Lighter-than-air vs. Heavier-than-air: How Can Network Effects Explain the Failure of Airship-Technology?

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Abstract:
Airships run the first commercial but rudimentary air transportation services. The airplane conquered this business more and more in the course of time. As the main reason for this development the paper identifies a much more rapid growing net of airfields affiliated with a service network for airplanes in comparison to airships. Huge rigid airships needed a different net with more expensive equipment and therefore this net grew much slower along with the affiliated service network. Thus, airplane networks surpassed a critical mass of net-building much earlier and displaced the airship in spite of the fact that in civil areas it was technologically advantageous.

Keywords
Airship lines, airplane lines, critical mass, growth of networks.

1 Outline of the problem

When German rigid airship *LZ 129 Hindenburg* exploded over U.S. Airship Base Lakehurst, New Jersey, on 6 May 1937 the sole operating commercial airship transportation service was abandoned totally (Bauer and Duggan 1999; de Syon 2002). This accident marked the end of the commercial airship era. This development appeared in outlines for a long period of time and was ignored by the main actors in this field. Usually the modern economic theory of the struggle between competing technologies and net effects is a useful tool to analyze this question. Therefore, any appreciable attempt to build a net or network by establishing operating bases and service routes in the United States, in Germany, and in intercontinental traveling both by airships and by air-planes had to be reconstructed.

In spite of the fact that in economic theory the terms “net” and “network” are used simultaneously we use these terms in a different manner: the term “net”

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indicates a kind of physical facilities such as airports, airfields or airship-bases. Their infrastructure is, however, very different: Airplanes need hangars, runways, avgas-stations, and airplane-specific repair-stations and preventive maintenance facilities. Huge rigid airships as like as Zeppelins, however, needed much greater hangars up gigantic and stable halls, mooring masts, avgas- or diesel-stations as well as lifting-gas stations, and airship-specific repair-stations and preventive maintenance facilities with totally different technical equipment and personal skills compared to airplanes. Common for both are terminals and facilities for provision of passengers only as well as transport connections to railways or the road-net. The sum and the geographic distribution of airfields, airports, or airship-bases respectively, define a physical net, but by the term "network" we indicate the use of this net as interlinked meeting-points or destinations of routes. They were served by regular services. As services we define any transportation of passengers, airmail, and perhaps commodities. The term "network" is affiliated by useful economic interaction to persons and need a physical net to work.

Based on these considerations it is to be analyzed how fast the very specific physical net both of airships and airplanes grew. In addition it is to be discussed, whether a perhaps not exactly quantifiable critical mass of destinations which define a kind of installed base of operation facilities as like as airfields or airport had been qualitatively surpassed by the two technologies analyzed. Then it is to show in a further analysis, how rapidly the networks of both technologies giving services to customers grew.

2 Theoretical considerations: The importance of the growth of physical nets if technologies compete

In economic theory regarding spread out of new technologies it was elaborated that ability of establishing a network of or for the user is a crucial factor. Establishing an attractive network, the existence of increasing returns to adoption of the facilities of a physical net is an essential part.

Main characteristics of a network-market are significant economies in scale of production, switching costs and lock-in effects, consumption externalities, and complementary, compatibility as well as standards (Shy 2001; Economides 1996). Economies of scale in production imply that the first device produced has huge and not recoverable sunk costs and all further produced devices are remarkable less costly (Arthur 1989). In our case it is to mention that nearby every airship was a unique device, airplanes, however, underwent mass production lately since World war I. If, like in reality, a relatively small number of produced airships had come into operation only in comparison to thousands of airplanes, it was more attractive to establish much more airfields and airports than airship bases. This is can be interpreted with complementary between airfields and airplanes. An airfield, however, has another demand for equipment than an airship-base – they are not compatible

if they were not equipped for both technologies. Sum of all existing airfields define a physical net on potential and technical equipped destinations. Adoption or network externalities then refer to the consumer of transportation services by airplanes or airships: A tight-knotted net of airfields makes it easier to reach a desired destination – and more profitable for airlines or airship-lines to offer different services to their customers, e.g. more routes to travel as well as shorter frequencies. Therefore, a net of airfields and airports, or airship-bases respectively, can be interpreted as the "hardware" being filled by the service-supplier and used by the customers comparable to "software" (Church and Gandal 1996; Gandal et al 2000). In our case the routes and the transportation-service were offered by airlines or airship-lines.

The considerations mentioned culminate in a race between the velocity of the growth of the two physical nets one usable for airplanes and the other for airships, but both affiliated with commercial service offers to the customer wanting to travel or his airmail to be transported as quick as well. If one of the net grew faster than the competing one, the network services of the slower growing net got more and more unattractive. Therefore, a critical mass of a physical net-size does exist and the net surpassing this critical mass wins first. Any investment by the later "winning" network is an entry-deterrence for competing networks starting later or growing slower (Dixit 1980). A switch to another net or network then again creates costs none is willing to pay even if the displaced technology is technologically better or supplies more individual utility (Lieberman and Montgomery 1988; Farrell and Saloner 1985). Because the velocity of net-building was a relevant argue one can assume that whoever was first to begin building "his" base of the net devices has a clear first-mover-advantage against his later competitor (Farrell and Saloner 1986; Katz and Shapiro 1986). The example analyzed here proves the opposite because the technology that lost the race was unable to realize significant economies of scale in production – the starting point of our theoretical considerations.

