AerForce Propulsion Technology Web

AerForce Propulsion Technology flight vehicles use tubular microthruster arrays that direct propellant fluids along small radius arcs to generate high radial outward forces and provide power densities that make air travel with VTOL and hover practical and low cost.

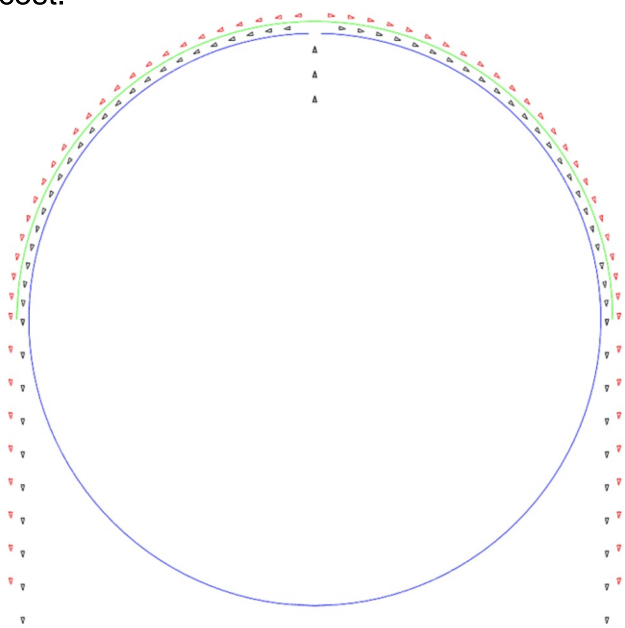

Fig.1

Fig.1 is a schematic slice of an AerForce Propulsive Technology element composed of a tube (blue) and a concentric arc (green). Air passes through the tube axially, enters and travels through the bilateral pair of 90 degree arc passages and escapes as thin jet sheets at the midplane resulting in a radial outward pressure proportional to the fluid density times the square of the fluid velocity divided by the arcs radius ($P=\rho V^2/r$).The black arrows are propulsive air and the red arrows are entrained atmospheric air.

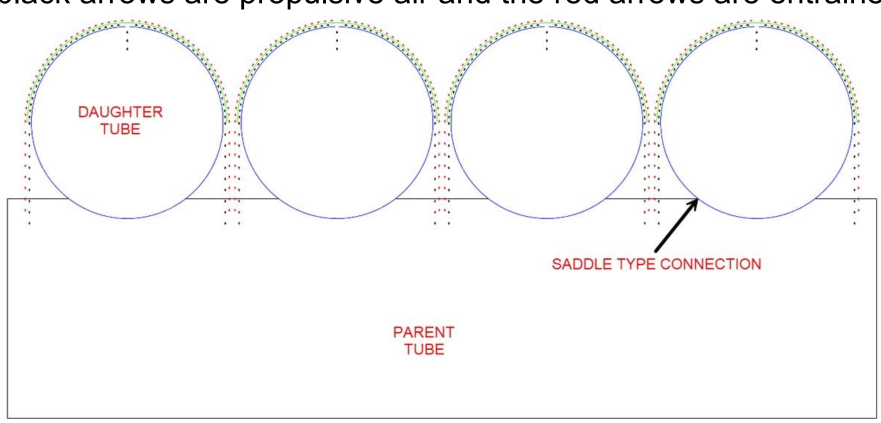

Fig.2

Fig.2 is a schematic slice of an AerForce Propulsion Technology array. Arrays can contain thousands of propulsive element tubes.

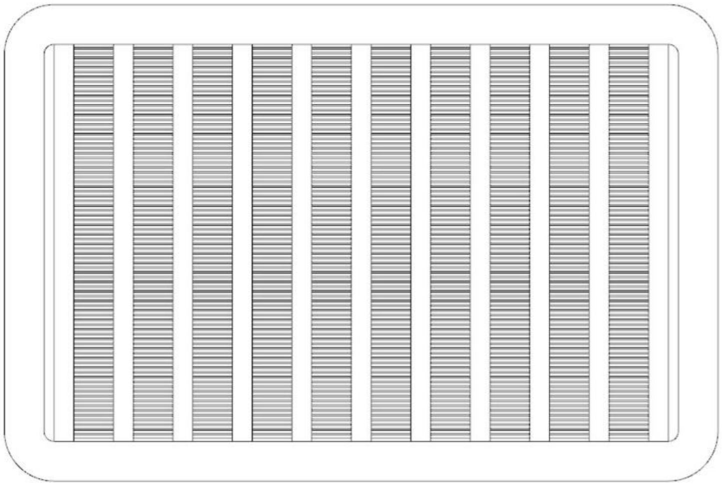

Fig.3

Fig.3 is a bottom up plan view of a microthruster array.

Lift/propulsion is accomplished by creating a pressure (density) difference across a solid.

