Airships as One Path to a Green Aviation System

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Ron Hochstetler – 25 years in LTA

- Deputy Program Manager for the SAIC SKYBUS 80K unmanned airship
- Project Manager US Army “Transport Airship” Study
- Technical support to Phase I DARPA ”ISIS” stratospheric airship program
- Chairman, AIAA LTA Technical Committee
- Chairman, FAA Airship Working Group (regulations revision project)
- Senior Project Analyst for CargoLifter GmbH, Germany
- Program Manager supporting US Navy Airship Program Office
- Tour Manager for Airship Industries commercial airship
- Assistant to Program Manager for Airship Industries YEZ-2A Navy airship
- Mechanic/Assembler on Helistat heavy lift hybrid airship

US Navy YEZ-2A Airship Mockup

CargoLifter Heavy Lift Airship Concept

DARPA ISIS Stratospheric Concept

Piasecki Helistat Hybrid Airship

1988 Pepsi Airship Tour

SAIC SKYBUS 80K

Airship Basics

- **Airships represent the "unexploited" air transport system**
  - They are filled with non-flammable helium
  - Payloads of 200 hundred tons or more are possible
  - Airship propulsion requirements are on the order of many times less that what's needed for jet transports with the same disposable lift
    - Airships can be low cost to operate
  - Infrastructure investment is in the airship, not on the ground
  - They are displacement vehicles, so they perform best at low altitudes
    - Do not rely on current jet airspace or airports
- **Airships can provide additional air transport capacity, AND increase capacity in the existing air transport system**
  - By offloading freight from the current air-freight system

Westinghouse-AI Sentinel 1000

Zeppelin N 07 on Takeoff

AMS Skyship 600 B Gondola

Classes and Categories of Airships

SAIC From Science to Solutions

Fully buoyant

- Conventional ellipsoid
- Lenticular
- Other shapes

Semi-buoyant

- Hybrid-rotary
- Hybrid-lifting body
- Hybrid-winged

AMS Skyship 600 Airship

Lenticular Semi-rigid French Airship

SkyHook Hybrid-rotary LTA Concept

Lockheed/Martin Hybrid-lifting Body

Dynalifter Hybrid-winged Concept

Two categories of transport airships

1. **<u>Long distance</u> carrier, optimized for speed and low drag. Some designs can land vertically while others require large landing fields. Payload handling equipment is needed unless designed for hovering load exchanges.**

1. **<u>Short distance</u> crane, optimized for precision lift and payload placement. Has higher drag and lower speed, but has controls needed for hovering payload exchanges**

Airships Today

Modern Airship Designs

- High strength-to-weight synthetic fabrics
- Composite material construction
- Computerized flight controls
- Semi-automated ground handling
- Vectoring propellers

AMS Skyship 600 Gondola

Zeppelin N 07 Cockpit

Zeppelin N 07 Airship Moored to Semi-automated Mast

Airship Operations

- Fully mobile and sustainable in the field
- Operate out of small airports or open areas
- Ground crew, can be as few as 1 person
- Weather limits, similar to helicopters
  - Winds of 35 mph or less are preferred
  - Max wind tolerance when moored is 90 mph

State of Airship Technology

Most advanced large airship program to date

- CargoLifter was a 1990's German start-up venture to manufacture 160 metric ton lift cargo airships
- Design featured a crane for vertical payload exchange with ground based ballast
- Wouldn't need to land to load or unload payload
- Company ended operations due to funding problems not technical issues

CargoLifter CL-160 Aerial Crane Airship Concept

- Developed new insights into design and manufacture of large cargo airships
- CL-160 experience provides modern airship database and reference point for subsequent heavy lift airship projects

State of LTA Technology (cont)

Largest recent LTA vehicle built

- CL-75 was constructed by CargoLifter in 2000
- Designed to be towed by large helicopter, surface ship, or ground vehicle
- Cargo container tethered below the balloon

CL-75 Specs and Estimated Performance

- **Diameter:** **61 meters**
- **Volume:** **110,000 cu. Meters helium**
  - **More than half the gas volume of the Hindenburg!**
- **Gross lift:** **100 metric tons**
- **Useful lift:** **75 metric tons**
- **Altitude:** **2,500 ft above sea level**
- **Towing speed:** **up to 70 km/hr.**
- **Range:** **250 km**
- **Cost to build:** **$10 million (approx.)**