3 Short-range and continental commercial transportation networks for airship-services

3.1 Failure of building any commercial airship network in Europe

Much earlier than airplane technology airship technology created functioning artifacts. After first substantial theoretical suggestions by French *Jean Baptiste Meusnier de la Place* in 1784, development of artifacts of dirigibles proceeded during the 19th century and first successful operating dirigibles date back to the French men *Henry Giffard* in 1852, to the *Tissandier* brothers in 1883 and in 1884, *Krebs* and *Renard* in 1884, *Henry Julliot in* 1897 as well as the Germans *Haenlein* in 1872 and *Wölfert* in 1896. Their constructions were so called blimps or keel-stabilized blimps. Large rigid airship constructions were suggested by French *Prosper Meller* in 1851

and by British *R. B. Boyman* in 1866. First experimental devices were built by Austro-Hungarian *David Schwarz* in the late 19th century. Theoretically elaborated in 1874 and firstly realized by a successful take-off in July 1900, German *Count Ferdinand von Zeppelin* demonstrated technical feasibility of a huge rigid airship, with a metal frame defining the rigid structure of the airship, propelled by internal-combustion engines and lifted with hydrogen. Even though military relevance was given, from the beginning *Count Zeppelin* emphasized commercial use of his rigid airship (de Syon 2002). His rigid airship was able to solve the lack of insufficient load-carrying capacity by not-rigid blimps which their technically limited size. The Zeppelin-airship exceeded this limit because it based on a rigid and cloaked but fragile aluminum frame with the lifting-gas balloons inside. Therefore, this kind of airship was extremely vulnerable on land in case the airship body had a collision with a barrier, e.g. a tree, by gust of wind. The first Zeppelin *LZ 1*, from 1900, had 128 meters in length and 11.65 meters in diameter; the famous *LZ 129 Hindenburg*, from 1936, had 245 meters in length and 41.2 meters in diameter (Hallmann 2002, 29-30). After a Zeppelin landed best protection was to put it in a stable hall but the size of the Zeppelin indicated the size of the hall demanded. The building of halls on the main destinations of Zeppelins was a very capital-intensive enterprise because a typical airship hall in the 1930ies were in total near 360 meters in length, 100 meters in width, and 55 meters in height. Additionally, every regular destination of a Zeppelin had to be equipped with hydrogen-producing facilities or tanks bunkering this extremely explosive lifting-gas to supplement lifting-gas which regularly diffused during airship operation (Knäusel 1997). The erection and operation of a full-equipped airship base, beyond a simple mooring mast, was therefore a very expensive investment. Such a kind of investment on every destination could be profitable only with an adequate number of landing and starting airships. This was only to be realized if an adequate number of airships using this expensive infrastructure were really in operation. The crux of the diffusion of the airship was, therefore, to create a homogenous growth of the number of airships both in commercial and even military operation and the number of adequate equipped airbases near those destinations which were attractive for passengers, too. Abstractly said, the crux was the establishment of a physical airbase net as a necessary condition for the creation of an attractive network for commercial services. If this does fail, any commercial airship service would fail sooner or later by insufficient profitability of the whole system containing airships *and* their bases. When was the idea of commercial services born and when and how occurred attempts to realize it?

Already in 1834, the idea for an air-borne civil service was born to connect Paris and London by commercial dirigible balloons. The idea of regular commercial use of balloons and dirigibles to transport passengers, commodities and for postal services spread out all over Western Europe (Marey-Monge 1847; Steinmann 1848) and later in the United States (Leary 1985; LZA 006/0098) but was not convertible yet due of technical obstacles. In 1903 French-Brazil *Santos-Dumont* dedicated his *airship No. 10* for

passenger transportation like an omnibus but he did not realize his plan (Mackworth-Praed 1990, 119). Similar examples can be found during the whole 1910th but only *Count Zeppelin* realized in December 1909 the concept of a preferably regular commercial passenger airship services in Germany by founding a stock-based company, the *Deutsche Luftschiffahrts-Aktiengesellschaft DELAG* as a division of his Zeppelin-holding. The business of the *DELAG* was to run several Zeppelins servicing a net of important German cities. Therefore, the cities interested should sign stocks from the *DELAG* and erect some infrastructure e.g. landing places and halls to protect landed Zeppelins from destructive weather events. Up to march 1914 *DELAG* created a net of routes connecting the German cities Frankfurt am Main, Düsseldorf, Gotha, airship- and airplane-port Berlin-Johannistal, Hamburg, Dresden, Leipzig, and the spa Baden-Oos. The service was delivered by a total of seven rigid airships which transported in over 1,588 trips a total of 10,197 paying passengers (Schiller 1966). The first years the *DELAG*, however, suffered some accidents of their airships but without loss of passenger lives. The service, however, was not as reliable and regular as planned. Consequently most of the time more capital-intensive equipped airship-bases were in operation than airships which were able to use it. Transportation capacities which could not be sold soon stressed balance-sheets of the *DELAG* by financial loss and it seemed that not for a long time yet civil airship services surpass the critical mass of profitable operation: the world's first realized network of airship service had a structure full of holes on the net as well as on service. Therefore it was a disaster, economically. Some months before the outbreak of World War I, *DELAG* sold their airships as well as the net of bases to German Military Forces and terminated any commercial airship activities (LZA 018/0272). In spite of the fact of the absence of any commercial competition by air-planes, the *DELAG* was not sufficient to capitalize investments by surpassing a critical mass of passengers and destinations. *DELAG* management realized these facts but concurrently was convinced that a future international commercial service would be a profitable enterprise (LZA 016/0459).

Soon after the end of World War I, however, the *DELAG* established two modest regular services between the German city of Friedrichshafen on Lake Constance to the German capital Berlin as well as to the German city of Weimar where the new German Parliament worked this time. For this service a new, small but modern Zeppelin, the *LZ 120 Bodensee*, was built. An even new built Zeppelin, the *LZ 121 Nordstern* exceeding the *LZ 120* a little bit in size, was dedicated to open a civil airship service to Sweden soon. But when the Treaty of Versailles has coming into effect in 1920 these two airships were confiscated by the allies and the services mentioned come out of operation (Kleinheins 1994). Those short-living services were technically more reliable than the Zeppelin services before World War I but they were far away from building a network for passenger transportation again. Because the ticket-earnings of the *LZ 120* solely in operation had to finance the whole overhead of the *DELAG* this airship service was an economic disaster as well. As from

now no attempt at all was made to establish a commercial airship network to service the European continent.

