A COMPARISON OF MODERN AIRSHIP DESIGNS FOR THE AERO / ECO TOURISM MARKET.

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Abstract.

Modern airships offer opportunities in the growing air tourism and ecotourism markets. This paper reviews the current size and predicted growth of these markets. Using "real world" numbers we compare current airship designs capabilities and cost / profit in the existing Las Vegas market. Technologies are discussed that minimize costs and increase use and profit at current established market prices.

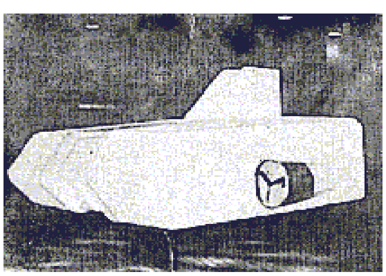
Introduction.

Las Vegas Nevada was the home, for a year, of the only fixed base commercial passenger airship tourism flights in the last half of the 20th century. These were carried out by a Lightship A-150 a nine (9) passenger airship built by American Blimp Corporation and leased by "Vegas.Com" from the "lightship group" until the stock market downturn in late 2000 when flight operations ended.

The LTAS Concept.

Lighter Than Air Solar (LTAS) is the worldwide licensee for the patent pending intellectual properties of Michael Walden and his unique airship designs and concepts, from LTA hull construction, and materials, to unique airship control and power systems.[1.]

LTAS has been at the forefront of the use of solar technology and hybrid power systems for its airships.



Historically recognized as the first solar powered rigid airship, LTAS XEM-1 R/C Solar airship 1974

The market, Tourism at a Higher Level

The World Travel & Tourism Council's assessment and projections of the economic impact and contribution to the global economy shows the travel and tourism industry to be one of the healthiest in terms of past growth and growth prospects in the future. International tourist arrivals and receipts have grown from $485 billion in 1990 to $661 billion in the year 2000, and will reach $937 billion by the year 2010.

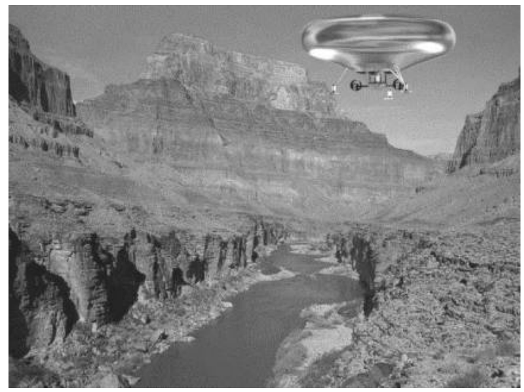
Worldwide travel and tourist expenditures have grown from $2.2 trillion in 1993 and will reach $5.8 trillion by the year 2005. Total tax revenue generated by travel and tourism will exceed $782 billion by the year 2005. Success in the tourism industry depends on anticipation of the changes in global travel trends and consumer taste. The global travel environment is in a state of change and development. Complacency in the approaches to tourism development will result in an economic stagnation for those markets which don't implement strategies for the future. Special interest travel such as eco-tourism will be the new "in" niche markets in the travel industry. There is a paradox in leisure behavior. Sameness and diversity and security and risk-taking seem to be side by side. Markets will be challenged to upgrade their tourism products and develop new ones in order to stay ahead of increasingly numerous and aggressive competitors. Promoting mass markets is no longer cost-efficient. Expanding the tourism product inventory can be a means of attracting new visitors with varying interests. Examples include developing new tour packages, and travel experience enhancement services. Environmental issues have come to the forefront. Efforts to minimize the environmental impact of tourism are inherent in most market area strategies. Due in part to aggressive competition, over development and maturing destinations, the travel industry needs to focus on "yield" rather than "volume". This will mean the development of new tourism products and high quality tourism strategies to attract high spending clients.

Technological developments and innovations are becoming an essential element in global competitiveness. The application of these developments inside the travel and tourism industry could affect the consumers destination choices, and their decision whether or not to travel. The development of more fuel efficient and multi-capability aircraft will allow more distant markets to be served and will increase profitability for air carriers and market economies. Effective promotion is the most critical ingredient for the future success of the travel and tourism industry. Promotion stimulates the economic activity and informs consumers about products, services and destinations.

The future of the travel and tourism industry must be prepared by developing, maintaining and modernizing facilities and services that support traveler and destination needs. The best and most appealing destination will not meet its potential unless there is transportation to get there. LTAS airships not only allow new, quiet, fast, comfortable transportation to existing venues without the development of new roads, parking, runways, or other expensive infrastructure, but allows the development of new more remote and exotic venues at low cost. Indeed the ships are an added attraction to such venues themselves.

The National Park System and Air Tourism.

