Airships 101: Rediscovering the Potential of Lighter-Than-Air (LTA)

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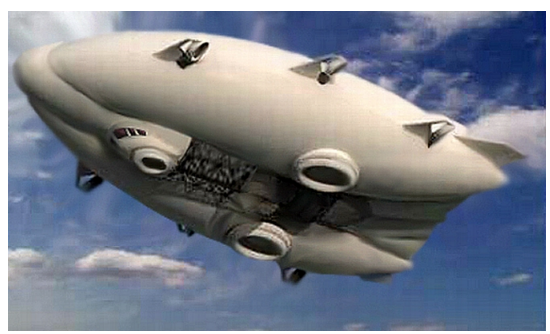
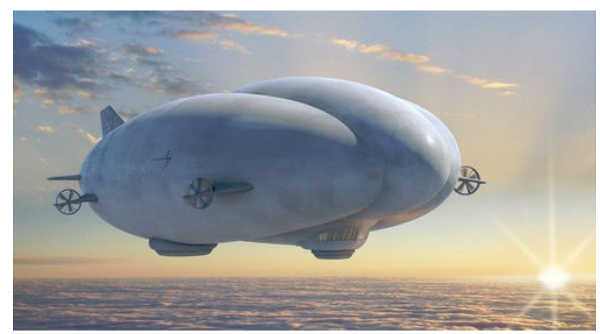
Agenda

- Intro to NASA Ames Aeronautics
- Airship classifications
- LTA Theory
- LTA Revival – Why Now?
- R&D Challenges
- LTA "Game-Changers"





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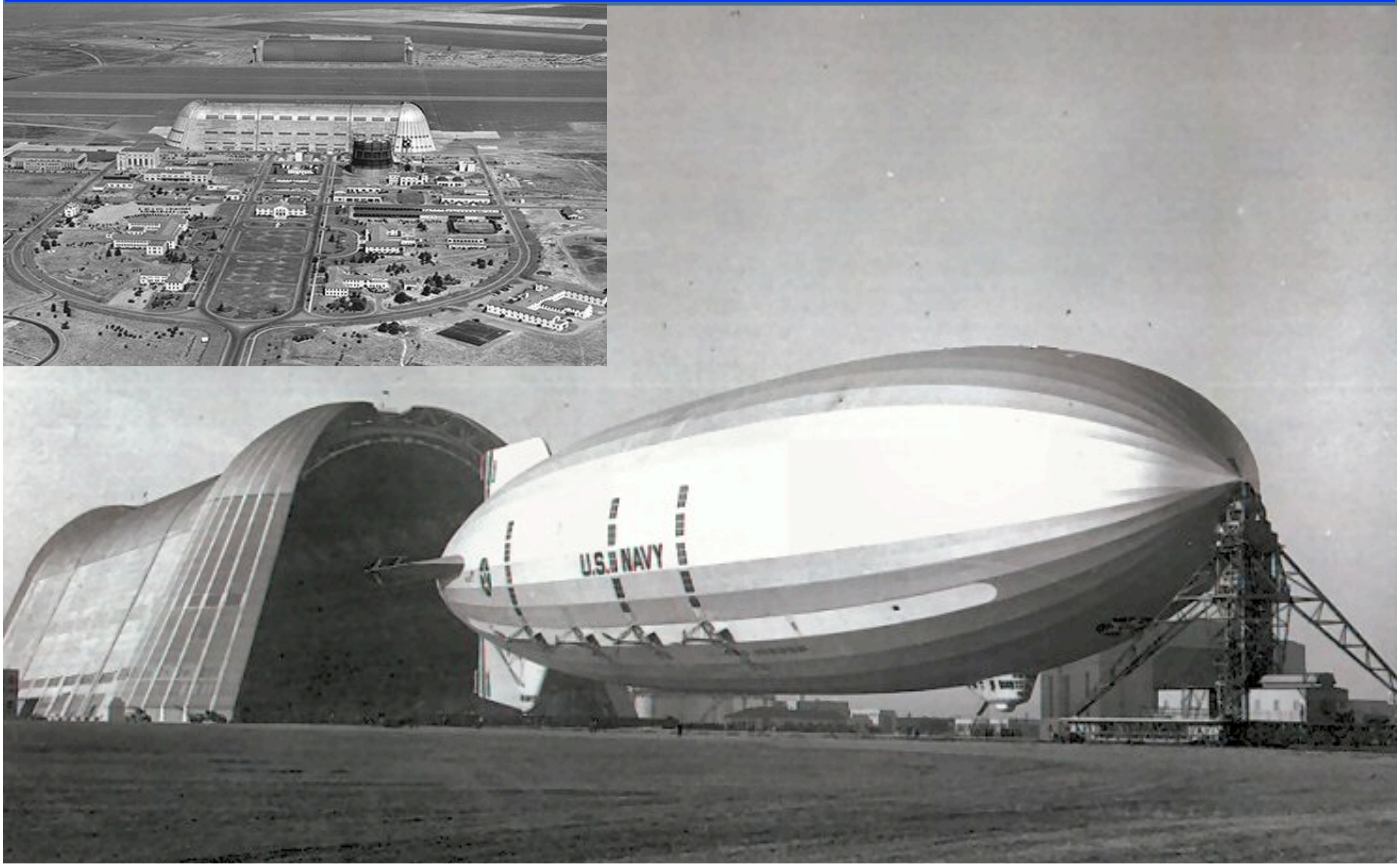
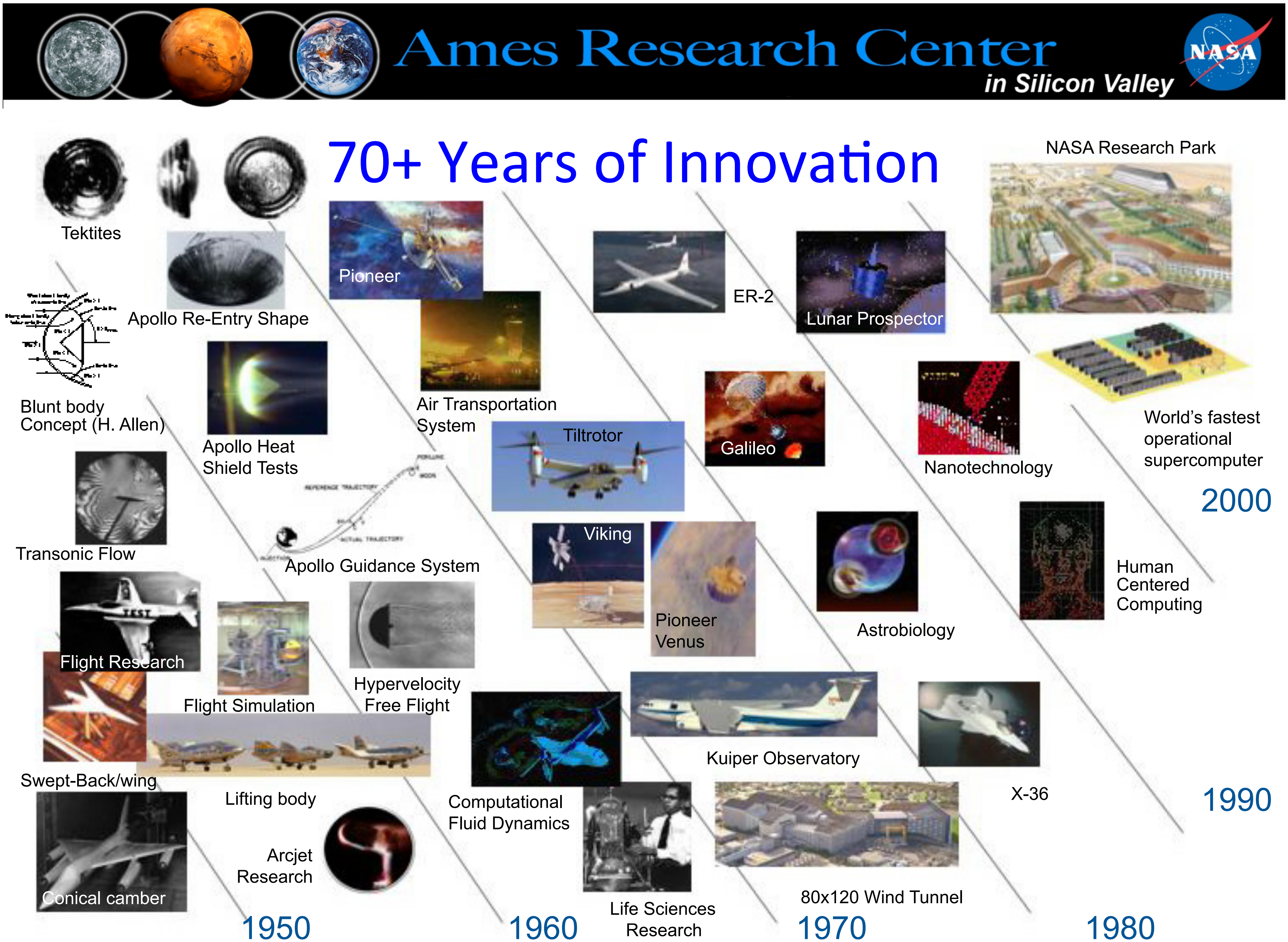
NASA Ames Airship Legacy

