N76-15018

COMPARATIVE AIRSHIP ECONOMICS

Capt. Robert Harthoorn*

ABSTRACT: As future LTA vehicles will be doomed right from the start if they do not fill a real need, some differences in transport philosophy between design engineers on the one hand and freight forwarders on the other are discussed. Watching rising costs of energy necessary to transport our cargo from A to B, and realizing that this price of energy is always included in the product's selling price at B, the apparent correlation between installed specific tractive force per unit of cargo weight and pure freighting cost are contemplated. Very speedy and progressive Airship designs are mistrusted by the author, because the key to any low cost transport tool is to design it for its given task only, without any unnecessary sophistication.

THE BEE AND THE PHYSICAL DISTRIBUTION SYSTEM

It is said that in order to collect one kilogram of honey, the bee flies an average corresponding distance of twice the equator's length, and thanks to his faultless computerized communication and balanced stock-and-distribution systems, not one bee ever flies one meter too far, and not one gram of honey is lost. Related to our present pattern of transport, this example teaches us in a nutshell how we ought to perform the so-called Physical Distribution System, which is up to the present still far away from this ideal situation. As a good excuse for our human and technological shortcomings in this field, we may remark that our bee is not tied down to the most numerous and complicated national and international laws governing commercial aviation, nor the very complex freight rate structures set by the (I)nternational (A)ir (T)ransport (A)ssociation, delaying customs formalities, political barriers, feedering ground transport, etc.

*General Manager, Equipment Control, Holland America Line, Rotterdam, The Netherlands

PRECEDING PAGE BLANK NOT FILMED

Having all the freedoms of the air, instead of the five freedoms embodied by the Chicago Convention; and in his own area, not bothered by other competitive means of transport, the bee flies and lands wherever he chooses and always ships the same commodity from production center to final destination at only one computed flat through-rate.

Coming to the Airship concept, I took this example because, when I read or listen to the promotion arguments of some Airship designers, I get the slight impression that the freight forwarder and/or the operator has to take it for granted that the Airship, figuratively speaking is going to substitute the bee, and solve all of our transport problems accordingly.

It is quite human and understandable that any designer,as a specialist, likes to take pride in a new and sophisticated design, but initially one has to realize that the Airship is not the only competitive way to transport paying loads, and secondly, one has to realize that the shipper or the paying passenger is the ultimate customer, and it is essential that these points of view are borne in mind when talking about the re-introduction of the Airship concept. Original thinkers who want to break some old habits of transport are badly needed, but it should be appreciated that there can be only one valid reason for accepting the Airship concept, and that is if Airship services can perform a profitable and useful function.

LAMINAR AIR-FLOWS OR "LAMINAR CASH-FLOWS"?

The varying Airship cost figures supplied up to the moment are rather frustrating. On this basis one cannot blame the investors' reluctance to invest a reasonable amount of capital, because he is neither interested in the difference between laminar and turbulent airflows, nor in propeller efficiency, but only in "laminar cash-flows" and returns on capital. This statement may sound a bit unsympathetic in some circles, but if one accepts that the profits of any businesslike undertaking are the lifeblood necessary for investments in the future, one has to realize that the investor wants a sound and reliable cost figure.

THE CAPITAL RETURN FACTOR

The economical crux of the whole matter concerning comparative Airship economics is embodied in one simple formula. This formula measures the profitability of an investment in terms of gross net income per unit of invested capital, called the Capital Recovery Factor Formula, viz.,

$$\frac{AFR - (DOC + IOC)}{\text{Total Invested Capital}} = \geq 0.15 \quad \text{or} \quad 15\%$$

In this formula, the total annual freight revenue (AFR) represents the product of (average actual loadfactor) x (maximum payload capacity) x (average blockspeed) x (number of operational hours/year) x (freight rate per ton/nautical mile). Taking into account the later deduction of state taxes and stockholders' dividends, we assume that the desired outcome of this C.R.F. Formula gives the investors the reasonable figure of at least 0.15, equal to 15%. The designer's responsibility now is to supply, within the limits of the given specifications, a valid and controllable breakdown of the direct building and technical operating cost figures, which are important parameters in the given formula.