Management of low-flying aircraft over the National Park System has reached crisis proportions. In more than 50 units of the Park System, the loud drone of commercial tour aircraft flying low overhead assaults visitors. In 1987 Congress passed the National Park Overflight Act (Public Law 100-91) to control noise and improve safety in Hawaii parks and at the Grand Canyon National Park. This has had little effect at the Grand Canyon, with air tour flights tripling in volume since then. Despite the passage of the 1987 laws, the number of air tours over the Grand Canyon has grown from around 40,000 in 1987 to nearly 120,000 currently.



The issues surrounding the air tour industry are complex. The facts are that air tourism is a growing industry and an essential part of the tourism infrastructure. At the same time the environmental consciousness of the public has been awakened. The desire to not only experience the splendor and majesty of our natural and cultural resources, but to also protect and preserve them for future generations must coincide. Air and ground based intrusions into our wondrous natural spaces can be regulated only to the balance of our responsibility to our environment and our need to personally interface with the magical places, plants, animals and peoples of the good Earth. The solution seems to lie in the deployment of a vehicle that would compliment the activities and the environment.

The established current air tourism market.

The “going market rates” for a Las Vegas “strip” tour flight by airship were set by the Vegas.Com airship in its year of operation. They are slightly lower than a comparable flight by local air tour helicopters that also operate in this area.

The airship flights were based at the North Las Vegas airport and from start to finish took about one (1) hour. There were six(6) flights per day starting with a champagne and cheese sunset flight at (7 PM in summer) and (4 PM in winter) costing $229.00 US and later night flights without the champagne and cheese for $179.00 US. From the flight schedule it looked as if these flights went up to $199.00 US on weekends and holidays.

Average passenger tour loads for the Vegas.Com flights was 70% full

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Las Vegas has a ground altitude averaging 2600 feet above sea level (ASL).
Average flight altitude was 1500 feet to 2000 feet above ground level.

Las Vegas has winds of less than 5 MPH on 200 days of the year. During the cooler part of the year (October to March) there are 39 days where the wind speed may exceed 30 MPH.
(Las Vegas chamber of commerce)

Models compared for this market study.

Four airships will be compared for this market costs study.

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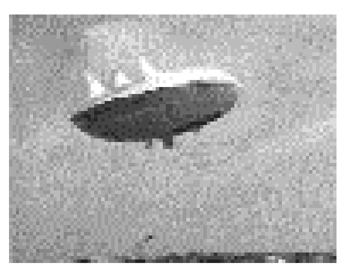
1. The **Lightship A-150** blimp already flown as the “Vegas.Com” tour ship.

2. The **WDL 1-B** blimp. Similar in scale to Airship Industries (now ATG) SK-600+

3. The **Zeppelin NT-07** “Semi rigid” airship.

4. The **LTAS TOURER-90** Ecotourism rigid hulled airship. (a modern version of the MLA-32-B)



Airship specifications comparison charts

LIGHTSHIP A-150

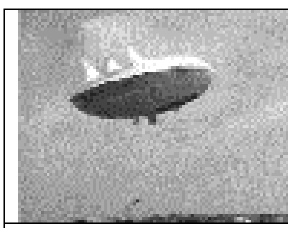
Length	165 feet
(In Metric)	(50 meters)
Width	46 feet
(In Metric)	(14 meters)
Height	55 feet
(In Metric)	(16.7 meters)
Total Volume	150,000 ft^3
(In Metric)	$(4{,}235\ m)^3$
Lifting gas	Helium
Seat Cap	10 (Pilot Encl.)
Engines	2 Lycoming IO 360
Power	180 BHP each
Operation Altitude	1000-6000 ft
(In Metric)	(300-1800 m)
Cruising Speed	40 knotts
COST	$3,800,000.00

ZEPPELIN NT-07

Length	246 feet
(In Metric)	(75 meters)
Width	64 feet
(In Metric)	(19.5 meters)
Height	57 feet
(In Metric)	(17.4 meters)
Total Volume	290415 ft^3
(In Metric)	$(8{,}200\ m)^3$
Lifting gas	Helium
Seat Cap	14 (Pilot Encl.)
Engines	3 aerodiesil
Power	200 BHP each
Operation Altitude	1000-6000 ft
(In Metric)	(300-1800 m)
Cruising Speed	45-60 knots
COST	$7,800,000.00

WDL 1B / SK-600+

Length	197 feet
(In Metric)	(60 meters)
Width	54 feet
(In Metric)	(16,40 meters)
Height	63 feet
(In Metric)	(19,30 meters)
Total Volume	255.000 ft^3
(In Metric)	$(7{,}200\ m)^3$
Lifting gas	Helium
Seat Cap	8 (Pilot Encl.)
Engines	2 Continental
Power	210 BHP each
Operation Altitude	1000-6000 ft
(In Metric)	(300-1800 m)
Cruising Speed	30-50 knots
COST	$5,400,000.00