CL-75 Cargo Balloon Lifting A Tank

55 ton German Mine Area Tank Inside CL-75 Load Frame

Transport Airship Applications

Moving "project freight" that is outsized or heavy

- **Short distance movement of cargo, equipment, and supplies**
  - Direct delivery of materials, equipment, prefab structures, etc…for roadway, rail, port, bridge, and building construction projects
    - Reduces ground footprint and disruption to areas surrounding construction sites compared to conventional approach
    - Permits "just-in-time" movement of materials and supplies;. reduces on-site storage, shortens project schedules, and reduces project costs
  - Moving cargo where deep water port facilities aren't available
- **Long distance freight transport**
  - Transport between multi-modal shipping centers (trucking terminals, etc.)
  - Transport within transportation poor developing countries
  - Transport into and out of remote or otherwise inaccessible regions

Ship Handling Facilities

Heavy Lift Helicopter

Drilling Rig Assembly

Canadian Ice Road

Major Project Freight Applications

Oil and Gas Pipeline Construction

- In-land logistics (from main entry port) represents 25% of construction costs
- 90% of cost is just moving heavy equipment, materials, and consumables up and down the project right of way
- For typical 52” pipeline, this represents $100 -150 million per 1000 km of pipeline
- $100 to 120 billion in pipeline projects scheduled over next 10 – 15 yr

Pipeline Right of Way

Logistics Support to Canadian Mines

- University of Manitoba study shows interest in airships for shipping fuel
- Forecast for transport airships in Canada alone could range between 185 to 635 airships, of 50 metric tons lift

Canadian Diamond Mine

Canadian Ice Road Truck

Vertical Lift for Precision Positioning

MAGLEV Pylons and Rail Segments

- **Installing pre-fab windmills and geothermal generation equipment in optimized locations**
- **Electrical grid installations**
  - Towers, transmission lines, switches, transformers, etc.
- **High speed rail components**

Generator Moving Through a Village

- **Supports regional movement of equipment which otherwise must be moved by conventional means**
  - Airship transport reduces handling steps, point-to-point distances, overall transport time, and overall expense
- **Vertical lift airships can deliver and install temporary capital equipment to meet cyclical industrial production demands**
  - Production equipment and facilities can be leased on as needed basis
  - Reduces investment commitment and financial risks
  - Encourages industrial expansion, and economic growth

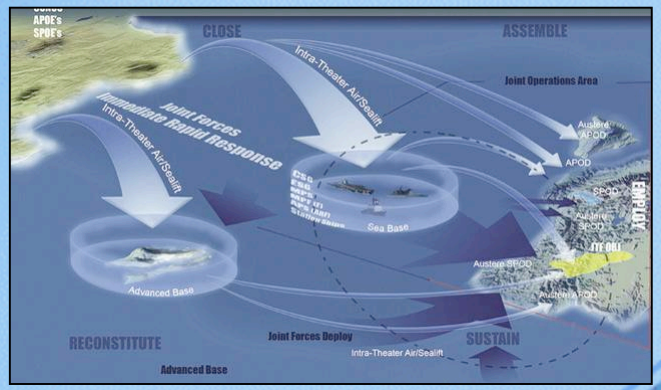
Crane Hoisting Propeller onto Windmill

DoD Mobility Needs

- **Insert materials into critical points that can't easily be reached**
- **Provide additional deployment lift for current force**
- **Service Operational Concepts + Network-Centric Operations (NCO)**
  - Reduce number of moves required in the Area of Operations
- **Move new things in new ways (support to Seabasing concepts)**
- **US forces need advantage of adaptive power projection**
  - Bypass choke points
  - Deliver intact capabilities at multiple entry points
  - Maintain uninterrupted deployment momentum
  - Move select air cargo forward from last secure area
  - Minimize surface convoys
    - Avoid IEDs and ambushes

