The Aeromobile: A Peripheral Jet Vehicle

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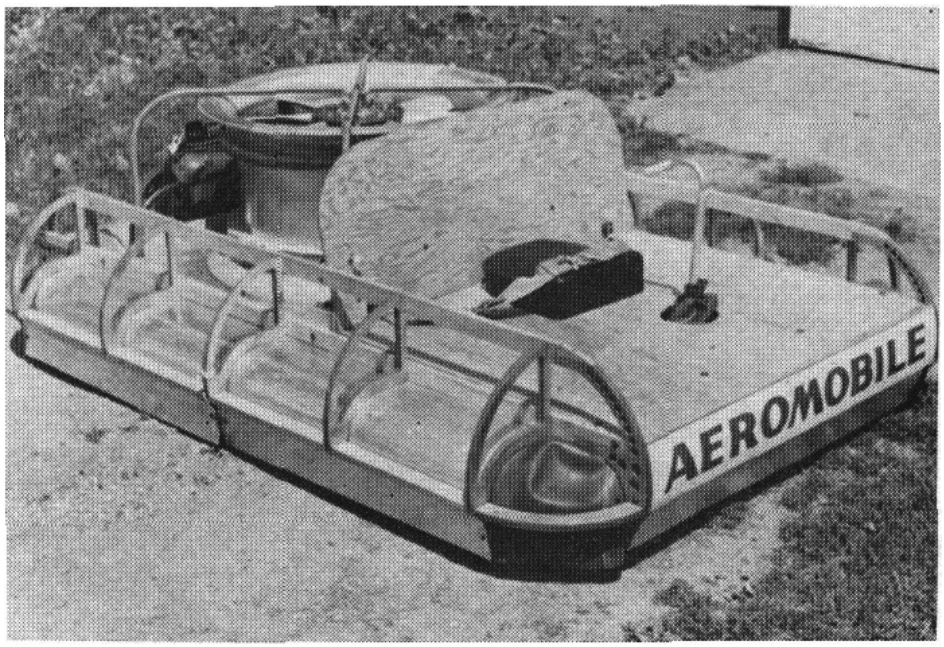

Fig. 1 An experimental model of the Aeromobile, a ground-effect vehicle

THERE are now two categories of aircraft. The first comprises those which receive lift through inertia, momentum, or thrust. This includes all familiar aircraft: the fixed-wing airplane, the helicopter, the autogyro, the ducted-fan flying platform, the tail-sitting jet vertical take-off aircraft, etc. These machines accelerate downwards a sufficient mass of air per second to sustain their weight by reaction.
The second category includes craft which sustain themselves mainly by pressure created beneath. So far these are confined to flight a few feet off the surface and are ground effect vehicles.

It is this newest category which promises to be of most immediate use to the general public for daily transportation and to certain users such as physicians, the military, farmers, ranchers, explorers, etc., for special purposes. The ground effect machine is at once comparatively simple in construction and operation and quite versatile as an omnivagant craft of high speed and large load-carrying capacity.

Ground effect has been known since men began to fly. It was noted early that more lift was obtained near the ground, and some unsuccessful aircraft would fly near the ground but would not rise out of the ground-effect region. Little note was taken of this phenomenon until Toivo J. Kaario in Finland began experiments with small models about 1935 and later built a man-carrying machine which was only partially successful. He was unable to interest anyone in his machines and stopped active work.

Within the last six years, independent work on ground effect as a means to transportation began in England, France, Switzerland, Canada, and several places in the United States. Apparently all of those workers were unaware of each other and of Kaario's work.

Types of Ground-Effect Vehicles

Air-lubrication type. This is a method of greasing the passage of a vehicle over its road by releasing a small amount of high-pressure air through pads or shoes on the bottom of the vehicle.

Pressure-leakage or plenum-chamber type. In this type the base consists of an inverted pan into which a motor fan forces a large volume of air at low pressure. As the air leaks away at the periphery, the fan replaces it to maintain a low pressure to support the craft.