LTAS TOURER-90

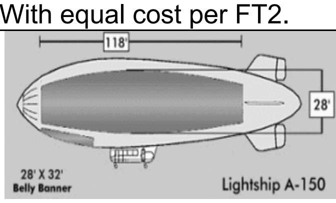
Length	120 feet
(In Metric)	(36.5 meters)
Width	120 feet
(In Metric)	(36.5 meters)
Height	56 feet
(In Metric)	(17 meters)
Total Volume	350000 ft^3
(In Metric)	$(9882\ m)^3$
Lifting gas	Helium
Seat Cap	27 (Pilot Encl.)
Engines	2 aerodiesil
Power	300 BHP each
Operation Altitude	1000-10,000 ft
(In Metric)	(300-3000 m)
Cruising Speed	40-60 knots
COST	$10,000,000.00

Airship ACQUISITION comparison chart.

Specifications	**LOGHTSHIP A-150**	**WDL 1B / SK-600+**	**ZEPPELIN NT-07**	**LTAS TOURER-90**
Seat Cap	**10 (Pilot Encl.)**	**8 (Pilot Encl.)**	**14 (Pilot Encl.)**	**27 (Pilot Encl.)**
Operation Altitude	1000-6000 ft	1000-6000 ft	1000-6000 ft	1000-10,000 ft
(In Metric)	(300-1800 m)	(300-1800 m)	(300-1800 m)	(300-3000 m)
Cruising Speed	40 knots	30-50 knots	45-60 knots	40-65 knots
Ground Crew Required per unit	7 to 9 *	16 to 20	6 to 8	0 to 2
Ground Vehicles Req.	5	14	6	2
Mooring Mast	**Yes**	**Yes**	**Yes**	**No**
UNIT COST	$3,800,000.00	$5,400,000.00	$7,800,000.00	$10,000,000.00
Basic per seat cost	$380,000.00	$675,000.00	$557,142.00	$370,370.00
Ships required to equal TOURER-90 seating capacity	3	3	2	1
Equal seating acquisition cost.	**$11,400,000.00**	**$16,200,000.00**	**$15,600,000.00**	**$10,000,000.00**

- The Lightship A-150 specifications say the ground crew is 16 persons.
- The “Vegas.Com” airship however operated with 7 to 9 ground crew because of the light winds in the Las Vegas area.

Airship ADVERTISING comparison chart.

Specifications	**LIGHTSHIP A-150**	**WDL 1B / SK-600 +**	**ZEPPELIN NT-07**	**LTAS TOURER-90**
Ship side dimensions	165 feet x 55 feet	197 feet x 63 feet	246 feet x 57 feet	120 feet x 56 feet
Side banner size (equal scale)	2 @ 118 feet x 28 feet	2 @ 141 feet x 32 feet	2 @ 175 feet x 29 feet	4 @ 94 feet x 30 feet
Belly banner size	1 @ 28 feet x 32 feet	1 @ 33 feet x 38 feet	1 @ 39 feet x 47 feet	4 @ 32 feet x 40 feet
Total airship banner size in square feet (FT2)	**7504**	**11772**	**11983**	**16400**
"Vegas.Com" advertising contract per month cost $ US	$189,000.00	$189,000.00	$189,000.00	$189,000.00
Per month per FT2 cost With cost equal to existing "Vegas.com" contract cost TOTAL COST / TOTAL FT2	**$25.18**	**$16.06**	**$15.77**	**$11.52**
Per month income With equal cost per FT2.	$189,000.00	$296,418.96	$301,731.94	$412,952.00
				

Not just "another blimp". The messages are larger, the shape is "unique" leading to more people looking at it (Higher Daily Observable Numbers **DON**) for longer periods of time, leading to longer message retentions.
Tourer-90 30 foot diameter "Gondola area" not included in this banner space.

Airship OPERATING COSTS comparison chart number 1.

Specifications	**LIGHTSHIP A-150**	**WDL 1B / SK-600 +**	**ZEPPELIN NT-07**	**LTAS TOURER-90**
Ship unit cost	$3,800,000.00	$5,400,000.00	$7,800,000.00	$10,000,000.00
Envelope / Hull life	5 to 7 years	5 to 7 years	6 to 8 years	10 to 15 years
Seat Cap	10 (Pilot Encl.)	8 (Pilot Encl.)	14 (Pilot Encl.)	27 (Pilot Encl.)
Basic per seat cost for pay back over equal hull life	$380,000.00	$675,000.00	$557,142.00	$370,370.00
Mooring Mast required.	Yes	Yes	Yes	No
Mooring Mast unit cost	$100,000.00	$100,000.00	$100,000.00	0.00
Masts required for equal seating ships	3	3	2	0
Total Mooring Mast costs for Tourer-90 equal seating.	$300,000.00	$300,000.00	$200,000.00	$0.00
Ground Crew Req.	7 to 9	16 to 20	6 to 8	0 to 2
Ground Vehicles Req.	5	14	6	2
Ground vehicle cost at $20,000.00 per vehicle.	$100,000.00	$280,000.00	$120,000.00	$40,000.00
Per ship Ground Support Equipment Costs.	**$200,000.00**	**$380,000.00**	**$220,000.00**	**$40,000.00**

Airship OPERATING COSTS comparison chart number 2.

