4. TRANSPORTATION MISSION SURVEY

4. TRANSPORTATION SYSTEMS SURVEY

A general screening of the whole transportation market was first done to isolate sectors where an LTA vehicle could be expected to find a slot. The section of transportation and missions which were selected for an analysis are shown in Figure 4-1 which also presents a brief summary of the conclusions.

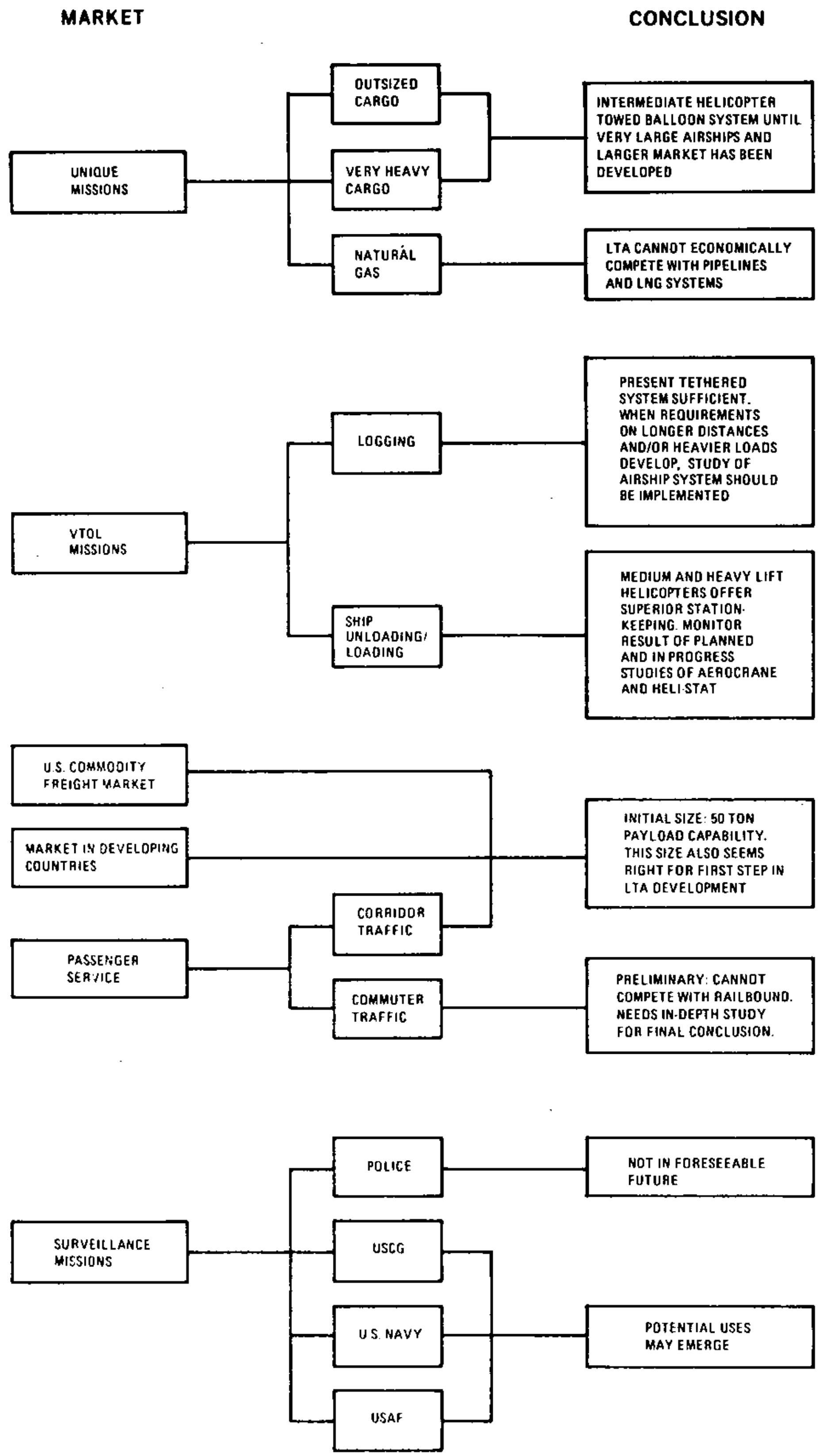


Figure 4–1. Summary of Mission Survey, Approach and Result

4.1 Summary and Conclusions

A certain section of the transportation market, namely, delivery of heavy and especially voluminous factory made components, to the construction site could today favorably utilize an airship design.[11] The "very oversized" goods started to come with the huge power generation stations, not only the nuclear type but also fossil plants. Larger construction components within industries, such as bridge building, transmission powerlines and pipelines, shipbuilding, house constructions, etc. may also come in the future providing suitable means of transportation are available from the factory to the construction site. Presently, the designs of the individual pieces consider the possibilities of transportation and thus limit the size. In many cases, it would be more economical to replace on-site assembly of several small components with a factory manufactured very large component.

Present market of unique missions for an airship of a 800 ton payload vehicle is very limited. A utilization of one airship only, can be estimated at about 600 hours a year. That kind of utilization cannot pay for the production cost of a 50×10^6 ft^3 ($1.4 \times 10^6 m^3$) airship, still less for the development costs.

The present problem with transportation of huge powerplant components and the excessive transportation costs could be solved with a helicopter towed balloon system as outlined in Paragraph 4.4. The transportation by such a system would many times be less expensive than present earthbound transportation and thus help to reduce the costs in construction of much needed energy generating plants. A Very Heavy Lift balloon system could be developed in a rather short time and at a reasonable cost because of the low technical risk involved as well as simplicity. Further, the appearance of a VHL transport system may develop the interest with other manufacturers of large components and plants to consider more economical factory made pieces. Thus, the market will be built up for a future large airship.

In search for a transportation market that could justify a revival of the airship, an investigation of the U.S. Freight Commodity Market was made. An airship size of about 50 tons payload capacity seems to be optimum. 0.5% of the estimated 1985 transport requirement would require 43 up to 87 vehicles with a utilization of 4,000 to 2,000 hours per year, respectively. 2% of the market would require from 174 up to 348 airships.

Transportation of natural gas in gaseous form by pipelines as well as liquefied in tankers are very cost-effective means of transportation. Although analyses of development costs and production costs of an actual gas carrying airship (the fail-safe containment of the flammable gas must be considered) were not within the scope of this conceptual study, it is apparent, by comparing the what-it-can-cost figures in Paragraph 4.5 with the discussion of economics in Paragraph 3.2.7 that an airship cannot successfully compete with present well-developed systems.

The passenger traffic in the U.S. West Coast corridor between San Francisco-Los Angeles-San Diego has been examined. This investigation indicates there are segments which offer a potential for an LTA vehicle of the 50 ton/250 passenger payload capacity with a cruise speed of at least 100 kt (51.4 m/s) and VTOL or STOL capability.

A brief comparative analysis between a commuter traffic airship system and a modern railbound system indicates that the airship may not be a competitive alternative. A more thorough analysis which should go more into detail than could be done within the scope of the Phase I conceptual study, should be made for a definite conclusion on this application. Such a study must address the full complexity of the installation of a new railbound system, an airborne system, airship development costs, airship certification, production, flight rules, all-weather operation, etc.

Potential U.S. Coast Guard surveillance missions have been defined and the required LTA vehicles have been sized in the computer program and considered in the Vehicle/Mission Matching and Selection, Paragraph 6.2.

A near future use of LTA vehicles in police traffic and law enforcement work cannot be foreseen. An LTA vehicle cannot compete cost-wise with a helicopter. Further, no requirements for a very long endurance surveillance vehicle which could require a remotely piloted vehicle exists. The acceptability of an unmanned, relatively large LTA vehicle loitering over populated areas is uncertain.

U.S. Navy missions in the surveillance field and a U.S. Air Force missile mission emerge as potential candidates for an LTA vehicle. Further work on definition of an LTA configuration should consider a matching of commercial missions and military to achieve a common size of the platform - the LTA vehicle.

In conclusion, the survey of transportation missions indicates that the first development step should be an approximate 50 ton payload airship. That size could find a market in commodity freighting as well as passenger service. Further, it seems to be an approximate size for research and development of improved subsystems as well as larger sizes. Large size LTA vehicles (10×10^6 ft^2 ($283 \times 10^3 m^3$) and up) will be rigid (see Paragraph 5.3.1.1), fully buoyant or partial buoyant configurations. Therefore, very little, if anything, can be gained by starting a step development program with a non-rigid airship, although some limited recent, operational experience exists. Too small a size of the first-step development airship will deceive the purpose and acceptance due to incapability to show useful performance.

The limited transportation problem with bulky cargo, requires such large airships that sufficient utilization is not here. Further, such a size will take several development steps to materialize. To solve the present problem, an intermediate helicopter towed balloon system is recommended to be developed. Such an undertaking must, however, be preceded by an in-depth analysis.

4.2 U.S. Freight Commodity Market

The present and projected transportation system for freight commodity within the U.S.A. has been analyzed to determine what segment would have a potential application for an LTA vehicle.

Data available on this market are the 1967 Census of Transportation, Commodity Transportation Survey prepared by the Bureau of Census, Department of Commerce.[26] The prime objective of these surveys is to measure the transportation and geographic distribution of commodities shipped by manufacturing establishments in the United States beyond the local area; it does not include data for agricultural commodities.

Other data used were the Freight Commodity Statistics for Motor Carriers of Property (1972)[27] and Class 1 Railroads (1973)[28] issued by the Interstate Commerce Commission, Bureau of Accounts. These data are for Class 1 motor carriers defined as those with average annual operating revenues in excess of $1 million.

Industry Profiles 1958-1969[29] issued by the Bureau of Domestic Commerce, Department of Commerce were used to estimate the growth of commodity shipments and shipment values.

Railroad freight costs vary from 3 to 4 cents a ton-mile and motor carrier from 7 to 10 cents a ton-mile. Motor carriers are used because they are quicker and more reliable and they do not involve a change of mode, i.e., they can transport freight from door to door.

It was concluded that commodities that were transported mostly by motor carriers would be better suited to the airship on the basis that those commodities could tolerate a cost per ton-mile over twice that of railroads for benefits that would be present in an LTA vehicle, i.e., door to door service (VTOL capability), lower journey time and higher reliability.

The low cost of the railroad is also the reason for its long delivery time. Freight railcars have to be loaded at separate yards then collected to make one long train. This adds non-movement time but reduces crew and fuel costs. Similar delays are present at the destination where railcars have to be dispersed to their respective yards.

Further delays arise because of transferring cars from one railroad to another and to shipments that have to complete their journey by truck at each end.

This also has been one of air freights' most intractable problems, the ground processing of freight since goods may spend as long a time on the ground as in the air. The payload of freight aircraft range from about 50 tons (Boeing 707) to about 130 tons (Boeing 747) but about 80% of air shipments are 100 pounds or less, resulting in high processing and collecting costs.

Even in motor carriers, the cost of terminal operations has been increasing at a faster rate in the last 10 years than the cost of longer haul intercity operations.

There are nearly 500 different commodities listed in the Bureau of Census and Interstate Commerce Commission statistics. These were examined to determine in which of them 60% of the tons or more were moved by road. In total 72 commodities were isolated, representing over 50% of the total tons moved by road and 13% of the total tons moved by both modes. These 72 commodities were reduced by eliminating those that had less than one million tons per annum; further reductions and additions were introduced due to data availability and/or high percentage of tons moved by modes other than rail, resulting in a total of 27 commodities listed in Table 4-I.

The growth rate per annum of the shipment of each of these commodities was obtained from Industry Profiles 1958-1969[29] and used to project the tons and ton-miles (assuming a constant distance distribution) to the year 1985.

