THE EVOLUTION OF INTEGRATED LIFT, PROPULSION AND CONTROL IN THE AEROMOBILE AIR CUSHION VEHICLE

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IN more than a decade of experimentation with man carrying air cushion vehicles, it has been affirmed and re-affirmed by this observer that proper controllability of the frictionless vehicles requires control forces of the order of magnitude of propulsion forces; and control forces must be available horizontally in all 360 degree vectors from points centering at both ends of an elongated vehicle. It is logical then to use these powerful control forces, which are of propulsion magnitude, for propulsion.

The air cushion vehicle has a unique motility unlike any surface vehicle, in that it is frictionless and totally unoriented as to direction of travel. This freedom of motion forwards, sideways, pivotally, or diagonally is a valuable attribute, but exact controllability by the pilot of attitude is essential.

Figure 1

The free frictionlessness of the ACV to move omnidirectionally in yaw axis rotation and horizontally becomes an increasing problem on non-level surfaces. Much force must be brought to bear on the freely suspended hovering vehicle merely to hold it on a hill. Furthermore, forces are needed to provide torque on the vertical axis around the center of gravity to maintain yaw orientation on hills and rolling terrain.

The ACV has weight, but it has no friction, and there is an inexorable downhill urge representing a fraction of its total weight, depending upon the slope of the grade. Force exceeding all possible inclined plane gravitational forces must be available to the pilot to maintain his vehicle on a hill and to climb that hill.

Figure 2

Moreover, maintaining the yaw attitude of the ACV on rough terrain is a more complex problem. As the craft proceeds over uneven surface, the front end may be on a right sloping surface, and the rear end on a left sloping surface, causing a powerful right turning moment in yaw axis. To counter this urge, the pilot must have at his disposal forces exceeding all possible yawing urges. He must have force on the front end to make the front end go right or left at his will, despite terrain or wind. He must likewise control the rear end under all operating circumstances. He may require a powerful lateral force to right or left on both front and rear simultaneously to maintain the craft on a side hill. If he then wishes to proceed along this side hill, he will require sufficient longitudinal force as well for propulsion. The magnitude of his required forces for control and those for propulsion are similar. Logically, both torque on the yaw axis and side force laterally on each end of the vehicle can be produced by originating thrust forces at each end of the vehicle.

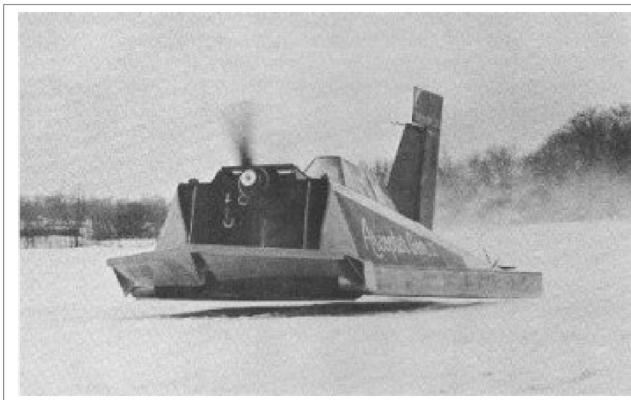

Figure 3

We have gone through four major stages in the development of adequate Aeromobile propulsion and control:

(1) the single vertical shaft fan peripheral jet vehicle;
(2) the dual vertical shaft fan peripheral jet vehicle;
(3) the single horizontal shaft fan ram wing plenum chamber vehicle; and
(4) the dual gimbal (variable shaft angle) fan plenum chamber vehicle.

STAGE I

The first Aeromobiles were elongated vehicles with the total mass flow from the single motor fan distributed downwardly to the lift chamber exiting through a peripheral jet, which is deflected for propulsion and control by movable control vanes (Figure 1). The vanes direct the outflow forward, rearward, laterally, or at each end differentially to provide yaw torque. Many vehicles have been built and flown successfully with this technique.

Figure 4

STAGE II

The 9th full scale Aeromobile, the A-250 (Figure 2), has peripheral jet distribution of the efflux from two vertical shaft fans, one forward and one aft in an elongated rectangular planform. This configuration increased the total mass flow of air through the system, increased efficiency, and increased control force produced by lift air deflection via peripherally distributed control vanes.

STAGE III

A series of ram wing air cushion vehicles was built, called Arcopter GEMs (arc-wing ACVs), in which the fan shaft is nearly horizontal with part of the slipstream diverted for pressurization of the lifting base and the other part directed over the top for propulsion (Figure 3) . Yaw control is achieved by deflecting the slipstream with rear-mounted, movable tail surfaces. On water and other level surfaces, ACVs can be successfully controlled with thrust at only one end of the craft. US Patent No. 3,322,223 was issued on this principle.

STAGE IV

To provide universal controllability plus lift with thrust forward, rearward, sideways and differentially, the Arcopter GEM over-and-under division of slipstream was carried further.
In Aeromobile 13, two motor fans were mounted fore and aft and ducted with spherical exterior shrouds on gimbal mounts with freedom in two degrees (Figures 4 and 5).

When neutral (with fan shaft vertical), 100% of developed power goes to the lift chamber. When tilted slightly, part of the slipstream exits over the deck and provides powerful thrust in any of 360 degrees while maintaining lift base pressure. Using two gimbal fans so mounted, there is available to the pilot control force consisting of up to half of the total propulsive force in any yaw axis direction from each end of the craft. Full propulsive power (about 90% of developed power) can be brought to bear in any horizontal direction by tilting up both fans on parallel axes. The magnitude of the propulsion (or control) force is metered by the degree of gimbal fan tilt. Up to 90 degrees tilt is possible for maximum horizontal thrust.

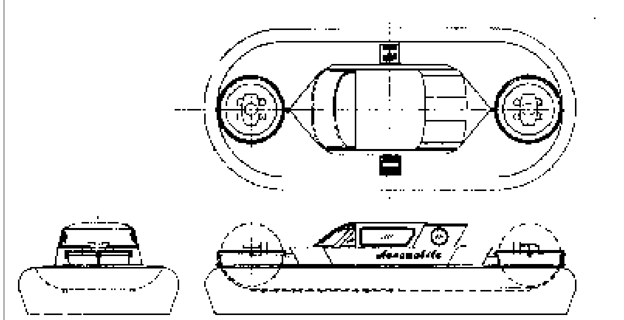

Figure 5

The twin gimbal ducts provide a fully self-sufficient ACV system for all conditions of operable terrain and wind, providing lift, propulsion and control of both ends of the craft, plus the benefit of twin engine reliability. The Aeromobile 13 is in production form and will hopefully soon demonstrate its singular qualities all over the world.