Specifications	LIGHTSHIP A-150	WDL 1B / SK-600 +	ZEPPELIN NT-07	LTAS TOURER-90
Monthly Support Cost $5,000.00 per ground crew and $1,000.00 per vehicle	$50,000.00	$114,000.00	$46,000.00	$12,000.00
Yearly Ship Support Cost at $5,000.00 per ground crew $1,000.00 per vehicle	$600,000.00	$1,368,000.00	$552,000.00	$144,000.00
Avg. Fuel use in US gallons per hour of flight time	12	14	20	10 (50% use with solar hybrid power.
Flight hours per year @ 6 tours per day 200 days per year.	**1200**	**1200**	**1200**	**1200**
Fuel cost per year @ $100.00 US per gallon.	$14,400.00	$16,800.00	$24,000.00	$12,000.00
Insurance Cost @ 10% ship cost per year.	$380,000.00	$540,000.00	$780,000.00	$1,000,000.00
Total per ship YEARLY COST.	**$1,736,857.00**	**$3,076,228.00**	**$2,551,000.00**	**$1,862,666.00**
Ships Required for TOURER-90 equal seating.	3	3	2	1
YEARLY COSTS FOR TOURER-90 EQUAL SEATING.	**$5,210,571.00**	**$9,228,684.00**	**$5,102,000.00**	**$1,862,666.00**

- Chart 2 notes Ground crew was left at 7 to 9 for A-150 for Las Vegas market costs.
- Mooring masts are required for EACH “conventional” ship in some conditions.
- GROUND SPACE, which is **4X** to **8X** as large as that for the Tourer-90 for each “conventional” craftto "weathervane, were not included in this chart.

Market INCOME comparison chart number 1.

Specifications	**LIGHTSHIP A-150**	**WDL 1B / SK-600+**	**ZEPPELIN NT-07**	**LTAS TOURER-90**
AIRSHIP UNIT COST	$3,800,000.00	$5,400,000.00	$7,800,000.00	$10,000,000.00
Envelope / Hull life (Years)	5 to 7	5 to 7	6 to 8	10 to 15
TOTAL PER UNIT YEARLY OPERATING COST.	$1,736,857.00	$3,076,228.00	$2,551,000.00	$1,862,666.00
Per ship per PASSENGER Seat Cap	9	7	12	24
Basic per seat cost for Pay back over EQUAL ship life	$380,000.00	$675,000.00	$557,142.00	$370,370.00
Tour flights per year @ 6 tours Per day 200 days per year.	1200	1200	1200	1200
Total yearly passenger Seating capacity of Single ship @ 1200 flights per year..	10,800	8,400	14,400	28,800
At 70% established Fill rate for past flights.	7,560	5,880	10,080	20,160
Per flight Passenger Operating cost. YEARLY COST / YEARLY CAP..	**$231.58**	**$530.38**	**$253.07**	**$92.39**
Highest current airship tour price per seat in the Las Vegas Market	$229.00	$229.00	$229.00	$229.00
PER SEAT PER TRIP PROFIT MARGIN WITHOUT ADVERTISING CONTRACT	- $2.58	- $302.38	- $24.07	+ $ 136.61
Break Even on flights at Vegas.Com pricing Without advertising contract.	**No**	**No**	**No**	**Yes**

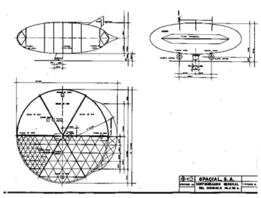
Market INCOME comparison chart number 2.