Table 4–I. Commodity Transportation Statistics

**TCC No.	Item	Transported Quantities: 1967 Data *Tons x 10^3	*T-Miles x 10^6	1985 Estimates Tons x 10^3	T-Miles x 10^6	Average Miles
2012	Meat Fresh Frozen	630	518	1,237	1,017	822
207	Confectionary	2,557	2,234	5,745	5,019	874
2096	Marg & Other	1,545	1,109	2,654	1,905	718
283	Drugs	1,912	1,073	6,354	3,566	561
284	Soap & Dets.	4,192	3,074	15,780	11,645	733
349	Misc. Fab Metal Prod.	2,453	2,135	9,617	7,848	870
353	Mat. Handl. Equip.	3,578	3,201	13,599	12,166	895
359	Misc. Mach. & Parts	909	617	4,432	3,008	679
369	Misc. Elect. Equip.	740	397	3,268	1,753	536
	Total	18,516	14,358	62,186	47,927	
		1972 Data		1985 Estimates		
222	Manmade Fiber	618	462	1,859	1,388	748
225	Knit Fabrics	397	317	998	797	798
227	Floor Coverings	2,781	2,158	11,844	9,191	776
228	Thread & Yarn	1,109	722	2,693	1.753	651
231	Men's Clothing	952	819	1,867	1,606	860
233	Women's Clothing	995	656	1,853	1,222	659
239	Misc. Textile Prods.	1,006	807	2,974	2,386	802
306	Misc. Fab., Rubber	895	752	1,811	1,522	840
307	Misc. Plastic Prod.	3,985	3,404	18,845	16,106	855
332	Iron, Steel Casts	2,235	1,382	5,790	3,580	618
335	Non-Fer. Basic Shapes	7,954	6,272	22,978	18,119	788
336	Non-Fer. Castings	654	570	1,907	1,685	884
339	Misc. Metal Prod.	1,319	841	4,093	2,610	638
321	Flat Glass	875	587	1,796	1,205	671
322	Glass Blown	3,157	1,773	7,418	4,166	562
325	Stu. Clay Prod.	5,469	2,628	9,003	4,326	480
326	Pottery	511	471	910	839	922
327	Concrete, Plas. Prod.	4,803	2,605	9,165	4,971	542
	Total	39,704	27,226	107,802	77,472	
	Grand Total			169,988	125,399	

* To obtain International System Units:

Tons x 907 = kg
T-Miles x 1.459 = Metric T-km

**Transportation Commodity Code

The data was reduced by eliminating those tons and ton-miles that were moved over stage lengths less than 300 miles, it being contended that the truck would have adequate journey time at those stage lengths.

This resulted in a total of 125,399 million ton-miles required in the year 1985. Table 4-I also details the average distance in miles that each of these commodities was transported, obtained by dividing the ton-miles by the tons. The distribution around those average distances has not been determined.

Of the 27 commodities, an analysis of the weight of individual shipments reveals that 80% of them weigh 45 tons or less; this is higher than a road truck (30-40 tons) but less by about 10 to 20 tons of that of a railroad car.

Table 4-II details additional features of these commodities; the value of the shipments was obtained from Industry Profiles 1958-1969[29] for the relevant years, 1967 or 1972, dollars per pound from dividing this by the Bureau of Statistics Commodity Transportation Survey[26] total tons for each commodity and the percentage moved by road and air from the same source. Tons per carload was obtained by dividing the total tons by the number of carloads obtained from the Interstate Commerce Commission Freight Statistics.[27] The average miles were obtained from the Bureau of Statistics data as for Table 4-I; however, the below 300 miles stage lengths are included in Table 4-II. Dollars per carload was obtained by dividing value of shipments for Industry Profiles 1958-1969 by the number of carloads and the cents per ton mile by dividing this by the average miles.

While the absolute values of the ratioed data in this table are not considered accurate and hold many inconsistencies because of the different data sources, the data gives a rough approximation of the value per pound to produce the commodity and the cost per pound to transport it. Other data giving the price per unit which the market will bear, i.e., the elasticity of demand could be generated to further define those commodities which could be viable candidates for an LTA transport system.

Table 4–II. Commodity Transportation and Cost Statistics

TCC No.	Item	Value $M	Value *$/lb.	% by Weight Road	% by Weight Air	Road Transportation Cost *Tons/ Carload	* Miles	$/ Carload	*¢/Ton Mile
2012	Meat Fresh Frozen (1)	15,576.3	5.55	86.7	-	17.94	498	653	7.3
207	Confectionery	2,694.6	0.31	73.3	-	15.73	575	435	6.4
2096	Marg & Other	1,725.6	0.24	70.2	-	18.69	391	341	4.7
222	Man-Made Eiber	4,006.0	1.35	94.9	0.1	13.52	384	370	7.4
225	Knit Fabrics	6,911.2	3.73	98.7	0.2	10.76	415	385	9.3
227	Floor Covering	3,373.4	0.46	80.9	0.1	12.20	630	502	6.5
228	Yarn & Thread	3,671.3	0.55	95.5	-	13.40	333	315	7.1
231	Men's Clothing (2)	2,677.8	0.70	89.5	1.8	9.25	591	523	9.6
233	Women's Clothing	8,531.4	2.77	88.8	3.8	8.57	487	447	10.7
239	Misc. Textile Prods.	2,904.7	0.85	70.7	0.3	12.78	550	434	6.2
283	Drugs	5,301.6	1.56	68.3	1.2	14.96	740	460	4.2
284	Soaps, Det., Etc.	7,126.0	0.37	74.4	-	16.22	428	333	4.8
306	Misc. Fab. Rubber	4,160.7	2.38	86.6	0.8	13.16	479	417	6.6
307	Misc. Plastic Prod.	10,000.9	1.25	82.9	0.3	11.54	516	436	7.3
332	Iron & Steel Castings	6,255.1	1.40	76.4	-	16.64	275	306	6.7
335	Non-Fer, Basic Shapes	14,828.0	0.93	63.5	0.1	15.82	454	446	6.2
336	Non-Fer, Castings	2,818.8	2.18	69.6	0.2	14.56	455	390	5.9
339	Misc., Metal Prods.	3,145.2	1.19	63.4	0.1	17.76	346	295	4.8
321	Flat Glass	857.1	0.49	73.4	-	17.50	433	413	5.4
322	Glass Pressed & Blown	3,274.5	0.52	88.9	-	14.67	259	271	7.1
325	Stu., Clay Prods.	1,202.6	0.11	74.5	-	18.97	217	272	6.6
326	Pottery	749.3	0.73	84.9	0.2	14.42	623	523	5.8
327	Concrete, Plaster Prod.	6,642.6	0.69	81.6	-	21.76	148	175	5.4
349	Misc. Fab. Metal Projs.	4,756.6	0.96	62.1	0.3	13.58	510	377	5.4
353	Mat. Handling Equip.	7,865.0	1.10	54.8	0.3	15.94	662	534	5.1
359	Misc. Mach. & Parts	3,712.0	2.04	91.7	1.3	13.20	394	530	10.2
369	Misc., Elect Equip.	2,773.7	1.87	89.7	0.6	12.42	373	495	10.7

Air is less than 0.1% of total in the following: 228; 332; 321; 322 & 325.

(1) Industry profiles shipment values are for TCC No. 201 Meat Processing Plants which is probably why the cost per pound of this item is too high.

*) To obtain International System Units:

$/lb X .4536 = $/kg

Tons/Carload X 907 = kg/carload

Miles X 1.609 = km

¢/T-Mile: 1.459 = ¢/Metric T-km

Table 4-II shows that air transport has been able to obtain from 0.1% to 3.8% of the transport market of these commodities. (In some regions the percentage is considerably higher, as much as 6%.) An LTA vehicle would have the door-to-door capability of the road vehicle, a possible five to six times speed advantage and if it was sized to minimize the processing and collection of freight, it could be expected to penetrate this market, if its cost of transportation was equal or less than that of air freight, 20 to 25 cents a ton-mile.

Table 4-III has postulated a 50 ton payload airship with at least 100 knots (51.4 m/s) cruise speed obtaining a 60% load factor and utilization of 2000 hours and 4000 hours a year operating in this market. Four market shares have been assumed, 0.1%, 0.5%, 1.5% and 2%; these values appear to be possible on the basis of air freight experience.

The number of airships required varies from 9 to 348 depending on market share. With a price of 15 cents a ton-mile, related to the 2% market share and 24 cents to the 0.1% (these values are purely arbitrary) market share, the direct operating cost of the airship with a 1 cent a ton-mile for indirect costs and a 5% margin for reserve/profit lie between \$487 and \$774 an hour.

This isolation of commodities that are candidates for transport by an LTA vehicle has not been exhaustive and has not included agricultural products which would represent a large market, especially in the transport of perishable foods across country. A cursory examination indicates that these 27 commodities represent about a quarter of the total potential of airship application, 14% of all road freight and 3% of the total freight moved.

It is concluded, therefore, that a 50 ton payload airship with at least 100 knots (51.4 m/s) cruise speed and with the capability of flying across country non-stop has a potential in the commodity transportation market, provided it has VTOL or at the least good STOL capability and can operate at a profit with a freight rate of between 15 and 25 cents a ton-mile.

The present analysis has confined itself to the freight market inside the United States; however, the 50 ton payload LTA vehicle would have a potential export market and could satisfy the requirements of the developing countries outlined by Mr. G. J. Beier and G. C. Hidalgo of the International Bank for Reconstruction and Development.[11] It could also have an application in the transport of pineapples and bananas from Hawaii and islands further west where the transport of these perishables is causing the shippers to seriously re-evaluate the current transportation mode and seek a system with a shorter delivery time.

Table 4—III. Number of 50-Ton Payload Airships as a Function of Market Share

Total Ton-Miles (1985) = 125,399 X 10^6 Ton-Miles

Annual Airship Potential = Payload (50 Tons) X Load Factor (60%)
X Speed (120 mi/hr/100 kt/51.4 m/s)
X Annual Utilization
(2,000 Hours and 4,000 Hours)
= 7.2 to 14.4 X 10^6 Ton-Miles

Market Share %	0.1	0.5	1.5	2.0
Ton-Miles (1985) x 10^6	125.4	627.0	1881.0	2508.0
Number of Airships				
2,000 Hours/Year	18	87	261	348
4,000 Hours/year	9	43	131	174
Freight Revenue				
Cents/Ton-Mile	24	21	18	15
Millions of Dollars	30.10	131.67	338.58	376.20
Fleet Hours - x 10^6 (1)	35.3	170.59	511.76	682.35
Revenue $/Hour	853	772	662	551
Less %5 (2)	810	733	629	523
Less Indirect (3)	774	696	592	487

(1) Contains 2% nonrevenue flying
(2) Reserve or profit
(3) Taken as 1 cent per ton-mile

To obtain International System Units:

Ton-Miles X 1.459 = Metric T-km

Ton X 907 = kg

4.3 Unique Missions

Particular unique missions that have been suggested for an LTA vehicle have been the movement of large indivisable loads which are precluded from movement by normal surface means because of the size or require devious routes and the possible provision of additional or modification of existing road structures. There also appear to be economies in certain other large products if they could be assembled in plant and transported to the site (houses, electrical transmission towers, bridges, highway overpass structures are examples of these). The logging industry has also used tethered balloons and helicopters to transport logs and has indicated an interest in a higher lift capability which could be an LTA vehicle.

The movement of the components of nuclear powered electrical generating stations would require a payload of up to 800 tons (reactor vessels and steam generators)[11] which would probably be also adequate for bridge and highway overpass structures. A block speed of about 25 knots (12.9 m/s) would probably be adequate.

The movement of completely assembled one-family houses and apartment building modules could be satisfied in most cases with a lift capability of 50 tons and transmission tower and logging requirements would be within the range of 10 to 20 tons.

Analysis of the requirements for the movement of large components of nuclear powered electrical generating stations proposed from 1978 to the year 2000, which were remote from navigable waters,[11] indicated a requirement of 4.53 million ton-miles in 1978 to 7.64 million ton-miles in 2000. For an LTA vehicle with a 800 ton payload capability and a 20 knots (11.2 m/s) block speed and assuming a 50% load factor, this would represent an annual utilization of 453 to 764 hours a year for one airship. It is possible that the utilization is underestimated as there would be some non-revenue flying and positioning flying and instead of transporting these components from the nearest navigable waters they would be transported from the plant to the site (this might reduce the total ton-miles); however, it has been assumed that all the components have been transported by the airship which is an overestimation.

In any event, it is unlikely that one 800 ton airship flying 1000 hours a year would not be able to more than satisfy this market. Estimates of other applications of this 800 ton LTA vehicle have not been examined in detail but it is considered unlikely that they would add significantly to this level of utilization until the market has been gradually developed by actual proof of the economical advantages that can be achieved by using an airship.

If an 800 ton payload vehicle were introduced into the commodity transportation market detailed in the previous section, the number of LTA vehicles would be reduced from 9 to 1 at the low end and from 348 to 22 at the high end (see Table 4-III) and would markedly suffer from the disadvantages of the processing and collection of shipments to fill such a large payload.

The 50 ton LTA vehicle postulated in the examination of the commodity transportation market would adequately meet most of the other particular applications identified.

