THE AIR CUSHION VEHICLE IN A MASS TRANSIT SYSTEM

William R. Bertelsen
Director of Research

BERTELSEN, INC.
113 Commercial Street
Neponset,
Illinois 61345

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Introduction

The members of the Canadian Aeronautics and Space Institute are perhaps more aware of the reality and potential of air cushion vehicles than any comparable group. Its members have been kept informed of the progress of air cushion transport ever since the early flights of the British Hovercraft and the American Aeromobile in the 1950's. The C A.S.I. knows that these machines are actual, real, existing hardware, with the Hovercraft plying the Channel, the 15th Aeromobile under construction, and ACVs operational in Canada.

After at least a decade of intense concern about transportation, with enormous expenditures for research and pilot projects, it is obvious that no possible combination of conventional vehicles can accommodate the demands of 20th century population, much less meet those demands without worsening pollution and depletion of energy sources.

A curious reaction has set in. On the one hand, there is a mood of renunciation, a feeling that people should give up wanting what industry and government do not know how to provide. In a spirit of self-denial more suited to the cloister than the research laboratory, the public is supposed to resign itself to disjointed interfaces and makeshift mass transport between a few densely populated areas. People are exhorted to relinquish their perfectly understandable desire to go where they want, when they want, in the company - or solitude - they want.

A counter-reaction to this stoical, negative surrender is equally unrealistic. It is an escape to that dreamy Never-Never Land of science fiction gadgetry that no doubt could be perfected some day, but for the present - and even for the future - offers at best only a slight improvement of the mass transit systems with all the disadvantages that mass anything implies, whether mass transport or barracks or mess halls.
It is the business of the inventor to innovate. He differs from the visionary in that he manipulates real things which can be combined to work in new ways for useful purposes. The following proposal describes how the properties of air cushion vehicles can be exploited with existing technological equipment to provide a new, better, practical system of transportation.

Attributes of the ACV

In the 20 years air cushion vehicles have existed, they have achieved too little utility and only limited use. Some of the reasons for the slow integration of the ACV into the transportation spectrum are found in the problems of the vehicle itself. What is wrong with the ACV?

Fig. 1: Aeromobile #3 in 1959 on a road

Several problematic attributes are:

1. Yaw instability allowing wide swinging of the craft in flight, demanding constant pilot attention and correction unless a vertical tail is installed which gives even greater problems of weather cocking, gust reaction, rolling moments, etc.
2. Low propulsive force, high cost of that force in terms of power and structure through air propulsion at low speed which limits grade climbing.
3. Slope sliding: The ACV slides inexorably downhill and down wind, off the crown of a road into the ditch because of its frictionlessness. (It is at home in the ditch).
4. Dust and spray throwing in certain conditions which makes it objectionable.
5. Noisy operation: The minimum power required to rise to cushion height and maintain cushion pressure is much more than an idling motor car or boat which are self-sustaining, and the ACV therefore seems noisy by comparison even if all noise suppression is accomplished.

But the ACV also has some redeeming features, such as:

1. Frictionlessness: On a smooth surface, very little ground contact or drag is detectable.
2. High speed: All aircraft speeds are theoretically possible for the ACV.
3. Very soft ride: A self-damping, deep cushion suspension is very comfortable.
4. Heavy load-carrying capacity for lifting anything from letters or parcels to people and freight.
5. Amphibious capability which is unaffected by adverse weather on any terrain.

Given this set of attributes, I have designed a transportation system to exploit both the "good" and "bad" features of the ACV. I call it the Aeromobile-Aeroduct System of High Speed Mass Transportation. By taking this frictionless, yaw-unstable, weakly propulsive, soft-riding, slope-sliding, load-carrying, dusty, amphibious, noisy craft and adapting it to fit a semi-circular groove or circular tube, it becomes an element in a highly efficient, guided transit system.

Because it is frictionless, it slides down slopes and gravitates to the lowest point and stays there. It is confined to the bottom of the "ditch." Its yaw instability then vanishes, and it is locked into longitudinal orientation with the groove. The low propulsive force is now sufficient to drive it at high speed down this smooth gutter carrying a load very gently and cushioned and damped on many inches of air. It stirs no dust or spray unless it rains or snows, in which case the dusty amphibian ACV both passes over the water and snow, and blows them clear of the right of way. The noise can be greatly reduced with carefully designed ducted fans and the craft put into deep grooves or tubes where noise is further attenuated.