Peripheral jet type. The base of a peripheral jet machine is solid in the center and air driven by the motor fan exits from a continuous slit around the periphery. This forms a jet curtain of air which both builds and confines pressure under the center body of the machine.

Advantages of the Peripheral Jet Design

Higher altitude and greater weight lifting for a given power can be achieved by the peripheral jet machine because of the dynamic screen preserving pressure below. Stability is greatest in the peripheral jet machine since all reaction thrust produced is at the perimeter at the widest possible base. Greater center-of-gravity travel is tolerable over the single plenum chamber type.

Propulsion is inherent in the peripheral jet design without additional power source or propulsion equipment if the machine is tilted in the direction of desired travel by varying the local thrust of the peripheral jet. Tilting is the method of propulsion used in the helicopter. A few degrees of tilt provides a strong propulsive force. Control is inherent in the peripheral-jet machine by varying the magnitude and direction of the peripheral jet exit locally. Pitch, roll, and yaw control and control of trim of eccentric loads is similar to fixed-wing aircraft or helicopters. The same control system will operate in and above the ground effect region for low or high flight. The peripheral jet machine can be designed lower in silhouette, lighter in weight, more compact; it is simpler and least expensive since it needs only one fan, one engine, a ducting system, and flaps with remote control. This type of machine can be designed with an unobstructed deck with a single motor fan at one end. A dual fan is not necessary, and only one end of the vehicle needs to be occupied with the power system.

Principles of the Aeromobile

The Aeromobile, a peripheral jet vehicle, has three sources of lift. The principal lifting force is from pressure built beneath the base, which accounts for over 90 percent of the total lift. The

other 10 percent is derived in part from reaction thrust of air accelerated downward and in part from a lowered air pressure above the craft and in particular at the rim of the duct inlet. The pressure developed by the fan in the Aeromobile is on the order of 0.1 lb per square inch, and this is applied to the base of the machine via the peripheral jet. Since there is over 6000 sq in. of area, the total force is about 600 lb. If the base area were increased, both the altitude and the total lifting capacity would increase. The character of the ground effect of the peripheral jet is that pressure and therefore lift rises inversely with the altitude. As the machine is forced closer to the ground by increasing its load, the lift rises to support that load. As a result, the ground-effect machine can lift enormous weight for a given horsepower. It equals or exceeds the efficiency of a fixed-wing aircraft which carries its load only at fast forward speed while the ground effect machine will hover and move at fast or slow speeds. It exceeds the helicopter in sheer weight lifting in hover or forward speed. The Aeromobile has lifted a total of 1340 lb just clear of the ground, and this is 18.6 lb per horsepower, even though it is a rather inefficient machine.

Propulsion

Once the machine and its load are lifted free and clear of the surface, however slightly, it can be moved without friction in any direction-forward, backward, sideways, pivotally, etc. Several means of propelling the ground effect machine have been proposed including conventional air propellers, ducted fans, jet or rocket engines. Another system is to bleed air off the fan and use its reaction to propel and control the machine. Others have attempted to direct the air as emitted from the jet for propulsion and control.

It is the author's conclusion that, for small vehicles as contrasted to huge ocean-going machines, lift, propulsion, and control should be obtained from the same power source. Adding special propulsion equipment increases the weight and expense of the craft. Bleeding air from the fan reduces its total altitude and produces a low order of horizontal force. Directing the air from the jets to cause translating force is relatively ineffective. We found that no other method could equal the propulsive force produced by tilting the machine in the direction of desired travel.

It proved to be very important to have control of the tilt of the machine because a hovering machine will move in the direction of tilt. If the craft is heavy on one side, it tilts to the heavy side and inexorably moves off in that direction. With local thrust control on the peripheral jet, it is possible to trim out a certain amount of eccentric load. On a slope the Aeromobile moves downward unless tilted toward the uphill side.

