N76-15049

A LTA FLIGHT RESEARCH VEHICLE

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ABSTRACT: A LTA Flight Research Program is proposed. Major program objectives are summarized and a Modernized Navy ZPG-3W Airship recommended as the flight test vehicle. The origin of the current interest in modern airship vehicles is briefly discussed and the major benefits resulting from the flight research program described.

INTRODUCTION

The renewed interest in LTA vehicles can be attributed to four major factors:

1) A growing awareness of the ecological and energy problems associated with current transportation systems, 2) the realization that the operational characteristics and capabilities of airships are either not available or available only to a limited extent in other transportation systems, 3) the conviction that the quantum advancements in aerospace and aviation systems technology can place modern airships on the same level of safety, economy, and performance capability as alternate transportation systems, and 4) the identification of many conventional and unique missions that modern airship vehicles could potentially perform cost effectively.

In contrast to these factors, certain limitations and purported deficiencies are often defined as also characteristic of airships. These broadly can be grouped in

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three major areas: technical limitations, economic uncertainties, and institutional uncertainties. Each of the four sources of interest, the technical limitations, and economic and institutional uncertainties are briefly discussed.

A LTA Flight Research Program, similar to the joint Army-NASA Rotor Systems Research Aircraft and Tilt Rotor Research Aircraft Programs is discussed as one approach to resolving many of the technical, economic and institutional uncertainties which must be investigated in order to insure realization of the full potential of modern airships.

A Research Vehicle, consisting of a Modernized Navy ZPG-3W is described and its performance presented.

ECOLOGICAL AND ENERGY FACTORS

The recent oil embargo and the resulting concern over the energy crisis has resulted in an increased awareness of the dependency of our existing forms of transportation on the ever decreasing supply of petroleum. Commercial aircraft, one of the most severely affected transportation modes during the embargo, join private automobiles at the head of every list in terms of fuel energy consumed per passenger mile or per cargo ton mile. In contrast, modern-airship vehicles, because no fuel is expended in overcoming gravity, offer an extremely fuel efficient transportation mode.

A second area of increased public concern is the ecological and environmental aspects of air transportation. Demand projections for air transportation indicate that many major airports will be considerably overloaded in the near future. Acceptable locations for the construction of major new airport facilities and STOLport facilities present an increasingly difficult environmental and land use problem. Also, the ground level noise enivronment in areas immediately adjacent to airport facilities, as well as the air pollution associated with commercial aircraft-ground operations, are significant considerations in the introduction and operation of future air transportation systems. In each of these areas, the potential operational characteristics of modern airships, such as vertical takeoff, low power requirements, operational flexibility, and safety, offer potential advantages as an alternate transportation mode for cargo and personnel.

The lower power requirement results from the use of buoyant lift rather than aerodynamic lift. The decreased power requirements result in reduced operational noise, decreased air polution and potentially reduced costs, through reduced fuel consumption per unit productivity.

MODERN AIRSHIP CAPABILITIES

Although the unique capabilities of airship vehicles compared with existing aircraft are fairly well recognized, they will be briefly identified:

1. Safety, resulting from their relatively low takeoff and landing speeds and the fact that airships cruise at low altitudes, usually well below conventional aircraft traffic.

2. Carry bulky and heavy payloads, either internal in specially designed, containerized cargo bays, or suspended externally beneath the hull.

3. Virtually all-weather operational capability, with ground handling in severe weather further aided by vectorable thrust.

4. Exceptional endurance capability unparalleled by any air transportation vehicle.

5. Operate where no airports or roads exist, unhampered by land-water interfaces.

6. Hover for extended periods of time, particularly in the hybrid mode, combining buoyant lift with propulsive lift achieved through vectored thrust.

7. From an environmentalist's point of view, airships offer one of the most attractive transportation modes available. Both reduced air pollution and lower noise levels result from the lower power requirements.

8. Finally, from an energy conservation point of view, airships offer an extremely fuel-efficient transportation mode in terms of cargo ton miles or passenger seat miles per pound of fuel.