Army Surface Convoy

Vertical Ship Replenishment



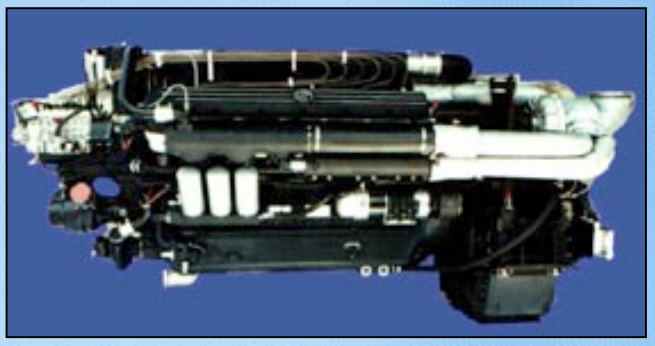
Seabasing Overarching Concept

Airships for Green Aviation

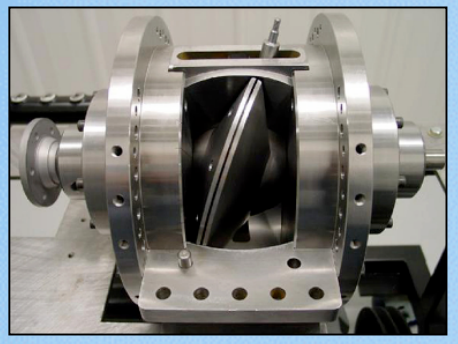
- **Airships can be used as platform for airborne research into green aviation propulsion systems**
  - A developmental airship could test alternative propulsion options
- **Airships can be use as a platform for operational research into LTA transport applications**
  - A developmental airship could explore commercial and military freight operations
    - Payload handling technologies
      - Hovering payload handling (the aerial crane)
      - Roll on, roll off
      - Modular payload bays
    - Weather optimized airship flight routing for weather avoidance
    - Human factors and duty rest requirements for long flights (24 hr +)
    - Low-manpower ground handling systems
    - In-flight maintenance concepts
    - Airship operational cost modeling

Green airship propulsion

- **Investigate new internal combustion engines that can burn bio-diesel or other alternative fuels**
  - The airship allows in-flight development and testing of novel, high power-to-weight engines
    - A 3000 hp Italian marine diesel engine was modified in the 1980's to provide primary propulsion for the YEZ-2A US Navy airship concept
    - The Air Force Research Lab (AFRL) is developing a "nutating" engine for unmanned aircraft propulsion
      - Engine runs on a variety of "heavy" fuels
      - Has power to weight ratio equal to turboprop engines



3000 HP, 18 cylinder, water cooled Italian marine diesel engine for US Navy airship concept (1980's)

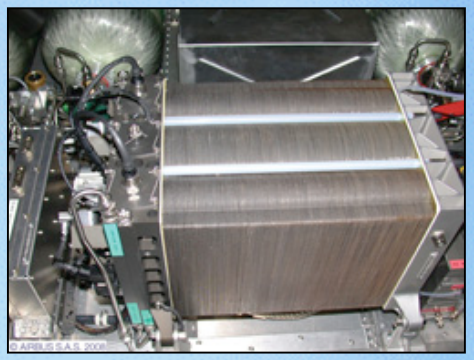


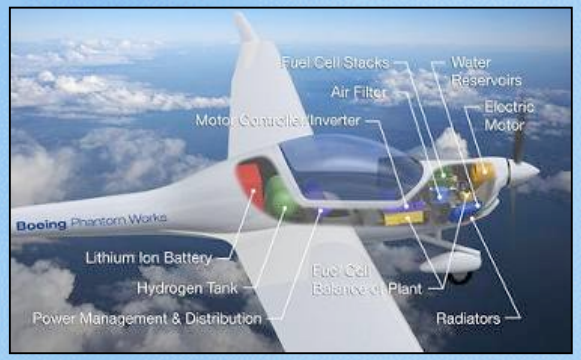
Experimental AFRL "nutating" engine

Green airship propulsion (cont)

- **Hydrogen fuel cells could power airship electric propulsion motors**
  - Gaseous hydrogen fuel ballonets can be safely installed inside the airship hull surrounded by non-flammable helium
    - Any leakage of hydrogen gas is safely diffused into the helium
  - Hydrogen gas fuel provides additional static lift
  - Multiple electric propulsion motors can be installed in optimal locations around the airship hull
    - Better weight distribution, enhanced maneuverability, and improved aerodynamics (boundary layer drag reduction)