Fig. 2: The Aeromoble 13 on cushion

The Aeromobile 13 is a very simple vehicle with two moving parts, the two gimbal fans. The hull is fibreglass molding, empty weight less than 2,000 pounds with flotation, gross weight 3,000 pounds, base pressure 25 pounds per square foot.

The gimbals provide lift, propulsion and control; either gimbal alone can lift, propel and control the craft on level ground (or in a groove.) With fans neutral as shown, 100% of the power goes to lift. By tilting the gimbals, 100% of available thrust force (approximately 75% of power) can be applied in any of 360° instantly and varied for propulsion, braking or steering. With a gimbal fan at each end of the craft, complete control is obtained so that sideways motion of the craft, pivoting around CG, and side hill negotiations are possible. The gimbals are mounted with freedom in two degrees fore-aft and lateral tilt capability. The engines are 125 HP Mercury outboards geared to a 36" fan.

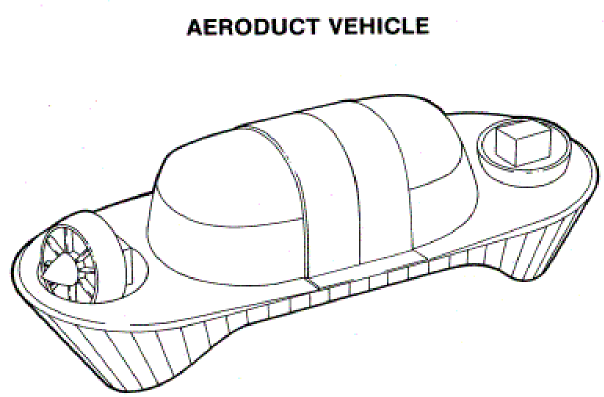

Fig. 3: The proposed Aeroduct vehicle in perspective

This is an adaptation of the basic A-13 craft to an 8-foot wide U-shaped groove with deep fore and aft skirts and shallow side skirts. One gimbal is shown in lift and propulsion angle, the other in lift only position. It is the basic vehicle of the transit system, a very light weight, simple, reliable machine.

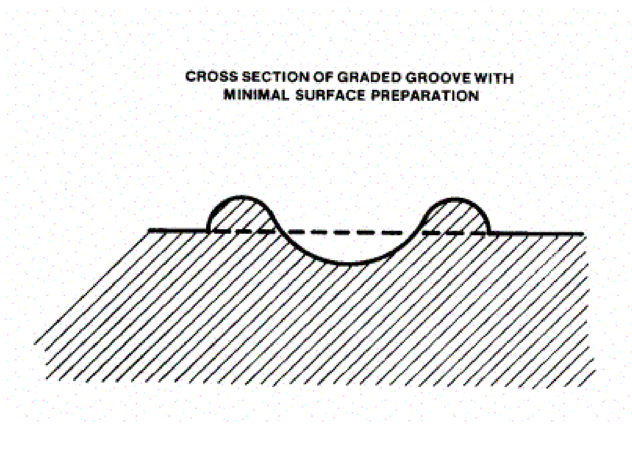

Fig. 4: A cross-section of a graded groove.

This is a cross-section of groove, showing how dirt can be graded into a groove. Preparation of the surface is minimal, such as soil cement stabilization. It only has to resist wind and water erosion, not vehicular contact, abrasion, traction, vibration and braking.

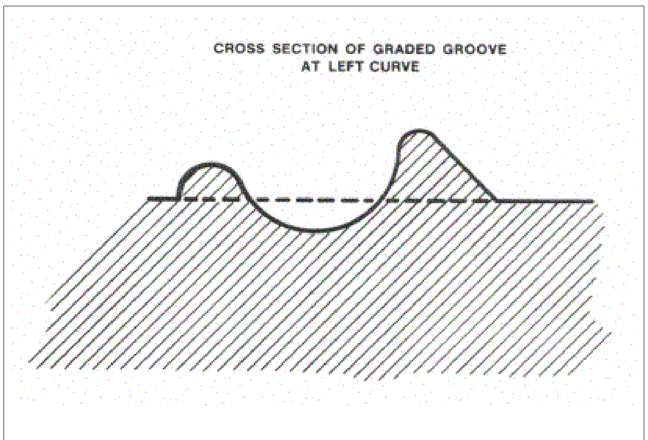

Fig. 5: Cross section of groove at a curve with graded banked curve.