Atmospheric pressure at sea level equals 1 kg/cm^2 or 10,000 kgs/m^2. AerForce Propulsion Technology arrays can easily provide many atmospheres differential pressure.

The radial outward pressure associated with air following an arc is proportional to the air density times the square of the air velocity, divided by the arc radius ($P=\rho V^2/r$). Assume an air density within the internal arc passages of 1kg/m^3, an air velocity of 30m/s, and a radius of 0.5mm.1X900/.0005=1,800,000 Pascals times 0.102 equals ~180,000kgs/m^2 or 18 atmospheres differential pressure. A cosine correction of 0.707 is needed as the radial force vector is 45^0. 180,000 kgs/m^2 X0.707=~127,000 kgs/m^2 . Internal air velocities can be much higher and arc radius can be much smaller leading to much higher values.

In addition to the force provided by the internal arc surface, the thin jet sheet exhaust entrains and accelerates atmospheric air causing reduced atmospheric pressure on the external arc surface allowing the pressure on the arc surface to be reduced to a much greater degree than legacy aircraft. Atmospheric pressure reduced to 0.7 atmospheres yields a force of 3,000 kgs/m^2.

Fluid following an arc results in a radial outward force inversely proportional to the arc radius (1/r). A large number of small radius elements with planform area equal to a single large radius element can yield greater force. Legacy aircraft use lift surfaces with radius in meters, whereas AerForce propulsive elements can have submillimeter radius. The arc surfaces see only the molecules in direct contact and minimizing the boundary layer thickness minimizes the work needed to create a pressure difference. Reducing the radius and the length of the arc reduces the boundary layer thickness. As the arc radius is reduced, so goes the energy needed for flight.

Force equals mass times acceleration (F=ma). The greater the acceleration, the less mass required for a given force. AerForce microthrusters cause propellant fluids to follow small radius paths to yield high acceleration rates. Small radius fluid paths can yield high pressures without high fluid velocity and the associated noise.

A small radius element can provide a force equal to a larger radius element with the potential for reduced cost, mass, and volume. Force is equal to pressure times area (F=PA) and as the effective area diminishes in proportion to the radius, the pressure increases in proportion to the radius reduction, such that the sum remains constant.

The hoop stress of a circular cylinder is proportional to the pressure times the radius, divided by the wall thickness (S=pr/t). The required tube wall thickness is proportional to the pressure and the radius and as the radius of the tube is reduced, the required wall thickness is reduced i.e., a 1meter radius tube requires 1,000 times the wall thickness of a 1millimeter radius tube for a given pressure. 1,000 1millimeter radius tubes have the same circumference as a 1 meter radius tube and 1/1000 of the required wall thickness, allowing 1/1,000 the weight. Microthruster hoop strength can be increased by connecting cap to tube periodically via adhesives, weldments, and/or parallel or helical tensile overwraps. Tubes and/or caps can have meridional corrugations to aid connection and to manage flow.

Circular array forms are more optimal structurally and fluidynamically than rectangular array forms. Simply curved array forms are more optimal than planar array forms and complex curved array forms are more optimal than simply curved array forms. Curved forms can reduce bending forces and allow the use of tensile members for reduced mass.

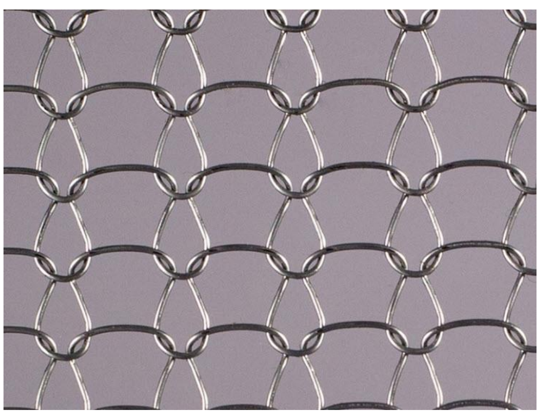

Fig.4

Fig.4 Knitted stainless steel mesh can be used as tensile structural elements and to provide array protection.