In turning corners, it is useful to bank the craft and have the centrally directed horizontal component of the tilted main lift vector keep the machine from moving out tangentially.

In hill climbing, a machine which assumes the tilt of the hill has a strong downhill component of the tilted main lift vector which must be overcome before the hill can be climbed. If the machine is tilted opposite to the slope of the hill, it will climb on its own lift. In this situation, the main lift vector points uphill and the horizontal component is in the uphill direction. Operation on a side hill becomes nearly an impossible situation for the machine in which tilt cannot be controlled. Enormous force is needed continuously merely to maintain the craft on the hillside, leaving little for propulsion. In addition the force holding the machine on the hill must act precisely through the center of gravity or the machine will rotate and become uncontrollable. No other system of producing horizontal force can be directed so efficiently in 360 deg around the base as tilting the machine.

Operation in crosswinds is also a problem to the ground effect machine, but can be adequately countered by a slight down tilt into the wind.

Braking the Aeromobile is accomplished by reversing its thrust by tilting away from the direction of travel. It then rears up like a polo pony. With the low power and low efficiency of the experimental machine, the forces for acceleration are not large. For emergency stops, the Aeromobile is throttled down and skids like a car with locked wheels.

Steering or yaw control is achieved by differential deflection of the side flaps to produce torque around the center of gravity.

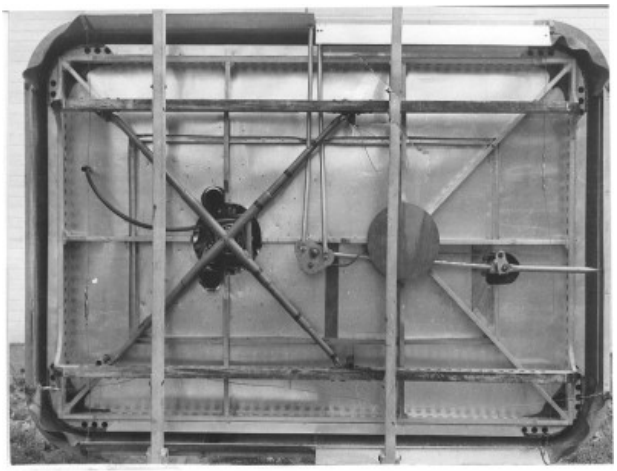

Fig. 2 Air driven by the motor fan exits from a continuous slit around the periphery. This forms a jet curtain of air which both builds and confines pressure under the center body of the machine

Agricultural Uses of Ground-Effect Phenomenon

If development of the principle goes no further than to provide all-weather transportation for rural people, it will have accomplished a great deal. The Aeromobile will do some things now impossible to land vehicles, but it will also make ordinary errands much faster and pleasanter. A road may be passable to an automobile, but deep mud makes it uncertain, dangerous and slow. The Aeromobile is unaffected by the nature of the surface that lies below it as it skims along at cruising speed. That means it will traverse roads, snow, swamp, water, ice, sand or soft ground with equal speed and ease.

The ground-effect machine opens up possibilities for the agricultural engineer to develop means for transporting heavy loads over unprepared ground, such as grain, fertilizer, water, cattle, men or machinery, either mounted or in transport.

Accessibility of fields and crops is another advantage. One could pass over growing crops as harmlessly as the wind. This might allow the farmer to dust, spray, or tend crops while hovering safely above them. For example, the rice grower could travel over his flooded fields to repair dikes.

There is an area of corollary use of the proximity effect in materials handling, lubrication, etc. We are studying the use of air as a lubricant for the share and moldboard of the plow and find this has some rather exciting possibilities for reducing draft and assuring scouring under all conditions. Needless to say, there remain problems to be solved in the use of ground effect vehicles, but enough experience has now been gained with these machines to know that their utility may be tremendous and that design and production of completely practical machines may not be too far in the future.