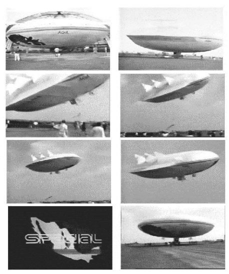
- **Specifications**	**LIGHTSHIP A-150**	**WDL 1B / SK-600+**	**ZEPPELIN NT-07**	**LTAS TOURER-90**
Tour flights per year @ 6 tours per day 200 days per year.	1200	1200	1200	1200
TOTAL yearly passenger tour capacity of unit.	10,800	8,400	14,400	28,800
At 70% established fill rate for past flights.	7,560	5,880	10,080	20,160
Per flight per passenger operating cost. Yearly cost / yearly cap.	$231.58	$530.38	$253.07	$92.39
Passenger income per flight @ 70% full at established VEGAS.COM Pricing.	$1,449.00	$1,127.00	$1,932.00	$3,864.00
Yearly passenger income @ 70% full at established VEGAS.COM pricing WITHOUT ADVERTISING.	$1,738,800.00	$1,352,400.00	$2,198,400.00	$4,636,800.00
YEARLY PROFIT MARGIN PER SHIP WITHOUT ADVERTISING CONTRACT.	- $1,943.00	- $1,713,828.00	- $352,600.00	+ $2,774,134.00
Vegas.Com advertising pricing per Tour flight @ $189,000.00 per month lease price.	$1,890.00	$1,890.00	$1,890.00	$1,890.00
Per flight income @ 70% full INCLUDING ADVERTISING.	$3,339.00	$3,017.00	$3,822.00	$5,754.00
Yearly income per ship WITH ADVERTISING CONTRACT.	$4,078,800.00	$3,620,400.00	$4,586,400.00	$6,904,800.00
YEARLY PROFIT MARGIN @ VEGAS.COM PRICING PER SHIP WITH ADVERTISING ONTRACT.	$2,341,943.00	$544,172.00	$2,035,400.00	$5,042,134.00

Are these numbers based on "Real" acquisition costs, operational costs, and use or just some projections?

All of the ships are real, costs are based on real world development programs,
operations, use and financial considerations, "Not just pretty pictures" or another "Paper study".

1.The "real" picture of the TOURER-90 is the MLA-32-B, an LTAS based design built in cooperation with SPACIAL of Mexico in the 1980s. It was an 80% version of the T-90 in most respects, built with "available technologies", it had a payload of 3.2 TONs. (20 Pax)





2. Cost of the whole MLA project, with hangar and 3 ships, was about $6 Million US. The Tourer-90 development can be done for the 10 million shown in the study charts.
3. The updated SK-600+ carries 14 so income would be closer to the ZNT-07's. Cost for TOURER-90 equal seating (now 2 ships) would be $10,800,000.00.
4. The NT-07 is charging $280.00 to $320.00 for the 1hour ride in Germany. Much higher than the "Established Las Vegas" rate.
5. Ground equipment / crew costs include "per diem" for hotels, meals etc besides pay. (lightship study AIRSHIP)
6. Insurance rates from AIAA Goodyear paper.
7. Small Passenger airships have a great future in air/eco tourism.. However, current designs have operating costs that are too high (ie the A-150 was costing $230.00 per seat to operate while its per seat price was from $180.00 to $220.00 per tour. (this was supplemented by the $189,000.00 per month "Vegas.Com" advertising contract and other advertising during conventions here in Vegas.) but it was barely breaking even on the tours themselves.)

Flights were limited to 200 days per year because

8. 39 days have winds unsafe for handling conventional airships.
9. The Vegas.Com ship was gone for 3 weeks for an annual "envelope check"
10.The ground crew will want some days off each week (104 per year if you count weekend days.)
11. Maybe a day or two where "something is broken"

This totals to 155 days of non-flight. or about 210 days... rounded to 200.

The T-90 is amortized over the shorter 7 to 8 year life of a blimp instead of the 10 to15 year life demonstrated for the TOURER series materials / technologies. Keeping things EQUAL, T-90 payments are actually about half as much as shown. Flight crew costs were left out as they should be equal for all 4 ships.

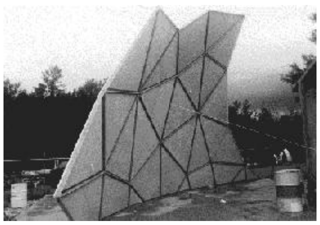
Cheaper to ACQUIRE, Cheaper to OWN,
Cheaper to MAINTAIN….Robert Ellingwood LTAS.

What about Delivery times and the time it takes to "Certify" a new design?

EVERY new aircraft / airship design has to be certified to carry passengers. The Lightship A-150, SK-600+ and Zeppelin NT have recently completed these trials. The Zeppelin took 8 years to complete its program while the Lightship A-150 took only 18 to 24 months. LTAS/CAMBOT is using the same FAA TC office that did the A-150 certification thus a certification period of 18 to 24 months is assumed. Current delivery times for NEW Lightships, and SK-600+ class airships is 8 to 10 months from order. Delivery time for Zeppelin NT-07s is 12 to 18 months. These ships acquisition costs are based on leases as they are only leased and are not purchased by customers. LTAS/CAMBOT systems subcontractors have estimated that construction of the first TOURER-90 will take 6 to 8 months, thus with construction of the ship and certification the total delivery time will be 24 to 32 months.