DETERMINING AIRSHIP'S SHADOW FREIGHT RATE

Presuming that the Airship's shadow freight rate is more or less determined by the direct competitor in this field, viz., the present aircraft carrier, it is essential that the Airship's freight rate be determined at a price which is preferably at least 30% less than the average actual airfreight rate applying to the same transport distances.

Taking a very average specific airfreight rate from Amsterdam to New York, viz., $0.45 per short ton/nautical mile, the average Airship shadow freight rate will be determined at, let us say, $0.30 per ton/nautical mile. Considering a long-haul designed Airship, having a trans - N. Atlantic payload capacity of 300 short tons, and presuming that the accepted break-even load factor of 0.5 (50%) provides no capital return at all--which means that total freight revenue equalizes total costs--we demand a capital return of at least 15%, obtainable at an average annual load factor of 75%.

Presuming 3,000 operational hours per year, and an average blockspeed of 80 knots, one may now reach the conclusion that after applying the C.R.F. formula, the total maximum admissible capital investment may not exceed the amount of 36 million dollars.

$$\frac{16.2 - 10.8}{y} = 0.15$$

$$y = 36$$

This system of approach may be a bit unconventional, but it serves perhaps the purpose in which way one may assess the commercial viability of Airship services.

SPEED AFFECTS THE CAPITAL RETURN FACTOR

I am aware that the notion of speed in Airship circles leads to a lot of disputes; however, to obtain an optimal economical speed for any given transport device is a rather complicated and tricky business. Mentioning rigid Airships, sailing up to 150 to 300 knots and more, the unhappy operator may find himself caught in the financial speed-trap if he neglects in what way this speed increment is going to affect the Capital Return Factor.

In other words, taking into consideration that extra fuel to be carried displaces payload capacity, the total ton/n.m. production may initially increase to a certain limit, but the question remains to what extent this particular speed does affect the several other parameters of the C.R.F. formula. It has to be appreciated that "speed boosting" negatively affects the maintenance labor and material costs, utilization hours, depreciation period, engines building costs, fuel consumption, and consequently, the Direct Capital Investment.

The positive or negative outcome of the balance will be determined by the return on capital, after having fed all the known parameters into this formula; however, some dimensionless parameters will always remain, such as service, goodwill, marketing policy, etc. We can appreciate that the Airship's minimum technical speed is determined by the average prevailing atmospheric conditions. A reasonable increase of speed, however, may be justified if the Airship, by offering increased sailing frequencies, also improves her average load factor. Marketing policy, however, is subject to the operator's responsibility, because the appreciation of speed depends upon the freight-forwarder's philosophy.

WHAT PRICE, WHAT FRICTION?

Technically speaking, one easily can increase the power of any small Volkswagen engine, so as to provide a speed of 100 mph and more, but the small Volkswagen was not designed and not intended as a very speedy automobile. The same remark applies to the bulky Airship, which ought to have a relatively low specific resistance coefficient at cruising speed, which means a favorable, relatively high lift-to-drag ratio number. It would be an unrealistic approach to presume that the Airship provides such a high L/D ratio number because she is such a fine aerodynamically shaped piece of machinery; the simple reason to keep in mind, however, is that only the heavy Airship is able to sail the sky with a relatively low service speed, and any thoughtless speed increment weakens her economical strength.

Let us please not take any given commercial transport device out of its natural, technical and economical area of environment within which it can operate. If we want to ship relatively high valued cargo, we do not object to paying for a low L/D ratio number, but in this particular case we would prefer the present pure freighter Boeing 747, which provides, for a given price, at least a real good speed.

A rather strange sense of humor is needed to believe in very speedy Airships having competitive freight rates combined with L/D ratio numbers which lie in the range between seagoing Hovercraft and the sleek, supersonic, payloadless Concorde.

IMPROVING L/D RATIO NUMBER ONLY BY ECONOMY OF SCALE

After doubling the original cruising speed of the pre-war Airship "Hindenburg" from 68 knots to 136 knots, the very favorable L/D ratio number of about 44 will drastically decrease to the rather poor ratio number of 11. This is even 6 points less than the L/D value of the Boeing 747, which flies at about 520 knots at normal cruising speed, even without the so-called miraculous boundary layer control system.

