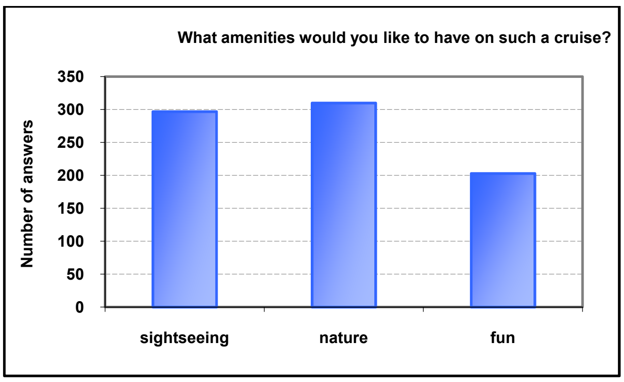

Fig. 16: Hannover convention 07survey – amenities

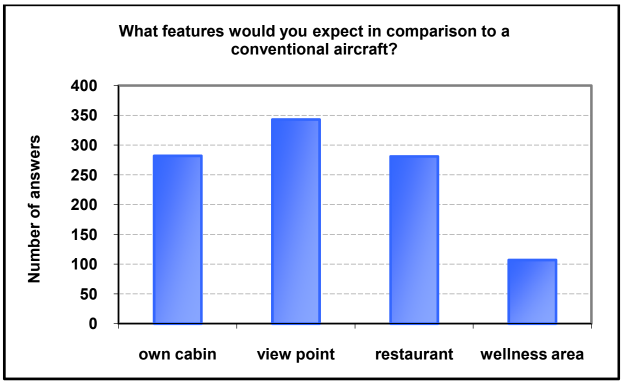

Fig. 17: Hannover convention 07 survey – expected features

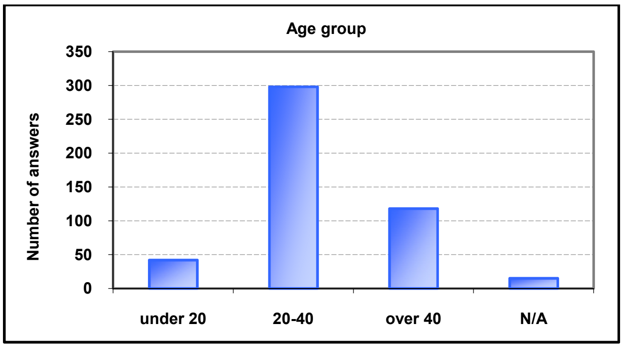

Fig. 18: Hannover convention 07 survey – survey taker's age group

5.2 Hybrid airship

Scheduled passenger service is another area Lighter-Than-Air technology could gain ground. Such an aircraft need to comply with the strict JAA and FAA regulations concerning civil air transport. Crucial within that market segment are on-time arrivals and departures, safety and reliability. Furthermore, capacity needs to be kept high and costs low in order to be economically advantageous. But according to the offices for engineering results assessment at the Lower House of German Parliament (Büros für Technikfolgen-Abschätzung beim Deutschen Bundestag) this application is not yet realizable.

Airships are relatively slow in comparison to other aircraft. The maximum cruise speed of a modern airship, such as the Zeppelin NT reaches about 115 km/h. Interestingly enough old LZ airships were able to cruise with more than 130 km/h due to their rigid structure. These zeppelins had an enormous speed advantage to all other conventional mass

transport during that time, such as passenger ships or railways. Especially when crossing the Atlantic travel time could be shortened quite drastically. Nevertheless fixed wing aircraft started to emerge and soon started to rule international air transportation. Even today, speed and slow maneuverability are key factors why airships are serving just a diminishing niche market. Since then commercial airships could not make a big step towards opening new and lucrative markets.
Conventional hull geometry and hence resulting drag will not allow an airship to fly any faster in the future. Concepts, which are based on different shapes can achieve better flight performances and thus needed. Hybrid airships as already mentioned could provide such a solution.
Figure 19 shows that hybrid airships have quite the potential to reach higher velocities, such as those of a helicopter.

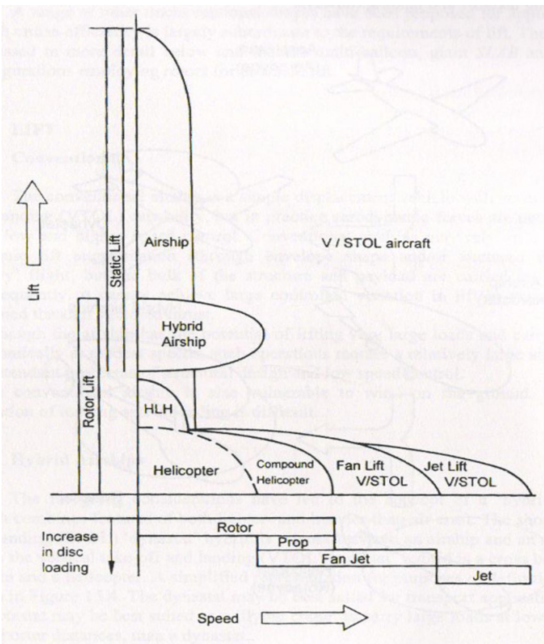

Fig. 19: V/STOL spectrum [5]

But in order to reach those speeds, the airship must have a low drag profile as well as a proper propulsion system.
Because fast cruise speeds require greater engine power it also can be used efficiently for hovering, take-off and landing maneuvers as well as for attitude stabilization. Concerning that idea, first rough sketches and preliminary calculations have been performed (Fig. 20).