- Airships were focus of much early NACA work (Munk, Zahm)
- ARC home of the Macon (1933-35) and various USN blimp squadrons until 1947
- Approximately 50 research papers from the mid-1970s to mid-1980s were spawned by the energy crisis of 1973-1974
- 1970s research identified three potential LTA roles:
  - Heavy-lift airship
  - Short-haul commercial transport
  - Long-endurance naval patrol
- 1979 AIAA LTA conference in Palo Alto
- 1980s studies confirmed potential role for LTA in lifting heavy and oversized cargo
- 1980s research focused on quad-rotor + LTA concepts for heavy lift
- Minor involvement with Piasecki quad-rotor and Cyclocrane
- 1994 operations research with Westinghouse used Vertical Motion Simulator

USS Macon on Mooring Mast near Hangar 1
Moffett Field 1935



NASA Ames Federal Airfield


Ames Research Center
in Silicon Valley
NASA
70+ Years of Innovation
Tektites
Apollo Re-Entry Shape
Blunt body Concept (H. Allen)
Apollo Heat Shield Tests
Transonic Flow
Pioneer
Air Transportation System
Apollo Guidance System
Flight Research
Flight Simulation
Hypervelocity Free Flight
Swept-Back/wing
Lifting body
Arcjet Research
Conical camber
1950
ER-2
Tiltrotor
Viking
Pioneer Venus
Computational Fluid Dynamics
Life Sciences Research
1960
Lunar Prospector
Galileo
Kuiper Observatory
80x120 Wind Tunnel
1970
NASA Research Park
Nanotechnology
Astrobiology
X-36
1980
World's fastest operational supercomputer
Human Centered Computing
2000
1990

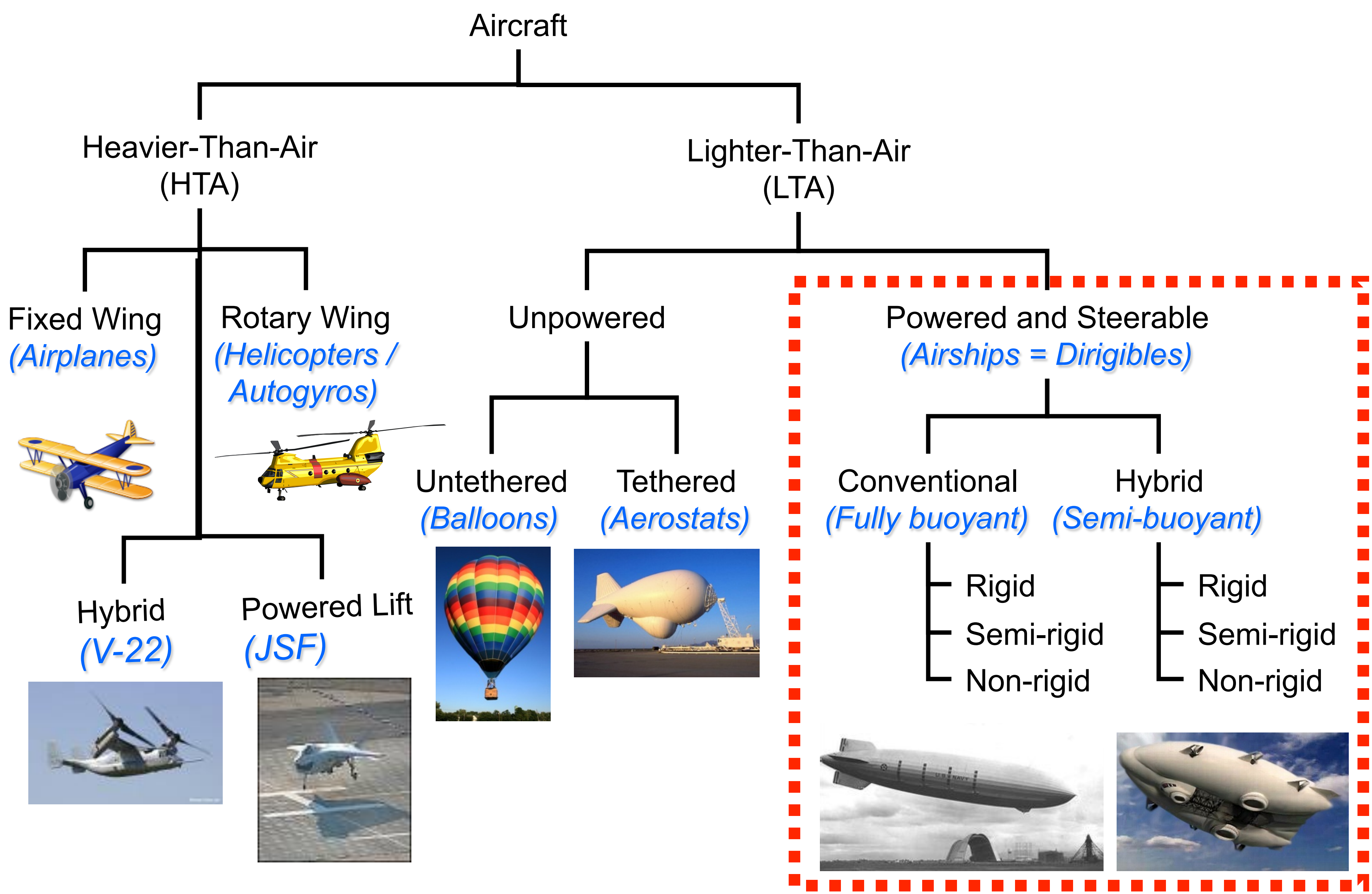
Ames Spacecraft and Aeronautics Expertise

- Inflatable (Fabric) and Lightweight Structures
  - Advanced FEA tools: LS-DYNA, Abaqus, NASTRAN
- Piloted Simulation requiring Vertical Motion Sims
  - Helicopters, Moon landers
  - Controls development for VTOL aircraft
- Aerodynamics Design, Analysis, and Test
  - CFD tools: OVERFLOW, STAR-CCM+
  - Large wind tunnels, Supercomputers

LTA vehicles face many of the same engineering challenges that confront current NASA Ames aircraft AND spacecraft programs

LTA Taxonomy and Theory

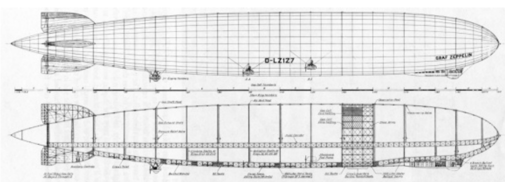
Aircraft Taxonomy



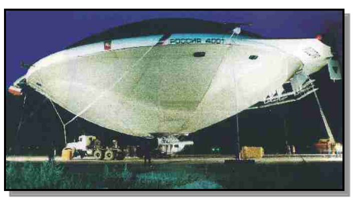
Airship Examples

Back…

AMS Skyship 600 Airship



Graf Zeppelin LZ-127



Russian Lenticular Airship

21st Century Airships
Spherical Airship

Powered and Steerable
(Airships = Dirigibles)

- Conventional *(Fully buoyant)*
  - Rigid
  - Semi-rigid
  - Non-rigid
- Hybrid *(Semi-buoyant)*
  - Rigid
  - Semi-rigid
  - Non-rigid

Design space for LTA is at least as large as HTA, but has only been "randomly sampled" with flight vehicles spaced over decades