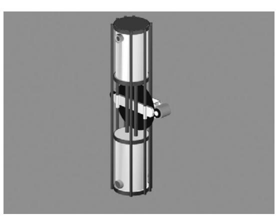
To equal the seating capacity of the TOURER-90 delivery time for 3 Lightship A-150s or SK-600+s is 24 to 30 months. Delivery times for 2 Zeppelin NTs has been 24 to 36 months, both equal in time to the TOURER-90 build and certification period.

Is the hull constructed indoors or outdoors? A number of similar structures have been built over the years, usually as stadiums or large entertainment buildings. These have been built outdoors and a number of the proposed subcontractors have been involved in this construction. The hull material is used in outdoor applications so is not vulnerable to weather in normal conditions. The structural panels are preformed, and hull construction should be rapid and fairly simple. Construction time for the first TOURER-90 is estimated at 6 to 8 months. (About the same amount of time as a "Standard "blimp".)



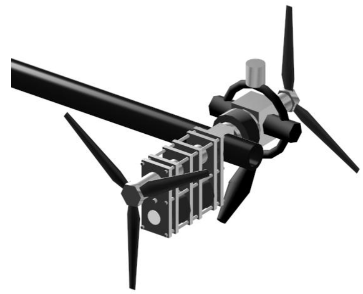
Mr. Robert Ellingwood LTAS/CAMBOT's president with over 25 years of large-scale project management would be overseeing the subcontractor subsystem delivery and testing, and the final assembly scheduling. All construction would take place at the assembly-retrofit plant and the unit flown to its mission location.

What kind of ballast system will you use? LTAS / CAMBOT's Density Controlled Buoyancy DCB unit. No competitor has a significantly comparable system. (additional points on this in the next section.)



Ship assent and descent are controlled by the LTAS/CAMBOT patent-pending Density Controlled Buoyancy (DCB) unit and is only dependent on the size of the air inlet tube. Generically, ascent can be at over 2,000 feet per minute. Descent is limited to pump size and is generically limited to about 1000 feet per minute. This is DCB rate only, not including vectored thrust. (DCB rate = the rate at which the DCB unit controls the ships static lift)

What kind of propulsion systems will you use? What is the estimated cruising speed, max speed and assent / descent speed? Vectored 3D thrust is part of all LTAS/CAMBOT designs. The ships will use LTAS/CAMBOT designed electric thrusters. Electric motors and hybrid "fast ferry" engines are FAA approved "off-the-shelf" production units.



It is this combination of DCB and 3D thrust that allows LTAS ships to operate without masts or ground crews. The TOURER-90's Cruise speed is 45 to 50 MPH and its max speed is 65 to 70 MPH.

What kind of solar systems will you employ? The original design used common crystalline thin film solar cells. Easy mounting of these cells is made possible by our rigid hull construction, it is still a "problem" for non-rigid type ships. An average 14% efficiency is assumed using ground level insulation. Today common off-the-shelf crystalline cells are running at over 20% efficiency. The system was designed around standard aerobatic aircraft batteries (part of a USCG patrol ship RFP). Improvements in battery technologies and thin film solar cell development have only improved the original LTAS designs. No new technology or systems need be developed, however several promising technologies will improve the stated performance significantly. It is how our ships' systems go together and LTAS/CAMBOT's unparalleled insights into the design of solar hybrid airships along with 30 years of development that make our ships and designs unique.

What kind of lift gas is used and why? Standard industrial grade helium has the highest lift under heating and other conditions for nonflammable lift gases. This gives us the smallest possible craft which is naturally light, with no heating for lower density required. The gas is non-caustic and is available as a byproduct of other industrial processes. Only nonflammable helium is used.

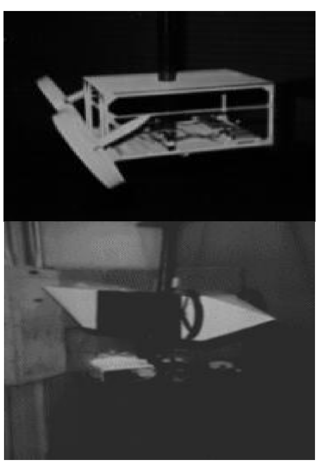
How do you propose to get approved by the FAA? The systems and scaling demonstrator will provide FAA certification. Initial meetings have already been held with the FAA TC office on the project and FAA Designated Engineering Representatives (DERs) have been identified. This program is designed to get a type certificate in the lowest possible time and lowest initial cost.

LTAS DCB System Feasibility.

System history.