This is a weather proof ROW. Ice and rain do not trouble the dust and spray producing ACV. Snow will not accumulate with traffic continually passing and blowing it clear. Guidance in this deep groove is superior to the railroad. Visibility is not needed for electronically controlled craft. These are one-way ROW's, and to return, the craft will make a full circle of the city or turn off to an opposite bound ROW.

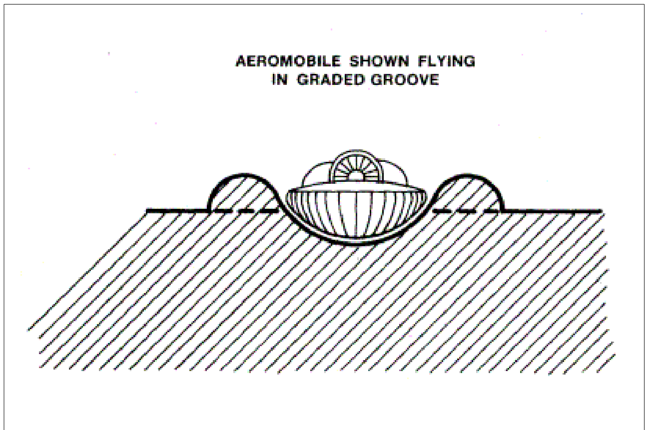

Fig. 6: Aeromobile in straight away groove.

Aeromobile shown (below) in a groove at a curve; the craft centrifugates up the wall of the groove or tube, making a comfortable increase in "G" force through the "vertical," relative to passengers' bodies and without lateral accelerations experienced on trains.

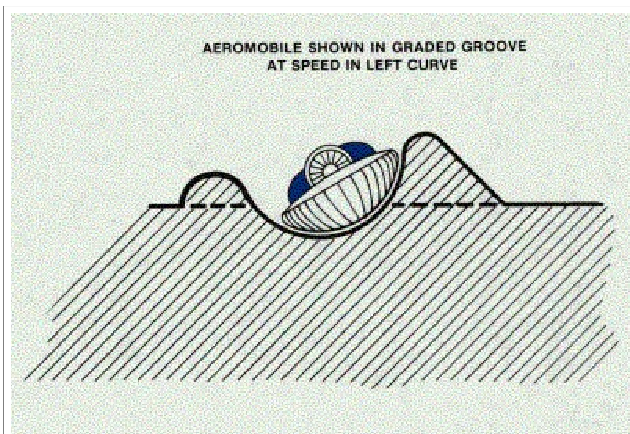

Fig. 7: Aeromobile banked at a curve.

Surface ROWs are becoming more and more costly and congested, and there is unlimited space below the surface. A circular tunnel is cheapest to bore, and an ACV tunnel requires no further preparation than the structures, which certainly makes it the least costly tunneled system. This shows an 8-foot diameter tube, much smaller than auto tunnels.

Fig. 8: Aeromobile in a tube.

The Aeromobile, if undeflected by side force from its gimbal fans, will pass through the "Y" in a straightaway. If forced to the left by fan reaction, it will take the left leg of the "Y". The merging intersection would be the same structure turned 180^0

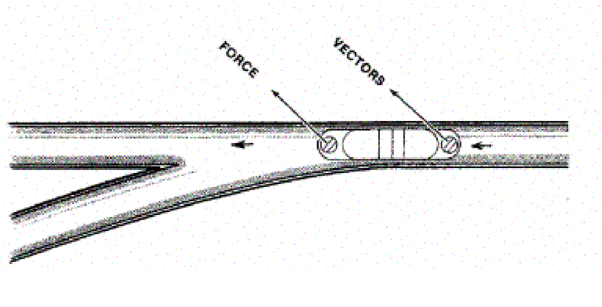

Fig. 9: Top view of existing “Y” intersection.