APPLICATION OF CURRENT TECHNOLOGY TO AIRSHIPS

Significant advances in structures, materials, and aerospace technology have occurred since the last detailed airship design effort was conducted. A few of the developments that could provide the highest payoff to airship technology include:

1. Extensive knowledge of weather patterns via Space Age weather forecasting and and on-board weather radar.

2. More reliable propulsion systems with improved fuel consumption and power to weight ratios.

3. Higher strength-to-weight ratio materials: fabrics, metals and composites.

4. Improved permeability plastics that will greatly improve helium retention.

5. Tremendously improved capability for the analysis and design of large rigid and semi-rigid airship structures resulting from the advent of modern high-speed computers and the developments of large-scale generalized structural dynamics analysis programs developed for Apollo and other NASA related programs.

6. Better insulation and high-temperature material capability to capitalize on the potential performance improvements resulting from super heating the lifting gas.

MODERN AIRSHIP MISSIONS

Perhaps the most significant factor contributing to the revived interest in modern airship vehicles is the identification of many promising conventional missions and several rather unique missions for modern airships. The missions most frequently discussed have arisen from a combination of the factors above: ecological and energy considerations, unique airship capabilities, and the promise of new technology. They may be loosely grouped into five general classes: commercial, public service, space related, AEC related, and military. Some of the most promising missions are listed below.

Commercial Missions: short haul passenger, oversized cargo, bulk (agricultural) cargo, natural gas transportation. Public Service Missions: police surveillance, environmental surveillance, disaster relief. Space Related Missions: shuttle transportation, solid rocket motor and external tank transportation. AEC Missions: radioactive fuel/waste transportation, delivery of large power plant components for remote plant site construction. Military Missions: Open ocean ASW surveillance with towed sonar arrays, sonar buoy field-deployment, monitoring repair and retrieval, mine sweeping vehicles, airborne command and control, cargo delivery, anti-ship missile defense.

MODERN AIRSHIP PROBLEMS AND TECHNICAL LIMITATIONS

With the many promising missions identified for modern airships, it is worthwhile to address the technical limitations and purported deficiencies often cited as limiting airship applications.

In the military area, airships appear to be ideal platforms, particularly for Naval ASW missions. Since airships served as excellent ASW vehicles during WW I and WW II, the question arises why they were phased out of these missions.

The reasons most often cited include (1) insufficient speed, (2) increasingly sophisticated submarine technology relative to detection equipment capability, and (3) vulnerability.

As submarine performance and speed improved, the pressurized airships were unable to maintain the required 30- to 40-knot ground speed under severe sea-state conditions: 60-knot head winds. With today's propulsion and design technology, improved pressurized, semi-rigid or rigid airships could easily provide the performance capability required to overtake the fastest enemy submarine or maintain station abreast of a convoy or task force in virtually any weather.

The second factor that contributed to the airship's retirement from naval service was unrelated to airship capability. Submarine technological and operational improvements outstripped detection equipment capability, particularly the sonar detection range. Sophisticated advancements during the recent decade have resulted in quantum improvements in ASW detection equipment. ASW airships could utilize extremely large towed array sonar systems, large area sonobuoy fields, new magnetic anomaly detection gear and improved radar equipment, as well as supporting systems, including onboard data processing, readout analysis, localization, attack and data link systems developed for the S-3 and P 3C aircraft and SH-3H and LAMPS helicopter ASW vehicles.

The final factor often cited in the demise of naval airships is their vulnerability. This topic seldom fails to arise when military applications of airships are discussed. In fact, recent developments in Soviet surface-to-air missile systems and anti-aircraft artillery systems often leads to doubts about the survivability of even our least vulnerable attack aircraft. For airships, however, acceptable levels of survivability can be achieved by employing the airship in missions and tactical environments compatible with their unique design and operational characteristics. Potentially airships could be equipped with self-defense systems, early warning and fire control radar, anti-air and anti-missile missiles, and various electronic countermeasures to further enhance their survivability.

