THE ULTIMATE VEHICLE

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It is good to be in England where as an air cushion craft enthusiast I do not feel like a foreigner. Though research on the air cushion principle goes back many years, the public has been aware of this kind of craft only a little over five years. Broad public knowledge of this new transportation medium is largely due to the British Hovercraft work. England alone has done a businesslike job of hardware building and field testing. The English believe in the Hovercraft as a new transportation modality with a great future.

I feel that the ground effect machine is the most important vehicle so far devised. I believe that the air cushion craft in all its variations is the ultimate vehicle. The application of proximity effect will ultimately prove to be far more significant than the wheel. The air cushion vehicle industry will ultimately be greater than the combined automotive, boat and aircraft industries. The air lubrication principle will be ubiquitous in transportation large and small, heavy and light, fast and slow, free roving and road restricted, land and water, arctic and tropical, public and private.

The air cushion industry will ultimately employ many people and do much needed work in transporting goods and people quickly and economically allover the world regardless of changes in conditions and weather.

We often think of the developing nations and their need for dependable vehicles in changing conditions; but a 12 inch snow in even the most advanced countries paralyzes all transportation except good air cushion vehicles , The need for air cushion craft is indeed world wide.

The attributes of a fully developed, mass-produced, "de-bugged" air cushion vehicle are impressive. No single vehicle of this character exists now, but should be hoped for and worked for in design.

The air cushion craft is essentially a simple vehicle with few moving parts and is therefore very reliable, very durable and cheap to purchase, maintain and operate. It can be operated safely by persons with minimal training and traverses any unobstructed terrain at high speed.

The ACV requires no roads or preparation, but if given lightly prepared specially graded roads, high speed guidance is inherent, and full automation of travel in a system becomes economically feasible.

The proximity effect is most obviously useful in vehicular transportation, but it is also important in certain other devices for agriculture and industry.

Air cushion vehicles fall into six categories:

1. Water vehicles with little amphibious capability, such as the Denny Hoverbus, Aquagem, the Captive Air Bubble Craft and the sidewall craft.
2. Amphibious vehicles such as the SRN-1, -2, -3, -5; Bell Carabao; Britten Norman Cushioncraft; Vickers VA-2, -3; Bell Hydroskimmer-1,

Arcopter GEM-2, -3; Aeromobiles 200-1, -2.

3. The roadable amphibious vehicles such as the Vickers Hovertruck, Vickers VA-2, -3, Bell Carabao, Arcopter GEM-3.

4. The flyable amphibious vehicles such as the Kaario ram wing vehicle, Warner Pressure Plane, and Arcopter GEM-2 and -3.

5. Special road vehicle adaptations including guidance, such as the Ford Levapad rail car, Cockerell's Hovertrain, and Bertelsen Aeroduct vehicles.

6. Track layers such as the Chance Vought Plenum Air Track and the Bertelsen Airtrack.

The non-vehicular proximity effect devices include the Airslide method of freight car unloading, air supported pallet loading systems such as Douglas or Bell Aircraft systems, certain air lubricated materials handling systems, and the Bertelsen Aeroplow.

The Aeroplow reverses the operation. The air, instead of lubricating the passage of the vehicle over the ground, lubricates the passage of the ground over the vehicle. The effect is to reduce greatly the power required to plow, to increase speed of plowing, and to allow plowing in wetter, more adverse conditions. We are able to pull five plow bottoms with a three-bottom tractor, using air lubrication to eliminate friction.

Design Philosophy

The biplane was the principal aircraft type built for 30 years after the Kitty Hawk biplane, not because it was better, but because it was successful and accepted. We must not get into similar fixations in ground effect design.

I feel that we cannot and must not be preoccupied with any one type base, such as peripheral jet. Freedom of mind in the design of these air cushion craft is all-important to produce the ultimate vehicle and to provide ground effect devices for all purposes.

In the air cushion craft we have the simplest powered vehicle. It must be kept that way, uncluttered by design complexities and free of excess weight.

My goal is to develop the inexpensive single motor fan vehicle for four passengers capable of traversing all unobstructed terrain in all weather, all seasons, all conditions and all climates.

It has proved to be far more difficult to provide lift and thrust from a single power source than the mere addition of propulsive units to the hovering vehicle. But the reward for accomplishing integrated lift-propulsion is the practical, salable, capable, successful air cushion vehicle. It will be well worth the extended research needed. I feel that integrated lift and propulsion is feasible in both large and small craft and has definite advantages.

The lift-propulsion integrated air cushion vehicle has a lower center of gravity and lower, cleaner silhouette than craft with added propulsive units. All fan and propeller blades are inherently guarded against personnel and foreign material, being internally contained. Noise level in shrouded buried fans is lower than exposed fans. Either maximum lift or maximum thrust may be obtained by diverting total power for one or the other. Lower cost and lighter weight is possible in the integrated system in large or small craft with less installed power and transmission weight. Small vehicles may be designed with an irreducible minimum of a direct drive single engine, single fan system. The lift-thrust integrated vehicle needs no troublesome weathercocking vertical tail surface a since yaw control comes from internal flow deflection.