20 kW Hydrogen - oxygen fuel cell tested on an A320

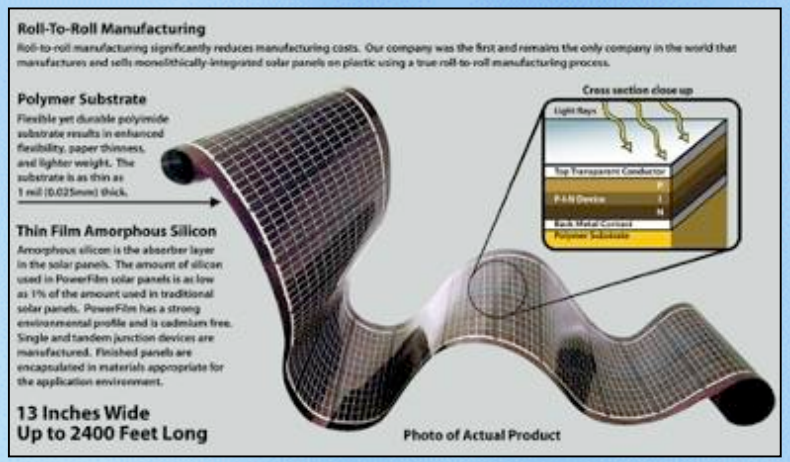




Boeing electric/fuel cell airplane

Green airship propulsion (cont)

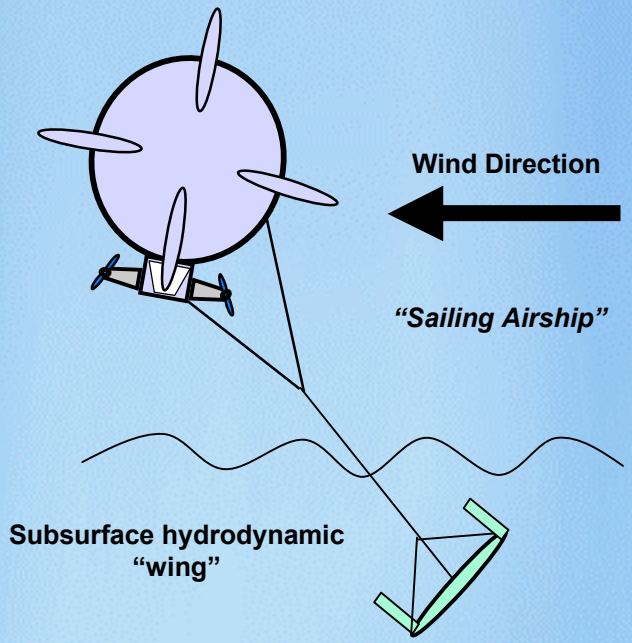
- **Investigate use of large photovoltaic arrays installed on the airship envelope exterior**
  - Could provide primary power for airship propulsion, or secondary power for airship systems
  - Electricity could be stored for use at night
    - May support development of a hybrid airship power system incorporating electric motors for low speed cruising, and reciprocating engines for dash speed or flight into headwinds

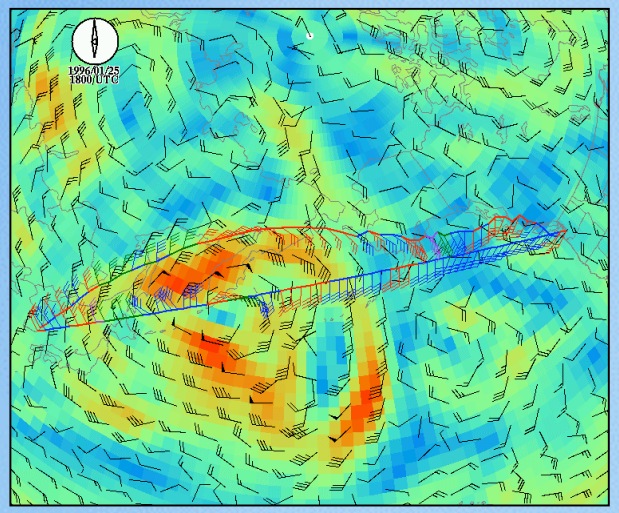


Flexible photovoltaic fabrics

Green airship propulsion (cont)

