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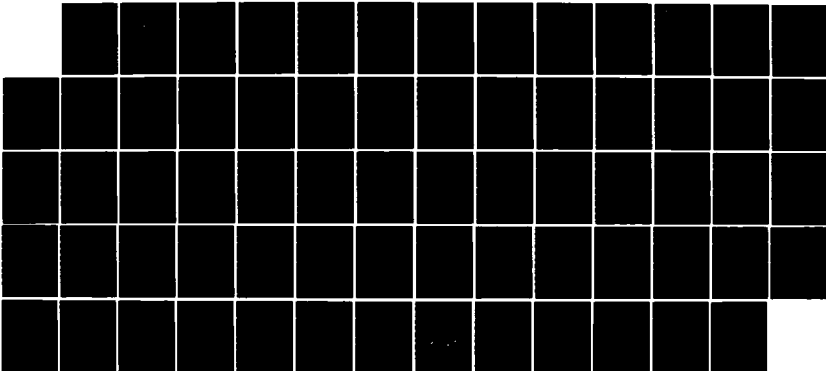
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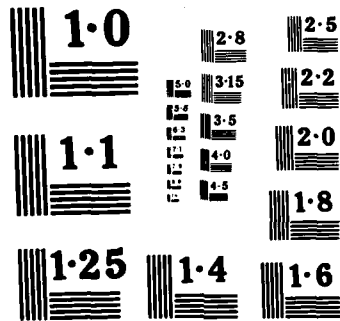
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AIR COMMAND AND STAFF COLLEGE

STUDENT REPORT

THE DIRIGIBLE: A CATALYST FOR
RESOURCE EXPLOITATION IN REMOTE
AREAS?

MAJOR JOHN C. MURPHY 85-1950

"insights into tomorrow"

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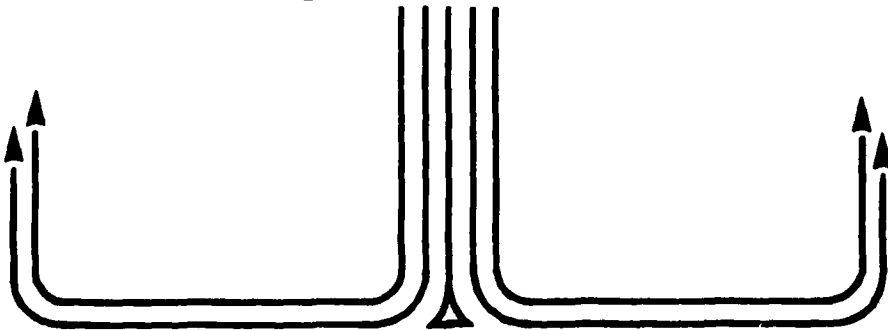
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REPORT NUMBER 85-1950

TITLE THE DIRIGIBLE: A CATALYST FOR RESOURCE
EXPLOITATION IN REMOTE AREAS?

AUTHOR(S) MAJOR JOHN C. MURPHY, USAF

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Submitted to the faculty in partial fulfillment of
requirements for graduation.

AIR COMMAND AND STAFF COLLEGE
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PREFACE

This study addresses a problem faced by many developing nations of the world. Although rich in natural resources, their fragile economies prohibit the exploitation of this wealth. Locked in remote, inaccessible regions of their land, the investment required to develop transportation systems simply cannot be justified in relationship to the many priorities pressing upon small, national treasuries.

This paper echoes a growing call to consider using lighter-than-air vehicles--modern day blimps--to exploit these resources. The advantages of low investment, flexibility, and operation without large "sunk" costs in time and money make them ideal for nations of limited financial means and great transportation infrastructure problems. The cost/benefit model in this paper will allow an objective evaluation of a dirigible transportation system in reference to present, planned, or proposed alternative networks.

I would like to acknowledge the assistance of several people in the preparation of this study. My sponsor, Col Donald R. Hargrove, USAF, for a fascinating idea and his comments on my final draft. Lt Commander John E. Jackson, USN, provided advice and information without which my sources would have been severely dated. Finally, Maj Michael D. Kozak, USAF, for acting as a sounding board and providing insightful and objective guidance which often supplied the focus I needed to answer "the next question."

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EXECUTIVE SUMMARY

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REPORT NUMBER 85-1950

AUTHOR(S) MAJOR JOHN C. MURPHY, USAF

TITLE THE DIRIGIBLE: A CATALYST FOR RESOURCE EXPLOITATION
IN REMOTE AREAS?

I. BACKGROUND: To extract minerals from the earth, remove timber from forests, or develop oil and gas fields requires considerable expense and poses many challenging problems even for a developed nation. The expense and problems increase substantially when an adequate transportation system is not already in place--the case in many developing countries of the world. However, creating the infrastructure to support resource exploitation, i.e., building roads, constructing airports or laying railroad tracks, is a major financial investment for a country. The expense, in many cases, outweighs the value of exploiting resources in remote areas.

One of these nations, Bolivia, is estimated to have substantial untapped sources of gold, silver, lead, copper, and a host of other minerals including the strategic minerals--titanium and uranium. In addition, there are large unsurveyed areas of potential oil and natural gas reserves. Further, there is considerable expansion available in the lucrative market of industrial wood.

A system that allowed these countries to tap this wealth would benefit the international monetary community, as well as their own. In fact, with the rapidly rising "Third World" debt

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problem, the greater benefit could be to the creditor nations.

II. OBJECTIVE: To provide a method of determining if airships can provide airlift for Bolivia, and other developing nations, to economically extract raw materials from jungle or mountain sites and take them to processing plants, consolidation points, railheads, air or seaports.

III. FINDINGS: Many studies and tests have validated the technical feasibility of using dirigibles for this purpose. So convincing is the evidence, several companies are on the verge of commercially producing airships ideally suited for light cargo duty. These vehicles are relatively inexpensive and can, in many cases, provide significant savings in transportation costs over conventional systems.

While any detailed study of a transportation system's cost effectiveness is dependent upon the specifics of the situation, the process is not. To provide a tool for useful analysis, I have developed a cost/benefit model for comparing transportation systems. Used properly, it should provide both the framework and mechanics to allow a "dollars and cents" evaluation of exploiting a specific resource using different transportation systems.

IV. CONCLUSION: The airship has returned as a feasible, cost effective transportation system and can offer developing countries an inexpensive, flexible, and capable method of transporting minerals, timber, or crops in areas without traditional infrastructure support. Even more importantly, they can stimulate agricultural or industrial development a significant distance from principal roads thereby unlocking the wealth of the land for a nation. With world population and energy demands increasing, countries need to obtain the maximum benefit from their natural resources. Much of the potential cannot be realized without extensive colonization of remote areas. The airship can be the catalyst for this colonization at the same time it strengthens their economies.

V. RECOMMENDATION: This study be provided to developing nations as a tool for analyzing their future transportation infrastructure development.

Chapter One

INTRODUCTION

Since 1973 there has been a rebirth of interest in lighter-than-air (LTA) vehicles. The LTA, a spin-off from what most know as the dirigible, has benefited from several world events and technological triumphs. The Arab Oil Embargo provided the greatest impetus for the renewed interest; however, the materials and structural wonders of the space age have allowed this interest to become more than the dreams of a few enthusiasts.

Although development has been slow, there are several LTA vehicles operational in different parts of the world. Examples of their practical applications include harvesting timber in the northwest United States (37:--); providing sea surveillance off the Florida coast (4:701); preparing to carry passengers around the Greek Isles (24:93); and, of course, advertising for the Goodyear Corporation around the world (4:700). These examples represent merely a small segment of the potential for their application to present transportation system shortfalls.

As technology continues to develop lighter, stronger materials, airships will offer opportunities bounded only by imagination and willing capital investors. In fact, the greatest obstacle to their development has been the lack of risk capital. While there is widespread acknowledgement of the feasibility of using LTAs in many roles, there is considerable doubt concerning their cost effectiveness. Further, the natural inclination toward caution in business is heightened by the nature of the vehicle. Since LTAs represent a seemingly giant step backwards in transportation systems, few corporations are willing to invest the amount of money required to validate markets which clearly exist. This paper will pursue one area of application that has potential for extensive development and financial reward.

BACKGROUND

To extract minerals from the earth, remove timber from forests or develop oil and gas fields requires considerable expense and poses many challenging problems even for a

developed nation. The expense and problems increase substantially when the transportation infrastructure is not already in place--the case in many developing countries of the world. However, creating the infrastructure to support resource exploitation, i.e., building roads, constructing airports, or laying railroad tracks, is a major financial investment for a country or corporation. The expense, in many cases, outweighs the value of exploiting these resources in remote areas. This lack of a transportation system can cause other significant problems in both economic and social areas.

Commercial agriculture and industrial activity cannot be developed without a sufficient transportation infrastructure. This prevents regional expansion of production and denies the host nation use of a valuable asset--its land. This removes many major sources of industry and inhibits the colonization of large areas (9:500). The ability to transport goods and materials is an absolute requirement for economic operations. Many of these remote areas are rich in natural resources, which are in high demand on the world market, yet the inaccessibility of these regions prevents their exploitation.