LTA engineering is MUCH broader than the Hindenburg (LZ-129) and Goodyear Blimp

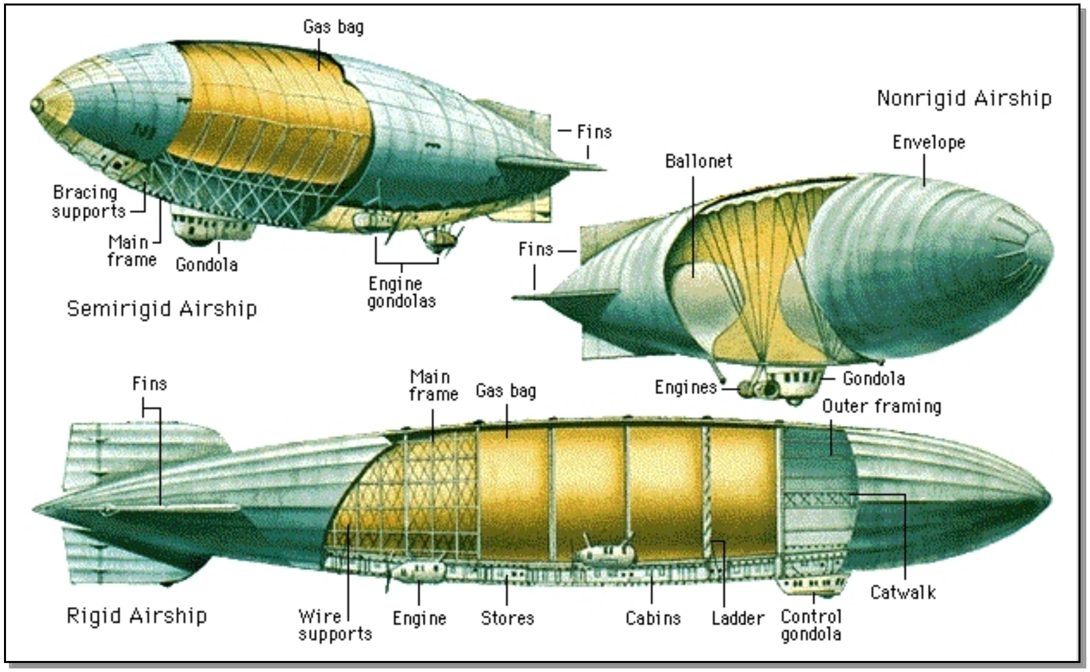
hybrid-winged concept

Lockheed ADP P-791

Piasecki PA-97 Helistat

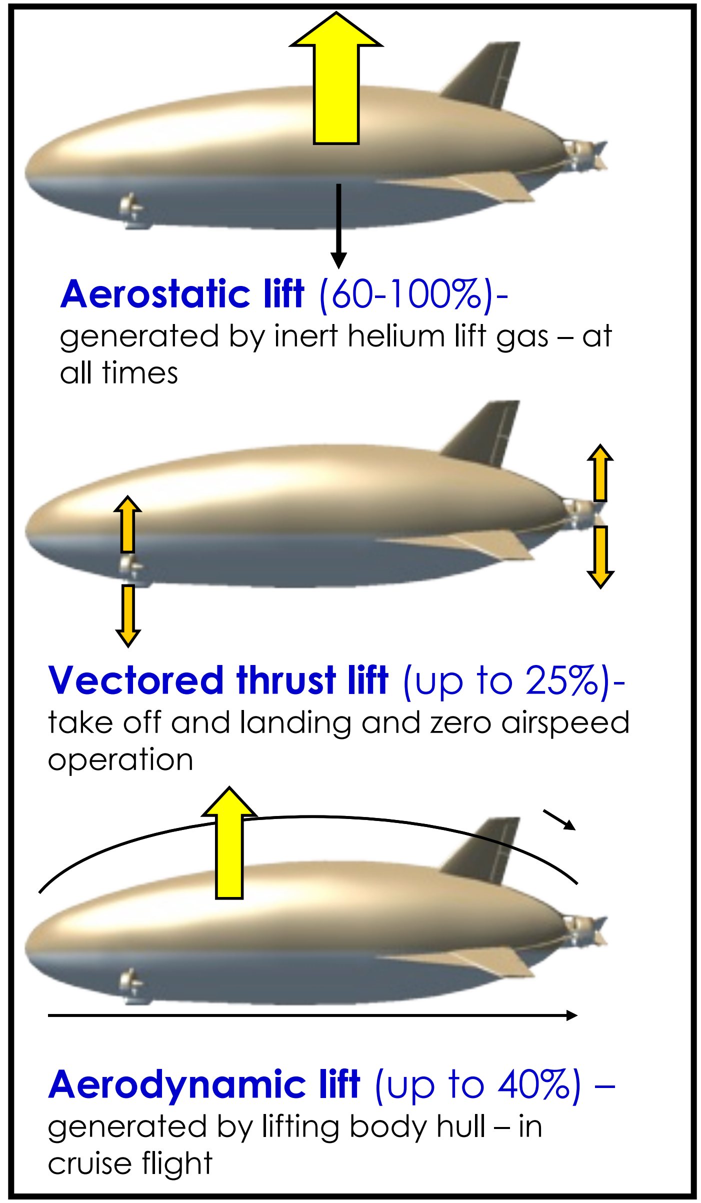
BOEING SkyHook

Conventional and Hybrid Airships



Conventional airships control heaviness by changing aerostatic (buoyant) lift and ballast

Hybrid airships combines aerostatic (buoyant) lift with aerodynamic lift (wing-borne) and direct (propulsive) lift



LTA Theory

- Lifting force from displacement (Archimedes, 287-212 BC)
  - Useable Lift = $\underbrace{Vol * (\rho_{He} - \rho_{air}) * g}_{\text{Displacement Lift}} - W_{dead}$
  - Hydrogen (H_2): 70 lbf per 1000 ft^3 (1.14 kg/m^3)
  - Helium (He): 65 lbf per 1000 ft^3 (1.06 kg/m^3 or 93% of H_2)
- Dead weight historically > 50% of displacement lift
  - Hindenburg (H_2): 54%, 260K lbs Dead, 220K lbs Useable
- Fuel, ballast, crew, consumables further reduce useable lift available for cargo
- Lift, Drag, Weight, and Thrust still apply – but apparent mass, buoyancy control, and ballast complicate design

Useable Lift and Size Comparisons

Behemoths in the Air

Dirigibles, which use enormous balloonlike cells filled with lighter-than-air gas for lift, are drawing renewed interest.

GIFFARD AIRSHIP (MAIDEN FLIGHT: 1852)

Created by Henri Giffard, a French engineer and architect. The first powered aircraft, it used a propeller driven by a lightweight steam engine to travel 17 miles on its only flight.

144 feet long; 1 pilot

LZ-129 HINDENBURG (1936)

More than 1,000 passengers traveled on 18 trans-Atlantic trips to Rio de Janeiro and Lakehurst, N.J. But in May, 1937, the Hindenburg caught fire and crashed while landing in Lakehurst. It was filled with hydrogren, a buoyant but highly inflammable gas, not helium, which is inert.

803 feet long; about 50 passengers and about 50 crew

GOODYEAR GZ-20 (1968)

Well-known due to their prominence at sporting events, these blimps are some of the current airships used for advertising and broadcast.

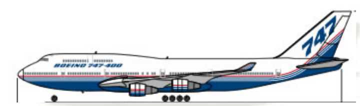
3.3K lbs

192 feet long; 6 passengers and 1 pilot

ZEPPELIN NT (1997)

Built by ZLT Zeppelin Luftschifftechnik; the fourth NT airship is expected to begin service in California this fall, for sightseeing tours.

246 feet long; 12 passengers and 2 crew



BOEING 747-400

231 feet long; 400 passengers

>500k lbs

Sources: Boeing, Deutsche Zeppelin-Reederei; Goodyear Blimp; "Graf Zeppelin & Hindenburg" by Harold G. Dick and Douglas H. Robinson, 1985 (Smithsonian Institution Press); "The Airships: A History" by Basil Collier, 1974 (G.P. Putnam's Sons).

THE NEW YORK TIMES

Airships 101b

LTA Revival and Missions

Reviving the LTA Dream – Why Now?

- Commercial – the "E's"
  - Environment, Emissions, Energy, and Economics
  - New market opportunities
  - New aerospace exports
  - Endurance for scientific and commercial missions
- National Security
  - DoD transport and surveillance needs
  - Homeland security
  - Humanitarian airlift

There are numerous LTA missions besides tourism and advertising!

Environment, Emissions, and Energy

- Low noise
- Pavement "optional" – concrete not required
- Reduces port, freeway and railway congestion
- Reduces cargo aircraft at airports, reducing ram taxi delays and emissions
- Utilization of secondary airports and shallow ports
- Operations at lower altitudes reduce air traffic conflicts
- Large size and low speeds promote autonomous operations

Airships have minimal infrastructure requirements and their low-altitude operations are inherently green

Environment, <u>Emissions</u>, and Energy

- Safe, convenient, airborne platform for the development and demonstration of green propulsion technologies: biodiesel, electric, solar technologies
- Emissions restrictions:
  - will continue to tighten
  - provide barriers to trade
  - may supercede fuel costs
  - are aviation's biggest environmental challenge

- Low altitude operations eliminate high-altitude aviation emission concerns

Unlike 1973-74, emissions will become increasingly important regardless of short-term oil price trends. Airships can stimulate the development of low-power green aviation prototype propulsion systems

Environment, Emissions, and Energy

- Dramatically reduced power requirements

$$\text{Power} = D\,V = \tfrac{1}{2}\,\rho_{air}\,S\,C_D\,V^3 = \text{Fuel Flow/SFC}$$

- Uncertain future of oil prices and supply
- Energy independence is a national goal
- Speed will likely become MUCH more expensive due to rising energy costs and emissions
- Strong arguments for LTA in 70s and 80s…
  - NASA CR-2636, 1976 “Cargo Transportation by Airships: A Systems Study”
  - NASA TM 86672, 1984 “Missions and Vehicle Concepts for Modern, Propelled, Lighter-Than-Air Vehicles”