By applying some elementary formulae determined by nature, one now has to enlarge the original volume 64 times in order to obtain a sun eclipse, cause by a nearly 13 million cubic meter Airship with sufficient propulsion power to develop 136 knots; but now having regained the original L/D ratio number of 44; or in other words, having the same specific resistance coefficient of the original "Hindenburg."

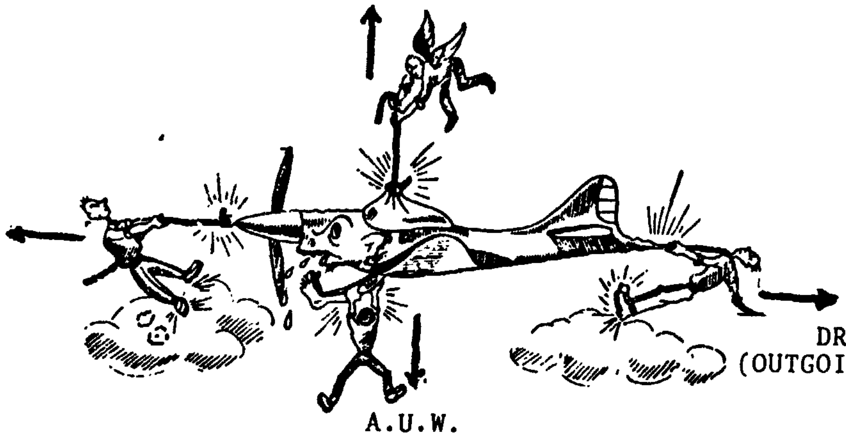
At 68 knots.................................... $\frac{L}{D} = 44$

At 136 knots............................ $\frac{L}{4D} = \frac{1}{4} \times \frac{L}{D} = 11$

At 136 knots/volume x 64.......... $\frac{64 \times L}{(\sqrt[3]{64})^2 \times 4D} = \frac{L}{D} = 44$

L/D RATIO NUMBER AS A PARAMETER OF THE CAPITAL RETURN FACTOR FORMULA

Pointing to the thesis that the L/D ratio number is inversely proportional to the fuel consumption and directly proportional to the maximum payload capacity, it will be appreciated that in reference to the C.R.F. formula, this ratio number has a certain economical significance, if one considers the (L)ift as representing the incoming dollars and the (D)rag representing the outgoing dollars.



SURFACE TRANSPORT SYSTEMS

As a consequence of our welfare growth and increasing world population, many types of transport craft with specific designs have to become available to deal with the growing variety of commodities which have to be transported in the most efficient way.

If one observes the development of surface transport systems, the future Airship has to find her place among Ro-Ro-Ships, gigantic 50 knot container ships, gasturbine-driven freight blocktrains, powerful roadtrailers combined with computer guided traffic systems, waterjet-propelled fast Hover and Hydrofoilcraft, etc., offering within their own speed ranges, very competitive freight and/or passenger tariffs.

Now, one may object by arguing that present types of motor vehicles and trains are relatively slow and that the speed advantage of fast aircraft, serving European travelling distances, is wiped out by the time losses caused by too long distances to the airports and waiting times. Watching the future development of tracked aircushion and/or linear induced magnetic trains (Advanced Passenger Trains), running up to 270 mph, one may conclude that the now existing speed gap between the conventional train and the aircraft at travelling distances between 200 miles and 1,000 miles can be filled by future A.T.P.'s.

In view of the Modal Split assumption regarding proposed regular passenger services by Airships in Western Europe,it is of some interest to realize that before the introduction of the Tokaido "Bullet Train" running from Tokyo to Osaka and vice versa, 26% of the travellers between these towns went by plane, which percentage rapidly dropped to a bare 6% after the introduction of this Tokaido Line.

Summarizing those competitive services offered by surface transport in Western Europe, it seems evident that unless considerable door-to-door time and total transportation costs can be saved,the regular short haul freight Airship has small prospect of success in competition with the relatively cheap surface transportation systems.