Specifications

General:	Height 32 in. Width 71 in. Length 101 in. Empty weight 410 lb Gross weight 585 lb
Engine:	McCulloch 0-100-1, 72 hp, 2 cycle, 4 cylinder, 4000 rpm Fuel consumption - 5 gph
Fan:	30-in. diameter, 8 blade, aluminum, 10-deg twist, adjustable pitch, 10-in. hub diameter, 11-in. starter ring gear
Performance:	Maximum altitude at 585lb gross weight - 6 in. Maximum attained forward speed - 40 mph Operating terrain - any unobstructed surface without steep grade or projections higher than the operating altitude. It travels over snow, ice, open water and ice, paved roads, plowed ground, marsh land, etc. Grade climbing - maximum of 6 percent at gross weight
Construction:	Aluminum sheet, marine plywood, spruce wood, steel tubing
Control:	Moveable aluminum flaps surround the base and control the angle of the

	peripheral jet discharge and the local volume of the jet. By control of the thrust at the periphery, powerful forces in pitch, roll, and yaw moments can be produced.
Propulsion:	By tilting the machine in the desired direction of travel by means of the control flaps operated remotely from the control stick, the horizontal component of the main lift vector propels the machine forward, sideways and backwards. Pivot turns and yaw control are produced by differential deflection of the front and rear sections of the side flaps.

Ground Effect References

Aerodynamic theory of the annular jet, Part 1, Aerophysics Co., 17 Du Pont Circle, N.W., Washington, D.C. December 1958.

Boehler, Gabriel D., Remarks on the ground effect machine, American Helicopter Society Fifth Annual Western Forum, 2 East 64th St., New York 21, N. Y. September 25-26, 1958.

Boehler, Gabriel D., Aerodynamic theory of the annular jet, Paper No. 59-77, Institute of Aeronautical Sciences, 2 East 64th St., New York 21, N. Y.

Butz, J. S., Designers study air cushion vehicles, *Aviation Week*, p. 74, January 12, 1959.

Chaplin, Harvey R., Effect of jet mixing on the annular jet, Aero Report 953, Navy Dept., David Taylor Model Basin, Washington, D.C.

Chaplin, Harvey, and Stephenson, Bertrand, Preliminary study of the hovering performance of annular jet vehicles in proximity to the ground, Aero Report 947, Navy Dept., David Taylor Model Basin Aerodynamics Laboratory, Washington, D.C. August 1958.

Chaplin, H. R., Theory of the annular nozzle in proximity to the ground, Aero Report 923, Navy Dept., David Taylor Model Basin Aerodynamics Laboratory, Washington, D.C.

Locomoting on a bubble of air, *Business Week*, p. 34, August 1, 1959.

Mann, Martin, Here come cars without wheels, *Popular Science Monthly*, p. 51, July 1959.

Matthews, G. B., and Wosser, J. 1., Ground proximity: A critical review, Paper No. 59-121, Institute of the Aeronautical Sciences, 2 East 64th St., New York 21, N.Y.

Rethorst, Scott, and Royce, W. W., Lifting systems for VTOL vehicles, Report No. 59-123, Institute of the Aeronautical Sciences, 2 East 64th St., New York 21, N.Y.

Symposium on ground effect phenomena, Princeton University, Princeton, N. J., October 21-23, 1959.

Tinajero, Anibal Alfredo, Comparison of experimental and theoretical design parameters of a 6-inch diameter annular jet model with a jet angle of -45 degrees hovering in proximity to the ground; and experimental results for forward flight at

zero angle of attack, Aero Report 954, Navy Dept., David Taylor Model Basin, Washington 7, D.C.

The ground cushion phenomenon, Hearings before the Committee on Science and Astronautics, House of Representatives, Eighty-Sixth Congress, House Office Bldg., Washington, D.C. April 1315, 1959.

Von Glahn, Uwe H., Exploratory study of ground proximity effects on thrust of annular and circular nozzles, National Advisory Committee on Aeronautics, Technical Note 3982, NASA, Washington, D.C. April 1957.