In the nonmilitary mission area, other problems often cited limiting airship applications include low speed handling and control, ground handling, ballast requirements during load transfer, control of buoyancy and trim, and airship response to severe gusts and turbulence. None of these areas constitute unsolvable technical problems or limitations utilizing existing technology and operational procedures. However, airship performance and operational capability could certainly be improved by dedicated engineering design and development effort utilizing Apollo-era technology.

Ground handling of the latest and largest Navy airship, the Goodyear ZPG-3W, was considerably improved by the use of motorized "mechanical mules". Addition of vectorable thrust capability could also appreciably improve airship low-speed control and handling characteristics during landing and ground handling. Vectored-thrust capability was employed by the Goodyear Akron and Macon rigid airships in the early 30's and could be appreciably improved utilizing 1974 technology in conjunction with a developmental flight test program. Small amounts of aerodynamic lift and vectored thrust could also be utilized for control of buoyancy and trim. Water recovery from fuel combustion products have been successfully applied for reclaiming ballast as fuel is consumed and warrants further investigation for modern propulsion systems. Initial heating of the lifting gas or intermediate, enroute ballast recovery are also promising avenues to buoyancy control.

Problems associated with airship response to severe turbulence can be minimized utilizing modern weather forecasting, navigation, and avionics to avoid severe turbulence. Modern computerized structural analysis and design capabilities would result in airship designs as air worthy as any modern aircraft.

Load transfer of massive cargo loads is an area that can benefit by actual flight experience and research and development efforts. Cargo/ballast load transfer approaches have been defined utilizing both water and solid ballast containers that simultaneously transfer the cargo to the ground and the ballast to the airship. Other approaches that offer promising solutions to on ground handling and cargo transfer include small reversible bow and stern-mounted ducted propellers and internally suspended cargo transfer platforms free to rotate independently of the airship's response to ground winds. For many airship applications, cargo transfer actually presents no major problem not previously solved in airship operations. This area would require appreciable research and development only for the transfer of large indivisible loads characteristic of some modern airship missions.

Thus, none of the major technical problems or limitations often associated with airship applications to either a military or nonmilitary missions represent problems that have not been adequately solved in the past and could not be appreciably improved upon via modern technology. While some modern applications might require airships of unprecedented size - 20 million, 40 million, perhaps even 100 million cubic feet - compared with the 6. 5-million-cubic-foot Goodyear-built Akron and Macon, their development can be achieved by an orderly evolution from historical technology and experience.

The successful evolution will benefit significantly from the technology advancements of the last few decades and could be further enhanced by a research aircraft approach, not necessarily at full scale, aimed at investigations and improvements of airship technology and operations, particularly in the areas of low speed control, improved handling qualities, ground handling, cargo transfer, and advanced buoyancy control and ballast recovery systems.

ECONOMIC UNCERTAINTY

The fundamental problem that has deterred the revival of airship utilization is economic uncertainty. Research and development cost estimates for large rigid airships have ranged from zero dollars by Airfloat Transport Limited of England to half a billion dollars. Cost estimates of pressurized airships similar to these last employed by the Navy can also be misinterpreted. Historical cost data generally reflect extensive engineering and design efforts to meet rigid performance specifications and achieve significant technological advancements in performance capability. Sophisiticated military equipment, and airship design characteristics for its utilization, resulted in specialized design features and costs.

These uncertainties in the R&D costs and production costs for unknown production quantities directly affect the operating costs estimates via indirect operating cost charges to amortization, interest charges, insurance, fees, taxes, etc. Uncertainties in the ground facilities and personnel costs associated with performance of the many different mission applications further confuse operating cost estimates, which will ultimately determine the economic viability of airship applications.

INSTITUTIONAL UNCERTAINTIES AND CONSTRAINTS

The third problem area that will affect the development of modern airship transportation systems for commercial applications may be defined or broadly grouped under the heading of institutional constraints. These include government regulations, state regulations, economic regulations, and so on.