Where the journey in W. Europe involves a seacrossing, Airship services might have certain advantages in saving handling and transferring times and costs. These advantages, however, are partly offset by the fast growing number of Ro-Ro-Ferries operating in the North Sea, Mediterranean and Baltic Area, etc.

COMPARING DIFFERENT TRANSPORT DEVICES; THE DANGER OF CONVINCING FIGURES

If one wants to sell a special piece of transport machinery, it is not too difficult to find convincing arguments, accompanied by even more convincing figures; the danger with figures, however, is that one can sweep them together under all kinds of carpets to meet the required qualifications. Comparing overall efficiency in terms of transport capability between different commercial transport devices might be a useful mental exercise, but only in order to reach some general conclusions. Generally speaking, those comparisons do not produce real economical usefulness if one omits the Total Cost Concept from door-to-door, which is the ultimate and decisive marketing factor. Trying to prove that the building cost per ton structure weight of an Airship having the same transport potential as the freight Boeing 747 has to be considerably cheaper than the comparative cost per ton of that particular aircraft does not impress any investor unless, of course, he wants to sell this craft for scrap value. In terms of horsepower per ton All Up Weight (A.U.W.), the average private motorcar needs an installed engine power of about 100 h.p. per ton and is in this respect more efficient than the Boeing 747. However, in terms of installed h.p. per seat/mile it is good to realize that the private automobile is in this respect one of the most expensive ways of transporting yourself from A to B, but as we have already stated, there are a lot of other factors to be taken into account.

By neglecting the total transportation costs, including door-to-door saving time for a given transportation distance, one may easily jump into a financial trap, if somebody convinces you to purchase his train tickets, arguing that the number of installed h.p. per seat/mile as well as his tariff are considerably less than the comparative figures of your private motorcar.

Comparing direct operating costs of two modes of transport, even if both are operating in the same environmental area, often gives no clear picture either. One may,for instance,easily draw the wrong conclusion that the full container ship in comparison with the conventional dry cargo ship, is so expensive that she could never be operated on a competitive basis, if one neglects the total transportation cost concept.

PROFIT EARNING PAYLOAD, DRAGGING UNPROFITABLE TARE WEIGHT

Accepting the philosophy that the only profitable work done by any commercial transport vehicle is the overcoming of the resistance of the payload in its motive container consequently means in reverse that each ton of motive payload has to drag a certain amount of unprofitable resistant deadweight.

To overcome this unprofitable resistance, one can imagine that figuratively speaking, each ton of motive payload has to be provided with a certain amount of tractive force. If we further accept the reality that the main reason cargo commodities are shipped from seller to buyer is to make a profit, then this consequently means that any shipper wants to transport each ton of cargo at the greatest possible speed, combined with the lowest price for tractive force, which price of energy is always included in the product's selling price.

As high speeds are usually in contrast to relatively low specific resistance coefficients, the following comparison between several modes of transport (past, present and future) may be of some interest.

THRUST COSTS - DOLLARS

Total installed specific thrust in kilograms to move one ton of pure profitable payload at service speed, arranged in rising sequence of their respective resistance coefficients, based on a 100% loadfactor and taking into account the deadweights of fuel, lubes, stores, equipment, and empty containers, etc.

MODE OF TRANSPORT	TOTAL INSTALLED SPEC.TRACTIVE FORCE IN KG/TON PAYLOAD	KNOTS/HR SERVICE SPEED
1. Super Tanker "Esso Deutschland" (Europe - Pers. Gulf Trade)	2.484 kg	17
2. Dry Cargo Ship "Hamburg" (Trans N. Atlantic Trade)	8.10 kg	19
3. Average Container Freight Train	23.57 kg	38
4. Full-Container Ship (Sea-Land Galloway)(Trans N. Atlantic Trade)	29.40 kg	31
5. Road Truck (Mercedes Benz LPB/2224	63.36 kg	38
6. Large Airship (Future) Airfloat Trans-[1] port Ltd.)(Trans N. Atlantic Trade)	175.00 kg	100
7. Future Sidewall Surface Effect Ship[2] (C.A.B.* System)(S.E.S.)(Tr.N.Atl.)	229.00 kg	100
8. Freight Hovercraft,,type Voyageur I '73 (Bell Aerospace)(300 km range)	464.00 kg	35
9. Airship "Hindenburg" (1936/37) (Trans North Atlantic)	518.00 kg	68
10. Boeing 747 F. (Freighter) (Trans N. Atlantic)	1,002.00 kg	514
11. Heavy Lift Helicopter Sikorsky S64E (70 km range)	1,534.00 kg	95
12. Supersonic Concorde (Trans North Atlantic)	5,449.00 kg	1,160