Modern airships can be a component of GREEN aviation

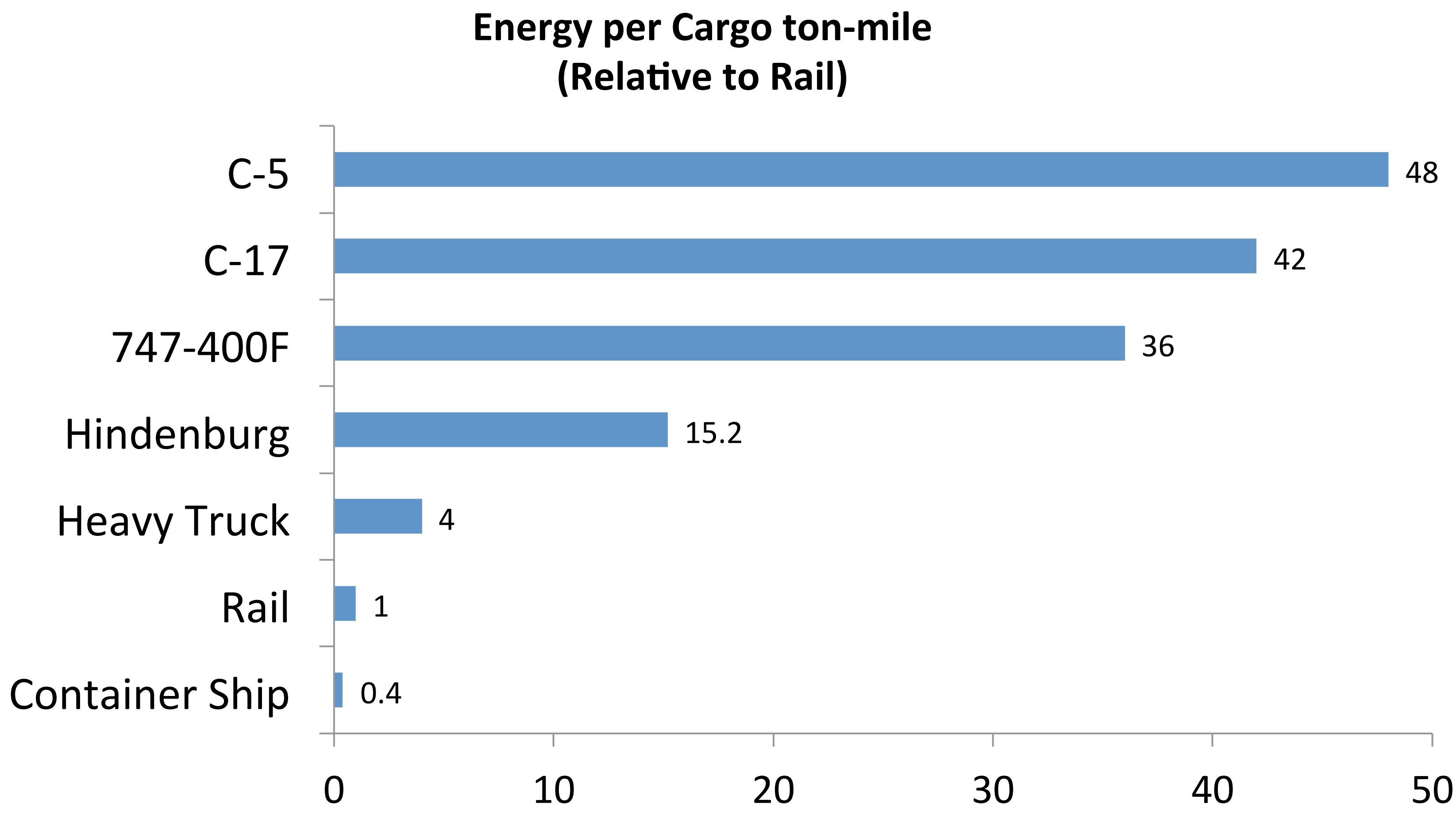
C-130, C-17, B747-400 and Hindenburg

	C-130	C-17	B747-400F	Hindenburg
Fuel + ballast (tons)	32	119	200	53+16
Cargo (tons)	22	85	124	43
Useful Lift (tons)	54	204	324	112
Range (miles)	2360	2785	5120	6840
Fuel/cargo-kmile	0.62	0.50	0.31	0.18
Power (hp)	4x4300		4x22000	4x1200
Speed (mph)	460	518	560	90

Data is VERY approximate and from multiple sources

- LTA can be VERY competitive on fuel use
- If Hindenburg ballast is considered cargo, F/c-km = 0.13
- Productivity comparisons *must* include speed differential

Relative Cargo Transport Fuel Efficiency



Advanced cargo airships will be the only aircraft capable of approaching trucks in freight fuel efficiency

Economics

- LTAs open trade and supply routes to regions lacking surface transportation infrastructures
  - Logging
  - Mining
  - Oil exploration
  - Arctic/Africa/Asia and others
- Satellite surrogate, WiFi/Broadband relays
- Short haul passenger transport/feeder
- New class of aerospace vehicles for export (aka, *jobs!*)

Airships can promote new markets for US exports and service environmentally sensitive and remote regions

Transport Airship Markets

- 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

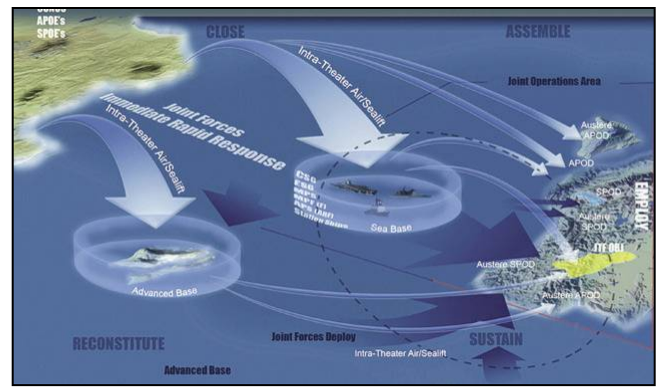

Heavy Lift Helicopter


Drilling Rig Assembly


Canadian Ice Road

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



Seabasing Overarching Concept

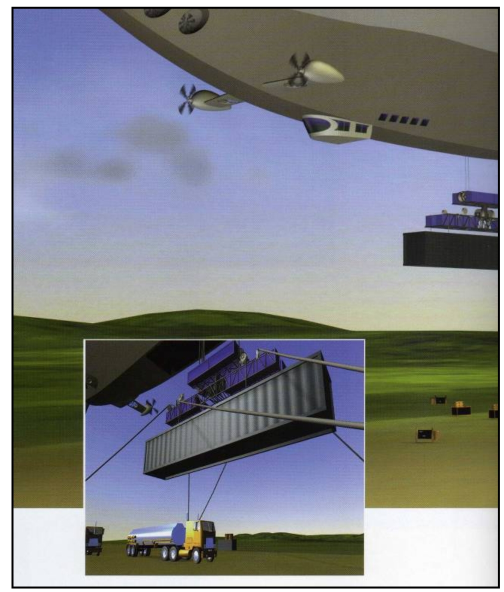
Army Surface Convoy

Vertical Ship Replenishment

2005 CAA Transport Airship Study

- Heavy lift airships are feasible with current technologies up to around 90 tons
- Follow on development to larger sizes require timed S&T investments
  - 5 years and 8 years for two distinct development phases
- 12 years development to achieve conventional airship with 360 tons lift
- 18 years development to achieve hybrid airship with 450 tons lift
- Commercial market demand is strongest for project freight
  - Ranges for commercial demand are 25 to 250, and 400 to 800 miles
  - Ranges for military demand are 400 to 800 miles, and (1,000 to 3,000 miles)
- Recommended airships be commercially developed, for lease to DoD

ATG SkyCat-1000 Hybrid Airship Concept



CargoLifter CL-160 Aerial Crane Airship Concept

Major Project Freight Applications

Pipeline Right of Way

Oil and Gas Pipeline Construction

- In-land logistics (from main entry port) is 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 is $100 -150 million per 1000 km of pipeline
- $100 to 120 billion in pipeline projects scheduled over next 10 – 15 yr

Logistics Support to Canada

- 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

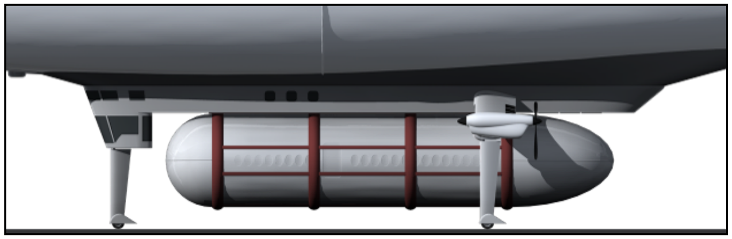
- Supports regional movement of equipment which otherwise must be moved by conventional means
  - Airship transport reduces handling steps, point-to-point distances, overall transport time, and overall expense
- Vertical lift airships can deliver and install temporary capital equipment to meet cyclical 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

Outsized Freight and Load Exchange Handling

- Internal winch in gondola can accommodate high point loads
  - Supports sling loads and palletized freight
- Wide landing gear stance can handle outsized payloads
  - Extended fixed landing gear provides ground clearance for large outsized items
- Internal payload bays can be equipped for roll-on-roll-off load handling