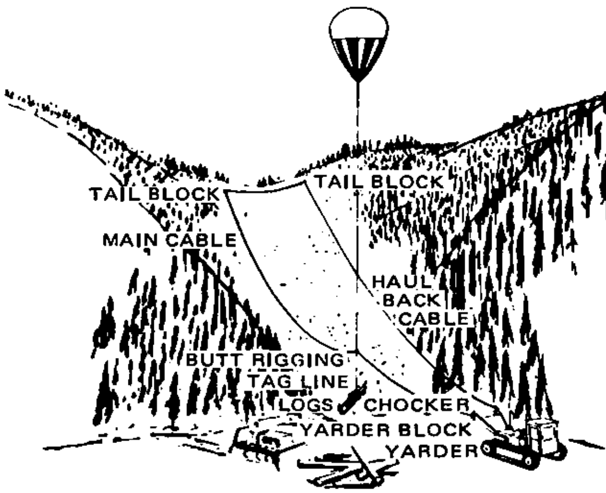
Many unique uses for the helicopter in commercial applications have been postulated in the past because of its VTOL capability and some have come to fruition, in particular in logging, movement of pieces of engineering equipment onto high structures, in electrical transmission lines and in personnel movement onto off-shore oil rigs. All the types being used have had a military market base to offset their development costs. Even so, the marketing of a large heavy lift helicopter, the Sikorsky Flying Crane, S-64, while it has been actively pursued for over 15 years, has results in sales and leases of less than 10 aircraft.

This experience cautions the development of a first LTA vehicle that does not have a broad based market. Also, the development cost and technical risk associated with an 800 ton payload vehicle are much higher than a 50 ton payload vehicle. For these reasons it is considered that the 50 ton payload airship with at least 100 knots (51.4 m/s) cruise speed is a better candidate for development of the first modern airship. This size would be suitable for a research and development vehicle as well as for commercial use.

4.4 Very Heavy Lift Missions

Several applications of airship to "crane" missions have been suggested by practically everybody who advocates a revival of the airship. Such missions, most of them falling in the very heavy lift category, include construction work (buildings, bridges, power lines, pipelines, etc.), ship unloading/loading, strip mining, oil shale cracking, logging, timber harvesting, oil exploration, transport of space shuttle booster, thermal power generating plant components, factory assembled houses, etc. Many of these missions do not require high forward speed. Some require a relatively exact stationkeeping-over-a-spot capability. Here concepts like the Aerocrane (All American Engineering Co.) and the Heli-Stat (Piasecki Aircraft Corp.) could be suitable, although there would be a long development time until very heavy lift capabilities in the 800 ton class could be operationally available.

Balloon logging is now being successfully used, although not yet with very heavy lift capabilities. The system with unmanned aerostat, tethered to a cable being reeled back and forth between two winches, could be developed into higher capacities as and when required by the logging and timber harvesting industry with relatively low technical risk. Figure 4-2 shows one of the latest developed balloons by Raven Industries, Inc. for logging operations.



RAVEN'S 530,000 f^3 (15,010 m^3) LOGGING BALLOON

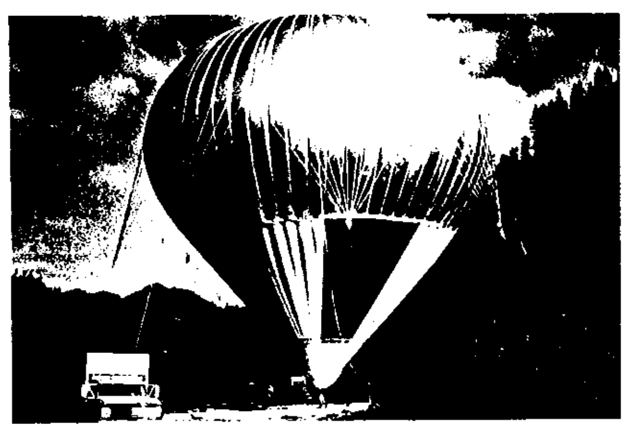


Figure 4–2. Ballon Logging

It will be a long time until an 800 ton payload airship of approximate 63 x 10^6 ft^3 (1.28 x 10^6 m^3) volume (if conventional) for transport of bulky cargo such as nuclear power plant components[11] will be available. It is most likely that a gradual growth of the size of airships will take place. This will reduce the risk and would also allow the transport market for airships to accommodate itself and grow so that it is ready to use the larger airship at an economical utilization factor.

Meanwhile, another simpler concept can be visualized for the very heavy payload transport. Such a transport would be at a low speed and be a fair-weather mission. Still it would considerably simplify the transport by passing over obstructions like bridges, power lines, etc.

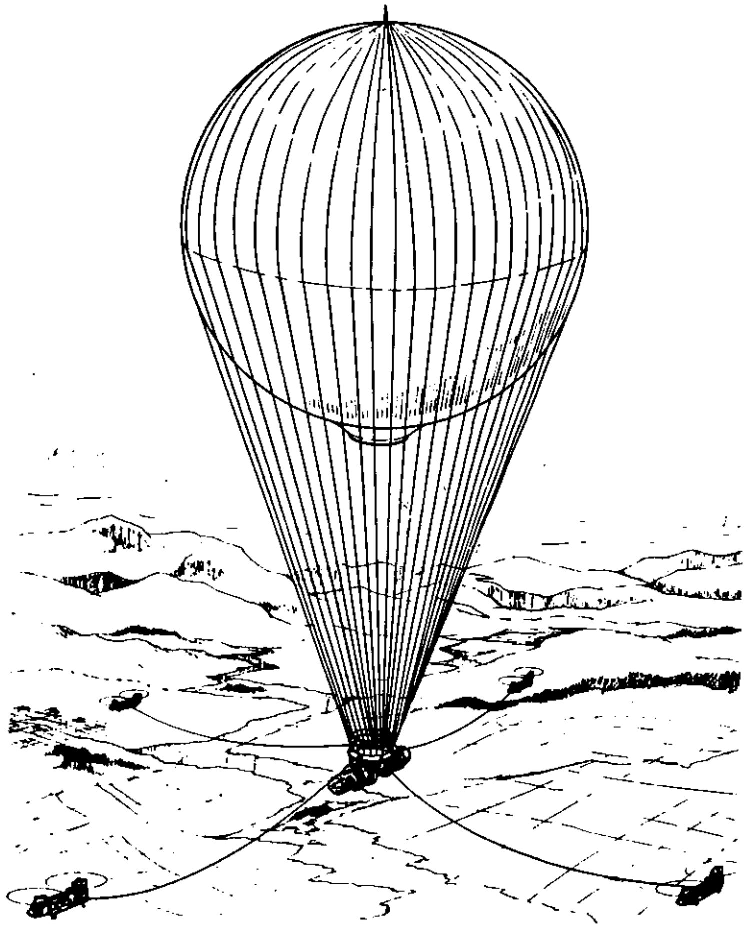


Figure 4–3. Towed Balloon Very Heavy Lift Transport System

Figure 4-3 shows an artist's sketch of a towed balloon transport system. The cargo is securely attached to a large balloon supplying required static lift which can be remotely controlled by ballast, gas valving, or any other lift control systems which may be developed. (A spherical shape in lieu of the elongated shape mostly used for unmanned aerostats will be less costly and is further acceptable due to the low airspeed, fair-weather operation.) Propulsive force and steering is supplied by four (or less) helicopters. Figure 4-4 is a plot of required towing force for different sizes of load at varying airspeeds. The towing capability of different size helicopters is also indicated.

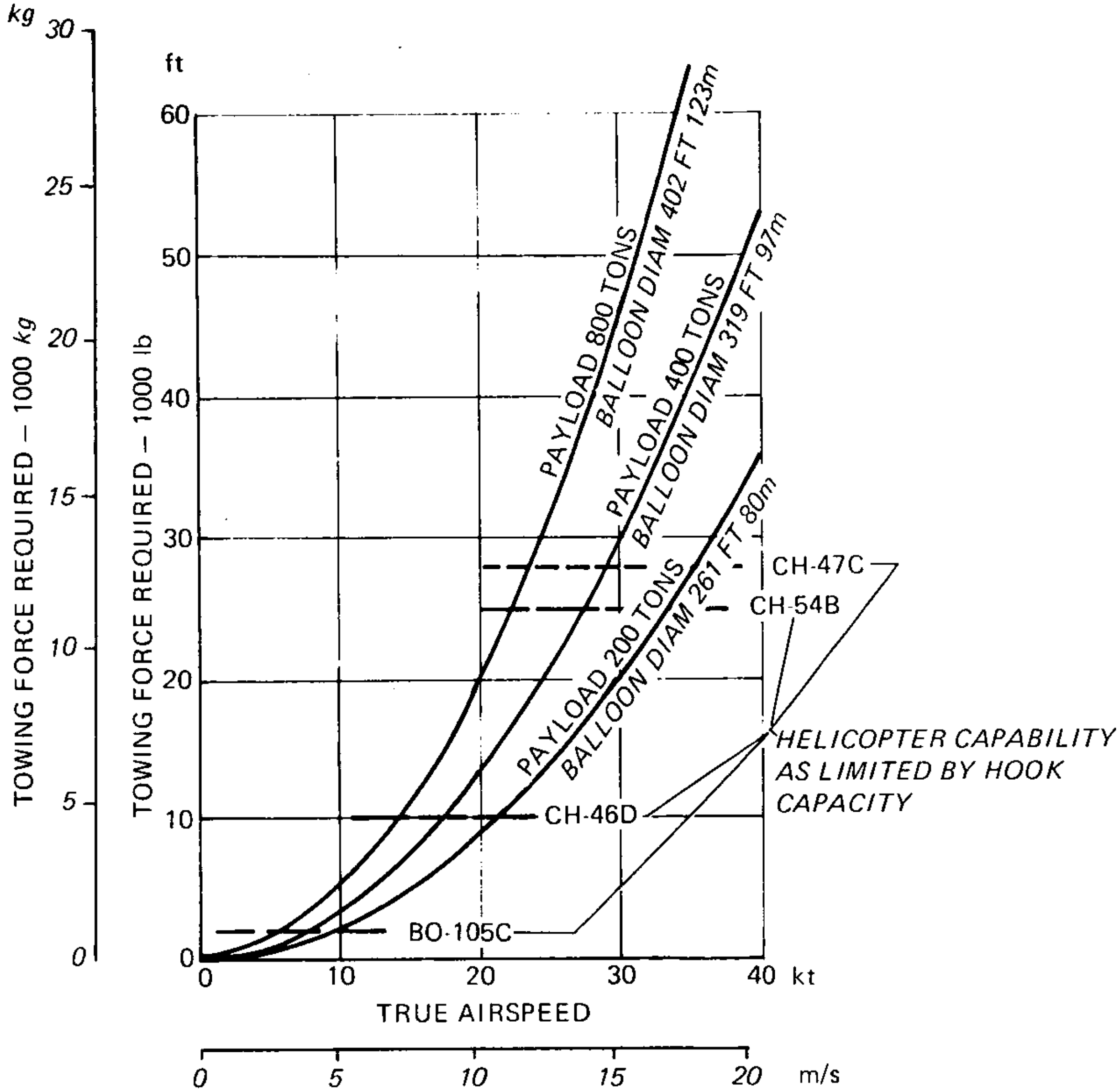


Figure 4–4. Towing Force for Very Heavy Lift Transport System

Helicopter towing of an aerostat with ballast is feasible and has been made for aerodynamic performance tests of the Family II Tethered Balloon System at the Cape Canaveral Air Force Station during late 1973 and early 1974. Figure 4-5, borrowed from Reference 10, shows the configuration flown.