3.2 Failure of building a continental airship net in US

The European, more exactly the German experiences were, however, ignored by the U.S. Company *Goodyear*. Ever since 1911 *Goodyear* produced balloons and during World War I the production of blimps started. By the end of the war a first attempt was made to produce blimps for civil purposes but in 1919 an accident with ten victims stopped this development for a short time. Because of the great interest in blimps and huge rigid airships by the U.S. Navy especially, *Goodyear* identified profitable economic opportunities in the building of all kind of airships furthermore. Therefore, a co-operation was made with the German *Zeppelin Corporation*, which built the in 1924 North-Atlantic crossing *LZ 126*, later named *ZR III Los Angeles*, for the U.S. Navy. This co-operation culminated already in 1923 in the foundation of a common owned firm, the *Goodyear-Zeppelin-Corporation* in Akron/Ohio to make technology transfer and to build huge rigid airships for the U.S. Navy in future (Braun 2004; Meyer and Duggan 2001).

Using the own wartime experience, *Goodyear* additionally decided to make a further effort to establish a commercial network of airship services. From 1922 up to 1925 a small semi-rigid airship and over twenty blimps had been produced by *Goodyear* for running a self prosecuted but humble passenger service in California (Rodengen 1997, 79-80). In spite of the fact that we have found no data about the success of this service, *Goodyear* seemed to be satisfied with the success. Because from 1925 on *Goodyear* produced a modern helium-filled blimp, the *Pilgrim*, which was commercially used to transport two passengers over a maximum distance of 100 miles all over the United States. Up to the year 1932 *Goodyear* brought a fleet of totally twenty blimps, most of them larger than the *Pilgrim*, in civil operation. During the seven years of service 92.874 passengers were transported commercially and a sign of optimism was, in 1930, the erection of a never used mooring mast on the top of the new Empire State Building in the heart of New York (Allen 1932, 95; O'Reilly 1983, 65-66; Solberg 1979, 91; Dierikx 1997, 191). In regard of the destinations of the blimps literature show different data: *Allen* mentioned that the small fleet of 20 blimps operated 42 US-States and had destinations in Washington, New York, Los Angeles, Miami, Chicago, Cleveland, San Francisco, Dallas, New Orleans, and Memphis (Allen 1949, 289-291). *Hansen* (Hansen 1977, 219 asserted that more or less permanent bases were in operation only in New York, Washington, Miami, Akron, Los Angeles, and Chicago. In Chicago a small base was erected on the area of the *Century of Progress Exposition* which was held later in 1933/34. Additionally, destinations in the foreign cities Toronto (Canada) and Havana (Cuba) were mentioned. Under these circumstances, this small fleet of small-scaled blimps was not able to create a stable network of routes and destinations in permanent operation which could secure a sustainable economic development. The

blimps, however, had a small load-carrying capacity only because of their non-rigid construction principle. Their operation fields only needed a physical net of cheap mooring masts and did not demand the gigantic halls like the huge rigid airships did it for protection purposes. Therefore, the costs of erecting a base for blimps has been much more lower than for rigid airships, but literature does not give any data about building and running any base. Finally the *Goodyear* blimp service was abandoned in 1932 caused by the economic problems during the Great Depression. Additionally, profitable air postal service was not open for the civil *Goodyear* blimps because the air postal transport in the United States was strong regulated and only specialized firms with air mail airplanes could enter this market (Rodengen 1997, 83-94).

It remains clear now that in the United States as well as years before in Europe a continental airship service did not work economically because every attempt collapsed before surpassing the critical mass of the net of an essential number of airbases or destinations in permanent and regular operation, respectively. This can be derived for all the cases discussed from the small number of the airships in operation. But what happened in the competing technology of the airplane?

4 Development of commercial airplane networks

4.1 Beginnings and exploding dynamic in Europe after World War I

Before World War I airplane technology created artifacts far away from any commercial consideration. Only marginal attempts of occasional and more private mail transportation by German *Hans Grade (*Schulz 1990*)* around 1910 and an anecdote about a momentary test of Russia's early large-scale airplane *Ilia Mourumetz* in 1914 are mentioned in literature (Haddow and Grosz 1962, 66-67; Demand and Emde 1990, 124-125). An important fact is, however, that in all European countries where individuals were engaged to developing airplanes or to test military usefulness a rapid growing number of civil and military airfields emerged: in 1912 in Germany 23 airfields were in operation, early in 1914 the number grew up to 31 airfields (Schwipps 1984, 81 and 107). A similar development occurred in France with more than eight airfields already before 1909, in England with estimated seven airfields 1913, and some airfields in Austria (Schmitt 1985, Prendergast 1980). Important airfields e.g. Berlin-Johannisthal were equipped with great areas of runways, a lot of smaller hangars, airplane manufacturers and repair-stations, avgas-stations, terminals, and public viewing tribunes (Tatzkow and Henicke 2000). As mentioned above, only a small number of airfields, e.g. Berlin-Johannisthal, were also equipped with the very special, capital-intensive infrastructure (gigantic halls e.g.) for huge rigid airships because these airships in opposition to airplanes needed a very different kind of infrastructure, and equipment. A fully equipped airbase for Zeppelins is much more capital-intensive than a fully equipped airplane airfield. A German newspaper estimated a sum of 40 million Mark for erecting the first U.S. rigid airship base Lakehurst on the East