There are no switches or mechanisms to act or fail at the multiplicity of intersections, no costly installations or maintenance. An inert, smooth-walled, elongated groove or tubular fork of any structural material will safely pass millions of high-speed Aeromobiles year after year.

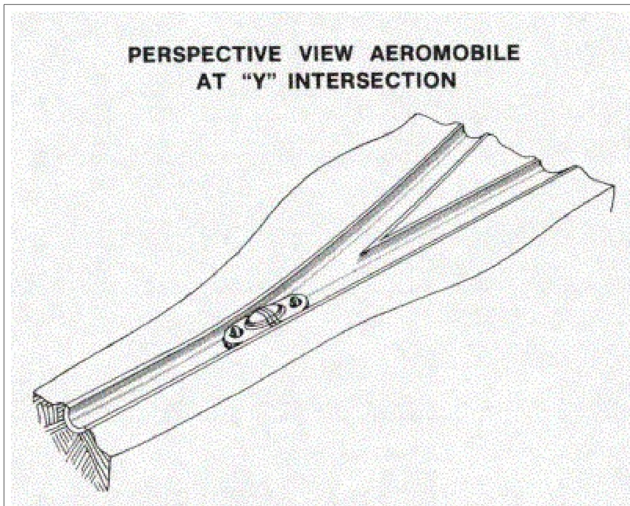

Fig. 10: Perspective view of exiting "Y" intersection

The land over which the Aeroduct system travels is not all level, and the ACV, like the railroad, has a maximum grade-climbing capacity. Unlike the train, the ACV has a soft skirt capable of accepting certain discrepancies in the terrain. The thing the ACV does best is to raise weight vertically on its cushion. The thing it does worst is to push that weight up a grade. But if we have the Aeromobile plane over a step in the groove, it will raise its weight gracefully again to full cushion height. The tread of the step may even be inclined down hill, so that the vehicle is actually going down hill while climbing by cushion. By this method the ACV becomes a truly "all-terrain" vehicle and can actually climb mountains. Down hill will no longer be a frictionless toboggan run.

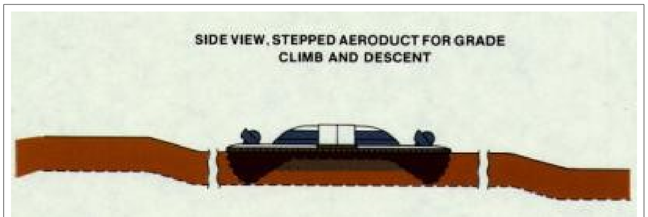

Fig. 11: Side view of stepped Aeroduct

The railroads whose routes go exactly where people want to go--to the center of cities--are falling into abandonment. Rail ROW's, either abandoned or in service, can be readily adapted for ACVs at less cost than almost any other modification for transport.

It is not illustrated, but the median strip of Interstate and other highways is available for groove travel at very low cost of installation, since the basic contour and slope grading is done, and only groove grading and surfacing plus access ramps remain to be done.