*Captured Air Bubble

GENERAL CONCLUSION

One cannot force the laws of nature, but one can balance them against each other.

Now one may draw a lot of conclusions, but as far as land - surface transportation is concerned, the freight train makes in this respect a very efficient mode of transport.

Realizing that the propeller efficiency of the pre-war "Hindenburg" was about 67%, it is obvious that she would provide a slightly better figure,if I had taken the presently accepted efficiency of 85%,combined with current building materials and construction methods,which provide in turn a more favorable payload weight to structure weight ratio.

Further it may be noticed that the "Economy of Scale" does really pay off, if one compares the figures of the large Trans North Atlantic Airship with the relatively small Trans Atlantic "Hindenburg," which economy applies also to the surface displacement ships.

In sequence of specific motive forces on a ton payload basis, the large Airship ranks as number 6 on the list, but arranged in sequence of increasing service speeds, this large Airship has to be listed between helicopter and transatlantic aircraft.

In other words, the large Airship needs for each ton of shipped payload a relatively small tractive force, combined with a relatively good speed.

Since the Concorde is designed as a pure passenger carrier, it is, of course, not fair to compare this aircraft with pure freight carriers.

Looking at the heavy lift helicopter, one is inclined to believe that nobody can afford to transport loads with this very expensive carrier, but the comparison with regular freight carriers is also a bit misleading, if one does not judge the helicopter on her proven merits as a very specialized transport tool.

AN IMAGINARY HEAVY AIRCRAFT, HAVING A L/D RATIO NUMBER OF 40?

If it were possible to scale down the speed of the Boeing 747 ("F") to about 130 knots the specific motive force per ton payload would drop to the comparative value of the Sea-Land Full-Containership. As every type of aircraft is designed for their own speed, this example of wishful thinking is of course a bit of theoretical nonsense; flying close to stalling speed with extended flaps makes economics relatively worse than they are; but what if one reverses this problem by putting forward the question,"Will it be possible to construct a heavy plane, carrying 200 tons of payload with a speed of 130 knots and having an overall lift-to-drag ratio number of 30 and over?"

The expected answers which I got from some aeronautical engineers were that this trick could not be done, because the very low loaded wings would introduce increased frictional drags, structural problems and weight penalties, etc.

If we accept that the "curse" which lies upon heavy aircraft is that it has to induce its own lift by considerable forward speed, we have to accept the Airship as the only natural way to solve this L/D ratio problem, which consequently means a mechanical, as well as an economical, restriction as far as the transporting of less valuable commodities by air is concerned.

THE (DESIGN) DENSITY STORY

In view of the relatively roomy cargo space of the Airship, one may safely presume that an Airship is practically always weight-restricted, which means that if the Airship is loaded to her full permissible take-off weight, she usually has some cargo space left, regardless of the average densities of the shipped cargoes.

Referring to several density studies concerning airfreight commodities, one may draw the conclusion that present aircraft often have a problem with their cargo design density, which statement also applies, but to a lesser extent, to the 747 pure freight Boeing. This density problem often causes aircraft to cube out before they are loaded to their maximum permissible payload weight, which causes in turn a loss in revenue potential.

The reason is that any transport device is essentially a compromise; building aircraft with lower density design specifications involves structural weight penalties, or as it is said: "Aircraft cannot afford to carry air inside their belly holds."

As 9 lbs.per cubic foot is the limiting figure set by present aircraft between weight and volume tariff (dimension weight rule), this figure is an important key regarding the economics and freight tariff structures of future Airship freight services.