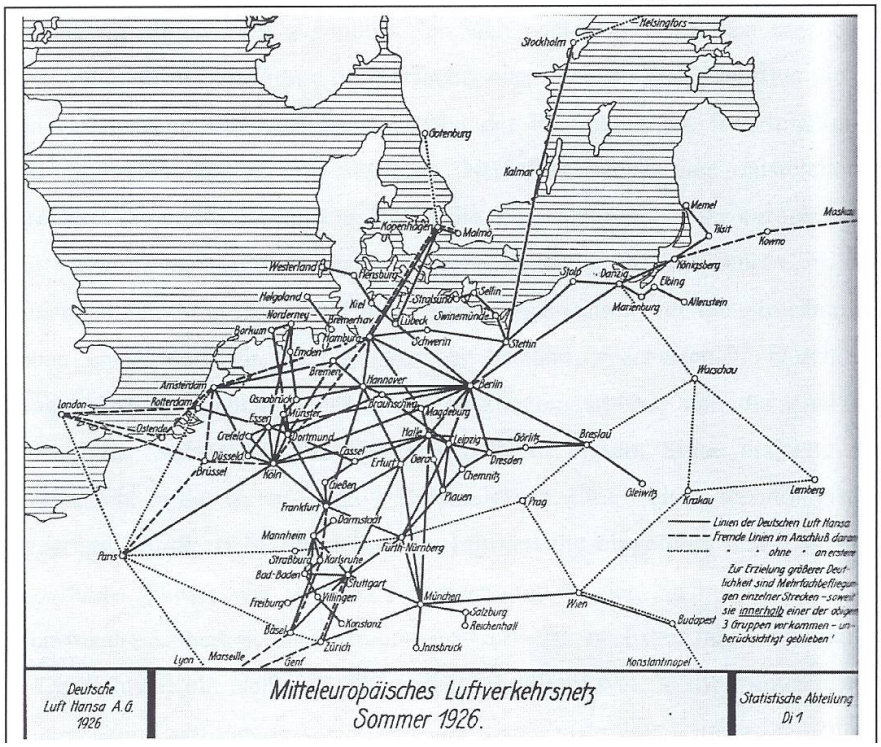
Coast. The costs to erect the Californian airship base Moffet Field were estimated to 20 millions of Mark (Without author 1935). Therefore, the arrangement of a new airfield for airplanes only was much cheaper than a base for a rigid airship.

An exploding technological development during World War I made the airplane reliable and robust technically. Airplanes could be produced in cheap mass-production in different scale and size and were cheap to operate – in comparison with a Zeppelin (Braun 1990). It was a clear fact that after the ending of the war military airplane technology and thousands of pilots in all countries had to be transformed in civil and commercial use to save the high-level experience and knowledge. Already in wartime some businessmen e.g. Walter Rathenau from German firm AEG in 1917 and George Holt Thomas from British De Havilland Aircraft Company in 1916 lay the foundations of post-war commercial airplane services (Wagner 1987, 13; Allen 1981, 18). In the most important European countries commercial air transport started immediately by individual entrepreneurs, by firms producing airplanes, and soon by governmental support (Pollog 1930, 6). Using former military airplanes or first pure civil airplanes built, e.g. the German model *F 13* by Junkers, the number of commercial airplane services to transport passengers and occasionally mail exploded (Braun 1991). Already in 1920 in Germany a net of 25 airfields and destinations, including four foreign destinations, was in operation and served by a lot of regional domestic and some foreign airlines (Archive of German Lufthansa). Because of bad weather conditions the development of inner-British airplane services showed lesser dynamics but already since December 1918 a regular service between London and Paris was opened by a British airline; a French airline offered the same service from February 1919 on, interlinked with the most important French cities and since 1921 interlinked with destinations in Poland, Belgium, Italy, Spain and in North Africa, too (Fisser 1922, 125-126). In 1922 in Germany 6,820 passengers were transported, in England 11,850 passengers, and in France 5,700 passengers (Allen 1981, 70).

Germany, geographically located in the mid of Europe and over years under some kinds of control by the victorious countries after World war I, was the central field of foreign and domestic interest interlinking new civil airplane routes between the countries in the whole neighborhood. In more and more European countries an organizational development started soon to stop competition between different national airlines because of a waste of resources and subsidies by free competition, as some politicians argued and to secure technical progress for military purposes. Therefore, during the whole decade of the 1920ies in all European countries either voluntarily or by pressure of the national political authorities airlines merged to powerful national carriers, mostly controlled, sometimes owned, but always subsidized by national government to strengthen the competitiveness of the national carrier compared with foreign carriers (Wüst 1927; Fürst 1936, Allen 1981, Fischer 2003). National competition between some small airlines before the merger to a national carrier led to an oversupply of commercial routes inside a country or

to near located foreign cities because some cities desired to be linked with the growing net of airline routes and therefore installed airfields by own action. Most of these destinations survived the concentration of the airways and offered their airfields to new national carrier. After the foundation of national carriers, e.g. British *Imperial Airways*, Dutch *KLM*, and German *Luft Hansa*, now competition was between the national carriers and the governments behind it. This forced installation of always more routes and serviced parallel by more airlines in always more, interlinked destinations in all Europe. This is e. g. shown by the following figure:

Figure 1 Network of routes and destinations by the German *Luft Hansa* in 1926



(From the archive of Deutsche Luft Hansa, Ordner Flugpläne 1926-1933, Cologne).

Because building such a network of routes was a very similar development in all other developed European countries it is evident that there was no place

for a competitive network of commercial airship-services. The airship had no chance to be subsidized by national governments in addition to the very rapid growing airline services and airplane technology. Under a kind of competition and due to the military relevance of airplanes in future as it was made clear by World War I all European governments had voted for the support of the airplane technology both civil and military and against the civil use of airships inside the domestic areas and inside Europe. Up the outbreak of World War II, all regional airfields included, hundreds of airports has been installed as a net, spread like a cobweb all over the European continent and Great Britain, connecting all important cities and some smaller towns. Based on this physical net a network of hundred of routes served the passengers to all destinations regularly. This European wide network of airplane-based passenger routes was additionally linked with the national railway nets and the national as well as the international postal services (Fisser 1922; Arnoldi 1928; Altmann 1939). Did the same development happen in the United States?

