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A SEMIBUOYANT VEHICLE FOR GENERAL TRANSPORTATION MISSIONS

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ABSTRACT: The concept of small, semibuoyant, lifting-body airships is discussed. Estimates of important performance characteristics are made and compared with other flight vehicle systems.

INTRODUCTION

This paper discusses the concept of a small, semibuoyant, lifting-body airship with either a disposable or nondisposable buoyant fluid. Estimations of fuel consumption, payload capability, power requirements and productivity are made and compared to other flight systems. Comparisons are made on the basis of equal cost vehicles. The assumption is made that, to a first-order approximation, the costs of developing, procuring, and operating a commercial air transport vehicle are proportional to vehicle empty weight. It must be noted that no historical cost data exist for the lifting-body airship and therefore these comparisons must be considered preliminary.

VEHICLE CONFIGURATION

The vehicle configuration that was studied is shown in Figure 1. It is the NASA M2/F2 space reentry vehicle, which has been flight-tested in a gliding mode and

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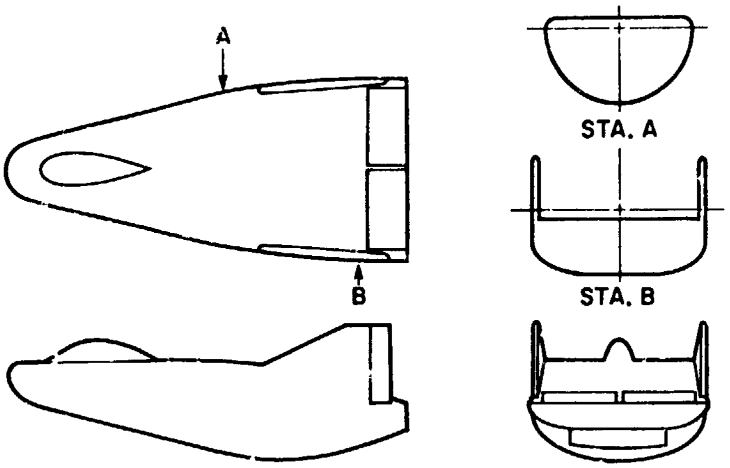

Figure 1
M2/F2 Lifting Body

extensively tested in wind tunnels. It was chosen because of the extensive amount of aerodynamic data available, but as an airship it may be inferior to a different configuration optimized for that purpose.

VEHICLE SIZE

The vehicle that has been studied most thoroughly has a length of 200 ft and a volume of 373,000 ft^3. This is quite small relative to airships in general and would seem to contradict the widespread belief that airships become more efficient as their sizes increase. However, this belief is not borne out in Figure 2, which shows data for 75% of all commercial rigid and nonrigid airships ever built. These data indicate no change in structural efficiency with size for more than an order-of-magnitude size change with nonrigid airships, and almost an order-of-magnitude size change with rigid airships. The dashed lines in this figure indicate the three-halves scaling law. Therefore, the penalty associated with small vehicles does not appear to be real. This is important to the small vehicle concept because the smaller capital investment costs, compared to those of large dirigible concepts, allows a broad range of operational experience to be obtained without excessively high economic risk.

BUOYANT FLUID

The choice of a disposable or nondisposable buoyant fluid must be made on the basis of the vehicle operation at cruise. If a vehicle must fly around storms instead of over them, and around mountains instead of over them, then severe limits are placed on scheduling and mission flexibility, especially at shorter ranges. However, when using a costly nondisposable buoyant fluid such as helium, introducing altitude capability results in reduced payload since only a fraction of the vehicle volume can be filled with helium at takeoff. The variation of useful lift as a function of altitude capability is shown in Figure 3. The lower curve corresponds to inert weight fractions of dirigibles of the 1930s, while the upper curve represents possible weight ratios that might be achieved with current or future technology. The severe payload reduction is apparent, as appreciable altitude capability is built into such airships.