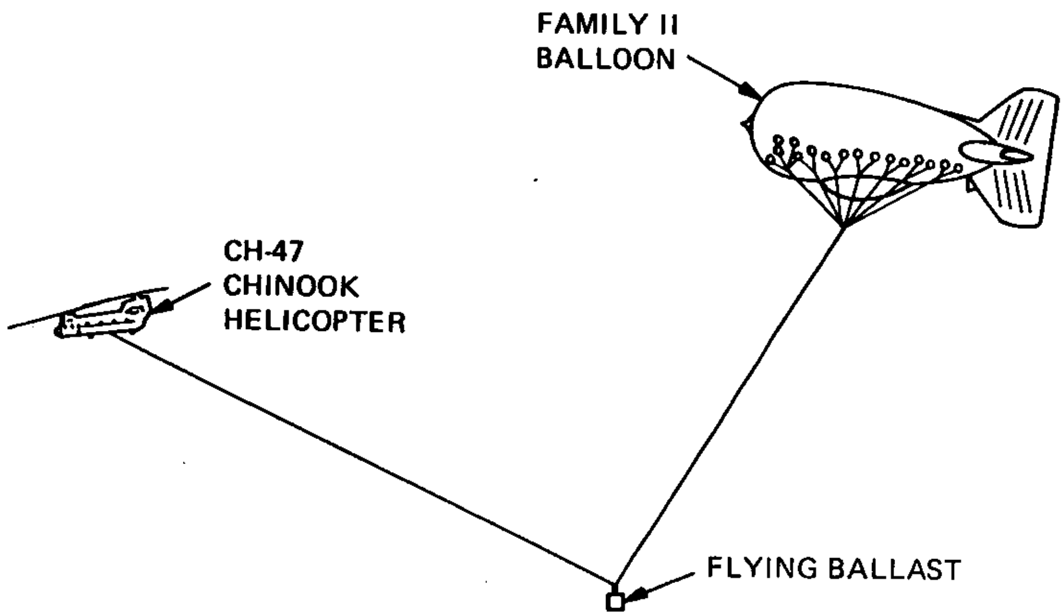


Figure 4–5. Helicopter Tow-Test Configuration

4.5 Natural Gas Transportation

Transport of natural gas from the well to a distribution terminal has been proposed as a potential mission for an LTA vehicle.[11,34,35,36,52] It is an interesting concept from that point of view that the cargo supplies its own lift and can also be used as the engine fuel. The analysis here considers only a fully buoyant airship. An airship with a low buoyancy ratio is out of the question in as much as the cargo is a gas with some lifting capability and as large a volume as possible is wanted. An airship configuration with some heaviness will not change the conclusions. The average natural gas has a lifting capability of 27 lb per 1,000 ft^3 (425 kg per 1,000 m^3). This is too little to lift the weight empty of an airship designed for general cargo and passenger service (see Paragraph 5.2.2). However, an airship for natural gas transportation will be a special purpose vehicle and of a very large volume. By advanced technology it should be possible to achieve for an 100×10^6 ft^3 (2.83×10^6 m^3) a weight empty around 30% of the maximum gross weight/lift. The maximum gross weight/lift defined as the lifting capability with 97% pure Helium. It should be noted that extensive research and development will be required before an airship of such a large volume can be built at the predicted structural weight. It should also be noted that a fail-safe containment system for the natural gas must be developed to prevent any accidents due to the flammability of natural gas. A steam lifting system, if used, will also be the subject for extensive development (see discussion in Paragraph 5.2.2).

A 30% weight empty plus a crew of four and some mission equipment plus fuel with reserve for a 2,600 miles (4,183 km) distance will amount to a weight which just can be supported by $100 \times 10^6 ft^3$ ($2.83 \times 10^6 m^3$) natural gas. See Figure 4-6.

The plot also shows required volume of other buoyant fluids, steam, helium and hydrogen, to lift different ratios of mission weights. (The requirements on development of a hydrogen-lifting system is discussed in Paragraph 5.2.2)

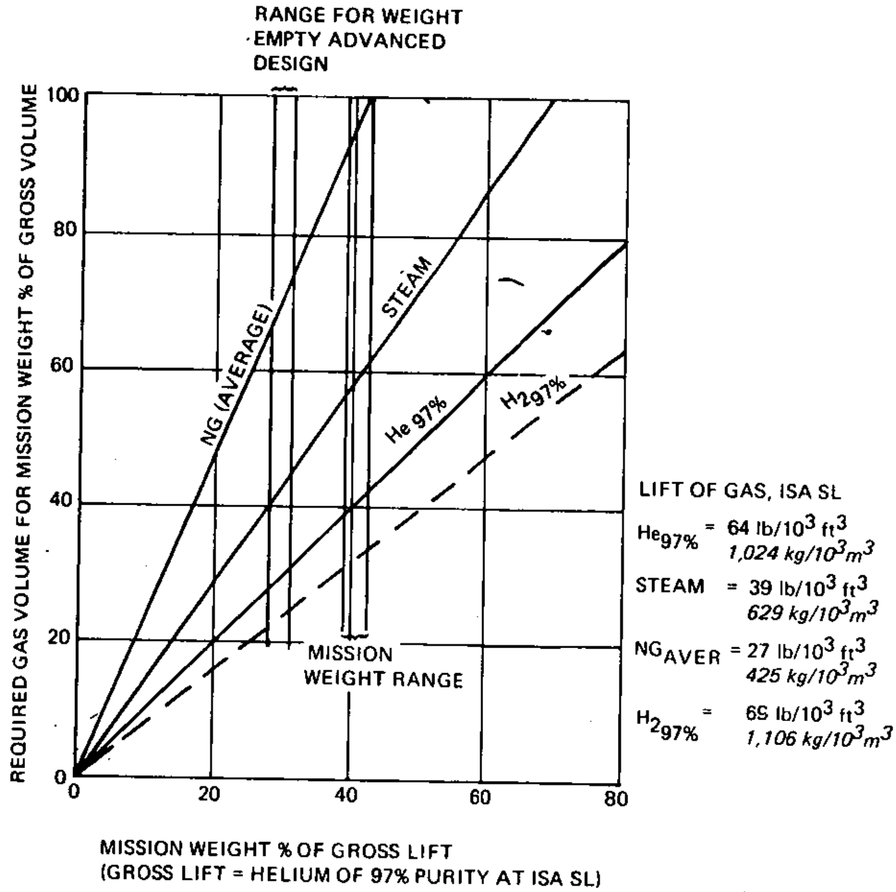


Figure 4–6. Required Gas Volume to Lift Mission Weight of an Airship for Natural Gas Transport 2,600 Miles

Two specific missions have been analyzed to determine the feasibility of using an airship; transport of natural gas over 2,600 miles (4,183 km) and 3,500 NM (6,482 km) ranges. The analyses have been made as a comparison with regular means of transportation; the planned 2,600 mile Alaska natural gas pipeline and a hypothetical liquid natural gas import project analyzed in the Natural Gas Survey by U.S. Federal Power Commission.[53] Inasmuch as development cost, unit cost and operation cost of an airship for natural gas transport cannot be estimated without an extensive preliminary design work far beyond the scope of this conceptual study, the approach has been to establish the allowable competitive cost which must be met by the airship to be in par with other means of transportation. From the costs so determined, it can be easily judged if an airship can be competitive and if transportation of natural gas is a potential airship mission.

Figure 4-7 illustrates the delivered natural gas quantity of a $100 \times 10^6 ft^3$ ($2.83 \times 10^6 m^3$) airship as a function of the distance between wellhead and distribution terminal. Using JP-5 as a fuel for the approximately 74,000 HP turboprop engines, 100 x $10^6 ft^3$ ($2.83 \times 10^6 m^3$) natural gas can lift the operational weight empty plus fuel (including 10% reserve) for approximately 2,400 NM (4,445 km). At shorter distances, additional payload, such as crude oil, could be carried. This will complicate and prolong the unloading time as natural gas terminal and crude oil terminal probably is not at the same location.

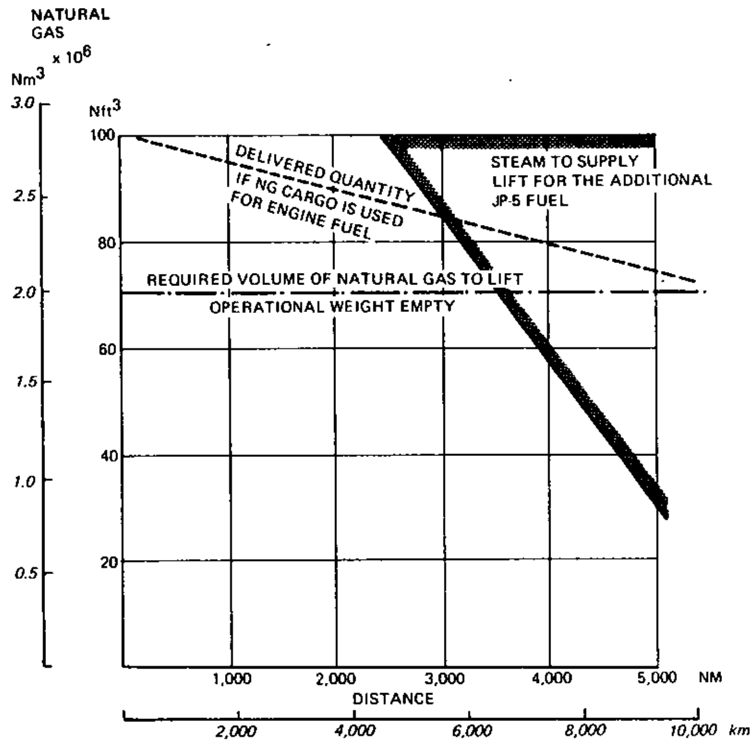


Figure 4–7. Natural Gas, Delivered Quantity by One 100 x $10^6 Ft^3$ ($2.83 \times 10^6 m^3$) Airships vs One-Way Distance

For longer distances another buoyant fluid must complement the lift. Figure 4-7 shows this additional lift by steam and corresponding reduction in delivered quantity of natural gas.

The natural gas cargo could be used as engine fuel in lieu of JP-5. This will, however, decrease the delivered quantity of natural gas as can be seen from Figure 4-7 up to a distance of 3,000 NM (5,556 km) where it equals the delivered gas volume of a JP-5 burning airship.

Steam as the buoyant fluid to make up for the additional JP-5 fuel load for distances over 2,400 NM (4,445 km) gives more payload (delivered natural gas) than helium, although the specific lift of steam is only 61% of helium of 97% purity. The amount of complementary lifting gas is determined by the return flight requirement. The amount of complementary lifting gas required for this leg is considerably more than required for delivery of maximum volume of natural gas over long distance. The high cost of helium (and also long-term availability) prevents release of helium when natural gas is loaded. It could be stored, but it is a one-way street with a steady increasing helium storage at the wellhead, where it is not needed. Steam is sufficiently inexpensive (see Paragraph 5.2.2) to be valved off when loading natural gas.

The delivery rate in volume per hour of a 100 x 10^6 ft^3 (2.83 x 10^6 m^3) airship with a cruise speed of 100 knots (51.4 m/s) as a function of distance is illustrated in Figure 4-8.

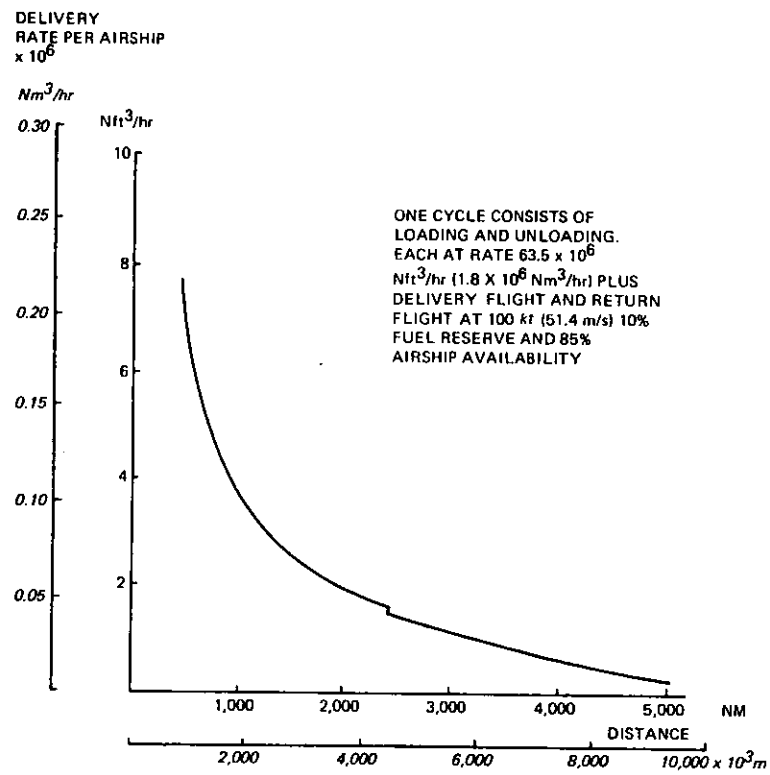


Figure 4–8. Natural Gas, Delivery Rate by One 100 x 10^6 Ft^3 (2.83 x 10^6 m^3) Airship vs One-Way Distance

Transport of natural gas by airship does not negate the need for processing plants at the wellheads. Most of the paraffin hydrocarbons (ethane, propane, the butanes, pentane, helane, heplane and octane), plus quantities of sulphur, helium and carbon dioxide, will be removed because of their commercial value. From an LTA vehicle point of view, it should also be done. The specific gravity of the hydrocarbons varies between 1.5 and 2 (air = 1). The boiling point of the butanes falls between 20-34°F (-6 to + 1°C) and propane is -44°F (-42°C). They would easily condense if left in the natural gas. Safe heating of the flammable gas is probably further away from a safe solution than the safe containment system of the natural gas.

4.5.1 Summary and Conclusions

The analyses discussed in following Paragraphs 4.5.2 and 4.5.3 show that

a. To match the proposed Alaska natural gas pipeline, 130 LTA vehicles, volume 100 x $10^6 ft^3$ (2.83 x $10^6 m^3$), cruise speed 100 kt (51.4 m/s) and availability of 85%, will be required, Each airship cannot cost more than $44 million for equal initial investment costs. The total operating cost will be approx. 2.2 times higher than the pumping cost for the pipeline.