4.2 Building a commercial airline network in US

Innovated by the Wright brothers, the air-plane in commercial services in the United States started as slow as in Europe (Solberg 1979; Smith 1991): when in November 1910 Postmaster General *Hitchcock* predicted that airplanes will be used to transport mail, it was not until eight years later that U.S. Army Air Service started to establish a nationwide air postal service. U.S. Post Office adopted this idea and started in 1919 an air postal service from Chicago via Cleveland to New York. It was stepwise extended to a continent-crossing service to San Francisco. Therefore, U.S Post Office managed airplanes and pilots as well as airfields with their equipment to fuel and repair airplanes. Since some cities tried to join this postal service network they quickly tried to open airfields financed by their own. Soon airfields as well as routes as a whole were equipped with light beacon for day and night flying operation. The governmental programs “Model Airway” and “Air Service Reserve Flying” supported the foundation of more airports by renting of municipal estates and financing the required equipment. Over the years the “backbone” of a continental-line from the east to the west was supplemented by some “side-arms”. Due to the range of airplanes being limited technically with a necessary stop every 150 up to 200 miles, a lot of airfields were disposed along the routes. Consequently, a sum of estimated 4,000 airfields, first airports in cities and military airfields formed an impressive physical net (Bednarek 2001; Leary 1985). Until 1926 U.S. Post Office established a national airmail service network by airplanes and a physical net of well-equipped routes by beacon and airfields. In contrast to the European development during the early 1920ies which emphasized more on passenger transportation services than on airmail, in the United States transport of airmail was offered only. By the Kelly Act 1925 and the Air Commerce Act 1926, from 1926/27 onwards step by step air postal services were established using a concession-system to private enterprises. However, U.S. Post Office defined the routes and, therefore, the

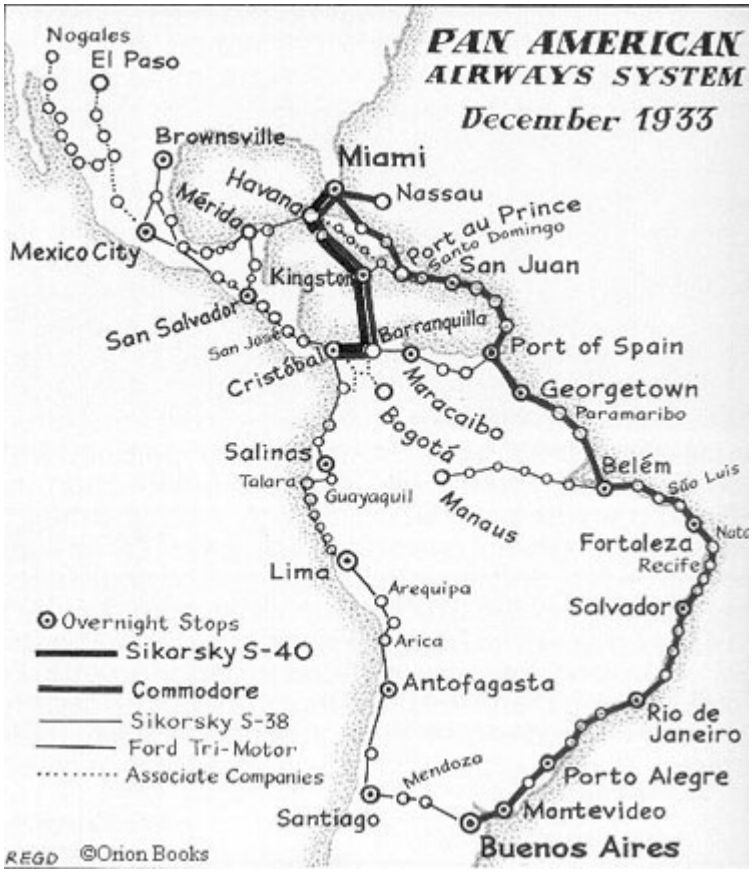
structure of the net; a parallel service of two competing private enterprises was forbidden. Some of the circa 100 private small and mid sized airways in 1925 were founded already since 1920. Some of them served a so called Foreign Mail Route, e.g. to Cuba or to Canada (Pollog 1929, 58). After this kind of "privatization" a lot of new airways were founded, subsided by the Government via the U.S. Post Office and protected from ruinous competition by the concession-system. Therefore, soon some new airmail routes were opened to knot the network tighter. But until 1928 passenger transport services were insufficient because airmail transportation was much more profitable. From 1930 onwards Government gave strong incentives to enterprises in the airmail business to offer passenger transport services, too (Pirath 1931, 52). Additionally, new Postmaster *Brown* accomplished more competition in all air services and forced the establishment of two new and additional transcontinental routes. One consequence of the governmental incentives to realize more competition was the creation of new and large holdings, often a combination of airways and airplane manufacturer. The airways *American Airlines, Eastern Airlines, United Airlines,* or *Trans World Airlines* and so on were examples for the emergence of large holdings which established their very own network but interlinked it among themselves.

Figure 2 Network by American Airlines in the year 1934 as one example only

(Source: http://www.timetableimages.com/ttimages/aa3406i2.htm, called 29. August 2006).

A special case was *Pan American Airlines*, which was specialized to transport airmail and later passengers to destinations outside the United States only (Josephson 1943). Up to the year 1933 the network of monopolistic working *PanAm* ranged from Mexico, the Caribbean and Mid-American states to South-American states, e.g. Bolivia, Brazil, Argentina, Chile, Peru, and Venezuela. Thus a net and a network for airplane services existed inside the United States as well as by destinations of important cities in the rest of the continent. By the end of 1935 *PanAm* explored Pacific Ocean by flying boats to establish a monopoly in regular postal and passenger services to the Philippines, Hong Kong, and Australia as well as the same was planned over the North-Atlantic to Europe (Hugill 1993, 264-265).