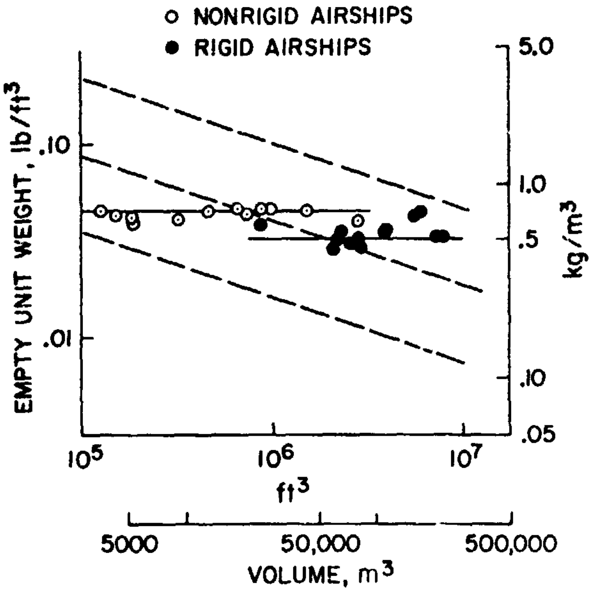

Figure 2
Empirical Weight Characteristics of Dirigibles

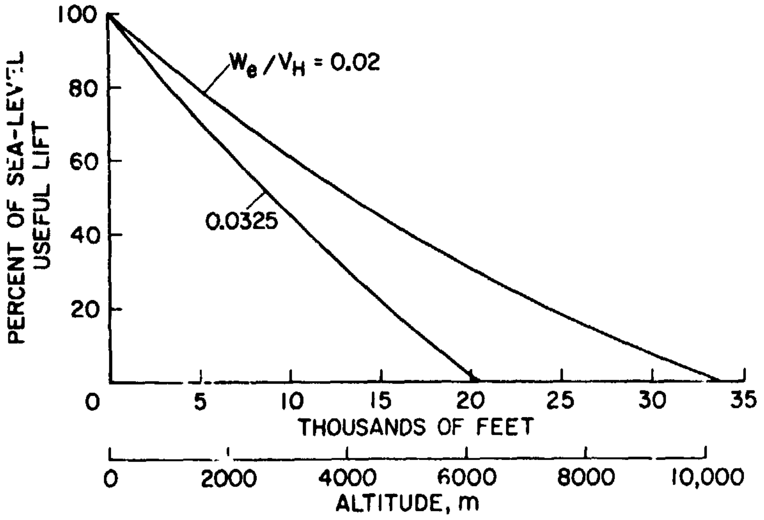

Figure 3
Lift Variation with Design Maximum Altitude

For a disposable fluid such as hot air, the unit lift at reasonable temperatures is less than helium, but regardless of altitude capability the vehicle is completely filled with fluid at takeoff. Therefore, if air is heated to a temperature at which its unit lift is half that of helium, and if an altitude capability is desired that limits the helium volume at sea level to one-half the vehicle volume, then takeoff lift for the two fluids is equal. Data are presented in Figure 4 showing the required temperature for hot air at which it has equal takeoff capability. It is obvious that if appreciable altitude capabilities are required, hot air at feasible temperatures can be equal or superior to helium in its lifting capacity. Also shown

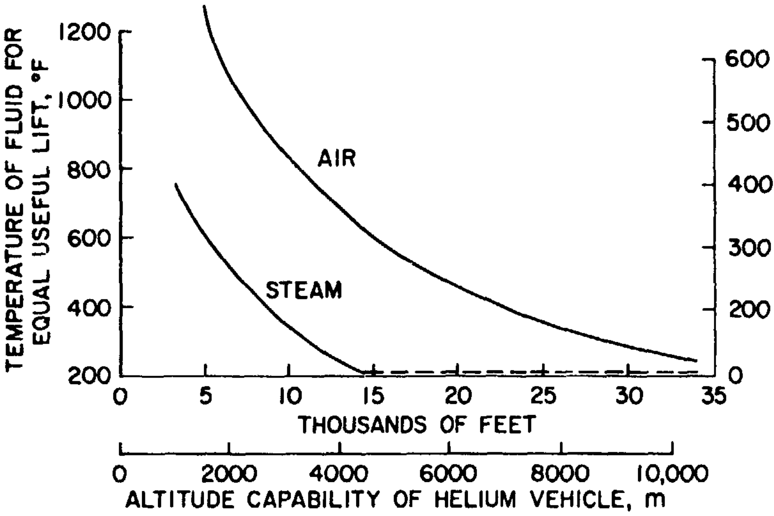

Figure 4
Temperature of Buoyant Fluid for Equal Takeoff Lift

in Figure 4 is the potential value of superheated steam as a buoyant fluid. At 600° F steam has greater lifting capacity than helium if altitude capabilities greater than 5000 ft are required.