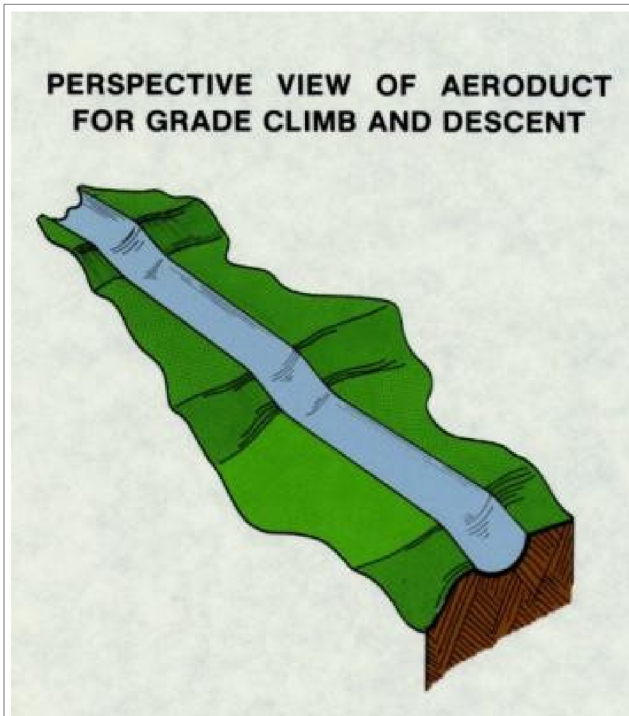

Fig. 12: Perspective of stepped Aeroduct

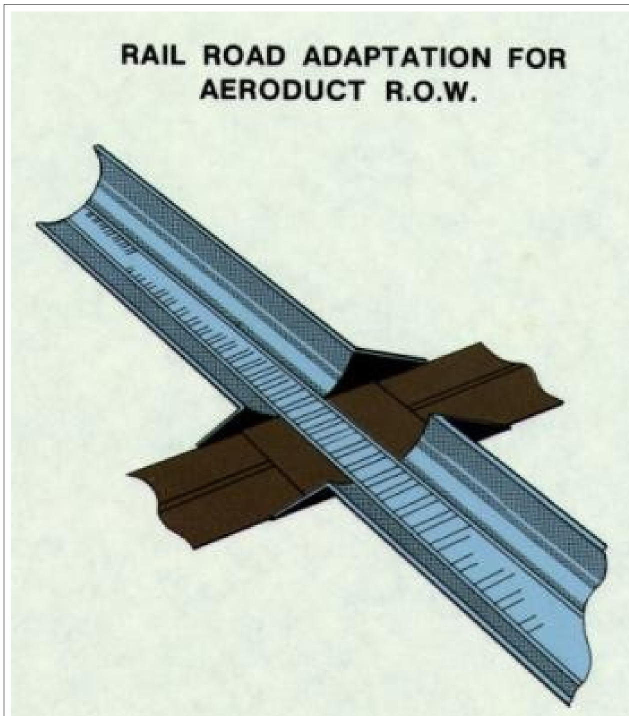

Fig. 13: Railroad ROW adaptation.

The groove or tube can be put over any land, level or sloping, by stepping the Aeroduct. It can be bored through hills or tunneled below the surface. As a tube, or groove of structural material, it is inherently rigid for cantilever spans for elevation over buildings, water, other ROWs, gullies, etc.

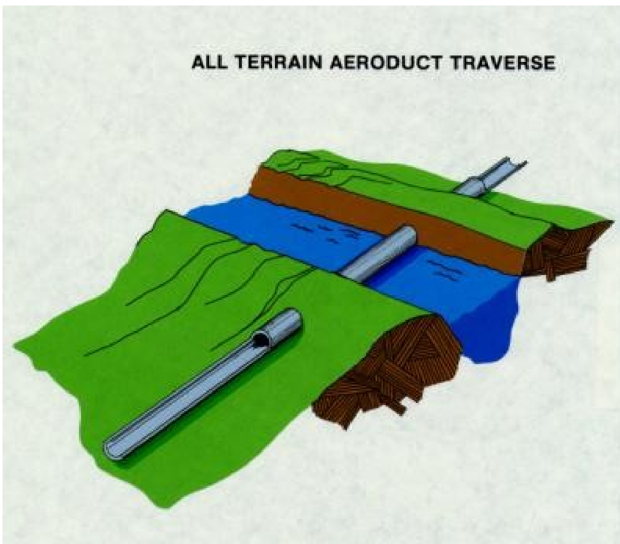

Fig. 14: All-terrain Aeroduct panorama

Operation

A system made up of grooves and tubes consisting of straight sections, curves, and "Y" intersections with inherent perfect guidance can be automated.

The traffic will go one way only at a constant speed for any given segment. Very high speeds are possible, depending on the distance, curves, and turn-off deceleration.

The vehicle will choose its route and locate itself from received electronic signals at each intersection. It has two choices at each intersection: straight ahead, or exit. Side force from the gimbal fans can force the craft to turn off. There will be no stopping in the ROW, only in station loop turn-offs at homes, office buildings, shopping centers, schools, etc.

Ideally, the station will be similar to the automatic elevator where the doors of the building and the vehicle open simultaneously, and entry is from floor flush with vehicle floor. Private entrances are possible at homes, theaters, offices, etc., with obvious benefits in safety and security.