- **Investigate taking advantage of prevailing trade winds to "sail" an airship on long overwater flights**
  - This concept was first proposed by C.P. Burgess
    - Design Memo # 322 "Sailing Airships at Sea" (1940)
  - Subsurface hydrodynamic device acts as a keel
    - Propeller equipped generators in the underwater device can send electric power up the cable to run airship systems
    - Onboard engines mainly used for landings and takeoffs
  - SAIC advanced weather model can create weather optimized airship flight routes to capture the best winds enroute

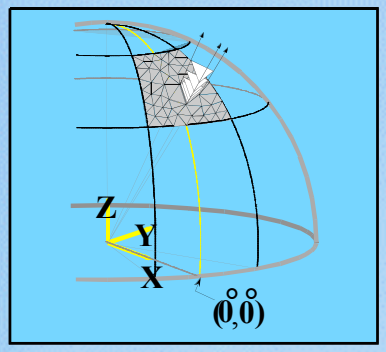




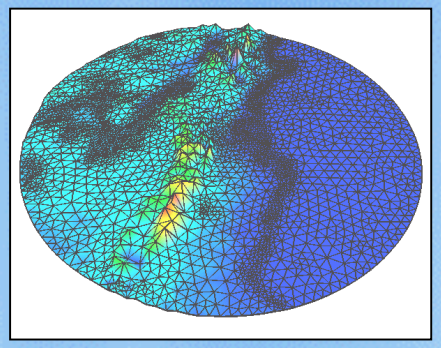
Weather optimized route vs GCR route

Airship Weather Route Optimization

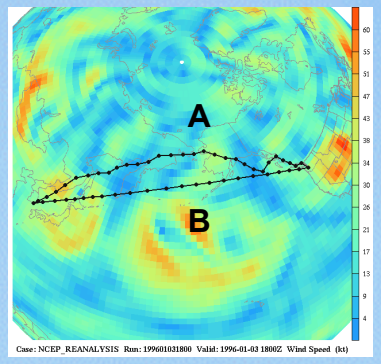
- **SAIC modeling tool provides optimal route planning for airships**
  - An optimal route avoids dangerous regions and yields time and/or fuel savings
  - The “OMEGA” model produces flight routes optimized for each airship and mission
  - Estimated fuel savings could run 20% to 50% for large airships, depending on the weather
- **Can provide weather optimized route plans to multiple airships on a 24/7 basis**



OMEGA Grid Structure



Grid of Triangles Overlaid on Terrain Map

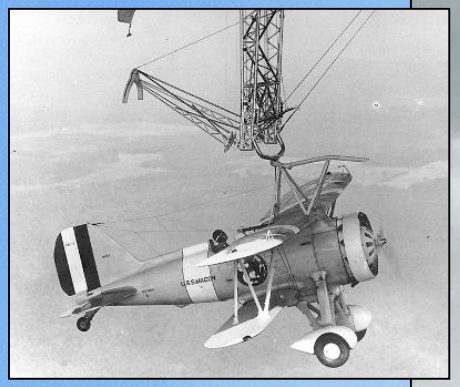


Optimized Airship Route (A) vs Great Circle Route (B) between Ft. Lewis and Pusan

OMEGA displays wind direction (yellow arrows) and speed, along with optimized airship heading (magenta arrows). Airship true heading, altitude changes, and minimum safe airship altitude are depicted in the direction and height of the wall (green) which tracks the optimized route. Route maps can be displayed via Google Earth or other suitable ortho-rectified graphics.