THE PROBLEM

Bolivia is a country of about 5.3 million people and 424,052 square miles (2:21). In this vast area, there are roughly 40,000 kilometers of roads of which less than fifty percent are paved (17:57). To exacerbate the problem, only about 1500 kilometers of the paved roads are major transportation arteries outside cities (37:--). The majority of all paved roads, like the population, are found in the western half of the country (17:58). The rail system is in similar condition. A survey in the mid-1970s revealed the country had only 3,579 kilometers of railroad trackage (1:31). In short, it is a country with a poorly developed transportation infrastructure. It is partly this lack of developed road/rail networks, and the expense of their construction, which keeps Bolivia from more fully developing and exploiting its resources.

It is estimated they have substantial untapped sources of gold, silver, lead, copper, and a host of other minerals including the strategic minerals titanium and uranium. In addition, there are large unsurveyed areas of potential oil and natural gas reserves. Further, there is considerable expansion available in the lucrative market of industrial wood (17:58). All the information points at an unexploited wealth of sizeable proportions in many market areas. Yet, these resources continue to go untouched or poorly developed, in part, because the costs of building traditional transportation systems are

too high. For example, roads cost between \$250,000 and \$1,000,000 per kilometer depending upon gradient, location, and intended use (29:2). Even when built, they are impassable much of the year and are hard to maintain. Some sources quote monthly upkeep as \$800 to \$1300 per kilometer (8:36). An additional expense is incurred in supporting the vehicles that use them. They deteriorate rapidly, and therefore, need a great deal of maintenance (7:494).

It would appear Bolivia has several alternatives in dealing with these riches. The first is to not develop the resources. Obviously, the option to do nothing requires no study. The second option is development of an infrastructure for surface or conventional aircraft transport. This conventional transportation system development poses no significant problems aside from cost. The third, and most radical choice, would be to ship the material by airship (7:492). This proposal, unlike the first two, raises significant questions in two areas--technical feasibility and economy of operation. In the remaining chapters I will address these two basic questions.

OBJECTIVE

The original objective of this paper was to determine if airships can provide cheap and flexible airlift for Bolivia to economically extract raw materials from jungle or mountain sites and take them to processing plants, consolidation points, railheads, air, or seaports. Unfortunately, during my research I faced several very severe limitations in gathering the information essential for a detailed analysis of such a specific objective. As a result of those limitations, discussed in the next section, I modified my objective.

Since the specific information necessary was not available, I decided to concentrate on the process, not the result. I found there were methods available to determine answers to parts of a cost/benefit problem, but no streamlined way for a layman to derive the cost/benefit relationships between transportation systems for the exploitation of a given resource. Since the initial work on an exploitation project is completed before the professional transportation analysts are tasked, it would appear a model for the non-professional analyst would be of value. With this intent, I modified my initial objective.

The new objective is to provide a *method of determining* if airships can provide airlift for Bolivia, and other developing nations, to economically extract raw materials from jungle or mountain sites and take them to processing

plants, consolidation points, railheads, air or seaports.

A second objective is to provide future researchers an update on the body of knowledge concerning current airship capabilities.

LIMITATIONS

All the limitations revolve around the lack of information. As noted above, these limitations resulted in a modification of the initial objective. Not knowing where, in what quantities, and in what quality these minerals exist, prevents a definitive comparison of costs between current transportation means and LTAs. The comparison is further hampered by incomplete knowledge of the efficiency of Bolivian operations. The final limitation, with respect to Bolivia, is a lack of knowledge about the existing road, rail or air networks, their capacities, and the extent of development in the areas concerned.

The above difficulties in obtaining accurate information are compounded by the lack of a large volume of historic, operating expense data. This will remain a limitation for any cost/benefit analysis of LTAs until more work has been completed by the airship industry.

ASSUMPTIONS

Throughout this paper I will assume transportation infrastructure development will remain a long term goal of the Bolivian, or any developing nation's, government. Further, the problem of exploiting the natural wealth of the country is a pressing one and would provide significant impetus in stimulating the economy. Finally, the airships considered must be available for purchase now or within the next three years.

ORGANIZATION OF STUDY

This study is organized into five remaining chapters. Chapter two covers availability and applicability of airships. Chapter three discusses the specific cost data of the most suitable airship for the Bolivian operation. Chapter four provides a cost/benefit model for use in evaluating the relative costs and benefits of using an aircraft, airship, train, or truck for exploiting a specific resource in a given location. Chapter five addresses unique Bolivian considerations and possible applications. Finally, Chapter six provides a summary and some considerations which cannot be

identified quantitatively for use in any decision model but that can have a dramatic effect on a project's success or failure none the less.

DEFINITIONS

The family of LTA vehicles includes many distinctly different types of members. Throughout the paper, my sources may refer to any one or combination of these member vehicles. I have included these definitions to provide a quick reference to the jargon of the LTA world.

Balloon. A light bag filled with hot air or light gas. A basket may be attached to hold passengers. Wind provides the only propulsion (20:370).

Airship. Differs from a free balloon by being steerable under power at the control of its pilot (20:370).

Nonrigid airship. The shape of the elongated gas bag is maintained by pressure alone. From the bag, a car for the accommodation of crew and power plants is suspended by ropes or cables (22:370).

Semirigid airship. The elongated gas envelope is built around or attached to a structural keel. The keel runs fore and aft and provides housing for the crew and power plant. If the gas escapes, only the envelope collapses (22:370).

Rigid airship. An external, structural skeleton is covered by some lightweight material. The overall shape is maintained, even when not inflated with gas. Normally, the lifting gas is contained by internal gas cells. Power plants, passenger and crew accommodation, cargo storage, and control surfaces are built into the main structure of the airship (22:370).

Blimp. A nonrigid airship (28:13).

Dirigible. A rigid airship (28:13).

Hybrid. A heavier than air vehicle which combines static (gas) and dynamic (propellers, jet engines) lift to provide sufficient buoyancy for flight (23:417).

Chapter Two

TECHNICAL FEASIBILITY

RECENT STUDIES & TESTS

A number of studies have addressed the technical feasibility of using airships to augment transportation systems in developing countries (7:--;9:--;19:--;8:--). In addition to "paper" studies, a test using a German dirigible was conducted in Africa during 1976 (8:31-33). Those studies which concern short distance, light cargo transportation are summarized in this section. They should provide an appreciation for the extent to which airships are accepted as viable transportation systems.

Studies

Africa.

Zaire. This 1973 study of a shuttle service for copper between Katanga and an Atlantic port was sponsored by The World Bank. It compared railroad and river barge operations with the use of a conventional airship as an alternative.

Burundi. Another World Bank sponsored study addressed movement of nickel from a strip mining operation to a seaport. The alternatives evaluated included road and railroad development, as well as, construction of an airfield in the vicinity of the mine.

In both these cases, it was concluded, "...airships of known and tested technology could, in some cases, perform routine transport missions...." (7:485). Neither of these studies seriously questioned the feasibility of using airships. They accepted both, as givens, the applicability and possibility of their use and concentrated on determining the economic advantages.

Cranfield Institute (9:--). A number of situations were considered to identify areas where an airship could, "...provide transportation facilities far superior to any other

transportation option" (9:499). Although no trade names were identified, the author studied a number of traditional, non-rigid designs (9:502). He found, "The most promising result of this study was the unique advantage displayed by the airship...to provide transport facilities in those regions presently lacking in transport infrastructure..." (9:499).

Peru. A study in 1982 addressed using the airship for transportation in the Amazon basin of Peru. The government has plans to exploit the basin's natural resources, including timber, and extensively develop the area's agricultural potential. A major obstacle has been found in the lack of a sufficient transportation system (19:1).

The region reaches from the mountain side [Andes] in Peru, to the Amazon valley....The altitude varies from 1500 meters in the mountains to 700 meters in the east into uncharted country, forests, and eventually into tropical jungles through which run the head waters of the Amazon. The valleys are sparsely populated, and the area is, for the most part, undeveloped. These areas could potentially support a much larger population if better transportation and communications are supplied and if agriculture production is improved (7:494).

The general conclusion was, "...dirigibles can be operated in the Selva Central" (19:10). After extensive study of the effects of weather, topography, and workload characteristics of these type operations, it was determined, "...neither weather nor terrain would prevent use of dirigibles as transports" (19:10).

This study has been the most directly applicable to Bolivia because of the geography and demographics of the Peruvian study area. A zone with similar characteristics is potentially one of the wealthiest regions of Bolivia (1:5-7). Since the areas are so similar in the critical aspects of topography, lack of transportation infrastructure, and industrial development, it seems reasonable to assume the results could be applied to Bolivia as well.