   To meet the capacity of the planned Alaska pipeline, one airship must arrive every 26 minutes. There will be a string of airships 43 NM (50 miles) (80 km) apart in both directions, not to mention the crowded situations at the two end terminals.

b. To match the LNG transport system over a distance of 3,500 NM (6,482 km) 24 LTA vehicles, volume 100 x $10^6 ft^3$ (2.83 x $10^6 m^3$), cruise speed 100 kt (51.4 m/s) and availability of 85%, will be required. Each airship cannot cost more than $23 million. The price of the gas at U.S. port, delivered by airship, will be approximately 4 times higher than the LNG gas.

   Every four hours an LTA vehicle must arrive from a 3,500 NM (6,482 km) voyage.

Considering the well developed and highly efficient natural gas pipeline system and LNG system as well, and the maximum allowable airship unit cost for compatibility, it is most improbable that the airship can find a market in the natural gas transportation field. Some very unusual conditions in regard to location of the gas source must be at hand in combination with extremely high prices of all kinds of energy, to make airship transportation of natural gas feasible.

4.5.2 A Comparison With Proposed Alaska Pipeline

4.5.2.1 Baseline

The planned Alaska pipeline "Trans-Canadian Pipeline" for natural gas will have

- a length of 2,600 mi (2,259 NM) (4,183 km)
- a utilized capacity of 5,479.5 x 10^6 N ft^3/day (155.2 x 10^6 Nm^3/day); 228.31 x 10^6N ft^3/hour (6.47 x $10^6 Nm^3$/hour)
- a construction cost of $5,700 x 10^6 (1974 estimate No land acquisition cost in as much as it is Canadian Government land.)

The pumping cost will be \$4.986 million per day; \$207,764 per hour based upon an average pumping cost for existing pipelines in 1974 of 35¢ per 1,000 ft^3 per 1,000 miles (76.8¢ per 100 m^3 per 1,000 km).

4.5.2.2. Loading and Unloading

To establish required time for loading and unloading of the natural gas cargo, the performance of a typical pipeline with the following characteristics was used:

Diameter: 36 in (.914 m)

Average Gas Velocity: 25 mi/hr (11.2 m/s)

Average Pumping Pressure: 1,000 lb/in^2 (689,476 N/m^2)

Thus, loading and unloading will take place at a rate of 63.473 x 10^6 N ft^3/hr (1.798 x 10^6 N m^3/hr). 100 x 10^6 N ft^3 (2.83 x 10^6 N m^3) will be loaded in 1.6 hours. Unloading will take equal time. Assumption is made that the buoyant fluid for the return flight is inflated and deflated, respectively, during the cargo unloading/loading time.

4.5.2.3 Mission Profile

With the loading and unloading times defined above and a cruise speed of 100 kt (51.4 m/s) the total time for one cycle (delivery flight + return flight) will be 48.4 hours. See Figure 4-9. Servicing of the airship is optimistically assumed to take place simultaneously with loading and unloading.

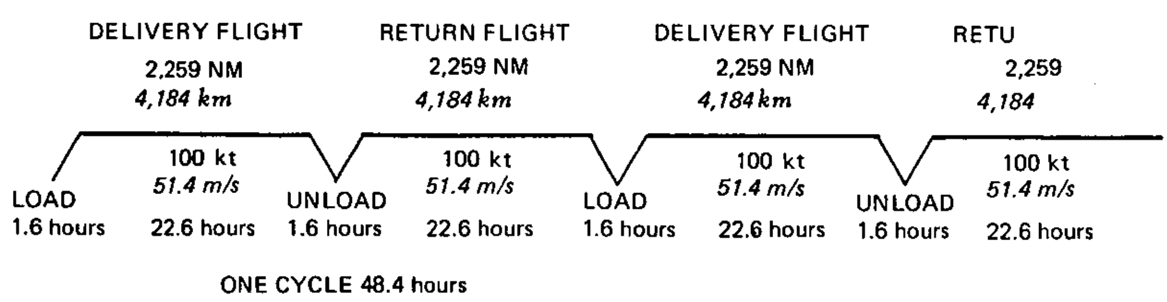


Figure 4–9. Natural Gas Transport Mission Profile (Alaska Line)

The delivery flight is a low altitude flight to facilitate maximum volume of natural gas cargo. The return flight using steam as buoyant fluid requires a gas volume of 60% of the total available volume at sea level. The return flight can thus take place at 12 - 13,000 ft (3,660-3,960 m) altitude (pressure altitude approximately 16,000 ft (4,880 m)) at a lower fuel consumption.

4.5.2.4 LTA Vehicle Configuration and Required Quantity

The LTA vehicle will be of an advanced design with a volume of 100 x 10^6 ft^3 (2.83 x $10^6 m^3$). The advanced design will result in a mission weight which can be supported by average natural gas. There will be no capability for additional payload such as crude oil or LNG. (See Figure 4-5) Such an advanced design and large volume as well will require a great deal of development. It is assumed that the airship will operate with an availability of 85%. The moderate sophistication of equipment and accessories for an airship solely transporting natural gas and the technology in the time period when such an airship can be operational, justifies the assumption of an availability factor of .85. To match the pipeline capacity as stated in 4.5.2.1 Baseline, 130 LTA vehicles will be required.

4.5.2.5 Costs

To be competitive in the first investment cost with the planned Alaska pipeline, the outlined airship cannot exceed a unit cost of \$5,700 x 10^6: 130 = \$43.85 millions; approximately the same as the Akron of 6.50 x 10^6 ft^3 (.184 x $10^6 m^3$) volume should have cost in 1974, by simply inflating the 1931 price with no consideration to the cost increase due to the technology advancements.

Very approximate operating cost per airship per flight hour has been estimated at \$3,519, broken down as follows:

	$/FH
Capital cost, amortization and interest	639
Crew	164
Fluid, JP-5 for propulsion and steam for return buoyant fluid	1,313
Maintenance,spares and amortization and interest for base facilities	1,083
Profit 10%	320

The operating cost for a fleet of 130 LTA vehicles will amount to \$457,470 per hour, 2.2 times higher than the pumping cost (see 4.5.2.1, Baseline).

4.5.2.6 Summary

The comparison between the planned Alaska natural gas pipeline and a fleet of airships to supply the same capacity is summarized in Table 4-IV.

Table 4—IV. Transport of Natural Gas. LTA Vehicle vs Pipeline

BASELINE: PLANNED ALASKA NATURAL GAS PIPELINE					
LENGTH MI		CAPACITY N FT^3/DAY	FIRST INVESTMENT COST $	PUMPING COST $/HOUR	
2,600		5,479.5 X 10^6	5,700 X 10^6	207,764	
LTA VEHICLE					
VOLUME FT^3	CRUISE SPEED KT	REQUIRED NUMBER OF LTAs TO MATCH CAPACITY (AVAILABILITY 85%)	ALLOWABLE COMPETITIVE FIRST INVESTMENT COST PER LTA $	OPERATING COST FOR 130 LTAs $/HOUR	RATIO OPERATING COST LTA: PIPELINE
100 x 10^6	100	130	43.85 x 10^6	457,470	2.2

CONVERSION FACTORS: 1 NM = 1.852 KM, 1 FT^3= 0.0283 M^3, 1 KT = 0.514 M/S

4.5.3 A Comparison With An LNG System

4.5.3.1 Baseline

The baseline for comparison of the performance of an airship fleet is a hypothetical LNG import project, analyzed by U.S. Federal Power Commission.[53] This case is based upon actual data, adjusted to 1975.

- Delivered capacity by LNG tanker — 479×10^6 N ft^3/day (13.6×10^6 N m^3/day)
- Round-Trip — 7000 NM (12,964 km)
- Investments for LNG System — $\$556 \times 10^6$
  - Liquefaction Plant — $\$221 \times 10^6$
  - LNG Tankers — $\$263 \times 10^6$
  - Receiving Terminal — $\$72 \times 10^6$

4.5.3.2 Loading and Unloading

The same assumptions as in 4.5.2.2 apply. Loading and unloading time will each be 1.11 hours for 70.185×10^6N ft^3 (1.988×10^6N m^3) (See discussion of delivered volume in Paragraph 4.5.3.4).

4.5.3.3 Mission Profile

Loading and unloading times have been established above. The mission profile including time will be as shown in Figure 4-10.

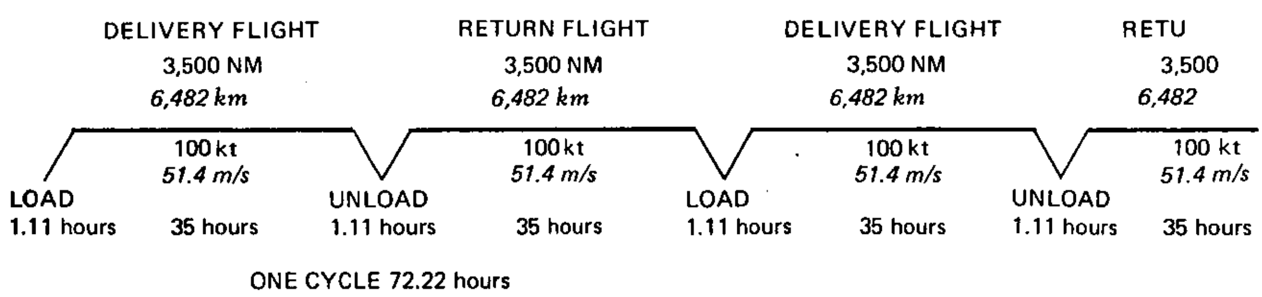


Figure 4–10. Natural Gas Transport Mission Profile (Lng Case)

The delivery flight is a low altitude flight and the return flight a high altitude flight. The pressure altitude of the airship on the return leg is about 13,500 ft (4,115 m). The sea level gas volume being 66% of volume capacity.

4.5.3.4 LTA Vehicle Configuration and Required Quantity

The LTA vehicle configuration will be as described in Paragraph 4.5.2.4 including the availability factor of .85. The payload, however, must be reduced as can be seen from Figure 4-6. The required fuel load for the distance of 3,500 NM (6,482 km) plus 10% reserve increases the mission weight beyond the lifting capability of a fully filled airship. Consequently, a buoyant fluid of higher specific lift has to be added. Steam was selected on the grounds previously discussed. The required volume of steam will reduce the natural gas volume to 70.185×10^6 N ft^3 (1.988×10^6 Nm^3)

To match the capacity of the LNG tankers in Paragraph 4.5.3.1 Baseline, a quantity of 24 airships will be required.

4.5.3.5 Costs

It is assumed that the first investment cost for the fleet of LTA vehicles cannot exceed the investment for LNG liquefaction plant, LNG tankers, and receiving terminal $556 million. (See Paragraph 4.5.3.1 Baseline) By doing that, the cost of required terminals for the airship is neglected. In other words, the assumption made is in favor of the LTA system. If all costs connected with the LTA system should be considered, the allowable competitive airship unit cost should be still lower.

Consequently, with all the optimistic assumptions, the allowable unit cost of an airship for the described mission is $23.2 millions. Such a low unit cost is unachievable.

The operating costs, very approximate and developed in the same manner as for the "Alaska Pipeline Case", Paragraph 4.5.2.5, are $80,184 per flight hour for the airship fleet of 24 vehicles. With these costs and a wellhead price of 70¢ per 1,000 N ft^3 ($2.47 per 100 Nm^3 (in U.S.A. end of 1974) the U.S. port price of natural gas imported by airship from a source 3,500 NM (6.432 km) away, will be $5.25 per 1,000 N ft^3 ($18.54 per 100 Nm^3);4 times higher than the average price paid in 1973 for LNG imported by tankers.[53]

4.5.3.6 Summary

The comparison between an LNG import case and an airship system for the same amount of natural gas in gaseous state is summarized in Table 4-V.

Table 4–V. Transport of Natural Gas. LTA Vehicle vs LNG Tanker

BASELINE: NATIONAL GAS SURVEY HYPOTHETICAL LNG IMPORT PROJECT						
ONE-WAY DISTANCE NM		DELIVERED CAPACITY N FT³/DAY	FIRST INVESTMENT COST, LNG SYSTEM $		COST OF NG AT U.S. PORT $/10³ N FT³ $/10² Nm³	
3,500		479 X 10⁶	556 X 10⁶		1.27	
LTA VEHICLE						
VOLUME FT³	CRUISE SPEED KT	REQUIRED NUMBER OF LTAs TO MATCH CAPACITY (AVAILABILITY 85%)	ALLOWABLE COMPETITIVE FIRST INVEST-MENT COST PER LTA $	OPERATING COST FOR 24 LTAs $/HOUR	COST OF NG AT U.S. PORT $/10³ N FT³	RATIO OF COST LTA: LNG
100 X 10⁶	100	24	23.2 X 10⁶	80,184	5.25	4.13

CONVERSION FACTORS: 1 MI = 1.609 KM, 1 FT³ = 0.0283 M³, 1 KT = 0.514 M/S

4.6 Potential Passenger Service Market

The main source for personal trips data in the U.S. is the National Travel Survey 1972 published by the Bureau of Census.[30] Tables 4-VI and 4-VII are excerpts from this document giving the person-trips in millions by origin region and destination region. Much detail is contained in the survey of the distribution of personal trips with mode of travel and socio-economical categories. However, personal trips between given city-pairs is not included.