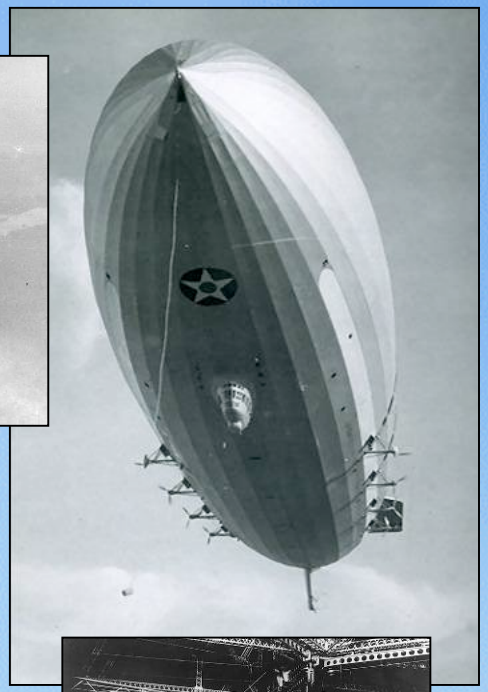
In-flight passenger transfer

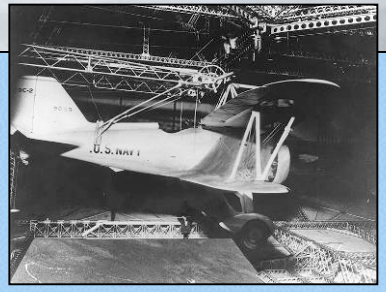
- **1930's USS Macon airship carried five bi-planes that could operate between airship and local airports**
  - **Airship useful lift: 50 tons**
  - **Airship cruise: 60 knots**
- **The Hindenburg had nearly 100 tons useful lift!**



Sparrow Hawk landing on the airship trapeze

USS Macon flying aircraft carrier





Aircraft inside airship hanger deck

In-flight passenger transfer concept

- A large transport airship could be built to support small, STOL aircraft that "dock" with the airship in-flight
- Passengers, crew, food, water, and supplies could be transferred to the airship without need of landing
- Airship utilization rate would be high, and point-to-point trip time would be lower due to reduced landings required
- The airship could also be refueled in-flight by this method

The Ultimate Green Airship???

- **There may be a design point where a large airship could become energy independent**
  - As airship dimensions doubles, its volume increases eight times (cube square law)
    - Gross helium lift increases more than empty weight increases
  - The larger the airship the greater the exterior surface area available for photovoltaic cells
    - Solar energy can directly power electric propulsion system
    - Solar energy can be used to obtain hydrogen by “cracking” water lifted from the sea
      - Hydrogen can power fuel cells, or be stored onboard for use at night or on cloudy days
  - If the airship is large enough it may be possible to obtain all the energy required from solar energy striking the photovoltaic cells
    - When there is insufficient sunshine the airship can slow down or come to a full stop to collect what solar power is available

The "Z-Prize"

- The **"Zero Emissions Transport Airship,"** ZETA, or **"Z-Prize"**
  - The Z-Prize is an international competition for self-funded teams to design, build, and race their cargo airships
    - Includes fully buoyant and semi-buoyant airships
    - Multi-million dollar prize to be posted by airship user community
    - Z-Prize organization establishes the rules and judges the competition

- **General goals of the Z-Prize:**
  - Create several affordable heavy lift airship designs
  - Demonstrate practical "low-to-no" CO_2 air transport
  - Establish several lighter-than-air transport manufacturers
  - Create a new and vibrant aviation technology sector
  - **Promote new markets and job opportunities for building and operating cargo airships**

Z-Prize Criteria and Awards

- **All Z-Prize contending airships fly a set course**
  - Approximately 1,000 kilometers round trip
- **Winning airship has the best average of**
  1. **Air speed**
  2. **Payload weight**
  3. **Payload transfer speed**
  4. **Cost per ton/mile**
  5. **CO_2 emissions per ton/mile**

- **Z-Prize purse is $30 million to $40 million**
  - Prize needs to be high enough to attract large investors to teams
  - Prize should be ¼ to 1/3 cost of building contestant airship

- **Best example is the Google Lunar X PRIZE**
  - **A $30 million international competition to safely land a robot on the surface of the Moon, travel 500 meters over the lunar surface, and send images and data back to the Earth**
  - **Seventeen teams are competing for the Google™ Lunar X Prize**

BACKUP SLIDES

Airship Operations

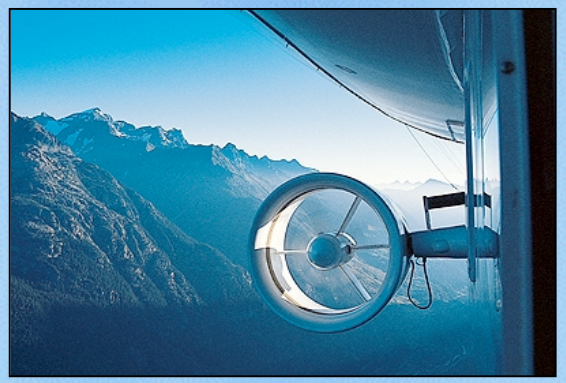
Only a handful of airship operators

- 20 plus airships currently operating in the world
- Small companies with limited resources
- All but two are owned by the airship manufacturer
- Extensive experience operating non-rigid airships in all climates
- Very small number of experienced personnel
  - There are more astronauts than airship pilots!