The Federal Aviation Act of 1958 specifically requires the safety regulation of airspace, air navigation facilities, aircraft, aircraft parts, airmen, carriers, and certain airports. Historically, aviation safety policies have been issued and delineated through safety regulations issued under those requirements through the regulatory process. Furthermore, economic regulation cover transport of mail, persons, and property. Policy guidance in the Federal Aviation Act is broad, primarily looking toward the development of a safe and economically sound air network. Twenty-nine states have promulgated safety regulations applicable to intrastate operations. The range from simple registration and investigation of accidents to elaborate assurances of compliance with federal regulations.

Some of the major questions which arise in considering commercial applications include - How will airships be certified by the FAA? How will the airships be tested and how long will it take to develop commercial operation and safety standards? Who will operate modern airship vehicles? What International and National regulations and agreements will apply? Questions such as these must be considered in the successful introduction of modern airship transportation systems. Availability of an operational vehicle to investigate LTA operations within the existing commercial aviation network could contribute appreciably to the early resolution of many of the institutional uncertainties.

PROPOSED FLIGHT RESEARCH PROGRAM

Many of the technical, economic and institutional uncertainties can be resolved by a LTA Flight Research Program. The program objective would be to conduct a flight research program using a LTA flight research vehicle with sufficient versatility to provide economical flight evaluation and "proof of concept" verification of: 1) Advanced Technology Applications and Theoretical LTA Analysis, Design and Performance Methodoloty, 2) Improved Operational Concepts, 3) Research On Promising Mission Applications. The program would also identify areas where advanced technology developments could significantly improve modern airship operations.

The major development areas of interest to the flight research vehicle program are presented below.

Low Speed Control and handling qualities of modern airships may be appreciably improved by utilization of vectorable thrust propulsion systems for vehicle control at speeds below the minimum speed required for aerodynamic stability. Promising vectorable propulsion concepts include - A) stern mounted propulsion with gimbal capability, B) fin mounted tractor propulsion, and C) tilt-rotor type propulsion. Canard control surfaces could also be employed to further improve aerodynamic control authority at low speeds. Each of the above concepts has been investigated either analytically, experimentally in wind tunnel programs or in modified full-scale vehicles and judged to be generally acceptable for improving low speed handling characteristics. The flight research program would further explore and develop these alternatives utilizing quantitative experimental flight test data correlated with theoretical predictions.

The research program objectives closely related to the area of low speed control and handling qualities include, A) Initial assessment of handling qualities and definition of safe operational envelope, B) verification of dynamic stability and control over the entire operational envelope, C) investigation of gust sensitivity, D) Investigation of gust and load alleviation systems, E) investigation of noise effects in hover or near hover mode of operations. Other technology evaluations could include A) improved ballonet/envelope pressure control systems, B) improved buoyancy management techniques, and C) high altitude cruise vehicles.

The second major area of investigation of the flight research vehicle program is improved operational concepts. Research projects would include, A) investigation of improved ground handling equipment and procedures, B) operation with large heaviness ratios, C) investigation of cargo/ballast transfer systems, D) in flight ballast recovery systems, D) investigation of terminal area guidance and navigation systems, and F) integration of LTA vehicles with existing aviation/air traffic control systems.

The third major area of investigation is research and evaluation of promising mission applications for modern LTA vehicles. These investigations would include the mission peculiar characteristics and requirements for the missions identified, as well as general requirements and characteristics of many promising missions. For example, investigations would include A) external carriage of bulky objects, B) passenger ingress/egress techniques, C) systems and techniques for transporting fluid cargos, and D) extremely low speed (hover or near hover) operations.

The high development costs which might be predicted or expected of the "first" airship or vehicle for the Flight Research Program can be avoided by utilizing an existing, flight-proven vehicle design.

FLIGHT RESEARCH VEHICLE

A "modernized" version of the Navy ZPG-3W pressurized airship is proposed for the Flight Research Vehicle.