African Test

The eight-week experimental test in Ghana and Upper Volta used a German dirigible with flights simulating a transport operation. Landings were made on both regular airfields and unprepared sites. The particular aspects of operations observed were the following:

Temperature of the envelope; biological and

atmospheric influence on the envelope; gas temperatures at different locations on a continued basis; control of power installation; interchange of cargo and efficiency of ground handling; landing on unprepared fields; required infrastructure for operation; navigation and meteorology requirements (8:32).

All technical aspects studied, including unprepared landing site operation, climatic effect on the envelope, and tropical rain-front penetration, were passed successfully.

The studies above, as well as many others, have established the general feasibility of dirigible use. I will now evaluate the current market by discussing the dirigibles available, then their applicability to this study.

AVAILABILITY

The Requirement

I have chosen the requirements of a NASA contracted study, "Study of Civil Markets for Heavy Lift Airships," as the base line for my evaluation of individual airships (25:--). These requirements most closely parallel the requirements for an airship alternative to conventional transportation systems and are listed in Table 3. Two factors of significant importance to this study are cost and the ability to operate in remote locations for extended periods.

The first important factor is necessitated by the economy and investment environment in Bolivia. With an inflation rate in 1983 of 328% and a \$3.4 billion foreign debt in July 1984, it is not a country with large amounts of money to invest (11:58). Further, although foreign involvement in the mining industry is being encouraged, the lack of a stable political base, poor exploration incentives, and a limited road infrastructure remain major disincentives to investment (12:176).

The second of these two factors, ruggedness, derives from the nature of the operating locations and distances to even moderate population and industrially capable centers.

Having made these very general comments, I will discuss the availability of airships and follow it by an evaluation of their capabilities within the framework of the NASA study cited above.

Availability on the Market. As stated in chapter

one, several airships are available in various stages of development. There are 16 airships listed in Jane's All The World's Aircraft 1983-84 (4:696-701). After carefully studying each, as well as several others not listed, I have eliminated all but three from serious consideration. Fourteen clearly, by design or manufacturer's statement, do not meet the requirements listed in Table 3. An additional two are not considered because I was unable to obtain sufficient information to make a judgment on their suitability. One will not be made available commercially. Finally, another is a foreign design nearly identical to a US manufactured airship I will discuss. Further, it is not as far along in development as the US counterpart.

For ease of reference, I have listed the reasons for rejection alphabetically with the applicable airships to the right. Rather than list individual models, I have placed the number of airships in each series in brackets immediately after the name.

<u>Reason for Rejection</u>	<u>Airship</u>
Available only as proof-of-concept demonstrator.	Goodyear Quadrotor (6:8)
Essentially same as US built Heli-Stat but still in "modeling" stage of development.	Japanese JPFA (18:137)
Inadequate lifting and/or speed capability.	Boland Series [2] (4:700) Cameron Series [4] (4:698) Colt Series [2] (4:699) Goodyear "Blimp" (4:700)
Information not available.	Soviet URAL - 3 (4:697) *German WDL - 1 (8:31)
Manufacturer's statement of unsuitability.	Skyship Series [2] (34:--)
Tethered only operation.	ILC Dover Series [3] (4:700)
<p>*The lack of information on this airship is particularly unfortunate because it was used for the test in Ghana and Upper Volta, Africa discussed previously. The final report indicated there were no problems with operations; however, costing data was computed inaccurately and the project appeared uneconomical. Further economic analysis has produced reports reaching opposite conclusions and the agencies involved are now considering another test with a hybrid airship (8:33).</p>	

TABLE 1. - Airships Rejected

The three remaining airships will be discussed next. All are hybrid LTAs designed specifically for cargo duties. One is a one-of-a-kind project while the other two are intended for full production in different sizes depending upon lifting

Capacity.

The vehicles considered will be the first production models. In two cases, larger capacity vehicles are planned for development and marketing in the out-years; however, this will be well outside the three year availability requirement I established in chapter one. I will describe each in detail and then chart their prices and specifications for comparison.

Cyclo-Crane. This joint US/Canadian venture by The Aerolift Corporation of Oregon is operating under a contract with the United States Forest Service. The first "free" flight was on 24 Oct 84. The aim is to produce a series of airships in different sizes to satisfy several heavy-lift markets. (Drawing at Appendix 3.)

The Cyclo-Crane is a hybrid aircraft utilizing aerostatic lift from a helium filled centerbody to support all structural weight plus 50% of the sling-load specification. The balance of the slingload support and thrust for control and translation is supplied by a system of airfoils that rotate in hover and become aligned with the direction of flight when the Cyclo-Crane reaches its maximum designed forward speed....

The criteria for selection of components or systems (e.g. [,] fore and aft bearings, hydraulic systems, etc.) is safety, low maintenance cost and low acquisition cost rather than the normal aircraft design concern for low weight....The design effort uses a very high safety factor that accepts weight penalties in return for a strong structure that can be fabricated from low cost components using simple construction techniques. Maintenance costs are likewise low (compared to aircraft experience) due to use of parts and systems far more massive and durable than normally used in airframe manufacture....The vehicle can be safely moored in winds up to 80 MPH by mast...and may be designed to float hundreds of feet high on a single line tether (30:1).

Heli-Stat. Although designed as a one-of-a-kind project, Piasecki Aircraft Corporation has provided performance, cost, and availability information for this hybrid airship. Sponsored by the United States Forest Service, they are now in the dynamic testing phase. (Drawing at Appendix 4.)

The Heli-Stat employs the buoyant static lift of a helium-filled 1,000,000 cubic foot airship envelope

to offset the empty weight of four helicopters and the structure interconnecting the helicopters with the envelope and alighting gear. The Heli-Stat's empty weight is thus brought to near zero, allowing the total thrust of the helicopter rotors to be applied to lifting the useful load. Precision hovering is obtained through the four helicopter rotors and their interconnected controls to one pilot... (32:--).

Van Dusen LTA 20-1. The Canadian based Magnus Aerospace Corporation expects to produce a manned prototype during 1986. The goal, like Aerolift, is to work the heavy-lift market at several levels. (Drawing at Appendix 5.)

The LTA 20-1 is a hybrid heavy-lift airship combining three types of forces: the buoyancy lift of helium, the dynamic lift of engine thrust and the aerodynamic lift of the Magnus effect. The craft's structural weight, including engines, gondola and sphere, is fully supported by the lifting gas.

During vertical takeoff, engine thrust is used to counteract the payload weight. In forward flight, the spherical envelope rotates about its horizontal axis. Since the top of the sphere rotates away from the direction of travel, there is a velocity differential between the top and bottom causing a pressure differential which results in aerodynamic lift. This Magnus effect directly compensates for the engines that have been vectored for full forward thrust. Stability is enhanced due to controlled boundary air layer shedding near the back of the gondola.

Attached to the axle inside the main sphere is a ballonnet which is used to alter the craft's buoyancy, providing in-flight trim control and air ballasting.

The crew cabin, gondola arms and axle form a triangle, the strongest geometric shape known. Engines mounted on the outboard sides of the gondola arms, opposite the axle, may be vectored to provide either vertical takeoff or horizontal cruise thrust.

The Magnus LTA 20-1: does not require a mooring mast or hangars...[and] can be easily stored and maintained in standard structures (33:--).

Clearly, these airships represent significantly different approaches to solving the requirements of the heavy-lift

market. Included in Appendices 3, 4, and 5 are drawings of the Cyclo-Crane, Heli-Stat, and LTA 20-1 respectively. They should provide a better appreciation of the diversity between, and complexity of, these airships. They are no more traditional "blimps" in appearance than in performance. Each is a highly specialized vehicle specifically designed to perform in the logging and light cargo transportation markets. The next page contains a table of prices and specifications to allow a clear comparison of their relative capabilities.

		Cyclo Crane (31:--)	Heli Stat (32:--)	LTA 20-1(9) (33:--)
	Unit			
<u>Cost in Millions</u>				
	\$	4.0	8.0	10.0
<u>Dimensions</u>				
Length	Ft	200	343	92(10,11)
Width	Ft	212(1)	188	119(10,11)
Height	Ft	212(1)	113	107(10,11)
<u>Weights</u>				
Gross	Ton	32.0	53.5	26.89
Empty	Ton	16.0	27.4	9.29
Useful Load	Ton	16.0(2)	26.1	16.1 (12)
<u>Performance</u>				
Cruise Speed	Kt	>100	60	>100(10)
Climb Vertical	Fpm	(14)	100	(14)
Climb Forward	Fpm	>1500	950	(14)
Range at Cruise	Km	(14)	275(5,6,7)	
Ferry Range	Km	5000(3)	3165(7)	520(13)
Hover Ceiling	Ft	(14)	3000	(14)
Operating Ceiling	Ft	(4)	8000(8)	3000

Notes

- (1) Major diameter 100ft + (2) 56ft wings.
- (2) Eight hours + reserve fuel.
- (3) Full slingload of fuel.
- (4) Variable. Dependent upon envelope size.
- (5) Includes 10% fuel reserve.
- (6) Range can be extended by trading payload for fuel.
- (7) Converted from statute miles.
- (8) With 21.4% ballonet.
- (9) Logging version.
- (10) Approximated.
- (11) Converted from metric.
- (12) With 3000Lbs fuel.
- (13) 50 KPH, 20 minute reserve.
- (14) Not provided by manufacturer. Other criteria drove selection; therefore, information is not necessary for decision making.