COMPETITIVE FREIGHT RATES - LOW DENSITY FREIGHT MARKET

Even if the future Airship cannot provide a reasonable gain in pure freighting costs regarding high density commodities,she is nevertheless highly competitive with present airfreighting, regarding voluminous commodities weighing less than 9 lbs. per cubic ft. In spite of the fact that the average "on dock" density for aircargo lies roughly in the neighborhood of 13 lbs. per cubic ft., there still exists a huge market of very low density commodities weighing less than 9 lbs. per cubic ft.

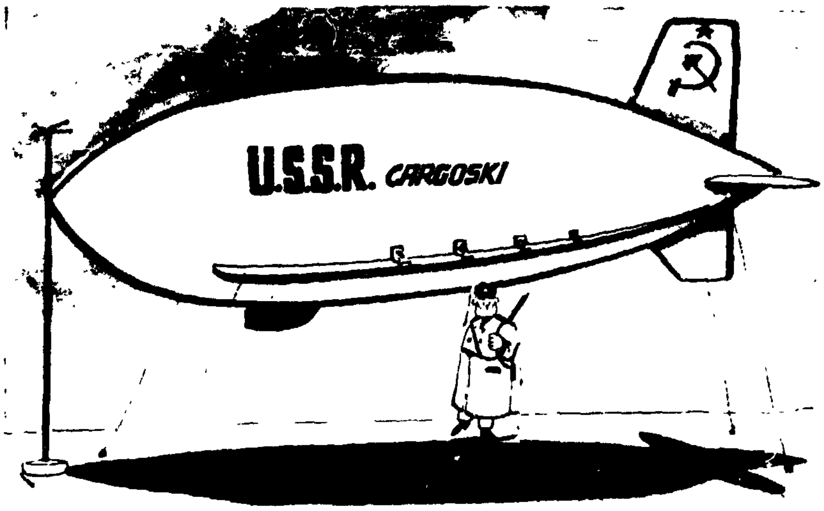
These low density commodities represent about one third of the total world number of air freight parcels forwarded at present by air, which amounts roughly to nearly half of the total world air freight package volume. As there is no economical need for the Airship to punish these lower density commodities by applying the volume tariff, it is of some interest to be keenly aware of the fact that the future trend inclines to lower densities of air freight commodities.

TRANSPORTING OWLS TO ATHENS?

Coming to the end of this paper, the dominating factor is the very competitive services offered by other means of transport. However, we believe in the Airship concept as a basically sound concept, and I fully agree with other speakers that the Airship, as a specialized tool has many useful applications, such as transporting heavy and/or indivisible loads, etc., in which case the Airship gets paid for the specialized job to be performed.

If the Airship can decrease the present airfreight rates in order to reach the commodities on the upper limit of the median value group,she may indeed have some prospects as a regular long haul freight carrier, not by trying to transport owls to Athens, but only by carrying selected commodities over wisely selected routes and distances.

RECENT DEVELOPMENTS IN RUSSIA



It will revolutionize cargo transportation--
She runs on vodka!

REFERENCES:

1. Mowforth, E., Dr., Airfloat Project, Royal Aeronautical Society, London (Sept. 20, 1971).

2. Decker, J.L., High Speed Marine Vehicles - A Design Outlook, Isle of Wight Branch of the Royal Aeronautical Society (Oct. 19, 1972).

3. International Freighting Weekly, London (1973).

4. Baton, Jean, The Place of Transport in Modern Society, International Air Cushion Engineering Society (Feb. 17, 1971).

5. Plesman, A., Exploitatie Van Vliegtuigen, De Ingenieur, No. 33 (August 14, 1936).

6. O'Hara, Clifford B., Moving Freight in the Future, Society of Packaging and Handling Engineers, San Francisco (Oct. 28, 1969).

7. Liberatore, E.K., American Surface Effect Ship Activities, Jane's Freightcontainers (1969).

8. Harthoorn, R., Naar een "Come-back" van het Luchtschip, Beta, Nos. 11, 12, 13, 14, and 15, Amsterdam (1971)

9. U.S. War Department, Technical Manual Aerostatics, TM 1-325, Washington D.C. (Oct. 1, 1940).