The ZPG-3W was developed for the Navy by Goodyear Aerospace in the late 1950's The primary mission of this airship was all weather Airborne Early Warning (AEW) patrols of long endurance in open ocean areas at an altitude of 5,000 feet. The original ZPG-3W configuration is illustrated in Figure 1.

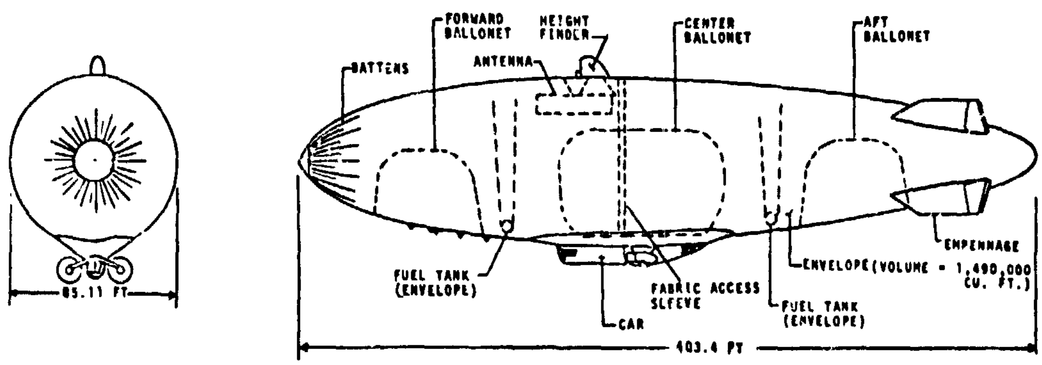

Figure 1
Original ZPG-3W Configuration

The ZPG-3W volume is 1,490,000 cubic feet. The distinguishing configuration features of the airship are twin engines mounted on outriggers which also function as a ram air intake scoop for the ballonets, an "X" tail for obtaining ground clearance, an internal antenna installation with a height finder and a tricycle landing gear for improved ground management. The engines are Wright Model R-182C-88 equipped with a cooling fan and a special gear box to obtain a lower propeller rpm.

The ballonets are connected by ducts from a plenum chamber for the egress of the air. The ballonet air is exhausted through pressure regulated "pop" valves. Air is supplied by electric blowers and ram air through ducts in the leading edge of the outriggers. The entire ballonet air system is automatic with manual override.

The battens are structurally designed to withstand the flight dynamic pressure and the mooring loads. The envelope which is constructed of two ply neoprene coated dacron fabric functions as a radome for the antenna. A vertical fabric shaft is installed for crew access to the antenna and height finded. The empennage and car are conventional airplane structures with the former fabric covered.

The interior of the car provides the pilot compartment, CIC compartment, ward room, galley, sleeping quarters and an aft equipment section. The latter section accommodated such items as tanks for fuel and ballast water, a crew relief station, hydraulic equipment, ballast provisions, APU, etc. Jettisonable fuel tanks are provided in the keel space below the floor for emergency ballast conditions.

The flight controls are similar to airplane arrangements in that they consist of a column and wheel. Rudder pedals are eliminated in lieu of directional control being obtained by actuating the wheel. Elevation is obtained by actuating the column in the conventional airplane manner. An autopilot and an automatic pressure system with manual overrides are provided. Demonstrated performance of the original ZPG-3W is presented in Table I.

Table I - Demonstrated ZPG-3W Performance

Operating Altitude	5,000 ft
Design Ceiling	10,000 ft
Maximum Speed	76 knots, EAS
Rate of Ascent	2,400 ft/min
Rate of Descent	1,200 ft/min
Endurance	75 hours with military equipment and 21 man crew
Gross Weight	93,485 (10,500 lbs heavy at takeoff)
Empty Weight	67,566
Envelope	33,115
Car	30,750
Empennage	3,701
Useful Load	25,919
Crew & Provisions	7,204
Fuel	19,712
Mission Equipment	(Included in Weight Empty)