TABLE 2. - Comparative Specifications

APPLICABILITY

The requirements and limits of the NASA study referenced at the beginning of this chapter are detailed below. They will be used to assess the applicability of the three airships charted above. Several of the requirements are easily quantifiable (denoted by asterisk) and can be traced directly to the specification chart. The rest apply, in some cases to design specifications, and in others to operating procedures. Those design-dependent specifications have been evaluated in respect to the basic design of the vehicles considered. In every case, they have been met through meeting the fundamental requirements of the particular vehicle. For example, since all three are being developed specifically for duties requiring precise hover capability, the hovering precision requirement has been met. The remainder are operating-procedure dependent and would have to be evaluated in the actual working environment, not this study.

Specifically, all the NASA study requirements are cataloged under logging and ship unloading operations. Since there are more variables involved in moving cargo from a ship to shore, i.e., the vessel movement and superstructure obstacles, I have assumed the movement of bulk material to and from land locations would be no more difficult.

See the next page for the table of requirements.

*Cost: As low as possible, relatively unaffected by operating conditions.

*Altitude: Up to 5-7000, occasionally to 12,000 [feet].

Temperature: Below freezing to +120F.

Elevation changes/cycle: 500 feet to 3-4000 feet.

Wind: Horizontal and vertical gusts to 30 mph,
occasional horizontal gusts and winds
to 70-100 mph.

Precision: Horizontal 1 to 5 feet, Vertical
1 to 5 feet.

Descent rate 5 feet per second.

Ground riggers to control lateral
movement of load.

Logistics: Prompt attention to schedule.

Load: Aggregate as much as possible....

Environment: Improve on helicopter and surface
transport capability with respect to

- bad weather, bad visibility,
day or night
- icing, rain, snow
- rough water and rough
terrain.

Safety: Static charges, load gyrations, multiple
engines, load release, cable snap back,
pilot fatigue, ground crew clearance,
rotor clearance, load swinging
clearance... (25:1-3).

Payload: 7 - 75 tons (25:1-4).

TABLE 3. - Required Vehicle Characteristics

As can be seen by comparing the specifications and characteristics charts, the Cyclo-Crane and Heli-Stat meet or exceed the performance criteria. Again, I point out the Heli-Stat is included only for comparison of a more conventional design with the radically new engineering concepts represented by the Cyclo-Crane and LTA 20-1 airships. Since the manufacturer has stated it is a one-of-a-kind vehicle, not intended for production, I will delete it from further consideration (36:--).

The LTA 20-1 fails to meet the operating ceiling requirement. The Van Dusen Company intends to address this deficiency when it markets an airship with a pressurized cabin

to allow high altitude flight. However, it will be in the 60 ton payload class, will cost considerably more, and is not expected until after 1988 (35:--). This will place it outside the three year window I established to ensure availability in the event a government or company desires to act on my findings in the near future. An additional consideration when comparing the Cyclo-Crane and LTA 20-1 is cost. The LTA 20-1 will cost two and half times more yet with no commensurate increase in payload or operating advantage. For these reasons, I consider the Cyclo-Crane best suited for the task and will use it in the next chapter to discuss the comparative economics of an airship operation.

Chapter Three

COMPARATIVE ECONOMICS

This chapter deals with three types of costs for comparison. The costs associated with the Cyclo-Crane, costs of alternative systems, and costs of supporting those alternative vehicles. First, I will use Aerolift Corporation's estimates for costs associated with the Cyclo-Crane. These figures will cover fixed annual and hourly operating costs, as well as acquisition costs. Second, I will compare estimates for cost per ton-kilometer figures with the most probable alternative vehicles to a dirigible operation in this region (7:494). Finally, I will provide information concerning the type and expense of the infrastructure necessary to support train, truck, and aircraft transportation systems in this part of the world.

Throughout this chapter I will be referring to cost data from several sources. These figures are all expressed in dollars, but with different base years. I have purposely not converted the costs to a constant year value for two reasons.

First, they are costs derived during studies in countries with significantly different economies. Therefore, any translation into later dollars would depend upon the inflation factors of those individual countries. Applying the US consumer price indices would serve no useful purpose and, moreover, would invalidate the comparisons. US inflation cannot realistically be applied to Peruvian or African costs. This is tantamount to the classic "apples and oranges" comparison.

The second reason is based on the results of comparison without any conversion. Even without allowance for inflation, Table 7 will show the airship is more cost effective in most cases. Further, this favorable comparison occurs with all costs of the Cyclo-Crane factored in, but without infrastructure support considered for any other method. It seems clear once the infrastructure is included for the other transportation systems, the results will be even more favorable. Again, my intent is to argue the data supports a serious evaluation of the possible cost advantages of an airship operation. This would require a detailed analysis

using current costing information for the situation studied.

Having addressed the reasons for the lack of any constant dollar comparisons, the next section will present a detailed explanation of the results.

CYCLO-CRANE

Investment Costs

The following costs are the manufacturer's estimates, in 1981 dollars, for one vehicle. They will be broken into categories of investment and operating costs. Within the investment category, I will identify those expenses associated with system acquisition separately from the fixed annual costs. This will allow a differentiation between the expense of acquiring the vehicle--the "sunk" costs--and the major expense items to operate it for a year. Since none of these expense elements depend upon the amount the vehicle is used, they are considered investment, not operating costs. Note, the fixed annual costs could vary greatly depending upon the depreciation schedule used, insurance premiums applicable, and cost of financing.

Support Equipment	₹	
Flight Equipment	4,000,000	
Support Equipment	100,000	
Spares Parts	75,000	
Total	4,175,000	
Fixed Annual Costs		
Depreciation	313,125	10-year life 25% residual value
Interest	414,400	15%
Insurance	320,000	8% x flight equipment
Helium Replacement	2,000	
Envelope Refurbishment	5,000	
Total	1,054,525	

TABLE 4. - Investment Costs (10:174)

Operating Costs

Hourly Operating Costs. Operating expenses, unlike those above, are dependent on the number of hours flown. While the actual expense incurred increases as the use increases, the cost per flying hour decreases. This effect is caused by the larger number of hours across which to amortize the investment expenses discussed previously. This reduction in cost per flying hour means lower "cost-to-income ratio" and an improved economy of operation. The second half of Table 5 will illustrate the impact higher use factors have on hourly operating costs.

These costs have been purposely figured without labor. Without accurate wage information for a skilled Bolivian crew, the cost model becomes inaccurate. If available, the labor charges for a crew (pilot, copilot, and mechanic) would have been factored into the formula for flying hour costs.

<u>Fixed Hourly (10:174)</u>		
Fuel		\$ 150.00
Miscellaneous		76.00
<u>Cost (\$) per Flying Hour (10:175)</u>		
Fixed Annual / Hours Use + Fixed Hourly + Labor		
1,054,525/1200	= 878.75	+ 226.00 + 0 = 1104.75
∴ /1500	= 703.00	+ ∴ + ∴ = 929.00
∴ /2000	= 527.24	+ ∴ + ∴ = 753.24
∴ /3000	= 351.12	+ ∴ + ∴ = 577.12

TABLE 5. - Cost per Hour

Cost per Ton-Kilometer

Cost per ton-kilometer is a value used to enable meaningful, expense comparison between transportation modes. The figure is calculated by the formula:

$$\text{Hourly operating cost} / \text{speed} = \text{cost per kilometer} / \text{tons carried} =$$

Like the hourly operating cost, the cost per ton-kilometer can vary. It is dependent upon the hourly operating cost, speed, and payload capacity of the vehicle. In this case, I have used a constant 100 kilometers/hour (Kts) cruise speed and the designed payload of 16 tons. With these figures I have computed a cost per ton-kilometer value for 1200, 1500, 2000, and 3000 hours use per year.

Hrs	Cost(\$)/hr	Cruise	Cost(\$)/km	Cargo	Cost(\$)/ton-km
1200	1104.75	100Kts	11.04	16 tons	.69
1500	929.00	∴	9.29	∴	.58
2000	753.24	∴	7.53	∴	.47
3000	577.12	∴	5.77	∴	.36

TABLE 6. - Cost per Ton-Kilometer

COMPARISON

This section will compare the cost per ton-kilometer of Aerolift's 16-ton Cyclo-Crane with costs to operate a conventional, twin-propeller driven aircraft, 12-ton helicopter, five-ton truck, and train. For this comparison I will use the 3000 hours cost per ton-kilometer value computed for the Cyclo-Crane. I have chosen this rate to approximate an eight-hour day with roughly a three week period for maintenance, if required. These are the same conditions used in the Peruvian study discussed in chapter two (19:4). Again, this calculation was done using 1981 dollars. The cost per ton-kilometer values for the other vehicles have been taken from studies for economic development of regions similar to Bolivia. Their sources are associated with the figures in the table below. It is important to note, the studies of the aircraft, helicopter, and train were conducted in the mid-1970s; therefore, these values are in 1974-75 dollars. The study which provided the value for the truck was completed in 1983.