Figure 3 Pan American Airways System in 1933



(Source:http://www.centennialofflight.gov/essay/Commercial_Aviation/china_clipper/Tran5G1.htm, called 29 August 2006)

During the 1920ies only, a dense cobweb-like physical net of well equipped airports in the important cities and thousands of airfields emerged all over the United States. This physical cobweb was used at first by postal services only but later by passenger services, too. After a concentration process some mighty private airways, equipped with newest models of a progressive national airplane industry, used the physical net mentioned by filling it with interlinked routes to all important destinations to a service network which was shown for American Airlines for example. All these networks by different airways were linked with destinations in nearly all American states by the further expanding *PanAm*-created network as shown in the figure above. The service on the North-Atlantic from Europe to America only seemed to be an open field not serviced by airplanes, yet. Was this field the sole niche for the airships to build a net and a network?

5 Intercontinental transportation services up to 1937: a niche for commercial airship-technology?

5.1 Technical development of the competitors of the rigid airship

Since centuries, long-range intercontinental transportation of passengers, commodities, and postal services would only be realized only by ship. By the end of the 1920ies, interrupted by the Great Depression, up to the mid of the 1930ies new built and large passenger ships crossed the North-Atlantic in less than six days and International conferences of ship-owners kept prices for passenger-tickets high (Brandt 1935). At the same time, some pioneer flights by *Lindbergh* (1927) and *Köhl* (1928) with very small, one-person airplanes demonstrated that crossing the North-Atlantic by airplane is technically feasible (Streit and Taylor 1972, 194). These air-planes, however, were far away from any commercial service. In the shadow of the Great Depression, the very large experimental German flying-boat *Dornier DO X* only showed a kind of possible future of a large-scale commercial Trans-Atlantic passenger service: After an experimental flight over the Lake Constance with 169 passengers, in August 1931 *DO X* reached New York to demonstrate technical abilities (Pletschacher 1997). German *Luft Hansa* and German Government, however, did not show any concern in further development as well as British *Imperial Airways* abandoned interest in huge *Short Brothers* flying-boats which since some years flew to South Africa and India. Noteworthy, the flying-boat did not need any kind of special built airports with hangars, runways, and so on. However, in the early 1930ies, the land-based airplanes in normal use were not able to cross the North-Atlantic directly, but e.g. *Pan*

American Airways made an attempt to test transportation of mail and passengers by steps (Davies 1972, 259-261; Berendt 1961, 43). Not until before August 1938 a special equipped German *Focke-Wulf 200 Condor* had demonstrated a non-stop-flight crossing the North-Atlantic with a huge airplane perhaps usable for the transportation of some passengers (Dierikx 1997, 193; Bongers without year, 29). Did, therefore, a first-mover-advantage occur if the airships are able to cross the Atlantic more quick than traditional vessels?

From 1929 on, however, a more and more regular air-post service using a catapult-system installed on ocean-liners divided the long-range distance into short-range distances, but for airmail transportation only. Using this method, special airplanes landed and started from the special equipped Atlantic-crossing passenger-ships and reduced the time of ship-based postal delivery from Europe to North-America remarkable (Köhler 1983). This fact could be an obstacle for airship services.

5.2 Technical predominance of the airship: attempts to establish a network versus economic and political obstacles

The airship technology seemed to have an opportunity to realize a first-mover-advantage because passenger service by airplanes was not possible technically and service by ocean-liners suffered from an insufficient long duration of voyages on intercontinental routes. The advantageous technical facility of the airship was already demonstrated in July 1919 when British airship *R 34*, a copy of a German War-Zeppelin, for the first time crossed North-Atlantic non-stop by air (Maitland 1920; Abbot 1973). In 1919 and 1920 some persons in the German *Zeppelin Corporation* therefore discussed further plans to cross the North-Atlantic with the intact former War-Zeppelins *L 71* and *L 72* as well as the construction of a new huge Zeppelin to demonstrate the ability of German airship-technology in intercontinental voyages which were planned to South America, India, and the Philippines for civil and commercial purposes (Kleinheins 1994; Hebert 2002). Between the years 1920 up to 1923 similar plans were under consideration by *Schütte*, another firm which had experience in the building of huge airships since World War I. *Schütte*, additionally, tried to co-operate with U.S.-firms to establish a North-Atlantic airship service as well as a civil airship service inside the United States (Bleibler 2001). All these plans, however, could not be realized at this time.

After delivery of the Zeppelin *LZ 126*, the later named U.S. Navy rigid *ZR III Los Angeles*, built in Friedrichshafen for war-reparation to the United States and brought over the North-Atlantic directly in 1924, a new enthusiasm for Trans-Atlantic commercial services by airships rose up in Germany. All other countries using airship technology, most important in e.g. Great Britain, France, Italy, and the United States, however, stressed military or scientific uses only. After allied obstacles to build airships following the Treaty of Versailles were abandoned by politics in 1926, German *Zeppelin Corporation*