Table 4–VI. Travel by Origin Region

(In millions. Excludes trips with destinations outside the United States)

Region of origin	1972 Population estimates[1] (millions)	Trips (millions)	Trips per capita	Person-trips (millions)	Person-miles (billions)	Person-nights (millions)
New England	12.0	12.6	1.05	23.6	17.5	81.6
New York-New Jersey	25.7	18.4	.72	33.9	34.4	155.7
Mid-Atlantic	23.6	23.3	.99	44.0	33.5	158.7
South	38.2	39.3	1.03	73.0	59.5	253.0
North Central	47.6	54.5	1.14	109.7	89.7	408.4
Northwest	7.4	10.7	1.45	21.0	18.5	70.6
Southwest	24.0	32.0	1.33	65.8	51.6	202.2
Pacific	28.0	36.1	1.29	69.1	64.9	240.9

[1] July 1972 population estimates, Current Population Survey, Bureau of the Census, "Estimates of Populations of States: July 1, 1971 and 1972", Series P-25, No. 488.

Table 4-VII. Travel by Destination Region

(In millions)

Region of destination	1972 Population estimates[1] (millions)	Trips (millions)	Trips per capita (of origin)	Person-trips (millions)	Person-miles (billions)	Person-nights (millions)
New England	12.0	12.5	1.04	25.0	16.8	97.0
New York-New Jersey	25.7	15.8	.61	28.8	20.8	101.1
Mid-Atlantic	23.6	23.2	.98	43.2	27.9	137.6
South	38.2	46.5	1.22	88.2	85.9	385.2
North Central	47.6	47.1	1.00	94.0	59.0	278.7
Northwest	7.4	11.5	1.55	22.5	22.7	91.6
Southwest	24.0	32.5	1.35	66.8	53.5	207.0
Pacific	28.0	37.8	1.35	71.5	83.0	272.1
Outside United States	(X)	10.1	(X)	18.4	(X)	211.7

[1] July 1972 population estimates, Current Population Survey, Bureau of the Census, "Estimates of Populations of States: July 1, 1971 and 1972", Series P-25, No. 488.

The North East Corridor Study has data for some city pairs for 1966.[32] A study done for the Assistant Secretary of the U.S. Department of Transportation by the Mitre Corporation investigated the potential market for an Improved Passenger Train (IPT) and a Tracked Levitation Vehicle (TLV) and has relevant data on person trips between city pairs projected to the years 1985 and 1995.[31] The study also includes a Mode Split Model, which relates journey time, cost and 'acceptance' factor to market share for a particular mode. This data has been used in developing a passenger travel market potential for an LTA vehicle in 1985.

Table 4-VIII is taken from the study and shows the total person trips between given city pairs. San Francisco to Los Angeles and Los Angeles to San Diego was selected as the route to investigate for the application of the LTA vehicle because the annual passenger miles were high and approximately the same, the segments could be made over water and would require no high altitude operation, the climate is relatively mild and a sensitivity study had been done by Mitre into the Los Angeles-San Diego segment of fare level, speed and the effect of a 50% and a 200% increase in fuel prices.

Table 4—VIII. Estimated Total Travel Demand by Corridor, City-Pair, and Year

Corridor	City-Pair	Year			
		1970	1975	1985	1995
Chicago-Detroit (292 route miles)	Chicago-Detroit	1,386,000	1,566,180	2,037,420	2,578,000
	Chicago-South Bend	955,000	1,079,150	1,403,850	1,776,300
	Chicago-Toledo	332,000	375,000	488,000	617,500
	South Bend-Toledo	31,500	35,600	46,300	58,600
	South Bend-Detroit	93,000	105,090	136,700	173,000
	Toledo-Detroit	2,672,000	3,019,360	3,927,800	4,970,000
		5,469,500	6,180,380	8,040,070	10,173,400
Seattle-Portland (186 Route miles)	Seattle-Portland	2,612,600	3,108,300	4,440,400	5,772,500
California (683 route miles)	Sacramento-San Francisco	5,087,600	6,206,870	8,700,000	11,500,000
	Sacramento-Stockton	1,289,600	1,573,300	2,205,200	2,915,000
	Sacramento-Fresno	264,600	325,468	468,342	630,000
	Sacramento-Bakersfield	51,700	63,591	91,500	123,000
	Sacramento-Los Angeles	1,374,220	1,690,290	2,432,400	3,270,000
	San Francisco-Stockton	3,023,550	3,688,700	5,170,300	6,833,000
	San Francisco-Fresno	607,800	662,500	1,075,800	1,446,600
	San Francisco-Bakersfield	205,200	252,400	363,200	448,400
	San Francisco-Los Angeles	8,200,000	10,086,000	14,500,000	19,516,000
	Stockton-Fresno	152,750	187,882	270,400	363,545
	Stockton-Bakersfield	36,680	32,816	47,200	63,500
	Stockton-Los Angeles	590,500	726,300	1,045,200	1,405,400
	Fresno-Bakersfield	512,700	630,600	907,500	1,220,200
	Fresno-Los Angeles	1,042,650	1,282,500	1,845,500	2,481,500
	Fresno-San Diego	54,400	66,900	96,300	129,500
	Bakersfield-Los Angeles	3,252,400	4,000,500	5,756,700	7,740,700
	Bakersfield-San Diego	68,250	83,950	120,800	162,400
	Los Angeles-San Diego	27,000,000	33,750,000	49,780,000	68,040,000
		52,804,600	65,310,567	94,776,342	128,328,745

4.6.1 San Francisco - Los Angeles

Distance = 320 NM (593 km)

Estimated total travel demand, 1985 = 14.5 million person trips

Market Share for 95 m.p.h. (83 kt) (42.5 m/s) Improved Passenger Train on the Los Angeles to San Diego leg = 9.5% at 6 cents a passenger mile[31]

Using the Model Split Model equation in page A-9 of Reference 31, the market share for a 100 knots (51.4 m/s) airship was determined as 12.6% at 6 cents a passenger mile. Table 4-IX details the market share for higher fare levels and the required direct operating costs in cents per seat mile that the airship would have to achieve.

Table 4–IX. Market Share at Higher Fare Levels and Competitive D.O.C., San Francisco-Los Angeles

Fare Ratio	1.0	1.4	1.8	2.2
Fare (¢/px.mi)	6.0	8.4	10.8	13.2
Market Share (%)	12.6	9.4	7.6	6.4
Passengers per annum ($x\ 10^6$)	1.83	1.36	1.10	0.93
Px-miles per annum ($x\ 10^6$)	651.48	484.16	391.60	330.37
Px per day (One way)	2542	1889	1528	1292
Number of Px per Airship (1)	.363	270	218	184
Load Factor (%)	72.6	54.0	43.6	36.9
Annual Revenue ($\$ \times 10^6$)	38.09	40.67	42.29	43.60
Less 5% (2)	36.18	38.64	40.17	41.43
Less Indirect Costs (3)	16.63	24.11	28.42	31.52
D.O.C. $/hour (4)	1045	1515	1786	1984
D.O.C. ¢/seat mile (incl. 5% profit)	1.8	2.6	3.1	3.3
With No 5% Profit	2.0	2.9	3.3	3.5

To obtain International System Units:
¢/mi: 1.609 = ¢/km

The tabulation above assumes a 500 seat airship

(1) Assumes 7 flights a day each way

(2) Reserve or profit

(3) Based on $0.03 per passenger mile[32]

(4) Total annual fleet flying hours is 15,885 hours determined as follows: -

One way trip flying time = 3.09 hours

Number of trips per day, each way = 14

Total annual revenue flying hours = 14 x 3.09 x 360

= 15,574

Plus 2% non revenue flying 15,885 hours.

For 5 airships, this would require an annual utilization to which the direct operating cost should be related. However, the exact number of airships would be determined by the schedule and what reserve is carried.

4.6.2 <u>Los Angeles to San Diego</u>

Distance = 91 NM (169 km)

Estimated total travel demand 1985

= 49.68 million person trips

Using the Mode Split Model equation referred to in the previous section, Table 4-X details the market share with varying fare levels and the required direct operating costs of the airship.

Table 4—X. Market Share at Higher Fare Levels and Competitive D.O.C., Los Angeles-San Diego

Fare Ratio	1.0	1.4	1.8	2.2
Fare (¢/px mi)	6.0	8.4	10.8	13.2
Market Share (%)	10.8	8.1	6.5	5.5
Passengers per annum x 10^6	5.36	4.02	3.23	2.73
Px - miles x 10^6	578.88	434.16	348.84	294.84
Px per day (One way)	7444	5583	4486	792
No. of Px per Airship (1)	465	349	280	237
Load Factor (%)	98.0	69.8	56.0	47.4
Annual Revenue $ x 10^6	34.73	36.47	37.67	38.92
Less 5% (2)	32.99	34.65	35.79	36.97

Less Indirect (3)	15.62	21.63	25.32	28.12
D.O.C. $/hour (4)	1477	2045	2394	2659
D.O.C. ¢/seat mile (incl. 5% profit)	2.5	3.4	4.0	4.4
With no 5% profit	2.7	3.7	4.3	4.7

To obtain International System Units: ¢/mi: 1.609 = ¢/km

This assumes a 500 seat airship; it could be that because this is a shorter distance than the San Francisco to Los Angeles leg, less fuel would be required and the seat capacity could be increased to make the load factor at the lower fares more acceptable.

(1) Assumes 16 flights a day each way
(2) Reserve or profit
(3) Based on $0.03 per passenger mile
(4) Total annual fleet flying hours is 10,575 hours determined as follows:

One trip flying time = 0.9 hours

Number of trips per day = 32

Annual Revenue flying hours

= 32 x 0.9 x 360

= 10,368 hours

Plus 2% non-revenue flying

= 10,575 hours

For a 3 airship fleet this would represent 3525 hours a year.

Reference 31 estimates the effect on market share if fuel costs were raised 50% to 200% in this time period, i.e., by 1985. The effect on trip costs for each mode is different, trip costs for auto go up directly as fuel costs since the 'perceived' costs of auto travel are dominated by fuel costs. It is estimated that the effect on the airship would lie somewhere between that of the bus and the Tracked Levitation Vehicle (TLV) since the energy per seat mile of the airship is estimated to be somewhere between these two.

4.6.3 Effect of Increase in Fuel Costs

The effect of fuel costs on market share for the TLV is detailed in Reference 31. Tables 4-XI and 4-XII illustrate the effect of a 50% increase on airship share and direct operating costs for the two segments, San Francisco to Los Angeles and Los Angeles to San Diego.

Table 4–XI. Market Share and D.O.C. at 50% Increase in Fuel Costs, San Francisco-Los Angeles

Fare (¢/px mi)	6.0	8.4	10.8	13.2
Market Share (%)	15.4	11.5	9.3	7.8
DOC ($/hr)	1160	1861	2196	2415
DOC (¢/seat mile)	1.9	3.1	3.7	4.0
With no 5% profit	2.5	3.4	3.9	4.3

Table 4–XII. Market Share and D.O.C. at 50% Increase in Fuel Costs, Los Angeles-San Diego

Fare (¢/px mi)	6.0	8.4	10.8	13.2
Market Share (%)	13.2	9.9	8.0	6.7
DOC ($/hr)	1809	2502	2936	3254
DOC (¢/seat mile)	3.0	4.2	4.9	5.4
With no 5% profit	3.3	4.5	5.3	5.8

An increase of 200% in fuel costs will affect the market share and D.O.C. as shown in Tables 4-XIII and 4-XIV.