It should be noted that generally the maintenance of heat in the fluid following takeoff might not be desirable, thus causing a reduction in buoyant lift at cruise. Furthermore, even if fluid temperature is maintained there is an appreciable reduction in buoyant lift at high cruise altitudes. This requires that additional lift be supplied aerodynamically during cruise, and since conventional airship configurations are very inefficient, aerodynamically, they are unsuited to the use of heated disposable fluids. Lifting-body configurations are suitable to such use since their aerodynamic lift-drag ratios can be as much as two-thirds that of conventional aircraft. The aerodynamic advantage of lifting-body ships may be somewhat offset by the structural weight penalty associated with their noncircular cross section.

FUEL CONSERVATION

Airships are considered desirable because of their good conservation and pollution-free characteristics. The best measure of these characteristics is the quantity of fuel used to transport a given payload through a given distance. In Figure 5, the proposed vehicle is compared to a number of other approximately equal cost air transport vehicles in terms of pounds of fuel per ton-mile of payload transported. The identification key for these vehicles is shown in Table I. It is apparent that if sufficiently low flight speeds are used, conventional dirigibles are appreciably superior in this respect. This is of questionable value since the speed range for such superiority is in the range where surface transportation systems can be used, and surface transportation systems should have lower fuel consumption. For speeds higher than practical ground transportation limits, the proposed hybrids are far superior to all other vehicles. Furthermore, while the hot-air vehicles are not quite as good as the helium vehicles, the difference might be easily outweighed by other performance characteristics.

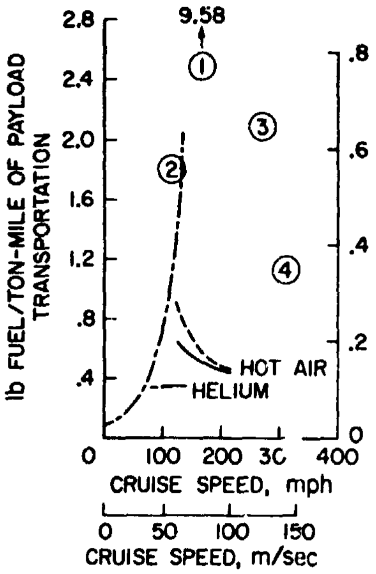

Figure 5
Fuel Consumption

TABLE I

Key for Figures 5 through 8

Symbol		Vehicle type
	HELICOPTER	
1		Boeing-Vertol M114
2		Siskorsky S-64E
	TRANSPORT AIRCRAFT	
3		Fairchild-Hiller FH-227D
4		G.D. Convair 600
	HYBRIDS	
- - - -		300° F Hot Air
———		600° F Hot Air
- —— -	DIRIGIBLE	

PAYLOAD

Another advantage commonly attributed to conventional dirigibles is an extremely high payload capacity. However, such payloads are a result of assuming extremely large vehicles. If approximately equal cost vehicles are again assumed, the results in Figure 6 are obtained. Here, payload for conventional airships is at best about equal to most Heavier Than Air vehicles. The data also indicate that, at higher cruise speeds, the payload capacity of the hybrid vehicles is superior to all other vehicles.