Privately owned vehicles are compatible with the system. It will be required that each vehicle owner have a parking loop where his Aeromobile automatically returns after each mission. Having only one single parking place for each vehicle frees up square miles of city streets, parking lots, and parking buildings. Unless otherwise directed, the automated Aeromobile returns to its parking loop from which it can be called to any location to pick up the owner or any of his family to go anywhere else.

Automation Control System

The elements of the control system for automation of the Aeroduct system are no more complicate than a car radio or telephone selector.

1. Electronic signals emitted at each intersection to identify it to the approaching vehicle and indicate its availability for use.

2. Onboard receiving equipment to register position from emitted intersection signals.
3. Onboard programming equipment to select a route from sequential data to arrive at the predetermined destination and to return the craft home in the absence of further commands.
4. Vehicle spacing and timing equipment to maintain spacing between the craft in the high-speed, one-way ROWs, and to direct turn off of a faltering craft in an emergency.

Safety

The twin engine craft have far greater reliability than automobiles, and less machinery to fail. There will also be a monitoring system on board to direct the craft to the first exit from the high-speed ROW in the event of developing trouble such as low fuel, falling RPM, dropping voltage or hydraulic pressure, or other signs of imminent shutdown. If the craft can continue to the exit, no further problem exists. If in the extremely rare event of sudden unpredicted and total failure of both power systems or equivalent occurrence sufficient to stop the vehicle in the main ROW, a signal is transmitted to following vehicles and to the upstream intersections to slow, stop, or exit to choose another routing. There will be such exits available on every ROW. The entrance to that stretch of groove or tube upstream would then emit a rejecting signal to all approaching craft, causing them to select the other alternative and be re-routed around the closed section.

It is unrealistic to imagine reducing hazard below the irreducible minimum, but that minimum can be achieved by unfailing guidance, redundancy in power, control and communications systems, and total weather-proof operation to incorporate maximum safety. Only a shuttle system such as the automatic elevator can be safer. The monstrous hazard of the manual-automobile-road system is our present problem, and the automated Aeromobile-Aeroduct System will be manifestly safer. The competing mass transit systems on rail, monorail, tracked air cushions, A.C. or D.C. magnetic suspension, vacuum suspension, wheels, etc., all have more serious problems in the rigidity of the ROW with switching, power pickup control complexity, programming, etc. - witness the BART system in San Francisco.

Reliability of any system is a function of the number of components , the reliability of those components, and redundancy , The air cushion vehicle is the simplest powered vehicle, having a minimum of moving parts, and the proposed Aeromobile will be redundant in power supply with two gimbal power units.

The right of way and guideway, being totally passive, cannot fail unless a natural disaster disrupts it. Control systems for routing are very simple electronic units with redundancy and duplication, failure of which would result merely in possible destination error, not disaster.

Safety is the most compelling reason to change from existing roads and vehicles which kill 55,000 people annually in the United States, largely because of human error, weather, alcoholism, and intractible, unchangeable factors of manual operation. Safety of automation is exemplified by the automatic elevator which holds the record for number of trips completed safely without injury or fatality. Horizontal travel will not begin to approach this degree of safety until totally automated and freed from human control. The Aeromobile-Aeroduct System can provide perfect guidance, total automation, and complete indifference to weather conditions.

Security

Security superior to the private car, and certainly superior to public transit, is readily attainable with Aeromobiles in Aeroducts, by having the terminals inside private homes and public buildings, avoiding dark parking lots, remote isolated stations, and long walks to and from those stations.

Energy Effectiveness, Pollution, Noise

Prime consideration in any new system design are those of energy effectiveness, pollution and noise. The air cushion vehicle at cruise speed with zero friction and only aerodynamic drag can easily compete with automobiles, trucks, trains and aircraft in efficiency. All vehicles have pollution output. The electrified types pollute less obviously only because the effluent is emitted from power plants elsewhere. Self-powered vehicles can reduce pollution output, and the system can remove the rest.