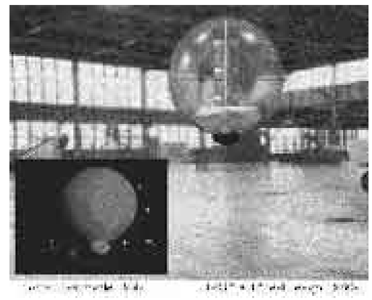
For nearly 30 years LTAS / CAMBOT llc has been flying and testing the DCB buoyancy control system in bench models and small RC airships. During most of this time "LTA experts" have questioned the Feasibility not only of the DCB system but of the monocoque hull construction, and lenticular hull form as well. This section of the paper is an attempt to not only show the economic benefits of such systems but also show how recent "discoveries" by these same "experts" has only confirmed the LTAS technologies as a fact acompli' and correct.

In the early 1970s the first DCB test unit was a simple foam cooler chest with an internal "balloon" attached to an external air pump. It was mounted on a balance and when the balloon was pumped up displacing some of the helium fill and adding air mass the balance changed and the chest got heavier. The terms "Displacement controlled buoyancy" and "Density controlled buoyancy" meaning a change in both lift gas displacement as well as an increase in mass both apply to the term DCB. A complete description of the entire DCB system was included in the 1970s US patent filing for "LTAS type airships and major systems."
The first flying model airship with a lenticular composite monocoque hull and DCB control was the XEM-3 flown in the late 1970s and early 1980s.



XEM-3 airship gondola with vectoring ducted props, and DCB pump / electronics under construction and complete.

Later in the 1980s LTAS designed a slightly larger DCB test unit with a spheroid rigid hull. Based on our SIZ-2 airship sizing and performance software we expect the average mass of the DCB system that can modify total lift by 25% to 30% is between 10% and 15% of gross lift. In the mid 1990s a NASA "GAINS technology development program" built a crude near duplicate of this same demonstrator making three test flights and confirming the LTAS power and mass figures.



1980s LTAS DCB demonstrator / 1990s NASA GAINS demonstrator (insert)

While aircraft safety considerations and limitations of their balloon power systems prevent NASA from licensing and using our system on this project to its full potential, dropping the balloon from 65K feet to 150 feet ASL twice per day, NASA testing of a DCB type system as shown in their report below[2] has proven the viability of such a system in several ways.

NASA Design Requirements

Balloon recovery for reuse is planned to make the system economically feasible.
These long-term goals are achieved through a series of prototypes. Design requirements for the prototypes are driven by available (i.e., off-the-shelf) technology.

Pumps

Early in the project it was recognized that the superpressure pump would provide the most demanding engineering challenge for a canniballoon which would operate from 200 mb to surface. An initial pump specification was developed from the mission requirement statement. The pump had to be very light in weight, high in efficiency, and displace at least 300 lpm into a 120 mm back pressure. It also had to operate from 1015 mb to 200 mb ambient pressure, and from +45C to -55C. Two readily available pump technologies were investigated for this application: A light-weight plug valve driven by a linear stepper motor was developed for this application. The valve provides a large passageway for air flow and does not consume electrical power except when opening or closing.

Power

Electrical power requirements for the
The Prototype II instrument package must operate over multiple days, perform one or more soundings per day, and operate at -40C. Secondary cell technology and solar cell recharging are required to meet these requirements. For the Prototype II instrument package the computer, GPS, and telemetry will be powered down most of the time, in order to minimize their electrical power draw. The majority of the stored power is therefore used for balloon control. The solar cell output power required for a daytime pump-down, in full sun, has been calculated at 160 W h. For a nighttime pump-down, under a clear sky, the power is reduced to 75 W h. These power requirements assume an overall 50% efficient pump and 80% efficient power conversion and storage. Commercially available solar cells have an output of approximately 15 W kg-1. If a 12-h charging time and a single nighttime pump-down are assumed, the solar cell weight will be approximately 1 kg. This weight is based on the assumption that the solar cell is pointing directly at the sun within a angle. Computer-controlled gear motors and solar sensors are required to achieve this requirement.

Secondary cells tend to have lower internal resistance and therefore less loss than primary cells. However, the secondary cells are more sensitive to low temperatures and experience significant losses in energy storage capacity at -40C. Cell chemistry must be selected based on minimum weight at the anticipated ambient temperature. Internal heating of the battery pack may be required to achieve acceptable performance. An energy management model will be used to determine the optimum trade off between battery pack ambient temperature and total power storage system weight.

NASA Test Results

A variety of indoor and outdoor tests have been performed starting in July 1995. The earliest tests were performed with the Prototype I As of May 1997, tests have been conducted with the PI instrument package and the PII-LF and PII vehicles. Highlights of these tests are outlined below.