Lightship A-60+ over Florida

Aeros 40-B in Malaysia

Zeppelin N 07 at Moffett Field



AMS Skyship 600 B over the Alps

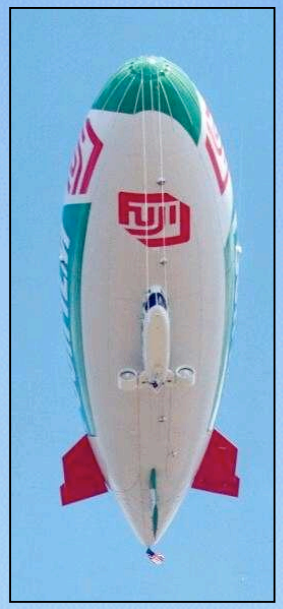
Goodyear GZ-20 Moored to Stick Mast

Current Airships

Performance Capabilities

- Operating altitudes up to 1250 m (3,000 m with reduced payload)
- Speed ranges - 0 to 100 kph.
- Useful lift 612 kilos to 1820 kilos.
- Flight endurance 8 to 24 hr.
- Certified for day/night flight (some are IFR certified)

Zeppelin-NT N 07



Airship Management Services (AMS) SKYSHIP 600

American Blimp Corporation (ABC) A-60+ & A-170

RosAeroSystems AU-30

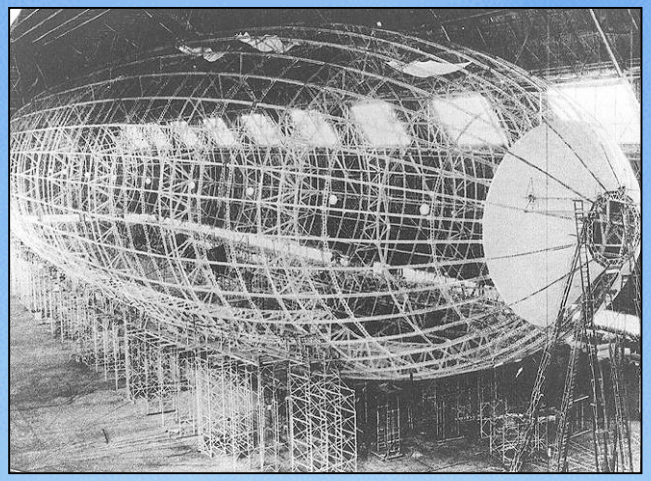
Aeros Corp. 40-B

Airship Experience Base

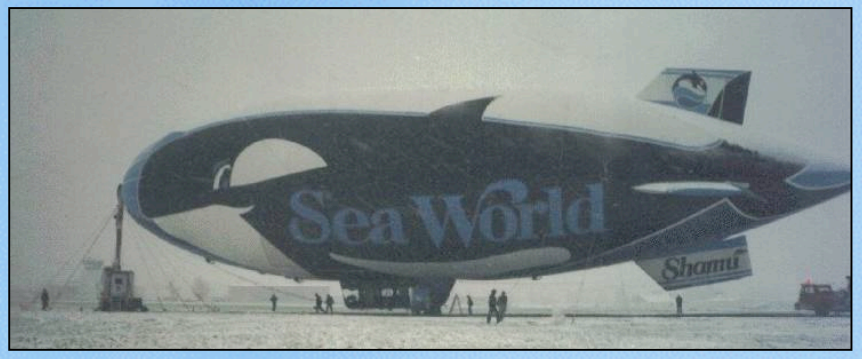
Over 100 Years Experience

Over 250 non-rigid airships constructed

Over 100,000 operational flight hours by USN Blimps



Nearly 130 rigid and semi-rigid airships constructed



Operations on 6 continents in all climates and weather conditions

Booz-Allen HLA Market Study - 1978

- **1978 Booz-Allen study; "Study of Civil Markets for Heavy-Lift-Airships" looked at civil markets for transport airships, referred to as "Heavy Lift Airships (HLAs)**
- **General interest was in aerial crane type airships**
- **Authors identified principal airship markets as:**
  - logging, relief of port congestion, power transmission line erection, construction of power generating plants, and general transport
- **Support for pipeline construction and offshore oil rig construction were singled out as very strong airship markets**
- **For localized movement of freight, a major factor affecting airship profitability was time required to ferry the airship between jobs**
  - The greater the distances between jobs, the lower the utilization rate

Application	Annual Market: North America	Annual Market: World Market	Units	Market Capture Potential (approx.)	Best Vehicle Payload (tons)	* Potential Number of Vehicles: 25 mph	or	* Potential Number of Vehicles: 60 mph	Parameters Critical to Reaching Stated Market Capture Potential
Transportation and erection of refineries and petrochemical plant components	05 x 10^6	33 x 10^6	Barrels per day	0	150 200 500 800	0 (1) (1) (2) (1)	or	0 (1) (1) (2) (1)	If HLA cost can be reduced 50% of case study estimate, capture potential becomes 100%, resulting in numbers in parentheses.
Support of construction of offshore permanent drilling and production platforms for oil and gas	40 to 90	50 to 150	Platforms constructed per year	100	500	2		2	Low HLA cost, high conventional barge cost, low offshore distance