Table 4–XIII. Market Share and D.O.C. at 200% Increase in Fuel Costs, San Francisco-Los Angeles

Fare (¢/px mi)	6.0	8.4	10.8	13.3
Market Share (%)	18.9	14.1	11.4	9.6
D.O.C. ($/hour)	1571	2276	2684	2975
D.O.C. (¢/seat mile)	2.6	3.8	4.5	5.0
With no 5% profit	2.9	4.1	4.8	5.3

Table 4–XIV. Market Share and D.O.C. at 200% Increase in Fuel Costs, Los Angeles-San Diego

Fare (¢/px mi.)	6.0	8.4	10.8	13.2
Market Share (%)	16.2	12.2	9.7	8.2
D.O.C. ($/hour)	1970	2726	3192	3546
D.O.C. (¢/seat mile)	3.3	4.5	5.3	5.9
With no 5% profit	3.6	4.9	5.7	6.3

To obtain International System Units: ¢/mi: 1.609 = ¢/km

It should be noted that the airship is in a very competitive air travel market in California. Pacific Southwest Airlines has a fare level of around 7 to 8 cents a seat mile; in other areas the market share could probably be achieved at higher fare levels.

An investigation was made into the Seattle to Portland travel market but the passenger miles generated by this city pair is some 88% less than that generated by San Francisco to Los Angeles and Los Angeles to San Diego and results in a very low frequency schedule and hence low annual utilization for a 500 seat airship to maintain reasonable load factors (30% to 60%). However, a 100 kt (51.4 m/s) airship could obtain 19.3% of this market at a fare level of 9.5 cents a passenger mile to 9.8% at a fare level of 20.9 cents a passenger mile.

On the assumption that the airship could take 25 tons of freight and had a 250 seat passenger capacity and the freight revenue varied from 15 cents a ton-mile to 33 cents a ton-mile with corresponding freight load factors of 80% decreasing to 30%. The airship would require a direct operating cost of from $1470 per hour to $1880 per hour with an annual utilization of 2400 hours a year for three airships. This mixture of freight and passengers requires more detail investigation of the advantages and use of the airship.

Table 4-XV summarizes the results of the San Francisco to Los Angeles and Los Angeles to San Diego investigation.

Table 4–XV. Passenger Traffic Summary Market Share and D.O.C.

Fare (¢/p.m.)	6.0		8.4		10.8		13.2	
Route	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Market Share (%)								
No Fuel Increase	12.6	10.8	9.4	8.1	7.6	6.5	6.4	5.5
50% Fuel Increase	15.4	13.2	11.5	9.9	9.3	8.0	7.8	6.7
200% Fuel Increase	18.9	16.2	14.1	12.2	11.4	9.7	9.6	8.2
D.O.C. ($/hour)								
No Fuel Increase	1045	1477	1515	2045	1786	2394	1984	2659
50% Fuel Increase	1160	1809	1861	2502	2196	2936	2415	3254
200% Fuel Increase	1571	1970	2276	2726	2684	3192	2975	3546
D.O.C. (¢/seat-mile)								
No Fuel Increase	1.8	2.5	2.6	3.4	3.1	4.0	3.3	4.4
50% Fuel Increase	1.9	3.0	3.1	4.2	3.7	4.9	4.0	5.4
200% Fuel Increase	2.6	3.3	3.8	4.5	4.5	5.3	5.0	5.9

(1) San Francisco-Los Angeles (2) Los Angeles-San Diego

To obtain International System Units: ¢/mi: 1.609 = ¢/km

This analysis has indicated that in the freight transport and passenger travel markets in the United States, there are segments that have potential for an LTA vehicle with a 50 ton/500 passenger payload capacity, a cruise speed of 100 kt (51.4 m/s) and a VTOL capability or, at a minimum, short take-off and vertical landing capability. To penetrate these markets, the LTA vehicle should have a direct operating cost of between $500 to $800 an hour in the freight market and between $110 and $2700 an hour in the passenger travel market with utilizations between 2000 hours and 4000 hours a year.

4.7 Commuter Traffic Analysis

It has been suggested that commuter traffic may be a viable mission for an LTA vehicle, especially if a rail network does not exist and must be constructed.

The scope of this phase of the conceptual study as well as time did not allow a complete trade-off study between a railborne and airborne commuter system. However, an analysis of the possible performance of an aerial commuter line has been done and compared with the performance of Boeing Vertol railroad car SOAC (State-of-the-Art Car), equivalent numbers of vehicles established, and the approximate price of the SOAC given.

The airship concept has assumed a 200 passenger Helipsoid airship with a buoyancy ratio of 67%. Approximate volume 2×10^6 ft^3 (57×10^3 m^3). The flight altitude is 330 ft (100 m) and the vehicle follows a fixed route lane guided by ground-located electronic beams sending signals to the autopilot in the airship. Each "station" consists of a platform at an elevation of 66 ft. (20 m). Figure 4-11 shows an artist's concept of the visualized commuter line.

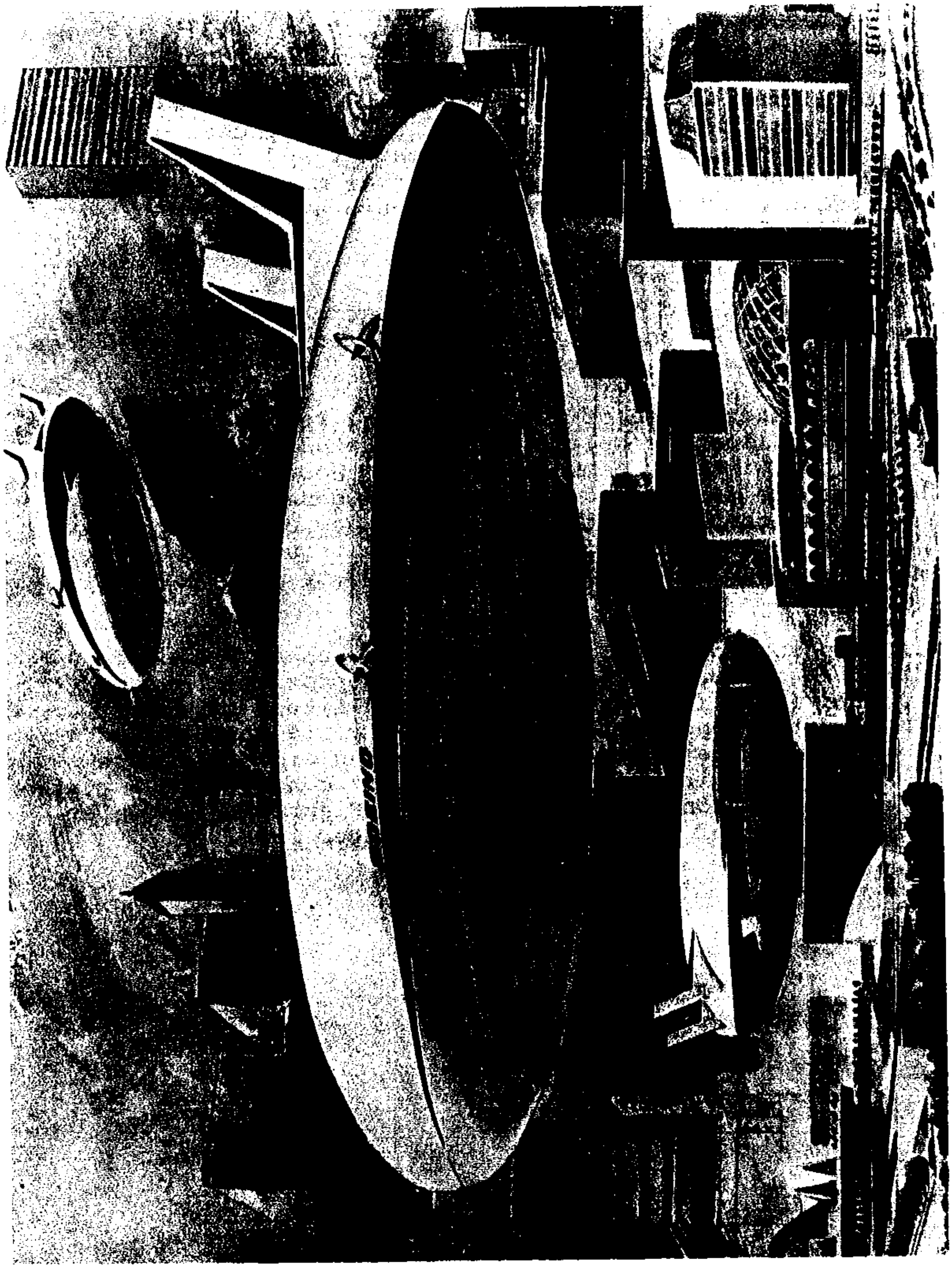


Figure 4–11. Airship Commuter Line

To assess the relative merits of the airship as an alternative transit vehicle, route performance was evaluated for a 200 passenger airship and compared with that of the State-of-the-Art Car (SOAC) which as it turns out has an almost identical weight for the vehicle less the passenger load. The urban transit route selected for this comparison is a low density route which was initially set up for the study of the advanced concept trains (ACT). This route possesses station spacing distances that vary from 0.5 to 1.8 miles (800 to 2,900 m). Peak passengers demand is 10,000 passengers per hour. A high density route which has station spacing distances as low as 0.25 miles (400 m) and passenger demand up to 60,000 passengers per hour was not evaluated as it was thought to be too severe an application for the airship. The route performance analysis served to establish vehicle block or schedule speed which together with known route and vehicle parameters (i.e. passenger demand, passenger capacity per car and total route distance) could be used to determine fleet requirements.

The results of the route performance analysis are illustrated in Figure 4-12 which presents the average cruise speed, block speed and block time as a function of maximum cruise speed. The SOAC vehicle was evaluated at maximum cruise speeds of 80 mph (36 m/s) and 68 mph (85% max.). The 80 mph (36 m/s) maximum cruise speed represents the limit speed for the rail transit route. The airship was evaluated at maximum cruise speeds of 80 (36 m/s) and 100 mph (45 m/s). Airship acceleration and deceleration capability was established based on data on positive and negative thrust capability for the airship propulsion system.

The station stopping dwell is 20 seconds for the SOAC, whereas it is 65 seconds for the airship. The airship dwell includes 30 seconds for descent from the 330 ft (100 m) cruise altitude 20 seconds for passenger loading/unloading and 15 seconds for climb to cruise altitude.

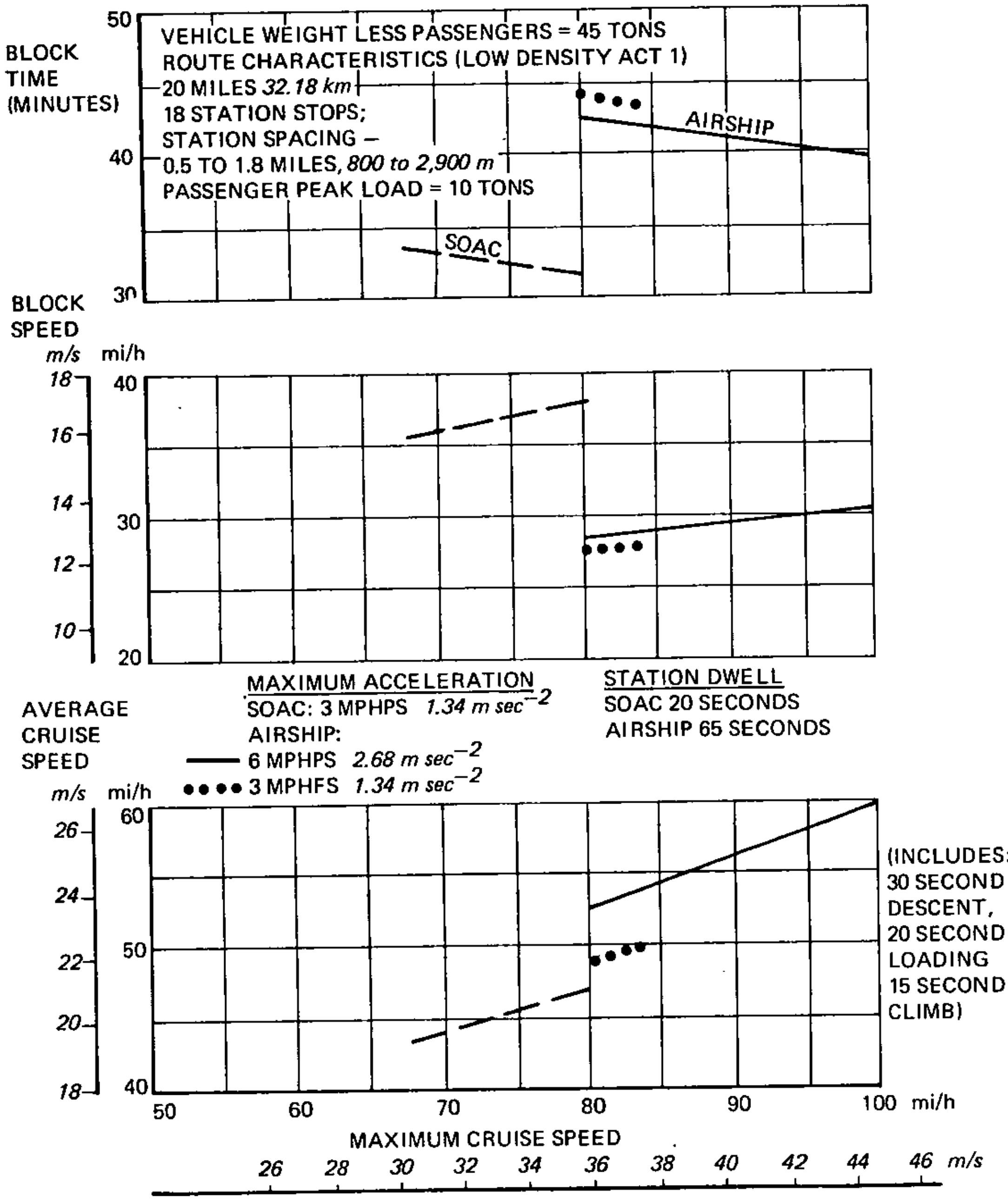


Figure 4–12. Airship Urban Commuter Capability

As shown in Figure 4-12, although the SOAC vehicle is constrained to a lower maximum cruise speed, it achieves a higher block speed or a lower block time than the airship to traverse the 20 mile (32.18 km) "low density" route. Increasing the maximum allowable acceleration from 3 mphs ($1.34\ m\cdot sec^{-2}$) which is the value for the SOAC, to 6 mphps ($2.68\ m\cdot sec^{-2}$) improves the average cruise speed of the airship but does not materially effect block time or block speed. The block speed accounts for dwell time which for the airship is considerably higher than that for the train. This is due to the fact that the airship takes time to climb to and descend from cruise altitude. This increment in time which is repeated at every station stop is not offset by either increased maximum cruise speed or vehicle acceleration.