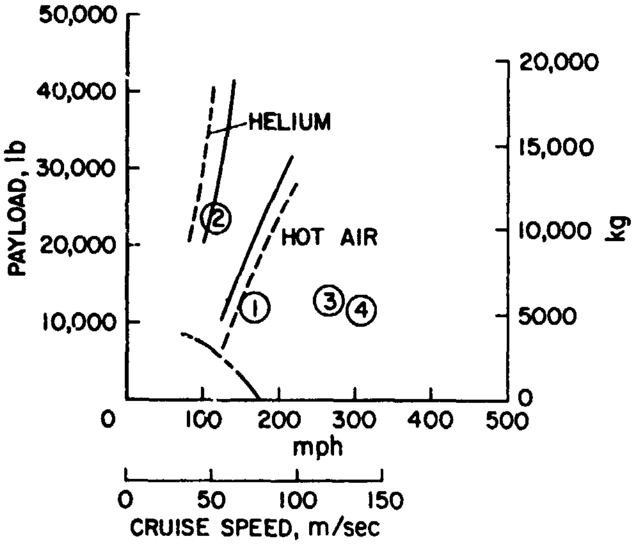

Figure 6
Payload Capability

POWER REQUIREMENTS

Since the hybrids being considered in these comparisons have a buoyant lift equal to only about 30% of their gross weight, 70% of the gross weight is lifted on takeoff by the propulsive system acting as a helicopter. One might conclude from this that power requirements for such vehicles are excessive. A comparison of the required horsepower per ton of payload (see Figure 7) shows that the power requirements for hybrids are less than or about equal to those for Heavier Than Air vehicles.

PRODUCTIVITY

While fuel conservation, pollution, payload capability, and power requirements have some significance generally, if economic factors or commercial viability are considered, the important factor is the quantity of payload transported over some distance in a given time. This quantity, called productivity, is shown in Figure 8. Herein lies the basic reason for many people resisting the return of airships. Heavier Than Air vehicles with about the same capital investment costs carry three to four times as much payload through a given distance in an hour, and thus have three to four times as much revenues. With such a large deficiency in productivity, dirigibles cannot hope to compete commercially with HTA vehicles in any mission that HTA vehicles can perform. However, the proposed hybrids have about twice the productivity of any other vehicle. Thus, their ratio of revenue to capital investment allows them to compete with HTA vehicles in conventional air transportation missions.

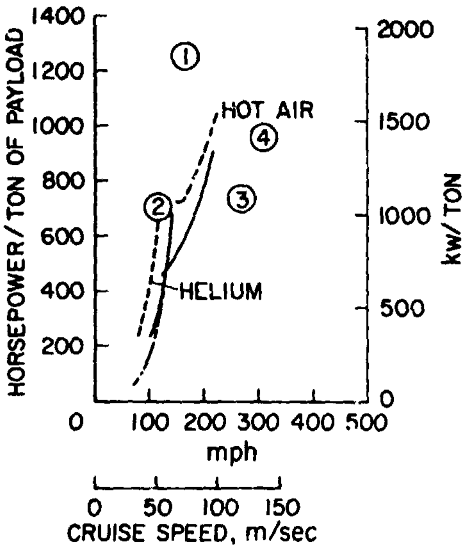

Figure 7
Power Requirements

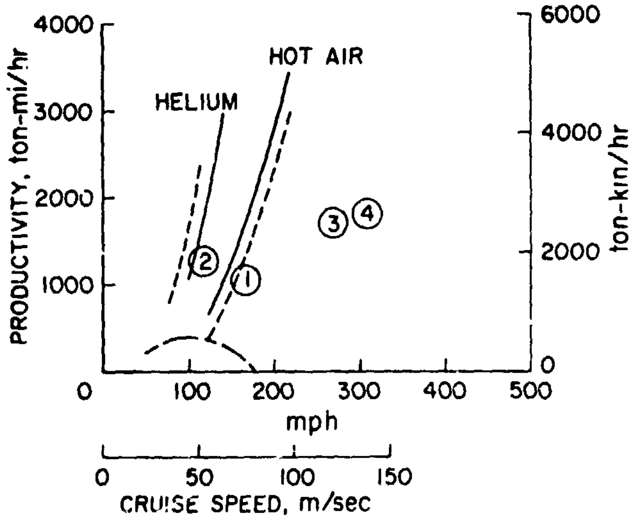

Figure 8
Productivity

In addition, their VTOL capability permits them to perform missions not possible for fixed-wing aircraft.