constructed the famous *LZ 127 Graf Zeppelin* and finished this large-scaled rigid airship in 1928, dedicated for long-distance commercial travel (Schiller 1966; LZA 016/0459). This planned use of the *LZ 127* was, however, inhibited by the external event of the outbreak of the Great Depression by end of October 1929. The North-Atlantic, since decades the most important business route of the world, lacked on enormous demand for transportation services during the Great Depression which knocked down both U.S. and German economy (Pirath 1938, 70). During these years the *DELAG* had no opportunities to run the *LZ 127* in a regular commercial service. As a consequence, the *LZ 127* made a lot of economically irrelevant demonstration voyages, e.g. a crossing round the world, and scientific voyages to arctic areas, up to the time when worldwide economy got over the bottom. By the end of 1931 a regular service had come into action, however, not on the North-Atlantic route but on a route crossing South-Atlantic to Brazil. This route has been chosen because some representatives of dominant German ship-owners in the board of the *DELAG* had intervened. Their interest was to secure the service of their new launched ocean-liners *Bremen* and *Europa* on North-Atlantic route from competition by the airship which was crossing the ocean in near the half of the time as the two quickest vessels mentioned. On South-Atlantic route the Zeppelin did not cause trouble in ship owners' interest; so *LZ 127* served North-Atlantic route casual only. Therefore, a mooring mast, a huge hall and all other equipment were erected in Pernambuco, Brazil, as well as in the trip-stop station in Spain subsided by German Government (Knäusel 1997, 344; de Syon 2002, 174). Because the route from Europe to Brazil was served only by slow post-steamers without any comfort for passengers the price for the transportation of a person by the Zeppelin was set on a high level: In 1934 for example, the tariff of a passenger-ticket for the LZ 127 from Friedrichshafen to Pernambuco was 1,550 Reichsmark during the main-season (Bruer 2002, appendix).

In the United States an airship infrastructure was installed step by step from 1919 onwards by the U.S. Navy at Airship Base Lakehurst, New Jersey, near New York. Because since 1930 different U.S. merchant airship bills were introduced in U.S. Congress commercial airship services seemed to have a flourish future and Lakehurst was fully equipped to an International Airship Base. But the base should be most frequented by the U.S. Navy Zeppelin *ZR III Los Angeles* and the new two giant U.S. Navy airships under construction (Althoff 1990). One of these airships, the *USS ZR4 Akron*, has come into operation in 1931 and should observe Atlantic Ocean but met with an accident in April 1933. The other airship, the *USS ZR5 Macon*, has come into operation in 1933, should be allocated on the new airship base Moffet Field on the Pacific coast but met with an accident in February 1935. Because of these facts, German civil Zeppelin *LZ 127* was able to use U.S.-Navy base Lakehurst during time of operation of Akron (1931 – 1933) occasionally only and, therefore, an additional argument was given to serve South-Atlantic route beyond domestic interests of ship-owners. The accidents of huge rigid naval airships *Akron* and *Macon* showed, however, important consequences:

following the U.S. Army which abandoned use of rigid airships already in the mid of the 1920ies, U.S. Navy now cancelled all of the former ambitious plans to build a fleet of rigid airships immediately; 1924 introduced *ZR III Los Angeles* was already shut down (Robinson and Keller 1982; Smith 1965). After *Goodyear* had given up the continental market for passenger services by blimps in 1932, *Goodyear* as the producer of *Akron* and *Macon* had at that time no more interest to invest in long-distance commercial air-shipping as any other private U.S. investor did. Not later than 1935 in the United States no huge rigid airship was in operation but there did exist the full equipped International Airship Base Lakehurst on the Atlantic coast.

This was an advantageous opportunity for the German Zeppelins to enter the North-Atlantic route by a regular service. This plan was supported by the national-socialistic German Government being at the controls since 1933 because the Nazis wanted to earn stable foreign currency greedily. For these reasons from summer 1936 onwards the new built giant Zeppelin *LZ 129 Hindenburg* has come into commercial operation to serve North-Atlantic route regular from Frankfurt am Main in Germany to Lakehurst until the disaster on 6 May 1937. In spite of the fact that *LZ 129* was not always fully booked crossing the North Atlantic the Zeppelin earned US-Dollars by passenger tickets and mail transport: comparable to first-class-tickets by travelling with a modern passenger-liner a one-way-ticket from Lakehurst to Frankfurt/Main by *LZ 129* had a price of circa 400 Reichsmark (Marschall and Archbold 1994, 170). But the operation of the now two sole huge rigid airships in operation worldwide depended on subsidization by the Nazi government and the German carrier *Luft Hansa (LZA 006/0668; LZA 006/0757)*. These two airships were far away from establishing an economically sustainable net of interlinked destinations: the two routes mentioned were point-to-point services only and not synchronized well to other means of transportation. The Zeppelin *LZ 130 Graf Zeppelin II* which was finished at the time of the Lakehurst disaster had never come into commercial operation in spite of the fact that this airship was dedicated to an eventually substitute the ten year old *LZ 127 Graf Zeppelin* with his limited commercial load carrying capacity. A further Zeppelin of the Hindenburg-class, the *LZ 131* was only at a very early stage of construction when *LZ 129* exploded (Bauer and Duggan 1994). Because Nazi-regime stopped any commercial service of the LZ 127 and the new LZ 130 immediately after the Lakehurst disaster, the installed net of the small number of airbases used in Lakehurst, Frankfurt am Main, Spain, Brazil, and on Zeppelin shipyard Friedrichshafen had been commercially worthless.

But what happened with commercial airship services by other countries? Why did the point-to-point routes between the United States, Germany, and Brazil remain a singular phenomenon, only?