Airship with CONEX boxes



Airship with 20 ft. diameter aircraft center body

Roll-on-roll-off loading systems

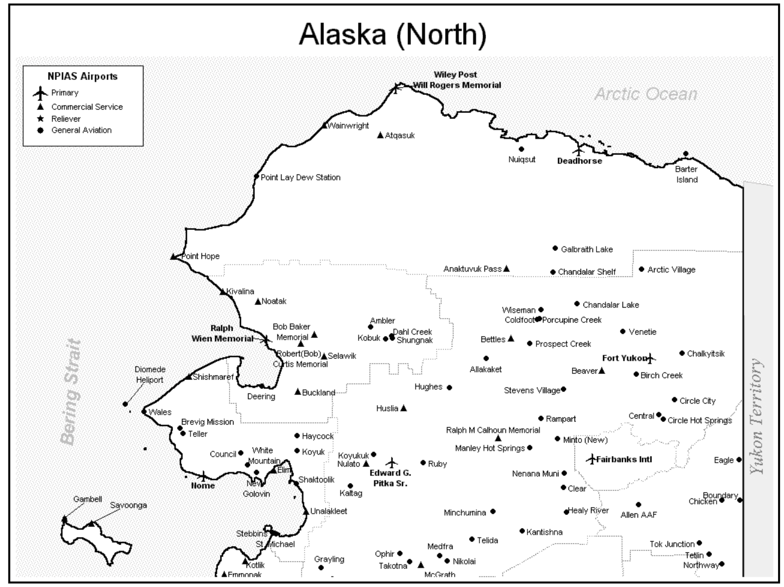
Rotary airship with sling load

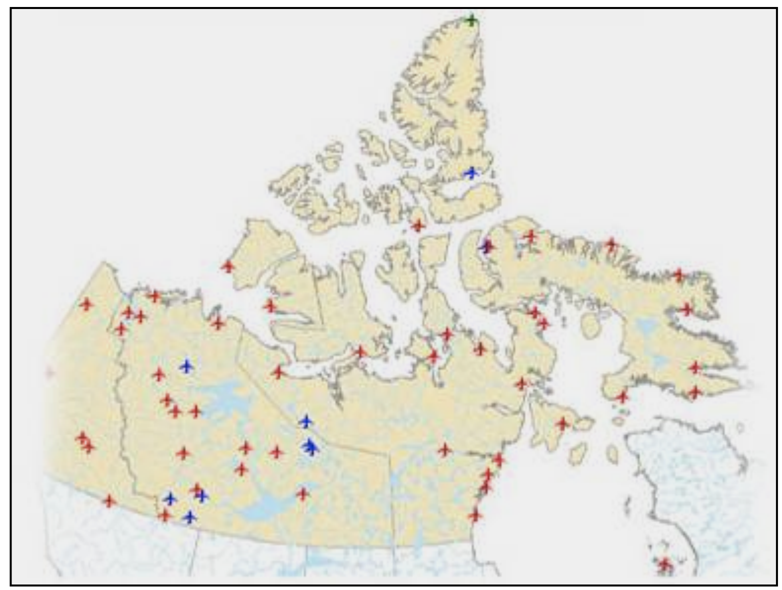
- Payloads can attach to flat underside of gondola
  - Handle standard CONEX boxes
  - Accommodate specialized cargo
    - Lightweight composite boxes allow more payload weight
    - Roll on, roll off boxes can facilitate quick movement of wheeled loads

- Initial operations can utilize ballast exchange
  - Pre-loaded ballast bags can be winched or loaded into gondola structure
    - Facilitates quick payload/ballast load exchange in austere areas
    - Ballast environmental issues minimized in short distance operations within region
- NASA Ames R&D needed to facilitate development of optimal buoyancy control system

Operational Concepts and Missions

- Approximately 82% of Alaskan communities are not served by roads
- The Canadian North has only 48 certified airports and 73 aerodromes
- How can a cargo airship operation best serve this community?
  - Cargo only, or combination cargo and passengers (combie)
  - Out and back flights from a central hub (with “deadhead” returns)
  - Three way (triangle) flights between sites
  - Two ships flying in opposite directions between several sites
- What mix of cargos will be most efficient, useful, and profitable?
  - Diesel fuel, jet fuel, gasoline, kerosene
  - Dry cargo in containers
  - Outsized freight in sling loads
  - Passengers





Why aren't there more Cargo Airships?

- Many cargo airships have been proposed but have failed to succeed or have yet to come to fruition for various reasons
  - Inadequate program funding and resources
  - Poor management practices
  - Shortage of designers and engineers with unique airship skills
  - Insufficient customer input on airship design and operation
  - Unmanageable gap between airship capabilities and customer expectations
  - Excessively short or unachievable development schedules
  - Investor or customer impatience with airship development time and costs
  - Reluctance by investors and customers toward staged development approach
  - Schedule delay or increased costs due to unanticipated technical obstacles
  - Investors and customers impatience with airship technology R&D efforts to reduce future program risks
  - Unfamiliarity by aviation authorities with factors governing airship design, operation, and promulgation of appropriate regulations

What is the Right Size for a Cargo Airship?

- The technology and engineering expertise to design and develop large cargo airships is available today
- But what airship size and performance capabilities are required?
  - Choose too large and it's too costly in time and money to develop
  - Choose too small and it's economic utilization is too limited for markets
- What is the performance "sweet spot" for a successful cargo airship?

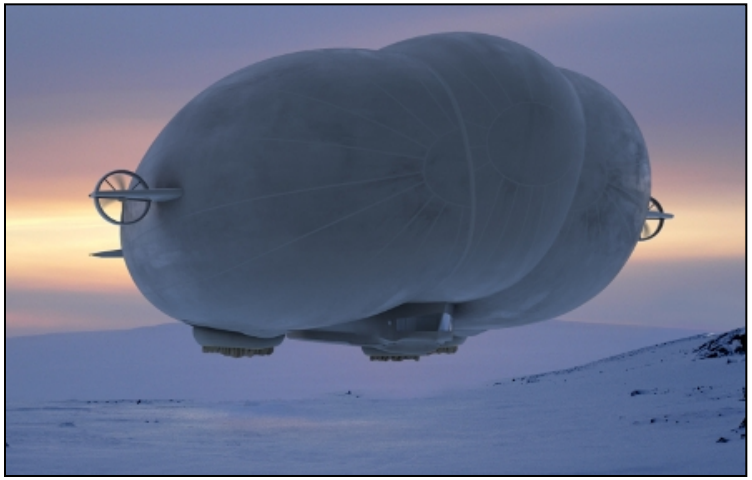
Cargo airship requirement considerations:

- Cargo airships need the right mix of mature technologies and advanced technologies
- Payloads need to meet the freight shipment sizes preferred by customers
- Utilization rates must be high to maintain operational profitability
  - The shorter the distances, or greater the speed, the greater the utilization
- Freight transport costs must be attractive compared to current alternatives
- Should accommodate current cargo shipping systems preferred by customers
- Have the capability of operating at well developed sites (airports) and austere sites
- Facilitate ease of operation and maintenance in remote areas
- **MUST MAKE MONEY FOR ALL PARTCIPANTS!**

Customer and User Inputs Needed

Alaska and Canada are the best initial markets for cargo airships

- **Designers need user inputs to develop the right airship and operation**
  - Cargo types, sizes, and weights
  - Priorities for freight type, delivery locations, and schedule
  - Critical cost points for freight and delivery locations
  - Specific cost factors that govern airship operations
    - Local cost and availability of airship fuel
    - Manpower costs for experienced aviation crews (flight and ground)
  - Local weather and site info on proposed airship cargo delivery areas



Airships 101c

Research, Challenges, and Technology "Game-Changers"

LTA Research Opportunities

- Incorporation into future airspace
  - Utilization of secondary airports
  - Impacts of low-altitude operations
- Lightweight structures (design, analysis, fabrication)
- Materials (engineered fabrics, composites)
- Controls and Dynamics, especially near ground
- Ground operations
- Drag reduction, BLC, and synergistic propulsion
- Thrust vector control
- Showplace for green power sources (solar, biodiesel, hydrogen, fuel cells, etc.)
- Localized weather prediction

LTA Research Challenges

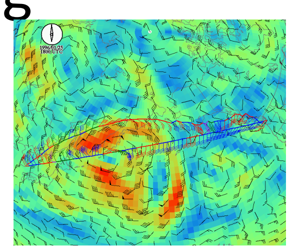
- Few modern examples, difficult to predict ultimate economic success
- Large lightweight structures are historically risky to build and fly
- Competition with HTA and surface transport industry
- Hindenburg imagery, public confusion of He and H_2
- Speed and Size do matter - must successfully match vehicles, cargo, and missions for economic success
- Weather and ground handling
- Conveying seriousness of emissions and environmental challenges
- Small number of LTA engineers
- LTA not included in aerospace engineering curriculum
- No existing national LTA "culture" (as compared to HTA)
- Existing LTA infrastructure (hangars) in disrepair…