Movements of strip mining power shovels	95	Not available	Shovels moved per year	700	200 to 300	1		1	Low HLA cost, low round trip distances
Support of high voltage power transmission line construction: 345 KVA 500 KVA 765 KVA	4,000 1,300 360	12,800 4,000 570	Miles of lines constructed per year	100	25 to 300	12		9	Increase in round trip distance increases number of vehicles
Electrical power generating plan construction	36,300	85,000	MW generating capacity added per year	100	150 and 200 to 300 and 800	1 (44) * and 10 (32) and 1 (10)		1 (43) * and 5 (27) and 1 (10)	No critical parameters for two sub applications. * If the HLA costs on the third sub-application can be reduced by a little over 50%, the numbers in parentheses result
Support of the construction of gas or oil pipelines	2,400 to 2,700	10,000 to 12,000	Added pipeline mileage per year	100	75	3		4	No critical parameters
Support of the high rise construction industry: HVAC Window Wash Cranes	4,250 to 5,200 5,000 to 6,000 250 to 300	Not available	Number of lifts per year	100	7 to 15 and 25 to 30	1 2		1 2	No critical parameters
Support of remote drilling installation and operations	34	100	Wells drilled per year	100	25 to 30	6		3	Increases in round trip distance increases number of vehicles
Logging	7,300	75 to 80,000	Millions of cubic feet per year	100	7 to 15 or 25 to 30 or 75	186 ** or 112 or 538		150 ** or 1,082 or 600	Increases in yarding distance increases number of vehicles. Increase in load/unload time increases number of vehicles
Unloading cargo in congested ports	0	325,000 to 575,000	Numbers of containers moved per year	100	25 to 30 or 75	37 or 13		27 or 10	Lower HLA cost, higher cost of competition, all increase number of vehicles. Increased trip distance rapidly decreases 25 ton, 25 mph market, the remainder have sufficient in reserve to be unchanged
Transportation and rigging of heavy and oversized components	300 to 600	900 to 1,800	Numbers of moves per year	60 to 100 0	500 and 800	5 0		4 0	Reduction of HLA cost of up to 50% would result in 100% market share for both sizes. Number of 500 ton vehicles increases with distance traveled

1978 Booz-Allen Heavy Lift Airship (HLA) market study summary

Annual Market figures refers to total tonnage

* These figures are for an assumed 2,000 hours per year utilization, without ferry. If this utilization is reduced to 1,000 hours, not including ferry, the number of vehicles increases by approximately a factor of 2.

** Low numbers at low payload reflect higher unit costs for HLA and low market share. Lower numbers at lower speed reflects lower market due to higher costs, as opposed to increased numbers due to productivity.