We have built a total of nine full scale vehicles, of which six are vertical shaft peripheral jet Aeromobile types and three arc horizontal shaft ram wing Arcopter GEM types. We have extensively tested these vehicles on various types of terrain and in year-round weather and have come closer to the optimum design.

The first controllable man-carrying flight was in a four foot. square peripheral jet Aeromobile of 35 H.P. Four more peripheral jet Aeromobiles followed, of greater size and power: No. 2), the Aeromobile 35; No. 3), the Aeromobile 72; No. 4), the Aeromobile 200-1; No. 5), the Aeromobile 200-2. All of these were propelled by tilting and thrust deflection which proved to be inadequate to obtain high speed, to resist high winds and to climb steep grades. The knife-like peripheral jet stream was excessively erosive and dirty in spray and dust. Experience proved it unnecessary to achieve a hover height sufficient to clear the highest obstacle encountered because the buoyance of the craft allowed "springing" over higher points and the flexible flaps would simply flip over projections. It was not necessary as originally expected to have high clearance by having the craft hover high enough to see daylight under it at all times. This is a sore point, because the news men consistently demanded to see it hover very high, and would not accept mobility, amphibious travel, frictionlessness and mere transportation as a substitute!

I was eager to obtain higher speeds and to control end make use of the aerodynamic forces generated in rapid transition to increase ground clearance. It was necessary also to decrease internal drag by straight through ducting.

Using horizontal fan shaft, over and under airfoil bathing with propeller slipstream and the flexible flap "soft bottom" technique, three Arcopter GEM vehicles have been built and tested. The first ram wing vehicle, the Arcopter GEM-1 (No. 6) was a 65 H.P. one place thick wing with side wall end plates flown in May 1961. It pointed up our center of lift control problems and led to the design of the Arcopter GEM-2 (No. 7) with greater length and area, two place, 115 H.P., first flown in August, 1961.

The Arcopter GEM-2 after much modification attained 75 m. p. h. speed; negotiated steep grades and rough ground; and was all-weather capable. The Arcopter GEM-2 was the first ground effect vehicle to cross the Mississippi, and this was done over ice, ice floe and open water alternately in January 1962.

Several features were obvious after testing Arcopter GEM-2, and we attempted to incorporate them into Arcopter GEM-3. A need for true roadability on wheels was obvious. It was as ridiculous to use the air cushion on dry paved roads as to drive a car in deep mud or open water. Where highways exist and are open, wheels are best in control, stability, drift resistance, and braking. Reverse thrust was needed for braking the Arcopter GEM-2 at high speed on ice and snow, and in descending slopes. A reversible pitch propeller with rearward opening flap in the lift chamber was provided in the Arcopter GEM-3 design.

The Arcopter GEM-3 (No. 8) has a 180 H.P. Lycoming engine, and four steerable and retractable wheels with brakes. The Arcopter GEM-3 has not been fully evaluated in flight, but its roadable qualities are well known. It is propelled on wheels by propeller thrust, which on roads and in town is very dirty. It takes about half throttle or more to begin rolling from a stop, which blasts cars behind it with dust; and in town its passage cleans out the leaves from gutters and is generally unpleasant. I concluded that wheels are essential and powered wheels are highly desirable on roads.

The Aeromobile 250 was our ninth vehicle and was our first dual engine machine with two vertical shaft 65 H.P. engines with two direct drive fans. This machine was built for Universal Pictures Co., Inc., as a "magic carpet" to publicize the movie, "The Brass Bottle." It was designed as a showpiece only, like the Aeromobile 200-2 for the United States Department of Commerce Office of International Trade Fairs. The Aeromobile 250 was taken on an 18,000 mile tour of the United States and was demonstrated in over 70 cities between February and May of this year.

Aside from problems of specific vehicle design which we are attempting to eliminate in successive machines, there arc chronic problems in all of them. Every machine we have built is far too heavy and much too costly. The design must become more settled before weight and cost studies can be made and lighter, cheaper vehicles turned out.

The utter simplicity of a direct drive single engine-fan system installed in an optimal lift chamber should produce a "Model T" air cushion vehicle of highest performance and lowest cost. To live up to and fulfill its promise to mankind, the air cushion vehicle must be efficient and available. In design terms this translates into light weight, low price and high capability.

I cannot at this moment say we have accomplished the ideal of lift propulsion integrated inexpensive craft, but I *can* say that we are now in sight of it.

The Future

Our common problem in the air cushion craft industry is the education of the customer for acceptance of these vehicles, both personal and public. Public acceptance awaits the development of really good, economical machines. Demonstration of both performance in the field and low cost with easy operation must come before wide sales. Considerable more capital outlay will be necessary by far sighted governments, industries or private individuals to arrive at optimum vehicles for mass production and world wide sales. The total investment made to date in air cushion vehicles is insignificant compared with the potential value of the concept to mankind.

If I say nothing else in this paper, let me say to the people working in ground of research, be liberal, free and flexible with design to consider all types of lifting systems; and to the people outside the field of ground effect research, be liberal, generous and open-minded in investment, purchase and promotion of our vehicles and services. The future of this field is extremely bright; the only doubt lies in how soon the maximum benefit from air cushion craft can be felt by everyone, everywhere.