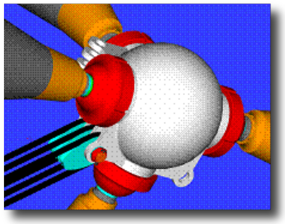
LTA Engineering

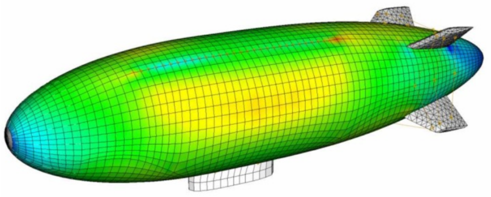
- Modern LTA can capitalize on advances in:
  - Materials and instrumentation
  - Digital/optical electronics and computers
  - Structural design, analysis, and testing
  - Aerodynamic design, analysis and testing
  - Digital control
  - Fabrication and advanced manufacturing
  - Weather prediction and avoidance
  - Propulsion system efficiencies
  - Systems engineering processes

LTA "Game Changers"

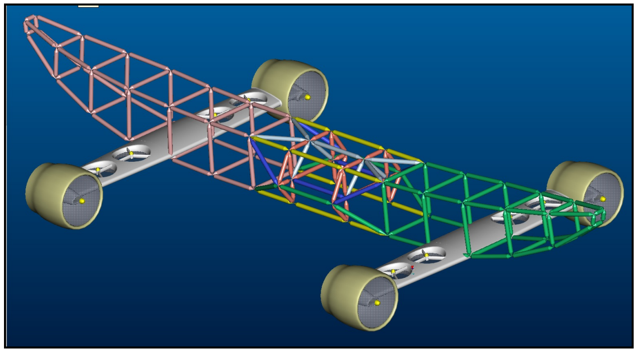
- Eliminating Ballast: Buoyancy control via compression/cooling
  - Regulations governing brown/foreign water disposal
  - Heaviness avoids the cargo/ballast matching required during offloading
  - Availability of ballast materials in remote areas
- Ground handling: Control systems, thrusters, micro-climate
- Emissions: Solar cells, biodiesel, fuel cells, ocean sailing
- En route weather information and path optimization
- Autonomous capabilities
- Electrochromic paints
- Distributed, synergistic propulsion reduce P_{req} by additional 30%
- Materials: Engineered fabrics, composite structures
- Advanced structures and engineered materials
- Lifting gases: H_2, H_2 encased in He, Hot Air, Steam
- Analysis and Design Tools: CFD, FEA, Controls



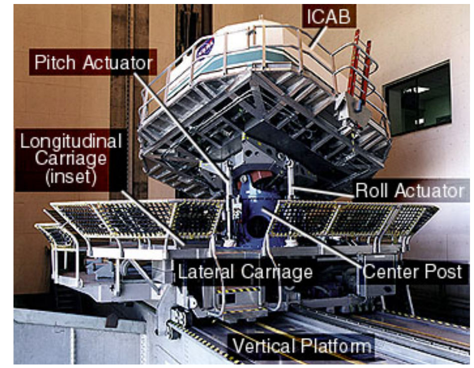




NASA Ames Airship Analysis

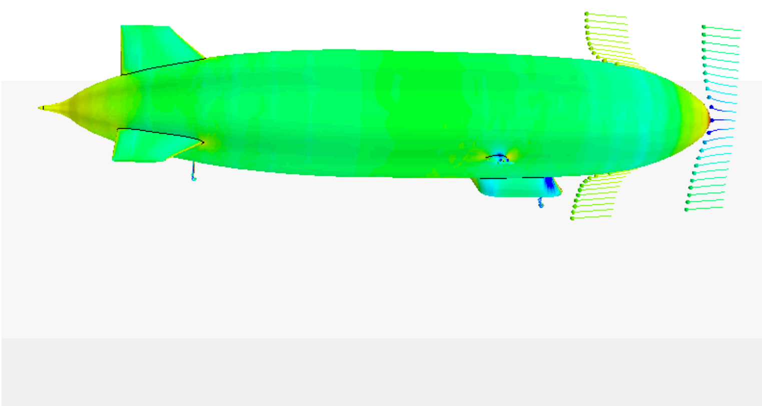


Structures
- Design and Analysis
- Testing and Instrumentation
- Materials

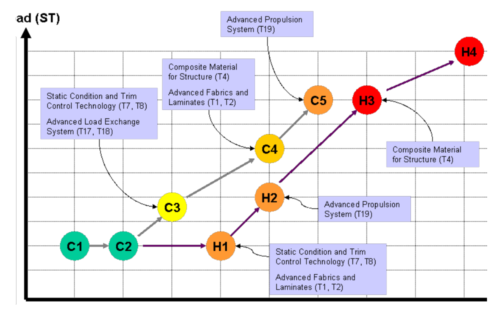


Aerodynamics
- Steady Loads Estimation
- Performance
-Gust and Fin loads

Flight Simulation
- Handling Qualities
- Controls Development
- Mooring
- Buoyancy Management
- Vectored thrust



Mission Analysis
- Airspace Operations
- Cargo Handling
- Risk Analysis



Conclusions

- LTA remains one of the last unexploited aviation frontiers

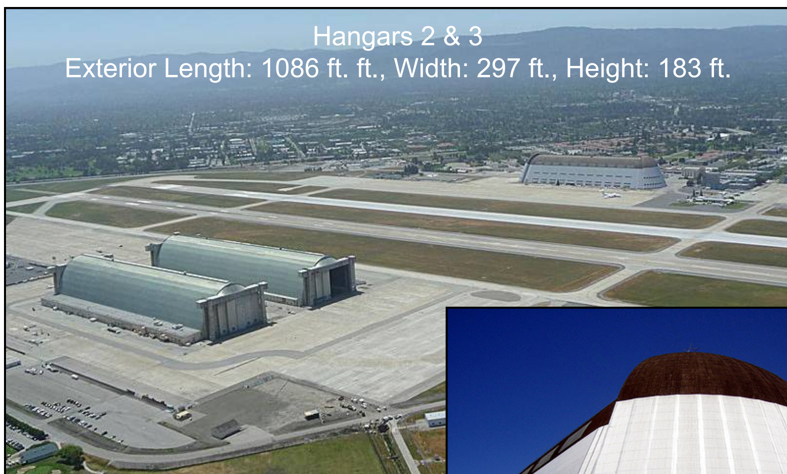
- LTA is the most environmentally responsible aviation transport technology

- LTA vehicles face numerous challenges, but today's technologies can provide the solutions

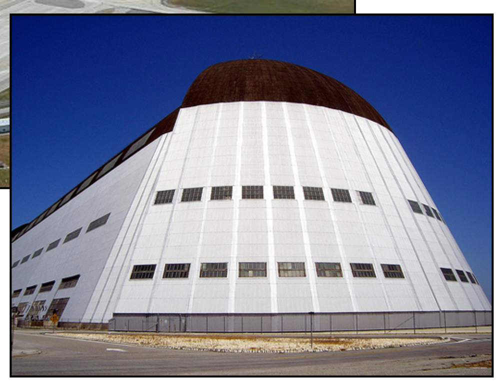
- LTA vehicles offer significant, game-changing capabilities for major economic and social advances

Backup Slides

- Three of the largest airship hangars in the world
- The largest low-speed wind tunnel in the world
- The largest Motion Simulator in the world
- Airship Ventures Zeppelin airship operates from Moffett Field
  - Ames will use Zeppelin for validation of airship simulation models, earth science



Hangars 2 & 3
Exterior Length: 1086 ft. ft., Width: 297 ft., Height: 183 ft.



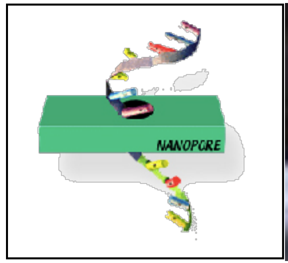
Hangar 1
Exterior Length: 1,133 ft., Width: 308 ft., Height: 198 ft.

Airship Ventures Zeppelin N 07 based at Moffett Field

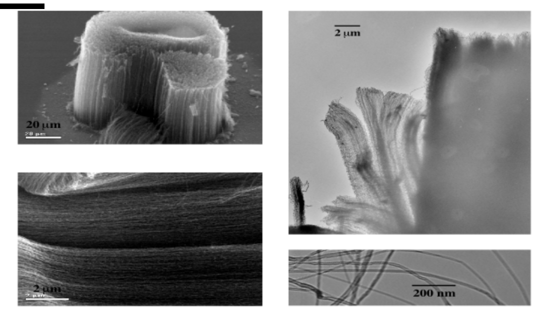
World’s largest low-speed wind tunnel

Ames Technology Areas

Aerospace and
Aeronautics

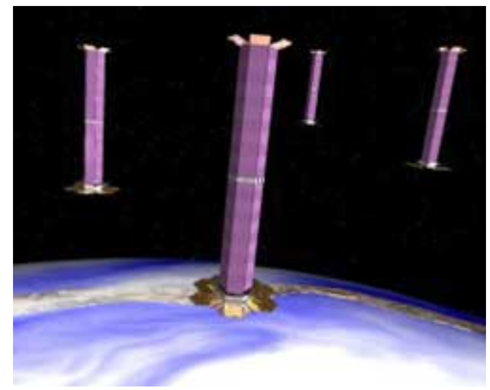


BioTech/Bio-Medical



Nanotechnology

Integrated Systems Health
Management (ISHM)