In Great Britain mid of the 1920ies a plan of a London centralized worldwide net for twelve huge rigid airships was under consideration. Different excursions of the routes suggested by airplanes proved to be to slow and burdensome. Five routes from London via Egypt to India and Australia, to Canada, two routes to mid-America, and an east- as well as a west-bound route

over Africa to Cape Town should be established supplying a Governmental courier service (Beelitz 1927). Soon mooring masts in England, in Egypt, in Canada, and in India were built as a net for the first routes. This ambitious British project can be qualified as a strong approach to create an imperial-wide network of airship services and it can be argued that similar airship services of other countries, e.g. of Germany, could be linked with this British "backbone" theoretically. Therefore, the first to airships realizing this project were built and the first airship, the *R 100* which was designed for 100 passengers and 10 tons of mail, crossed North-Atlantic in July 1930 and reached their mooring mast in Canadian Montreal without problems. The voyage back was absolved in 57 hours only and *R 100* reached their British base at Cardington. The next airship realizing this project, the *R 101* which was designed for 50 passengers, started to their first regular voyage to Egypt and then to India on 1 October 1930 but crashed already over France and all passengers lost their life. Because of the disaster of this hydrogen-filled airship the ambitious British project was terminated immediately and even a real chance to create a large-scale network of commercial airship services passed by in 1930 (Chamberlain 1984; Higham 1939; Higham 1960; de Syon 2002, 189). The mooring masts erected in Egyptian Ismailia, in Indian Karachi, and in Canadian Montreal had been conserved for some years to secure an option in air-shipping in future (Countryman 1982; Countryman 1992, 90-91). A small Britain syndicate did really remember this infrastructure and suggested in 1936 in the shadow of first successful voyages of *LZ 129 Hindenburg* a co-operation between a new founded *British Zeppelin & Airship Navigation Syndicate* and the *Deutsche Zeppelin Reederei*, the new corporation following the *DELAG*. The very ambitious project suggested should base on as far as eight Zeppelins of the *Hindenburg*-class and should create a worldwide network of regular commercial routes linking Great Britain, Germany, other European states, the United States, Canada, South America, South Africa, Egypt, India, Australia, and states in the Far East (Edmonds 1936). Still the rudimentary physical net of mooring masts and some bases in England, in Germany, in Brazil, in Spain, on the east coast as well as on the west coast of the United States, in Canada, in Egypt, and in India did exist. At the same time in the Netherlands vague plans seemed to be under consideration about a regular airship service from Amsterdam to Batavia in Dutch-Indonesia because the airplane service by the Dutch airline *KLM* since 1932 had an insufficient load-carrying capacity and travel time was ten days with eight stops (Kaefer 1999, 17-18; LZA 005/0601). All these projects, however, seemed to be dream-fully plans by the airship-enthusiasts in some countries and collapsed back upon itself when *LZ 129 Hindenburg* crashed.

But for all that it was recognized that an establishment of a *worldwide* net of airship bases would be a necessary condition to run any commercial services successfully and to form a network. If all of the projects under consideration during the 1930ies would have been realized this would have been the only chance for rigid airship technology to survive and to compete with deliberate starting of intercontinental airplane routes. In the mid of the 1930ies the

technology of huge rigid airships to conquer large distances under all climatic circumstances was fully developed technologically in comparison to the contemporary airplanes in the same field of operation. It seemed that the huge rigid airship has had a so called first-mover-advantage to create a net and a network before the airplane could do it. Then, the airship-technology had been able to occupy the market of intercontinental services by air-transportation and this perhaps had deterred now a more risky market entrance of airplane based services some years later. The different national airship protégées, however, did not co-operate with their net-projects and suffered evidently a lack of capital, necessary to finance the giant investments. Additionally, most of the governments supported the airplane and their networks massively because the airplane seemed to be extremely important in future military purposes. Even in one state an airship met with an accident, airship technology as a whole was terminated.

6 Conclusion: History does repeat

The most important result of our analysis was a strong relevance of the speed of the net building surpassing a critical mass of operation-bases which then was a precondition for the establishment of service networks. In all relevant states airport and airfield net grew faster than airship-base net. The slower growing and, therefore, failing technology together with their services exist only up to a hazardous disaster and would then as recently as promptly abandoned. Before, however, realized economic losses even over longer time were tolerated.

Here history does repeat as shown by the shutdown of the British-French supersonic aircraft *Concorde*: Similar to the late Zeppelins, the *Concorde*, with its first take-off in 1969, was designed for very high speed transport in long-range distance. Additionally, this aircraft was a very complex and expensive system both in capital- as well as running costs. At the beginning, some hundred potential buyers signed options to purchase this aircraft (Wilson 1973; Feldman 1985). However, administrative barriers soon caused service crossing the North-Atlantic connecting New York - London and New York – Paris, only. Therefore, the establishment of a worldwide net on supersonic services was impossible to realize and only a dozen of these aircraft had come in regular service. But not until thirty years later and after a horrible accident all *Concorde* aircraft were immediately shut down in commercial operation in 2000, similar to the Zeppelins in 1937. After a long struggle against its large but cheap rival Boeing 747, the technically more sophisticated *Concorde* was thrown from market just like the sophisticated technology of the Zeppelins in the overall struggle against the airplane. The historical event which throw away the great rigid airship from market was the Lakehurst disaster, and when U.S. policy refused to give the save helium-gas to lift Zeppelins to Hitler's Germany (Braun 2005). In the case of the Concorde, exploding prices for avgas by reason of oil-crisis and the awakening harm of noise were historical events stopping any attempt to reach a critical mass of destinations. The

accidents both for the Zeppelin-technology and the Concorde-technology were obvious facts to terminate both the technologies. But since long time ago they both failed economically because they were not able to establish a network of routes and destinations in comparison to their relevant competing technology, the "normal", at every time technically *and* economically gradually improved airplane.

But some people do not learn from historical lessons: The failed spread of the German invented magnetically levitated train *Transrapid* has the same structure as the huge rigid airship and the *Concorde* – because the *Transrapid* technology is sophisticated and expensive in comparison to the long time well-established networks of the technical competitors, the modern railway, the short-range airplane, and the automobile. Nobody does finance the enormous investments to install a totally new net for a Maglev. The Airbus 380-concept designed for a small number of hubs versus the Boeing Dreamliner as a competing concept is an actual example for the relevance of nets and networks. Because the Airbus 380-concept needs an expensive equipment of the airport such as longer runways, better passenger logistics, giant hangars for preventive maintenance, etc. the airports will have to carry out large investments in this specific infrastructure. Worldwide, will a critical mass of airports worldwide perform these investments?

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