The ideal fuel for self-powered craft is liquid hydrogen, which virtually eliminates gaseous emissions. Hydrogen has the advantage of being a renewable resource, and when high-volume manufacture and distribution is set up, the cost will be competitive with ever-diminishing hydrocarbon fuels. Meanwhile, however, using conventional gasoline fuel, exhaust antipollution methods plus ventilation of the tubes with air washing would be much cleaner in total result than is possible now. (For many reasons, tubes, which would confine emissions and allow them to be purified, would be used in the high-density areas where pollution would be most noxious.)

The ducted fan can be designed to be very quiet and vibrationless. Inside the cab of the vehicles, a very low noise level can be attained. Outside, the quiet ducted fan sounds will be further muffled by deep grooves, and totally absorbed in tubes. No crescendos and shaking of the earth will occur, such as those caused by trains and heavy trucks passing.

Taken as a whole, the inexpensive vehicle, right of way, and control system, combined with its high speed, efficiency and availability with present technology, competes successfully with all tracked systems, whether wheel, air cushion, vacuum or magnetic levitation. These other systems require more costly and precise ROW; more complex vehicles and control systems; guideways; switching; and may have miles of hot rail or wire, with trolleys which are sensitive to weather and moisture, causing earth electrolysis, arcing, and ozone production. Most of these "systems" propose to employ running gear and ROW yet to be developed and proved; and may depend totally on central power stations vulnerable to simple breakdown, strikes or terrorist attack; may use scarce materials in large amounts; may need cryogenics; and usually are best suited for high density traffic only. The Aeromobile-Aeroduct system eliminates all of these disadvantages.

Other considerations in weighing the merits of a transportation system are the costs and expenses which will be minimized or eliminated. In the United States, more than $2 billion a year is charged to needless maiming, death, medical expense and property damage with consequent high automobile insurance costs for everyone. This does not even include the loss of working days of those killed or injured. Other ongoing expenses of maintenance will be avoided with an Aeroduct system: there will be no snow removal, no salting or cindering of icy roads for air cushion travel. There will be no highway signs to erect, update and maintain. There will be no road lighting with its capital investment and energy drain.

The proposed system offers transportation service to persons of all ages and physical ability - or disability - without drastic change in the socio-economic-political structure of private vehicles on public rights of way, so well accepted by the public allover the world for centuries. It provides mass transit on an individual basis at a cost which is within present brackets, with far greater accessibility, comfort, security and safety than any existing mode or combination of modes. The required technology is already available for immediate application.

Utility

I offer this system for both congested, intensively developed countries, and for developing, sparsely settled areas as well. It can supplement the present inadequate transportation in densely developed countries by installation on the surface, in tunnels, or in elevated tubes or grooves. Developing countries which have not already made the mistake of investing in thousands of miles of highway or rail road bed can take a fresh look at the potential of a new system more suitable for their particular terrain, weather, economics and population distribution. I especially invite Canada, which has done so much for the amphibian ACV – a nation that has its vast wilderness resources as well as its thickly populated metropolitan centers - to consider air cushion vehicles for total transportation in a planned, complete, coherent system.

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TABLE 1: AEROMOBILE NO. 13 SPECIFICATIONS

Length	20 ft.
Width	8 ft.
Height at rest	4 ft.
Height on cushion	5.5 ft.
Empty weight	1,700 lbs.
Pay load	1,300 lbs.
Gross weight	3,000 lbs.
Flotation	8,000 lbs.
Power	250 hp.
Altitude on cushion	18”
Maximum forward speed	70 mph
Cruise speed	70 mph
Basic equipment	Electrical system Electrical starting Alternator Engine instruments Navigation instruments Heater, defroster Hydraulic system

TABLE 2: PROPOSED SPECIFICATIONS OF AUTOMATED AERODUCT-AEROMOBILE

Length	20 ft.
Width	7 ft.
Height at rest on flat surface	4'4"
Cushion Depth	6"
Empty weight	2,000 lbs.
Pay load	1,000 lbs.
Seating	6 passengers
Flotation	none
Power, two 125 H. P. engines	250 H.P.
Maximum forward speed	120 m.p.h.
Cruise speed	100 m.p.h.
Grade climbing capacity static with speed	 15^0 45^0
Base loading	30 lb./sq.ft.
Cargo space	240 cu. ft.
Hold dimensions height length width	 4 ft. 12 ft. 6 ft.
Operation	Fully automatic, computer actuated from destination information input