<u>Vehicle</u>	<u>Cost (\$)/ton-km</u>	<u>\$ Year</u>
Cyclo-Crane	.39	1981
Dehavilland otter (1)	.56	1975
12-ton Helicopter (1)	1.49	1975
Five-ton Truck (2)	.26	1981
Train (3)	.02	1974

Note: Only the Cyclo-Crane value includes infrastructure support expense.

Source:
(1) 7:494
(2) 8:37
(3) 29:2

TABLE 7. - Ton-Kilometer Cost Comparison

As noted, the Cyclo-Crane was the only system with its infrastructure support "costed" in. However, to accurately compare the systems, these support costs need to be factored into the equation. Unfortunately, the information needed to accurately compute cost per ton-kilometer with infrastructure support costs is very dependent upon the specifics of the

situation. The distances involved drive the cost of roads and railroads. These costs, in turn, drive the ton-kilometer cost. In the case of an aircraft, the number and type of runways and facilities are the key elements in cost analysis. The helicopter costs also rise and fall based on facility costs. Acknowledging specific comparisons are not possible within the scope of this paper, I will provide costs in terms of a reference unit for each transportation system. These reference units will be to a kilometer, runway, or maintenance facility depending upon the vehicle discussed. The source of these cost figures is a feasibility study of using dirigibles for the same purpose I propose--light cargo transport. This study uses the 1974 dollar and the figures are generally confirmed by another 1974 study conducted in Bolivia. The Bolivian study was done by Light Speed Corporation of Florida, but did not specify the region evaluated (29:--)

Vehicle	Reqd	Unit	Construction Time	Cost (\$ million)	
				Min	Max
Train	Rail	Km	2 wks-5 mo	.70	3.0
Truck					
5 ton	Road	Km	1 wk-3 mo	.25	1.0
15 ton	"	"	"	.50	2.0
30 ton	"	"	"	.75	3.0
Aircraft					
10 ton	Runway	800 m	1-3 mo	.50	3.0
12 ton VTOL	MX base		1 mo	.60	.90

TABLE 8. - Infrastructure Development Expense (29:12)

As can be seen, the costs of developing these systems are high in this region of the world. Compounding initial construction costs, the roads deteriorate rapidly and require a significant amount of maintenance. Further, many of the roads may be impassable during much of the year (7:494).

DISCUSSION

It is apparent the Cyclo-Crane would be able to compete favorably with traditional systems in situations where roads, railways, and airfields are not already in place. Having made

this sweeping generality, pinning down the specific economies is much more difficult. The distances involved and terrain to be traversed are only two of many elements I do not have available for analysis. Without these specifics, I cannot make a judgment on the efficiency or economy of a dirigible operation. The next chapter will address this problem.

Chapter Four

COST/BENEFIT MODEL

In chapter three I discussed the cost comparisons of a 16-ton Cyclo-Crane and several alternative systems. Now would be the time to analyze a specific situation and see if an airship is a reasonable alternative to traditional transportation modes. Unfortunately, without enormous assistance from the Bolivian government, as well as industrial, transportation, and country experts, the details necessary are well beyond the abilities of this researcher to ascertain. Therefore, providing a "yes" or "no" answer to the economic wisdom of using an airship is not possible. Any attempt would be merely an academic exercise not applicable to another situation with a different resource, set of distances, or exploitation efficiency.

While any detailed study of a transportation system's cost effectiveness is dependent upon the specifics of the situation, the process is not. It is this analysis process I will discuss here. In hopes of providing a useful tool, not simply a research document, I have developed a cost/benefit model for comparing transportation systems. The method of analysis has been derived and adapted from three models presented during the 1983 American Institute of Aeronautics and Astronautics LTA Systems Conference (19:--; 8:36-37; 10:--). Used properly, it should provide the framework and mechanics to allow an evaluation of different circumstances. This chapter will explain how to use the model to evaluate the relative costs of aircraft, airship, train, or truck transportation to exploit a resource.

ASSUMPTIONS

Since this study concerns the question of exploiting resources in remote areas, I have made a basic assumption about any system's transportation efficiency. I have assumed it to be the worst case. By this I mean, the sole purpose of the transportation system will be to move income producing cargo from the source to an off-load destination. Were this not the case, and the vehicle could generate income in both directions, the cost effectiveness would increase. This factor could be

worked into the model during the "profit(loss) per trip" computations contained in the calculations section of the benefit model. Further, all support costs of both the operations and the people are attributed entirely to the system being considered. Again, if these support costs were not amortized directly against a system, the cost effectiveness of that particular system would improve.

The cost accountability begins with the expense of transferring the material from its source to the load/pickup point for the aircraft, airship, etc. This acknowledges certain savings inherent in some systems over others. For example, it would be necessary to move the material from a mine to an aircraft parking area for onload to a airplane, but a truck could get much closer to the mine exit. The transfer costs required for the aircraft, since they are transportation system dependent, should be reflected in the price of doing business by aircraft.

ORGANIZATION

For ease of explanation, I have broken the model into its parts. First, I will discuss the "cost" portion by providing data definitions to standardize the expense categories between different transportation systems. In each case, the title will be presented, then costs falling in the area will be identified. Where significant differences exist between systems, they will be broken out under aircraft, airship, train, and truck subheadings. After identifying the data required for analysis, I will explain the computations necessary to complete the "costing" for the model. These will be the hourly operating cost, the cost per kilometer, and the cost per ton-kilometer. Next, I will explain the "benefit" part of the model. This section will determine profit or loss to be expected per trip and day for each system studied. It will provide the bottom line, dollars-and-cents, comparison of systems.

COST MODEL

The lists below may include more or fewer items of cost data than would be required in every case. For example, some locations may require a control tower to safely operate an airfield, others may need only a runway. Please note, the lists are provided as guides, the myriad factors possible in every situation prohibits an absolute "checklist" approach to identifying the subelements.

Group A - Capital Investment

Total capital investment will be the sum of the amounts under vehicle, support, and spares categories. These are considered "sunk" costs and, therefore, are not easily recoverable.

A-1 Vehicle.

A-1.1 Aircraft (Either fixed or rotary wing.). Cost of the vehicle, navigation/communication aids, and any other equipment associated with the structure or performance.

A-1.2 Airship. Same as above.

A-1.3 Train. Cost of the locomotive, rolling stock, and communication equipment.

A-1.4 Truck. Cost of vehicle.

A-2 Support. Cost of training operators and support personnel. Cost of any maintenance, repair, or support facilities required by personnel to live and work. Included should be all construction costs of the support base. Also include construction of loading and unloading facilities at both origin and destination unless they are already in place.

A-2.1 Aircraft. Cost of runway and ramp area, field facilities, navigation aids, material netting/containers, cargo tie-downs, and handling equipment. Additionally, fuel servicing facilities and equipment, as required.

A-2.2 Airship. With the substitution of a mooring station (if required) for runway and ramp area, same as above plus helium and ballast storage and transfer facilities.

A-2.3 Train. Costs of trackage, bridges, control stations (if required), cargo containers, tie-downs, and handling equipment.

A-2.4 Truck. Costs of roads and bridges.

A-3 Spares. Parts inventory for scheduled maintenance and repair capabilities to maintain operation of the system. Includes miscellaneous items (i.e. oil/fuel filters), as well as major parts i.e., generators, tires, batteries, bearings, etc.

Group B - Fixed Annual Costs

All costs should be expressed in their yearly share of

multi-year expenses.

B-1 Depreciation. Decrease in value of Total Group A (Capital Investment) (5:357). Residual value is the anticipated value of the items at the end of their expected service life.

Total Group A - residual value / service life = depreciation per year

B-1 Interest. Amount required to service loans necessary to finance any Group A items.

B-3 Insurance. Cost of insurance for loss, damage, or injury.

B-4 Other Annual Expenses. Costs of training to maintain proficiency or maintenance/inspection to maintain certification of the transportation systems. Included would be upkeep of material handling equipment and load/off-load facilities.

B-4.1 Aircraft. Required annual maintenance inspection to maintain safety standards.

B-4.2 Airship. Same as above. Examples include helium replacement and/or envelope refurbishment.

B-4.3 Train. Costs of maintaining rail network, as well as rolling stock.

B-4.4 Truck. Costs of upkeep of vehicles and maintenance of roads.

Group C - Fixed Hourly Costs

C-1 Fuel. Self Explanatory.