Small Satellite Systems

Robotics and Artificial
Intelligence

Systems Engineering
and Design

Materials Science
and Entry Systems

Software and
High-end Computing

Hangar 1

- First occupied in 1933 as a LTA (Dirigible) Hangar
- Currently closed due to contamination with PCBs
- Removal of contaminated materials is the responsibility of the US Navy
- Re-skinning and improvements to allow future use in work

Current Airship Characteristics

- Low flight altitude
- Low noise emissions
- Low-vibration cabin
- Low operating cost
- Low ground infrastructure requirements

- Simple ground handling with only three ground crew
- Precise hovering and extremely slow flight
- Long flight duration (up to 20 hours, depending on the payload)

- High safety standards due to rigid internal structure
- Payloads 1,300 lb – 5,000 lbs
- High operational safety for flight over densely populated areas
- High flexibility in cabin layout support short mission conversion times

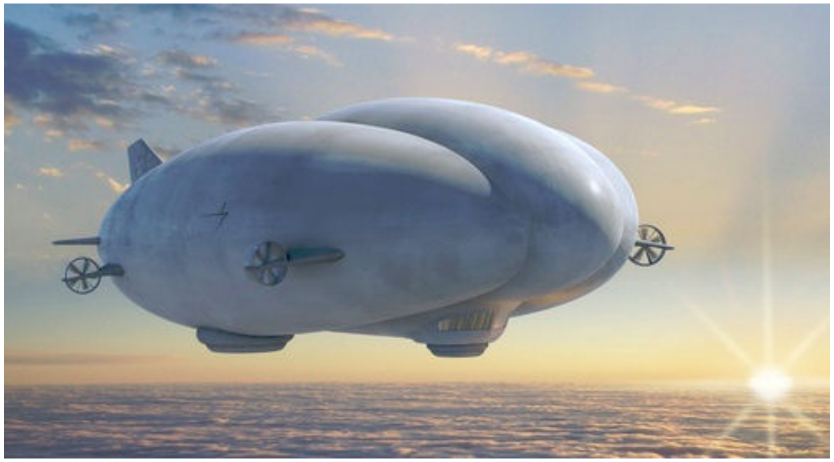
Humanitarian and Emergency Response

- VTOL capability with "infinite" hover
  - Station holding over urban canyons
- Mobile hospital or communications platform
- Airborne surveillance and sensors
- Coastal and border patrol
- Disaster relief when surface infrastructure is nonexistent or severely compromised

Airships can become ambassadors for US good will and provide humanitarian disaster relief in areas inaccessible to virtually all other modes of transport

DoD Transport and Surveillance

- Eliminate intermodal cargo transfers (Land-Rail-Sea-Land…)
- Large payloads to remote areas lacking transportation infrastructures
- Sea-basing and offshore operations
- Persistent ISR
- UAV "SkyCarrier"



LEMV, HiSentinel, HALE-D (ISR); P-791

Payload Weight –2,500 lbs
Payload Power –16 kilowatts
Duration –3 weeks

Payload Weight -80 lbs
Payload Power -50 Watts
Duration -> 24 Hours
Short Term (Fall 2009)

Payload Weight -80 lbs
Payload Power -150 Watts
Duration -> 14 Days
Short Term (Summer 2010)

Lockheed ADP P-791

How Our Need for Speed overcame Those Magnificent Men in their Flying Machines

Back…

The Rise of Fixed Wing Aircraft

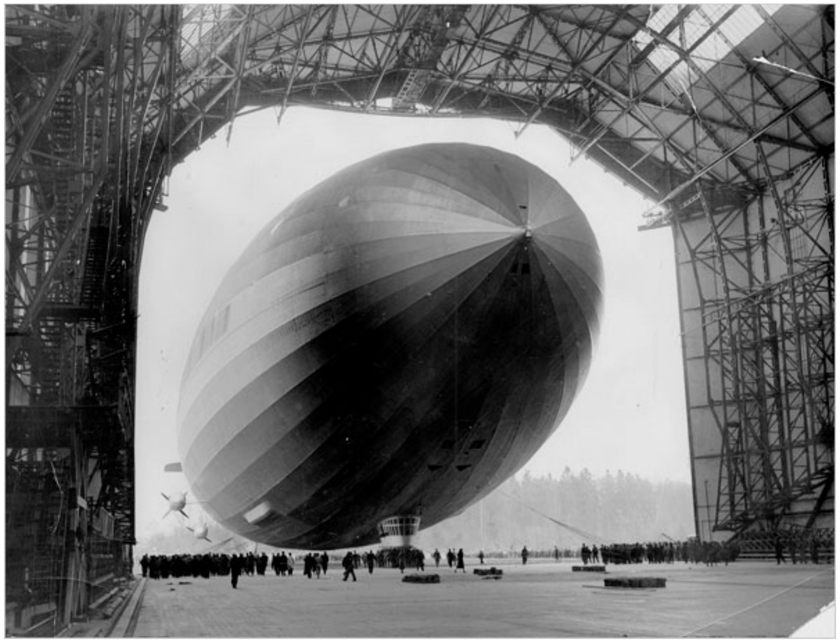
- WWII – 1958 (introduction of B-707)
  - Rapid development and unqualified success of the transport aircraft
  - Introduction of the jet engine along with modern materials, aero, etc.
  - Combined efficiencies, high speeds, and regular schedules make stratospheric transonic operations extremely productive
- Cheap petroleum

The Demise of the Zeppelin

- Tragedy of the Hindenburg
- Stigma of Shenandoah, Akron, and Macon accidents overshadowed operational success of USN WWII blimps

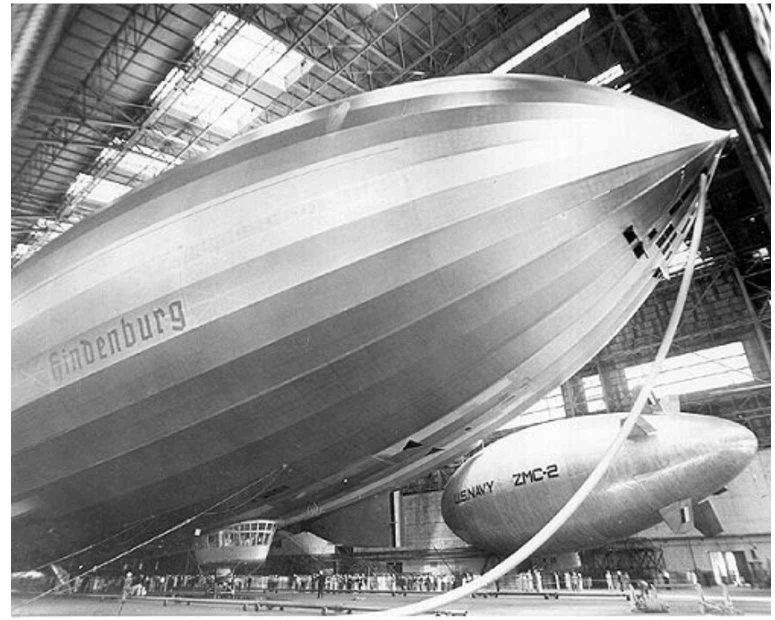
The Tragic Demise of the Hindenburg

- LZ-<u>129</u>
- 35 of 97 died
- Was to be the 11th round trip
- 50 wealthy passengers on a multi-day cruise, enjoying a pressurized smoking room
- Original design called for H_2 sacks surrounded by He
- US was only He provider, FDR and Munitions Control Board decided to withhold
- Political power of state-owned airlines



ZMC-2 "Tin Bubble" Metalclad

- 1929 Detroit Aircraft Corp.
- 150 ft long, 52.5' diameter
- 200,000 ft^3
- 52 cruise, 70 mph max
- 2 x 300 hp
- 0.01" Welded Aluminum
- 752 flights over 2,200 hours
- USN lost interest after Akron/Macon losses



October, 1934

USS Macon: 4/33-2/35

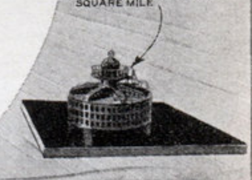
SUN'S RAYS TO DRIVE

Aerial Landing Field

RECENT experiments in the conversion of the sun's rays into electric power have led to an unusual idea in aerial equipment. It is a dirigible that not only would get its power from the sun but also provide space for a landing field in the air.

The ordinary cigar-shaped dirigible would in effect have a slice taken from the upper half of the gas bag. This would provide a large deck on which could be mounted solar photo cells, an airplane runway, and a hangar. Planes could land on the dirigible, floating over the sea, to refuel for trans-ocean passenger service.

Another unusual feature of this design, in addition to the landing field, is the use of sun rays to power the motors of the dirigible. Scientists estimate that the sun can develop as much as 86,300 kilowatts or 115,000 horsepower per hour in an area of a square mile. Photo cells convert the sun's energy into electricity. When this can be done on a practical basis, the roof of an ordinary house can be used to develop electricity for the home.



Legacy of Airship Technology

In 1959 four ZPG-3W airships, were procured from Goodyear for Navy AEW missions. Construction plans exist and provide basis for updated models.