Helium Diffusion

The rate of helium diffusion through the bladders was measured with an untreated and a treated bladder. In a 1500-g untreated bladder with 760 g (63%) of lift, helium diffused at a rate of 50 g d-1, leaving the bladder with a 60% loss in lift after 6 days. A 1000-g bladder was coated with 190 g of a sealant and was filled with 800 g (56%) of lift. This bladder lost an average of 2 g d-1 and was still floating after a month.

Pumpdown Demonstrations

Three tests demonstrating pumpdown have been executed. The first two were outdoor tests at the Department of Commerce Table Mountain Facility north of Boulder, Colorado. The balloon was tethered at 50 to 100 ft, and pumps were run until the balloon reached the ground. After 5 min at the surface, excess superpressure was released to confirm that the balloon would again rise to its tethered altitude and had not lost lift because of loss of helium. On 13 Nov. 1996 the balloon flew two Gillian pumps. Starting with a 5% free lift, and an initial superpressure of 1 in of water (2.5 mb), the balloon began to descend after 75 min when a superpressure of 12 mb was reached; the balloon reached the surface 4 min later. Wind conditions at the time of pumpdown (late afternoon to dusk) were calm. Descent was a vertically oscillating motion around a downward trend.

In the second Table Mountain test (21 Nov. 1996 Pumpdown to the ground occurred in about 15 min. The test took place in early afternoon, and wind winds were light.

The third test on 22 May 1997 was an indoor test in Hangar B at the former Tillamook Naval Air Station in Tillamook, Oregon. Blower superpressurized the shell and induced balloon descent after 19 min of pumping. Even with the combined maximum pumping rate of 500 l min-1, descent rate is still too slow at an estimated 10 ft s-1. Likewise, a small superpressure vent restricts ascent rate to approximately the same rate.

Issues

A free flight has not been attempted because of a number of unresolved issues. These include bladders, reliability of electronics, vertical control, parachutability, and weather data access.

Asymmetric air bladders not only stresses the Spectra shell, but also blocks the neck so that inflation is slowed and venting becomes impossible. The blocked neck has been overcome by using longer pipes in the neck that extend well into the interior of the balloon, beyond the material that shuts off the flow. However, these longer pipes are a potential hazard to the helium bladder when it fills the entire volume of the shell at float altitude; any pipe jutting into the shell will burst the helium bladder.

In past tests, GPS, superpressure, and various temperature sensors have failed to operate; laptop reception of transmissions have been intermittent; and automatically saved files of laptop data have not occurred.

Vertical control is still limited. The current pump/blower combination is too slow to bring the balloon to the surface in a reasonable amount of time. Likewise, the superpressure vent is too restrictive to raise the balloon quickly. A positive displacement pump is being developed for the Prototype II instrument package by modifying a commercially available positive displacement diaphragm wobble pump. The specifications for this pump are 100 l min-1 at 120 mb back pressure, 60% efficiency, and 1.5 kg mass. A fully functioning pump requires a flow rate of five times the pump currently being modified.

NASA GAINS conclusions

The objective of this project has been to test the feasibility of sounding the troposphere with a canniballoon. Using off-the-shelf components for the most part, much has been learned and several successful steps toward this goal have been made: a canniballoon capable of withstanding superpressures of 60 mb has been built and tested; prototypes of the pump, telemetry, microprocessor, power, and sensor systems have been integrated and used in both indoor and outdoor tests.

LTAS / CAMBOT solutions to the issues.

Bladders.

The LTAS/CAMBOT rigid monocoque hull designs[PP] keeps its form both under superpressure and without . It is several times as strong as the GAINS flexible Spectra envelope. In addition, using only a simple separation membrane instead of a full secondary shell the amount of surface area is reduced by at least 25%. and thus hull mass is also reduced. The properties of the hull system also insulates the control electronics from the extreme temperatures of the high altitude environment.

Pumps.

The LTAS designed positive displacement pumps and valve systems[pp] overcome the volumetric limitations and valve problems of the NASA units while being well suited to LTA / Balloon use because of their light composite construction and low RPM run speed.

Power.

The lenticular form of the LTAS hull reduces surface area for equal volume by over 9%. In addition the use of vectored thrust to replace fins in steerable LTA craft also reduces mass by an additional 20% and power / fuel required to overcome drag by over 50% even with the addition of the additional 10% to 15% mass for the DCB system total mass is reduced.

This reduction in mass allows for lower displacement with the same useful load. Recent papers on buoyancy control in modern passenger scale airships[3.] has shown that use of 25% of installed power will allow for a 25% change in gross lift in 5 minutes.

All of these features were included in the LTAS DCB demonstrator and the XEM-3 flying model that predates the NASA work.

CONCLUSION.

The systems included in the TOURER-90 and other LTAS/CAMBOT llc ships is not only technically viable, but in the economic sense allows LTA craft to be competitive with Helicopters and fixed wing aircraft where other "conventional" LTA craft are not.

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