A recent study has been completed by Goodyear Aerospace to define the performance potential of a "Modernized" ZPG-3W type vehicle suitable for use in the LTA Flight Research Program. The original design would be stripped of the AEW and other military mission equipment. Neoprene impregnated Kevlar with a strength to weight ratio twice that of dacron fabric would be used for the envelope material and the basic propulsion would consist of two GE T64-GE-10 or GE T64/P4C engines. This configuration would have the same outward appearance as the original ZPG-3W and a top speed of 100 knots. The performance characteristics of this LTA Flight Research Vehicle candidate is presented in Table II.

Further investigations are required to define the structural requirements of the car to accommodate the various propulsion system options to be investigated for low speed control improvements.

The proposed research vehicle would provide a flexible and economical research test bed which could be utilized for the LTA Flight Research Vehicle Program.

Table II - "Modernized" ZPG-3W LTA Research Vehicle Characteristics

Maximum Speed	100 knots
Gross Weight*	97,030**
Empty Weight	47,342
Envelope	17,018
Car	26,623
Empennage	3,701
Useful Load*	49,688

*10,500 lbs heavy
**3,000 ft pressure altitude, Kevlar fabric without stretch factor

SUMMARY

The renewed interest in modern airship vehicles is based on several well founded facts: 1) Airships are an environmentally desirable and energy efficient alternative to existing transportation modes, 2) airships have distinct advantages over existing transportation modes due to their unique operational capabilities, 3) Application of 1974 technology can significantly improve the capabilities of modern airships compared with vehicles of the past, and 4) because of the three facts above, many promising missions have been identified.

Three major areas must be investigated in order for the full potential of modern airships to be realized: technical limitations or uncertainties, institutional uncertainties and constraints, and economic uncertainties.

In the technical area, the successful revival of modern airship vehicles can be achieved by an evolutionary program based on airship technology of the past, upgraded to reflect the technology of today. With the possible exception of transfer of large indivisible cargos and incorporation of vectorable propulsion systems, technical problems do not exist that have not been solved in the past and could be significantly improved upon by the application, testing, and proving of equipment and operating techniques using 1974 technology.

The area of institutional constraints and uncertainties does not present any insurmountable problems but will require further investigation. Airship certification for commercial applications could be aided significantly by the availability of a research airship for actual flight-test programs.

Economic uncertainty is the major problem retarding the development and successful introduction of modern airship transportation systems. Cost uncertainties arise from unknown production quantities and unknown costs. These uncertainties in turn actually result from unknown market size (i.e., how many missions could airships cost effectively perform) and what characteristics (speed, payload, range, etc.) the airship should possess to perform these missions and the costs required to develop such a vehicle. The number of missions that airships can perform is uncertain because actual flight testing and operational investigations have not been conducted due to lack of a research or test bed airship. A research or test bed airship is not available because of the uncertainty in what size airship should be developed and the cost to develop such an airship.

One approach to eliminating the development cost/applications dilemma is through a Flight Research Program. The program would utilize a Research Airship, based on an existing ZPG-3W design, to serve as a flying test bed for evaluation of improved technological and operational approaches. Flight evaluation of a broad spectrum of mission applications would be performed.

RECOMMENDATIONS

Many of the applications being considered for LTA vehicles are practical and potentially economically viable. Unfortunately most of the applications taken alone do not justify the investment necessary to develop the required modern airship vehicle. Goodyear Aerospace believes that the country's military and civil interests would be best served by government support of an LTA Flight Research Program. The program would allow flight test evaluation of advanced technology applications and improved operational procedures as well as investigations of promising mission applications.

By utilizing a modernized version of the existing Navy ZPG-3W Airship, the Flight Research Program could be implemented at modest cost within two to three years.

In conclusion, Goodyear Aerospace is confident that the field of Lighter Than Air is an untapped resource with significant potential for current mission applications.

The sooner a practical, success oriented hardware program can be implemented, the sooner the payoff will occur for our nation.