Performance

Max speed:	75 knots
Cruising speed:	45 knots
Normal endurance at 35 knots:	70 hr.
Ferry flight: at 30 knots & 500 ft. alt. (standard day)	156 hr.

Design Specs

Width:	85.51 ft.
Length:	406.70 ft.
Volume:	1,509,489 cu/ft.
Static useful lift:	15,059 lbs
Max power:	1,275 hp.
Fuel Capacity:	4,375 gal.

LTA Infrastructure

- Hangars…
  - Can park outdoors, but likely need hangars for depot maintenance
  - Only 11 large airship hangars in CONUS…most in some disrepair
    - 3 at Moffett Field, CA
    - 3 at NAS Lakehurst, NJ
    - 2 at former MCAS Tustin, CA
    - 1 in Tillamook, OR
    - 1 in Akron, OH
    - 1 at Weeksville, NC
  - LEMV-size vehicles generally compatible with C-5 size maintenance facilities

Back…

Conclusions from 1984 LTA Survey Paper

"Missions and Vehicle Concepts for Modern, Propelled, Lighter-Than-Air Vehicles" by Mark D. Ardema, Dec 1984, TM 86672

- Lift/Weight: LTA "cube-cube" vs FW "square-cube"
  - Size increases favor larger airships compared to larger airplanes
- Low speed control via propulsive forces is key to solving ground handling issues
- Several viable potential missions for LTA
  - Ocean and coastal patrol
  - Heavy lift using a combination of LTA and rotors
  - High altitude surveillance
  - Short haul passengers (20-200 miles)
  - Long-range strategic airlift

To conclude this section, all evidence points to the conclusion that airships will have difficulty competing with airplanes over established transportation routes. It will take a strong combination of several of the following requirements to make a transport airship viable: (1) large payload, (2) extremely long or very short range, (3) expensive or limited fuel, (4) low noise, (5) VTOL, (6) undeveloped infrastructure, and (7) high-value or critical cargo. The best possibilities therefore seem to be either a short-haul VTOL passenger vehicle or a large, long-range strategic military vehicle.

Helium

- From Greek word for sun, “Helios”
  - Discovered in 1868 by French astronomer Pierre Janssen when sun spectral lines did not match any known elements
  - Second most abundant element in universe: two protons, two neutrons
  - Product of decay of uranium and thorium
  - ~5.2 ppm in atmosphere
- Recovered as byproduct of natural gas processing in seven countries
  - Not always enough to make it worth recovering (usually less than 7% of gas)
  - Natural gas investments dwarf helium recovery costs
  - In US, 0.3% Russia and Poland, 0.1% (Algeria, Canada, China, Qatar)
  - Compress and cool methane into liquid, while Helium remains gas until 4.2 K
- Short supply over last few years due to several factors
  - Mostly supply-driven
  - New plants in Algeria and Qatar have been slow to ramp up (16 plants worldwide)
  - Problems at US refineries, new restrictions on gas processing
- Largest application is MRI magnet refrigeration and cryogenics (28%), U.S. used 70.4M m^3 in 2007
  - Pressurization and purging (26%)
  - Welding (shielding gas, 20%)
  - Controlled atmospheres (13%)
  - Leak detection (4%)
  - Breathing mixtures (2%)
  - Other (balloons, 7%)
- Large reserves outside of U.S. (Eastern Siberia, Iran, Qatar)
  - Supply will likely improve as natural gas operations increase
  - Russia may be the major source in 30 years
- Strategic stockpile in Amarillo (609M m^3)
  - Predicted to be sold off by 2015 down to 2,900 tons
- Advanced helium recycling and capture, new MRI machines will help
- USGS predicts future total extractable He supply of 39 billion cubic meters worldwide, 8.2 in U.S.
- LZ-129 Hindenburg: 0.2M m^3 $3.25 * 0.2M = $650000
- Goodyear replaces 10-20K cu ft per year of 170K-180K cu ft per blimp

Helium

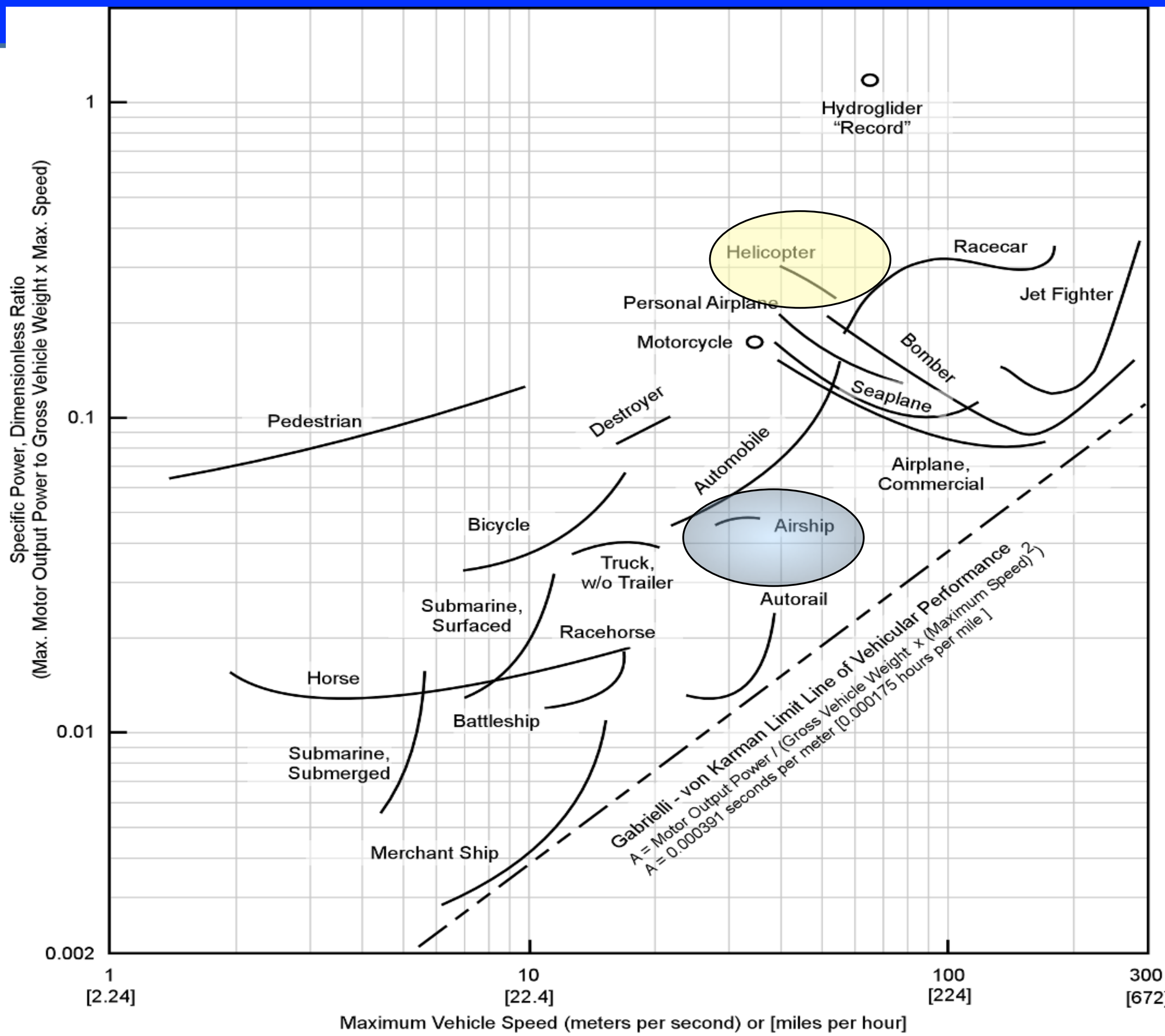
World Helium Production, Reserves and Reserve Base
Data in millions of cubic meters of contained gaseous helium

	2006 Production	2007 Production	Reserves	Reserve Base
U.S. (from natural gas)	79	80	3,400	8,200
U.S. (from National Helium Reserve)	58	58	--	--
Algeria	15	20	1,800	8,300
Canada	n/a	n/a	n/a	2,000
China	n/a	n/a	n/a	1,100
Poland	3	3	26	280
Qatar	4.4	5.5	n/a	10,000
Russia	6.3	6.4	1,700	6,700
Other countries	n/a	n/a	n/a	2,800
WORLD TOTAL	166	173	n/a	39,000

Price: The Government price for crude helium was $2.12 per cubic meter ($58.75 per thousand cubic feet) in fiscal year (FY) 2007. The price for the Government-owned helium is mandated by the Helium Privatization Act of 1996 (Public Law 104-273). The estimated price range for private industry's Grade-A gaseous helium was about $3.24 to $3.79 per cubic meter ($90 to $105 per thousand cubic feet), with some producers posting surcharges to this price.

Source: Adapted from the 2008 United States Geological Survey Mineral Commodity Summary on Helium

Airship Transport Efficiency



Specific resistance of single vehicles available in 1950. Diagonal is G-K limit line of vehicular performance. Adapted from original work by Gabrielli and von Karman [1], updating with modern SI units.