C-2 Labor. The assumption a certain number of qualified personnel will be on-the-payroll regardless of the amount of time they are actually engaged in their primary duties has been made. This category includes the salaries of crews, engineers, drivers, support personnel, and material handlers for each system. An individual supporting any facet from material transfer to the loading area through arrival and off-load at destination should be included, with two exceptions. One, if people used for the mining/timbering operation move the material to a loading area, they would be excluded from this labor cost data. Two, if the off-load support would exist whether or not this exploitation was in progress, it would also be excluded. In both cases the salaries of these individuals are not dependent upon the

transportation system used.

C-3 Miscellaneous. Parts for the vehicle, oil, lubricants, etc.

Summary of Cost Data

This concludes the calculation of the costing data. It includes the expense of acquiring the hardware, maintaining the right to use it (interest, insurance, etc.), having the facilities and fuels to make it work, and the qualified personnel to run it. The next section will discuss cost computations.

Computations

Hourly Operating Cost. This cost is derived using the data from above and the expected annual system use expressed in hours.

$$(\text{Total Group B} / \# \text{ of hours expected per year}) + \text{Total Group C} = \text{hourly operating cost}$$

Cost per Kilometer. To determine this value, the cost per hour must be known along with the average vehicle cruise speed in knots.

$$\text{Hourly operating cost} / \text{speed} = \text{cost per kilometer} / \text{tons carried} = \text{cost per ton-kilometer}$$

Cost per Ton-kilometer. This value is used to compare transportation system costs in the abstract. It provides a way to establish rough cost relationships between systems when specific information is not available. A planner could use this measure to eliminate all but two or three systems from consideration without further analysis. It is derived from the cost per kilometer value and the vehicle's intended payload.

$$\text{Cost per kilometer/intended payload} = \text{cost per ton-kilometer}$$

These calculations complete the "costing" model. This part of the cost/benefit model is the "gross" analytical tool. It can provide some assessment of relative costs without detailed resource, transportation, or distance information. Given the detailed information necessary, a refined analysis is possible using the formulas in the next section.

BENEFIT MODEL

This model will allow calculation of the gross profit or loss per trip and day. In addition to the cost per kilometer value computed above, specific information concerning the location of an unexploited resource, its market value, proximity to an already developed transportation infrastructure, and the vehicle being evaluated is necessary. As stated in the introduction to this chapter, the worst case for transportation efficiency has been assumed; therefore, all vehicles will return empty from the off-load destination to the pickup point. This section will list the information required for the computations and then the calculations to obtain the values needed for benefit comparison.

Required Information

A Non-vehicle Dependent.

Duration of work day:

Operation Efficiency: Transportable material per unit time.

Value at market per ton of material:

B Vehicle Dependent.

Cost per kilometer: Calculated above.

Payload: Given specification of vehicle.

Distance: Air, rail, or road kilometers to destination.

Average Transit Time: Round trip plus on/off-load times.

Calculations

Given the above information, the model can now be used to help determine the relative benefit of each system. Using the formulas below, cost per trip, profit(loss) per trip, and fleet profit(loss) per day can be determined.

A Profit(Loss) per Trip.

Cost per kilometer x distance in kilometers = cost per trip

Market value of material per trip - cost per trip = profit(loss) per trip

B Number of Trips per day.

$\text{Workday} / (\text{transit time} + \text{time waiting for sufficient load}) = \text{trips per day}$

C Gross Profit(Loss) per Day.

$\text{Profit(loss) per trip} \times \text{trips per day} = \text{profit(loss) per day per vehicle}$

$\text{Profit(loss) per day per vehicle} \times \text{number of vehicles} = \text{gross profit(loss) per day}$

DISCUSSION

As noted earlier, the model provides at least two decision points. First, the "cost per ton-kilometer" value provides a rough measure between systems in the absence of specific information. Second, the benefit model allows decisions based on projected profits or losses. Further, it can also help determine vehicle fleet size. Once the profit per vehicle is determined, the final formula can be worked backwards to see how many vehicles would be needed for a desired profit.

While I recognize this model will not provide the means to do the most detailed analysis possible, it will provide a method to determine relative system costs and benefits and whether more extensive study is warranted. To translate the narrative into a workable tool, I have included worksheets in the appendix. Appendix 6 is the cost worksheet, the benefit worksheet is at Appendix 7.

Chapter Five

BOLIVIAN APPLICATIONS

Clearly, the facts show the airship as a cost effective, flexible transportation mode. This system is ideal for regions with little infrastructure development. As a country with large undeveloped regions, it appears Bolivia could reap great economic benefit from airships. However, the ultimate value to Bolivia, or any other country, will have to be assessed in relationship to the many pressing priorities of their governments. Recognizing this limitation and, with the possible applications of the dirigible in mind, lets look very briefly at Bolivia's economic situation and potential for future development.

ECONOMIC SITUATION

Extraction of its mineral wealth has been the basis of Bolivia's economy for more than 400 years (3:33). Today the mines are becoming less efficient at the same time world demand for their product is declining. Bolivia is the world's fourth largest producer of tin, but its cost of production is double the world average (12:176; 17:56). Compounding the present situation, there is an already pronounced trend by end-users to substitute other materials for tin. For example, aluminum has replaced the tin can in three quarters of the US beverage market and is increasing its market share elsewhere (5:145). Similar trends are evident in the copper, tungsten, and zinc markets (16:165; 13:68; 15:153). These trends in the traditional export markets seem to underscore the potential value of diversifying the economy. New discoveries of gold, iron, lithium, nickel, phosphates, silver, and uranium have spurred development interest in minerals not previously mined (27:134-137). Moreover, these discoveries were made in the undeveloped, eastern part of the country (27:134). This region, nearly devoid of transportation support, is one in which a dirigible operation would be optimized. The airship would allow exploitation without the enormous expense, in both time and money, of building roads, railroads, or airfields.

Another potential market is in wood products. According to the US Department of Commerce, "...global demand for

industrial wood is being forecast to increase 50 percent between now [1984] and the end of the century" (26:4-9). Bolivia has vast areas of mahogany, cedar, and other trees suited to the wood industry (21:4). With nearly 43 percent of the total surface, about 180,000 square miles, covered by excellent species of hardwoods, the potential for exploitation is great (21:7). "Limited means of access...[has] delayed the development of these riches" (21:7). The airship could solve this problem. Further, since the Cyclo-Crane is being designed specifically for timbering, this would be the "ideal" environment in which to use it.

These are only a few of the potential markets in which a flexible, low investment, transportation system could help. While a complete discussion of all the possibilities is well beyond the scope of this paper, I would like to address one possible application and its potential impact on several areas.

POSSIBLE SCENARIO

One potential scenario for airship use could link benefits in the areas of resource development, economic diversification, colonization, and transportation system expansion. This plan could be effected by:

A. Airships would be used to establish and support a forestry operation to diversify the economy and exploit a resource in demand on the world market. These airships would provide for the logistics needs of the workers, as well as transportation of the felled trees to a shipping point.

B. As the forestry work cleared the land, people would be encouraged to farm it. Again, the airships, rather than returning empty from the timber off-load point, would carry whatever supplies this new population required.

C. When the agricultural output warranted, the airships would move crops to market. This would have a limited, negative impact on timbering, but overall, positive impact for continued colonization.

D. After the region had proven its value through extensive agricultural and economic development, a traditional transportation network would be constructed to service the area.

E. At this point the airship operation would be moved to help develop another area.

Admittedly oversimplified, this is one way an airship operation

could provide important secondary benefits--colonization and diversification. The last chapter will summarize the advantages dirigibles can offer developing countries.

Chapter Six

SUMMARY

I have shown the dirigible to a technically sound concept proven in many studies and at least one actual test. The economic advantages must be determined on a case-by-case basis, but it appears clear it can generate significant savings over traditional systems in some situations. I have listed several of the advantages and the disadvantages below for review.

ADVANTAGES

Speed

The speed with which an airship operation can be started as opposed to the time required to construct roads, railroads, and airfields can allow a country to immediately begin exploiting a potentially rich area when discovered. It is also a significantly faster mode of travel than train or truck. It increases this advantage further by its ability for direct, line-of-sight, travel.

Flexibility

The airship operates independently of surface conditions (8:501). It can be transferred quickly as regional markets are proven and alternative transportation systems can be justified.

Load

Heavier loads, fewer restrictions on size and bulk, and less labor intensive material handling requirements mean more cargo, moved more easily with fewer people.

Cost Effectiveness

As high capacity, low investment vehicles, airships maximize cost-profit ratios.

Catalyst to Development

In a study of roles for airships in economic development, it is stated, "...it has been amply demonstrated that transportation is indispensable to economic development" (7:496). As pointed out earlier in this paper, the cost of providing this transportation can be extremely high, in both time and money, in the still developing areas of the world. The dirigible can minimize these expenses.

Minimum Investment

Relatively little capital is required to obtain and operate an airship. Most of the expenses are in the vehicle and are not "sunk" costs. This is not the case in road, rail, or conventional air networks. All require large outlays in fixed support, i.e., roads, railways, and runways. This means they require large risk capital investment before a region has proven its value.