There is a practical limit to the maximum cruise speed attained between stations that depends on the acceleration, and deceleration capability and the distance between stations. This means that even though a vehicle may have a high potential cruise speed, it may not always be achievable because the point is reached where further increases in cruise speed will cause the vehicle to stop at some point beyond the station. Further, a speed profile which consists solely of acceleration to peak speed and then immediate deceleration to stop at the station with no constant cruise segment between stations does not produce a comfortable ride. This must be considered as it affects passenger appeal and demand.

The passenger loading and/or unloading time of 20 seconds, although used in the analysis for the airship, appears inadequate in consideration of airworthiness regulations which will probably require airship passengers to fasten seat belts as all airship passengers will have to be seated and secured. Some way to assure compliance with this requirement will have to be found. Possible alternatives are an "ignition" type seat belt - interlock or a steward service.

To satisfy the traffic volume of 10,000 passengers per hour for the low density profile requires 66 airship vehicles with a maximum cruise speed of 100 mph (45 m/s) or 56 SOAC vehicles with a maximum cruise speed of 68 mph (30 m/s). This assumes both vehicles have capacity for 200 passengers.

In light of the above analysis, required size and quantity of airships and considering that the cost of a SOAC is approximately 1975 $400,000, the preliminary conclusion must be that the airship does not appear to be a competitive alternative in the commuter traffic system. For a more definite conclusion, a separate analysis will be required addressing the full complexity of railbound system installation, airborne system installation, airship development, certification, production, flight rules, all-weather operations, effect of high-rise station platforms at cruise level to eliminate ascent/descent time, etc.

4.8 Surveillance Missions

Particular surveillance missions that have been defined for potential application of an LTA vehicle are U.S. Coast Guard missions, the police traffic and crime control tasks.

4.8.1 U.S. Coast Guard Potential Missions

The Coast Guard has five basic missions which describe most of their operational responsibilities. They are: (1) Search and Rescue (SAR); (2) Aids to Navigation (ATN); (3) Enforcement of Laws and Treaties (ELT); (4) Marine and Environmental Protection (MEP); and (5) Polar Operations (PO). Each one of these five missions has some application that could be satisfied effectively by a lighter-than-air device. The objective of this summary is to specify two, or, at the most, three missions and payload characteristics which would represent the summary of these activities.

There are similarities between the various missions. The ATN and MEP missions are predominantly heavy lift missions with relatively long-range requirements. Heavy lift in this case is upwards of 20 to 30 tons. A maximum ATN patrol could use 200 tons disposable load.

The search part of SAR, the ELT missions, and to some extent Polar Operations, is mainly surveillance type of activities. This means carrying electronic devices, maintaining a fairly long time on patrol, and some close station-keeping in moderate winds. Rescue and some aspects of the ELT missions require the ability to transfer crews, boarding parties, or rescue units from the vehicle which brought them to the area, to the vessel, raft or the surface, in some cases, in rather unfriendly seas.

Therefore, the following mission definitions have been established:

4.8.1.1 Mission 1 - Surveillance

To satisfy this mission the LTA vehicle will be required to possess the following general capabilities.

a. Possess precise maneuverability and have the ability to hold a position in 30+ kt (15.4 m/s) of wind within $\pm$ 5 ft (1.5 m).

b. Operate independently; i.e., not require improved landing facilities or close support from surface craft or other aircraft (this is not to mean it will not be expected to work with other units when the need arises).

c. Be able to conduct unrestricted operations with respect to wind and rain, etc., for enroute transit purposes and to possess a capability of self-preservation under severe operational conditions (hurricane force).

d. With the establishment of the 200 NM (370.4 km) economic zone, the Coast Guard will have the responsibility of patrolling an area having a perimeter of approximately 8700 NM (16,112 km) and including over 2×10^6 NM^2 (5.18×10^6 km^2). In order to effectively patrol this area, the LTA vehicle should have the following capabilities:

1. Speed -- 0-150+kt (0-77 m/s) with economical cruise at 25-30 kt (12.9 - 15.4 m/s).

2. Endurance -- 10-14 days (or trade-off quick response replacement) but contact has to be continuous on the vessel under surveillance.

3. Load -- Ability to carry full crew, observers, and a sensor package to collect and record data (round the clock crew as required by vehicle, sensor = 1500 lb (680 kg)).

4. Transfer personnel -- The LTA should be able to transfer crews and deploy and retrieve boarding parties (8 men). This implies the capability to hover with precise controllability within 10 ft (3 m) - transfers limited to 35 kt (18 m/s).

5. Weather -- All-weather capability from tropical to arctic conditions with wind tolerance to approximately 75 kt (38.6 m/s).

4.8.1.2 Mission 2 - Heavy Utility

This mission includes aspects of rescue, ATN, MEP, and special services:

The a., b., and c. capabilities in 4.8.1.1 apply in this case as well.

The capability d. has a broad trade-off between range and maximum heavy lift. The minimum lift capability is 20 tons to be airlifted 2000 NM (3,704 km) in 10 hours. The maximum heavy lift might be 200 tons to be transported 300 NM (555.6 km)

a. Speed at maximum load -- not less than 30 kt (15.4 m/s).

b. Endurance (trade-off with load).

c. Transfer personnel to surface.

d. Deployment of load -- ability to stay under control within winch capability when load is transferred.

e. Weather -- generally good - winds to 30-35 kt (15.4-18 m/s).

4.8.1.3 Mission 3 - Special

Remotely-piloted LTA vehicles: A potential exists to utilize smaller remotely piloted sensor-equipped vehicles to extend the coverage of a surface vessel. The vehicles would require moderate endurance and must have suitable ground-handling characteristics for deployment aboard ship.

If a water landing is possible, it would be beneficial for recovering survivors and search targets - either by the basic vehicle or by RPV.

Mission profiles have been developed based upon the three missions above for sizing by computer. This is discussed in Paragraph 6.

4.8.2 Police Potential Use

There are over 100 police departments using about 300 helicopters in the U.S. today. These are small helicopters with payloads from 500 to 1000 lb (227-454 kg), endurances of 1-2 hours, cruise speeds around 100 kt (51.4 m/s) and direct operating costs of from \$60 to \$130 an hour. Projections to the year 1980 indicate that the police helicopter fleet could be as high as 600. Payload and speed are adequate for the missions in which they are used, however, high operations costs and in some missions low endurance are considered limiting factors.

At maximum endurance speeds around 25 to 35 kt (13-18 m/s) the fuel consumption of these helicopters is of the order of 90 lb/hr (40.8 kg/hr). An LTA vehicle that could equal or be less than this with lower fuel consumption in a hover at zero wind condition and direct operating cost less than the helicopter could be expected to capture a part of this market. However, it is unlikely that ownership cost and direct operating cost can challenge the corresponding helicopter costs. It should be noted that the existing police helicopters are only a small portion of the total number of helicopters manufactured of this size.

The possibilities for very long endurance and remotely piloted airship with surveillance sensors installed could be attractive for certain missions.[25] Such a requirement does not presently exist. It has to be developed as well as acceptability of having an unmanned LTA vehicle loitering over populated areas.

Conclusions are that the "police LTA market" will not revive the airship in the near future.

4.9 Military Potential Missions

An assessment of the feasibility of a modern airship should not be complete without consideration given to military missions. The airship is nothing else than a tool or platform for carrying equipment and loads so that contemplated missions can be accomplished; commercial or military - the same LTA vehicle platform could be used.

4.9.1 U.S. Navy Missions

Two promising missions for an LTA vehicle are emerging in the airship study being performed by the U.S. Naval Air Development Center (NADC). Although the mission information is still in the preliminary stage, it is considered appropriate and beneficial to briefly discuss those missions and the requirements. The discussion is based upon information supplied by NADC.

The two potential missions are related primarily to ASW and surveillance. The first mission - long endurance ASW mission - will require a large LTA vehicle capable of sustained, independent operations for long periods of time.

The second mission - AEW/ASW/SS mission - reflects a much smaller LTA vehicle which could probably also perform many of the less demanding LTA missions and which would also have the unique capability to be supported at sea by surface ships for the purposes of increasing its basic payload and/or mission duration. This second mission is primarily directed towards Sea Control and the defense of surface forces.

The long endurance ASW airship will be self sufficient and capable of independent operations from land bases for periods requiring multiple crews and hotel facilities. It will be supplementary to both surface and aircraft resources, thus relieving the burden on these forces in situations where economics or threat levels make the long endurance LTA attractive. In simplistic terms, it is intended to fill the gap between relatively slow-speed, long endurance, large payload surface ships and high-speed, short endurance, small payload aircraft. Although the long endurance ASW airship will be self-sufficient, it will also be able, by virtue of its low-speed capability, to use ships for replenishment of fuel and other consumables when operating in conjunction with surface forces.

Endurance on station rather than reaction time is emphasized. It is expected that Remotely Piloted Vehicles (RPVs) or manned aircraft, carried onboard, will supply functions requiring high speed, threat exposure, or high altitude.

Preliminary characteristics for a fully buoyant (preferred for the hover requirement) airship for a long endurance ASW mission are:

Volume: 6×10^6 ft^3 ($170 \times 10^3 m^3$)

Cruise Speed: 120 kt (62 m/s)

Altitude: 10,000 ft (3,050 m)

Mission Duration: 10 days

The AEW/ASW/SS airship would be landbased, but will be dependent on ship support for long endurance missions. Ship support will consist of replenishment of consumables, crew changeout, spares, and avionics support. The LTA will rendezvous with support ships for turnaround approximately every six to eight hours. Total mission duration of 10 to 30 days are desired. Ferry capability from support ship to home base of about 2,500 NM (4,630 km) is desired.

Preliminary characteristics for the AEW/ASW/SS airship are:

Volume: $1.2 \times 10^6 ft^3$ (34×10^3 m^3)

Cruise Speed: 100 kt (51.4 m/s)

Altitude: 10,000 ft (3,050 m)

Mission Duration: 8 hours

The discussed U.S. Navy potential missions require a hover capability at all-up weight at sea level and preferably without power. That calls for a fully buoyant airship. Analysis more in depth than can be done in a conceptual study like this could define an LTA vehicle which could match both a Navy requirement and commercial; fully buoyant state will meet the hover requirement, partial buoyant it could offer a higher commercial payload.

4.9.2 U.S. Air Force Missile Mission

A preliminary long endurance mission for an LTA vehicle as missile carrier and launcher has been defined by U.S. Air Force Space and Missile Systems Organization (SAMSO). An analysis conducted in mid-1974 defined several unresolved technical questions, such as, all weather operations, mooring, handling, hangaring and maintenance difficulties, performance limitations, technical risk (technology has been dormant for 30 years), development of non-rigid envelope, manufacturing capability and resources, survivability. The type of airship considered was a conventional non-rigid airship of approximately $14 \times 10^6 ft^3$ ($397 \times 10^3 m^3$) volume.

Another analysis utilizing the results of this study and considering partial buoyant airships and of rigid design would change the answers to some of the unresolved technical questions, and may alter the rejection conclusion to a feasible alternative for the missile mission.