SPECIAL CONSIDERATIONS

Some other characteristics of LTA vehicles that are of significance in their evaluation are airfield requirements, unique missions, safety, and ride quality. Airship proponents claim that a dirigible, unlike commercial aircraft, only requires a level clearing with a mooring most at the center. One should first consider the area required. With reasonable safety requirements, the land area required for a 1000-ft-long dirigible is equal to the area of eight landing strips, 10,000 ft long. Furthermore, the eight landing strips will handle about 100 aircraft per hour, while only one dirigible can occupy this area during its time on the ground. Secondly, a simple cleared area is not sufficient since it must have a base to support cargo and cargo handling vehicles and any required ballast. Finally, except for the landing strips, commercial airport facilities are required for the handling of passengers and cargo, and there is no reason to suppose that such facilities would not also be required for passengers and cargo being transported by airship. However, reduced airport facilities might easily be factual where semibuoyant vehicles weighing three to four times as much as equal sized dirigibles are used. Such vehicles would not require mooring masts and would taxi from landing to loading area, leaving the former for use by other vehicles, as is the case with aircraft.

DEVELOPMENT FOR SPECIAL PURPOSE

Since conventional airships cannot compete economically with other commercial transportation systems, proposals have been made for their use in unique missions such as transporting power generators or transformers from factory to remotely located dam sites. While such proposals represent interesting solutions to some difficult transportation problems, it is difficult to support them if one examines capital investment costs and operating problems. Furthermore, it is difficult to envision enough unique missions to support any appreciable airship industry.

On the other hand, if conventional or hybrid airships were developed for some commercial purpose, they might have great utility in emergency situations as a rescue vehicle. In conditions generated by fire, flood, hurricane, or earthquake, one of the most severe problems is the loss of transportation routes. Frequently, the only way to provide rescue services when they are most needed is to use a VTOL air transporter with a high payload capacity. If airships are economically competitive and can be developed for conventional missions, then their availability during emergencies would be an additional value.

SAFETY

Probably the most significant advantage of LTA vehicles over HTA vehicles is their superior safety characteristics, and hybrid vehicles appear to be safer even than conventional airships. The hybrid, with its greater operational flexibility, can avoid the severe weather conditions that caused previous airchips to come to grief. Even with complete power failure, impact speeds would be low. Without any great expense, completely safe systems could be developed for such impact speeds.

RIDE QUALITY

Due to the square cube law, motion stability and ride comfort improve as size increases. It was reported that the Hindenburg, with $7\text{-}1/2 \times 10^6$ ft^3 volume, provided a more comfortable ride than any other transportation system in existence. It should not be concluded, though, that the proposed hybrids will have undesirable characteristics because they are small. The reason for increased ride comfort at larger sizes is the higher ratio of inertial mass to surface area. Since hybrids have three to four times the inertial mass of dirigibles, with the same surface area, such vehicles should have comparable ride quality with smaller sizes.

CONCLUSIONS

If the foregoing comparisons are valid, and hybrids will be economically competitive with HTA vehicles, then it is no longer necessary to invent unique or novel missions to justify their development. If the comparisons are correct, then such vehicles will be immediately useful in the broad spectrum of missions shown in Table II.

These estimates of general aviation aircraft indicate the use of 149,755 fixed-wing aircraft and 2,550 helicopters in 1975. If hybrids are economically superior, then most of the missions shown would be more effectively performed by them.

TABLE II

Predicted General Aviation Aircraft in 1975

Use	Number of aircraft		Comments
	Fixed wing	Rotary wing	
Aerial application	6,200	350	Crop dusting, seeding and fertilizing, restocking fish, cloud seeding, etc.
Industrial/ special use	1,900	400	Pipeline and highway patrolling, aerial surveying, emergency rescue, advertising, photography, helicopter hoist, firefighting, etc.
Air-taxi	12,100	900	Scheduled air-taxi, nonscheduled air-taxi, charter services
Business	31,250	900	Motives for justifying the acquisition of corporate aircraft are: Save valuable executive time Make own schedules Reliability, safety Reach off-airline cities Prestige
Personal	88,450		
Instructional	6,855		
Other uses	3,855		
Totals	149,755	2,550	