DISADVANTAGES

The primary disadvantages of airships are lack of availability or experience in their practical application. Additionally, the lack of sponsors with willing risk capital to invest has inhibited market development.

CONCLUSION

The airship has returned as a feasible, cost effective transportation system and can do an important job. The advantages are powerful arguments for taking the risk inherent in any unproven system. They can offer developing countries an inexpensive, flexible, and capable method of transporting minerals, timber, or crops in areas without traditional infrastructure support. Even more important, they can stimulate agricultural or industrial development a significant distance from principal roads thereby unlocking the wealth of the land for a nation. With world population and energy demands increasing, countries need to obtain the maximum benefit from their natural resources. Much of the potential cannot be realized without extensive colonization of remote areas. The airship can be the catalyst for this colonization.

As a country with large quantities of untapped natural resources in remote areas, Bolivia, in particular, could benefit greatly. The economy needs stimulating, and the situation is optimized for airship-supported industry to be the stimulus. On the surface the choice seems natural. The model

in chapter five provides the means to determine if detailed studies are warranted for Bolivia or other nations with similar problems of resource accessibility.

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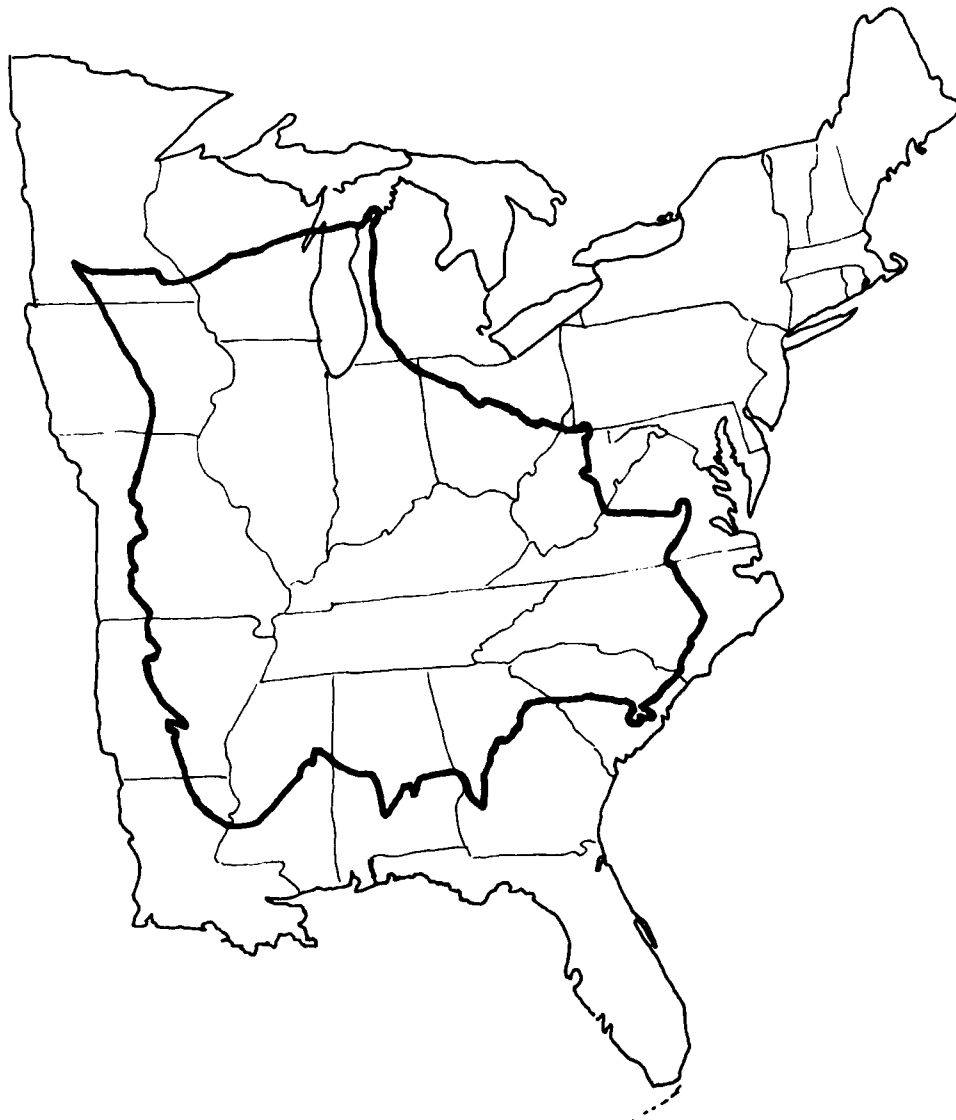
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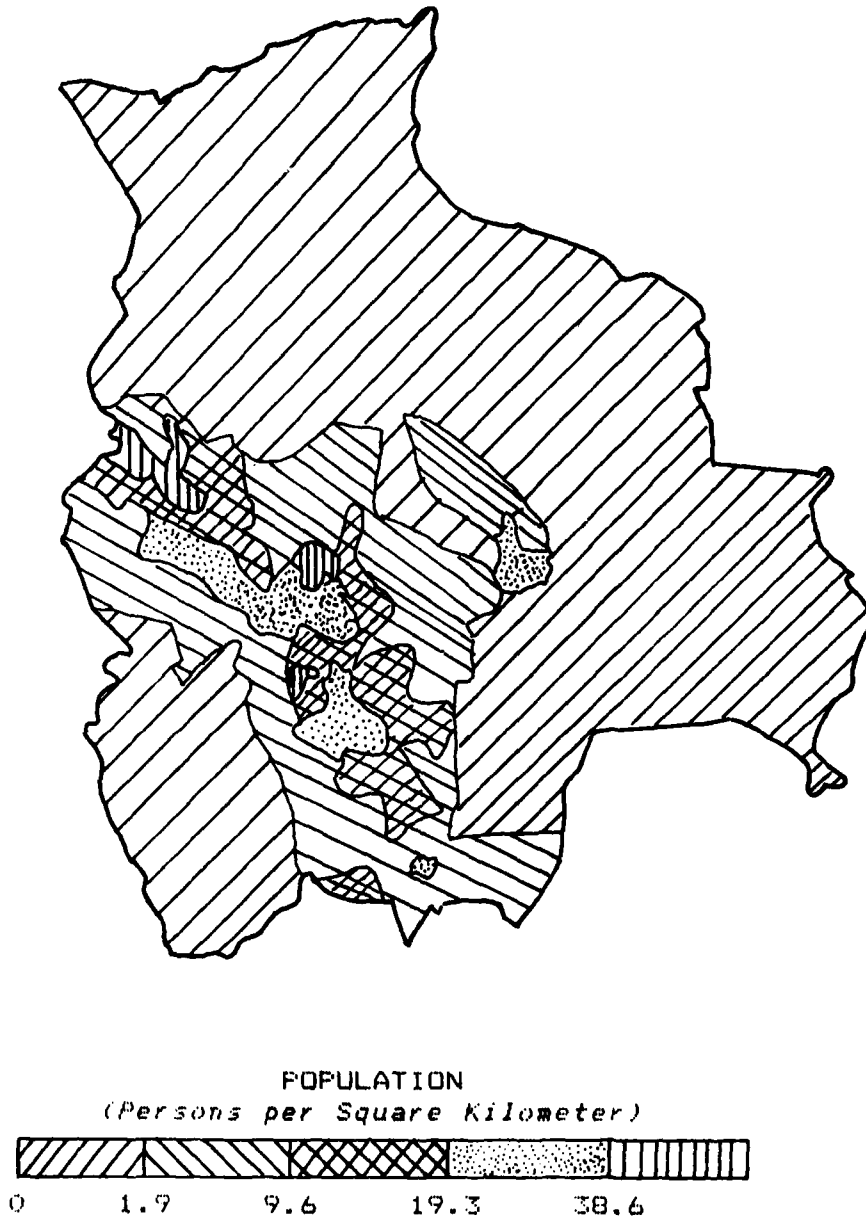
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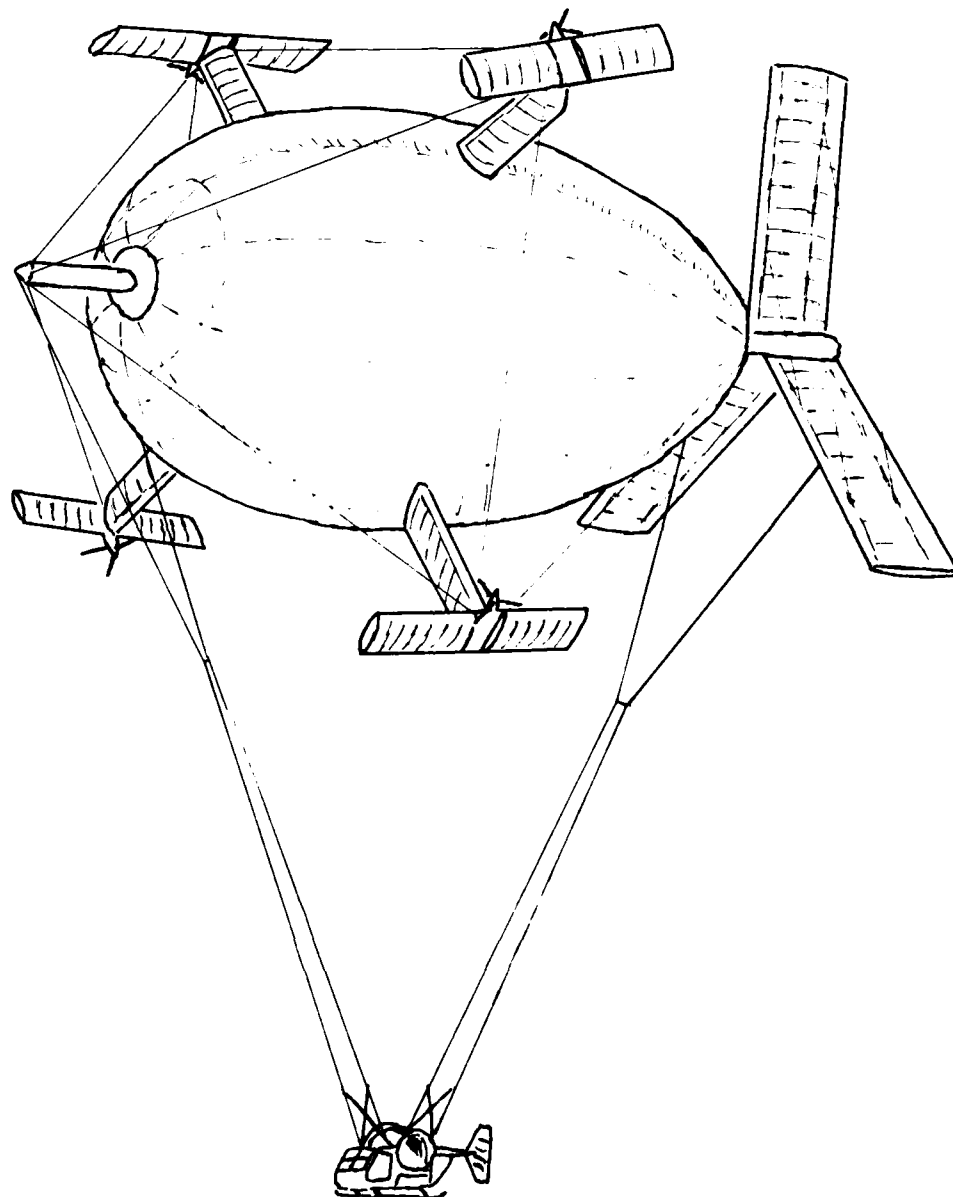
AFFENDIX 1 - BOLIVIA: RELATIVE SIZE (38:--)