Fig. 20: Bauhaus Luftfahrt hybrid airship design studies

But being able to operate independently without any ground crew, those airships need to be heavier than air. The static lift must not be higher than the operating weight empty of that aircraft. If the total weight of an airship cannot be carried by the lifting gas alone it is said to be Heavier-Than-Air.
Figure 21 illustrates the needed performance at different speeds for various aircraft. A comparison has been made with a conventional airship, a fixed wing aircraft as well as a fictive hybrid airship. The basis of comparison is a maximum takeoff weight of 7,500 Kg. All aircraft are being compared within their area of operation, e.g. best cruise altitude, etc… δ_{dyn} is the dynamic lift part of the hybrid airship concept.

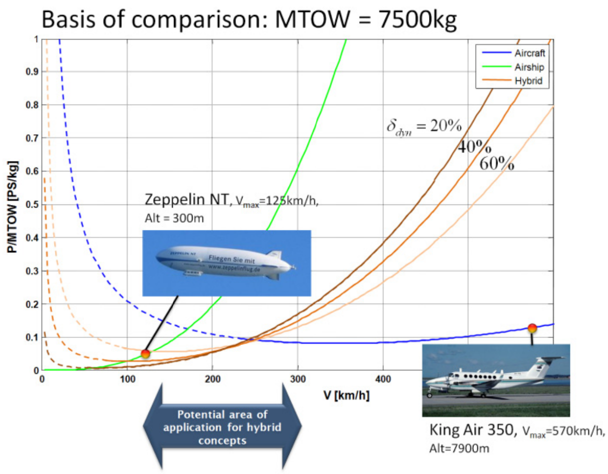

Fig. 21: Power requirements for hybrid airship concepts

Here the potential use of application for hybrid concepts can be seen. At speeds from about 100 km/h to approximately 280 km/h hybrid airships are relatively independent from their dynamic lift portion and more efficient than conventional airships and fixed wing aircraft.

Nevertheless it needs to be mentioned that heavy helicopters have not been used in this comparative analysis. This would be the next step in order to achieve a more exact prediction.
Figure 22 compares the lift coefficients of all three aircraft. The hybrid airship has still a lift coefficient of 0.2 at 80 km/h, which allows extremely slow speeds in conventional flying mode. If even slower speeds need to be reached, dynamic lift continuously has to be substituted by powered lift in order to keep the aircraft in the air.

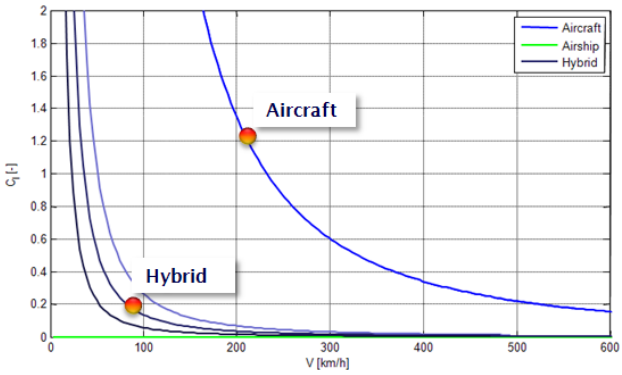

Fig. 22: Lift coefficients

Designers and engineers of the British Skycat want to achieve speeds of more than 157 km/h with their Skycat 20 model. The California based company Aeros has plans to even reach speeds of over 200 km/h with its Aeroscraft ML 16.
These and other concepts have one thing in common: The combination of airship and fixed wing aircraft. The application of a city shuttle or even a scheduled passenger transport under certain circumstances would then be possible. If the development and operation of such concepts make economical sense further research is required due to the fact that for the most part only niche markets are going to be served.

6. Problems and Chances

Airships definitely constitute the exotics in aviation. Wherever those flying platforms can be seen people gaze at them. The shape of airships did not change dramatically within the last 100 years. Even today the conventional cigar shape is being used for new airships. Application areas are very limited and have been reduced to sightseeing tours and marketing functions as well as some highly specialized markets such as aerial surveillance and research functions.
In general, very slow speeds and extremely low payload in comparison to the required size are the great disadvantages of this particular aircraft type.
Nevertheless various companies and research institutes are working on new technologies as well as fresh concepts. Airships need to be much more efficient in order to serve new markets. Especially Germany's LTA knowledge is top of the notch. But also companies in the USA and other countries are looking to find innovative solutions for actual problems.
The relative market share as well the relevant market growth for Lighter-Than-Air aircraft is very low. But being a so called 'poor dog', airships have the potential to grow in any direction. Moreover have innovative airships the chance to step into new specialized markets with the potential advantage of being the first mover.
Nevertheless will future airships only be able to serve niche markets. To become a serious competitor to fixed wing aircraft and helicopters many weak aspects need to be overcome, especially the very high weather dependability. But it is also the irremediable natural physics that makes airships no high performers with an everyday utilizability. But especially the market plays an immense role for future airship developments. Table 2 shows the number of certified airships in Germany from 1986 to 2005. Also here it becomes evident that Lighter-Than-Air vehicles represent an evanescent percentage within civil aviation.

Number of certified airships in Germany (source: LBA)

1986-1989	1990-1992	1993	1994	1995-2000
2	3	2	2	3
2001	**2002**	**2003**	**2004**	**2005**
5	5	6	4	4

Table 2: certified airships in Germany

7. Conclusion

As for today conventional airships have many weaknesses. The airship itself is essentially attractive, because it can serve as an ideal technology platform and also be suitable for highly specialized fields of application. However, this technology has been living a dire existence for the last few decades, but it absolutely has potential to grow - through new leaps in technology and innovative concepts.

It is not possible to estimate what volume future airship programs are going to have. In order to make the Lighter-Than-Air technology competitive new brave concepts need to be found. Doing research in the field of hybrid airships is already one step to push that technology forward.

Acknowledgements

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