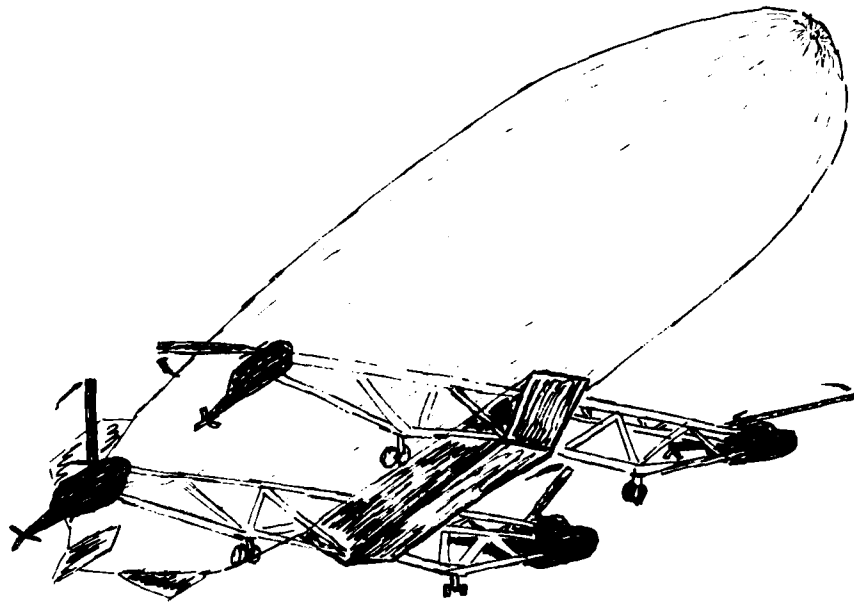
APPENDIX 2 - BOLIVIA: DEMOGRAPHY (38:--)



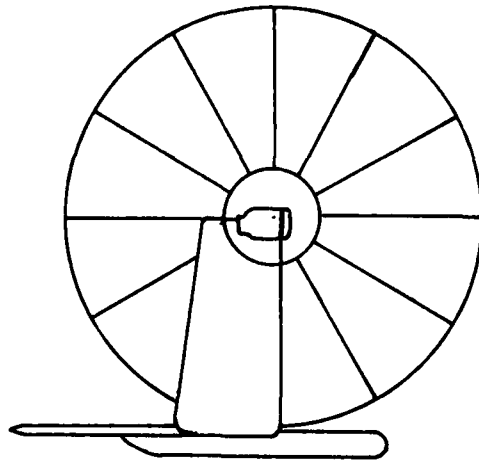
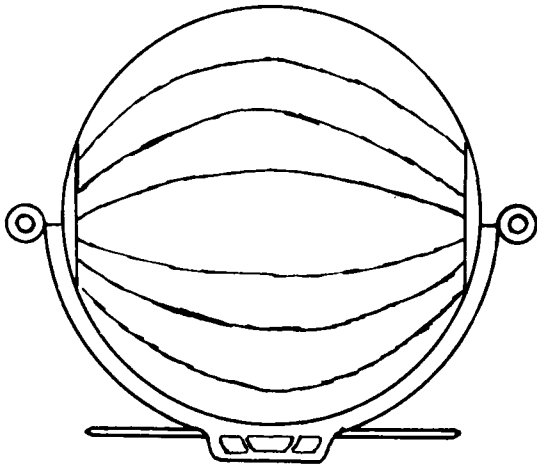
APPENDIX 3 - CYCLO-CRANE (31:11)



APPENDIX 4 HELI-STAT (36:3)



APPENDIX 5 - LTA 20-1 (33:9)



APPENDIX 6 - COST CALCULATIONS

Type of Vehicle: _____ Number: _____

Costs:

Group A		Group C	
Vehicle(s)	_____	Fuel	_____
Support	_____	Labor	_____
Spares	_____	Misc	_____
Total	[_____]	Total	[_____]

Group B

Depreciation	_____
Interest	_____
Insurance	_____
Other	_____
Total	[_____]

Use:

Specifications:

Hours/year	_____	Avg Speed	_____
	_____	Payload	_____

Hourly Operating Costs:

Group B	_____	_____	_____	_____
/ Hours/Year	_____	_____	_____	_____
+ Group C	_____	_____	_____	_____
= Hr Cost	_____	_____	_____	_____

Cost per Kilometer:

Hr Cost	_____	_____	_____	_____
/ Avg Speed	_____	_____	_____	_____
= Cost/ton-km	_____	_____	_____	_____

Cost per Ton-Kilometer:

Cost per Km	_____	_____	_____	_____
/ Avg Payload	_____	_____	_____	_____
= Cost/Ton-Km	_____	_____	_____	_____

APPENDIX 7 - BENEFIT CALCULATIONS

Type of Vehicle: _____ Number: _____

REQUIRED INFORMATION

Operation Dependent:

Distance to off-load _____
Workday _____
Production efficiency _____
in tons/hour _____
Value at market per _____
ton material _____

Vehicle Dependent:

Cost per km _____
Payload _____
Avg Transit Time _____

COMPUTATIONS

Number of Trips per Day

Workday _____
/ Time in transit and _____
waiting for a full _____
load _____
= Trips per day _____

Profit(loss) per Trip

Part A - Cost per trip
Cost per km _____
x Distance _____
= Cost per trip _____

Part B - Value per trip
Market value per ton _____
x Load carried _____
= Value per trip _____

APPENDIX 8 - LIST OF COMPANIES

Aerolift, Inc.
4105 Blimp Boulevard
Tillamook, OR 97141

Helitrans, Inc.
30 Vesey Street
New York, NY 1007

Airship Industries (UK) Ltd
84-86 Baker Street
London W1H 1FA
United Kingdom

Magnus Aerospace Corporation
200 First Avenue, 2nd Floor
Ottawa, Ontario, Canada
K1S 2G6

Goodyear Aerospace Corporation
1800 Massillion Road
Akron, OH 44310

Piasecki Aircraft Corporation
Elmwood Avenue
East of Calcon Hook Road
Sharon, PA 19079

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