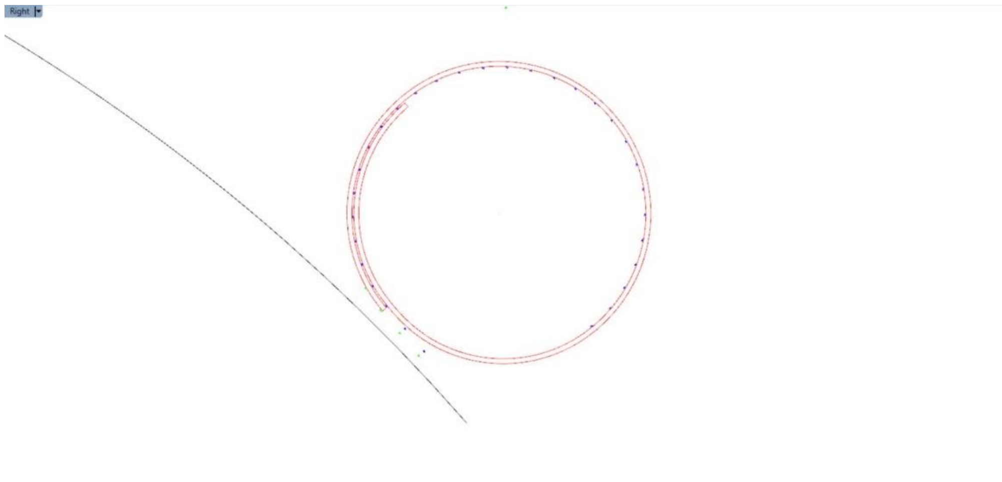

Fig.5

Fig.5 is a schematic cross-section view of a scroll microthruster positioned above the trailing edge of a wing and using the jet sheet exhaust to entrain atmospheric air and reduce the pressure on the top surface of the wing, providing lift and propulsion in addition to allowing higher lift wing forms. Multiple scroll arrays can be used above and/or embedded in wing. Wings can be stacked i.e., venetian blind array.

Airliners can have modular midplane microthruster arrays for lift, propulsion, and control, without the need for wings, horizontal, and vertical stabilizers. The airliners tubular upper body can also be a lifting surface. Aircraft can have on board compressors and compressed or liquid air storage for takeoff, climb, and emergency. Storage can be part of structure, especially with tubular elements.

Radial microthruster arrays can be used with domical lifting bodies where the jet sheet exhaust entrains and accelerates the neighboring atmospheric air that results in subatmospheric pressure on the convex dome surface for lift, propulsion, and control. Domical arrays do not suffer end effects.

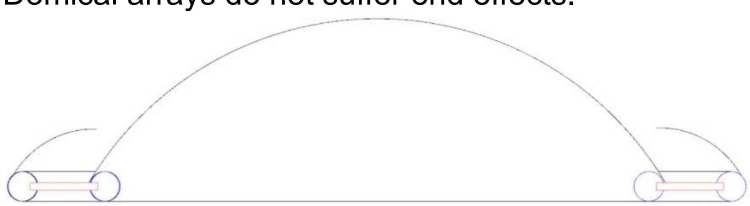

Fig.6

Fig.6 is a schematic slice of a domical lifting body with annular intake shrouds and concentric supply ducts. Domical elements can be transparent and part of cabin.

Safety

High power density, simple control via thrust vectoring, a high degree of parallelism, and the ability to hover and operate at low velocity reduces indoor and outdoor hazards. See addendum.

Cabin

Vertical cylinders with domical top are attractive for single person and smaller vehicles. Horizontal cylinders are attractive for larger craft.

Propellant storage can be part of structure. Rigid tubes can be structural elements.

Flight vehicles can be made with polymers rather than metals to reduce cost, reduce weight, and increase stealth. Metal foils and additive metal manufacture can be used for cryogenic and high temperature systems.

Power density is sufficient to lift and fly current automobiles and to use automobile power for flight. Flight when necessary is an interesting option i.e., rivers, traffic blockages, collision avoidance, ++.

Control

Control. Microthruster arrays can rotate, tilt, and vary in thrust. Modern computers greatly enhance control.

Propellants/Propulsion

Non-reactive propellants include compressed air, liquid air, liquid nitrogen, water, air over water, and steam.

Reactive propellants include hydrogen, alcohols, and hydrocarbons. Air or oxygen can be premixed in supply manifold and internal surfaces can be catalyzed.

Compressed air is the simplest and cheapest propellant. Firefighters and divers use 300 Bar compressed air tanks and thrust is proportional to pressure. Liquid air offers much greater storage density and self-pressurization or pumps can be used to provide high pressure. On board compressors offer increased range and duration. Automotive fuel injection pressures can exceed 1,500 atmospheres.

Compressed airs low energy density is contrasted by high power density, simplicity, safety, low cost, fast response, and instant operation. Rapid climb reduces time in gravitational environment making boost glide schemes attractive. Compressed and liquid air can be charged and discharged at much greater rates than “batteries” and air is much cheaper than batteries.

Compressed air VTOL drones for deliveries + offer low cost, high power density, instant operation, rapid climb, high speed, low noise, and extreme control via thrust vectoring. Compressed and liquid air can be rapidly recharged in the air or on the ground.

Liquid air or liquid nitrogen offer much greater range and endurance than compressed air, can be self-pressurizing or pressurized by pump and heated by atmospheric air to cause phase change and superheat in a simple, low cost, efficient system. Metal systems can provide high rate heat exchange for cryogenic propellants. Liquid air @78K and atmospheric air @273K allows a thermodynamic efficiency of 273-78/273=0.71or 71% with low material cost.

Cryogenic propellant fliers experience weight loss with travel making boost glide schemes attractive.

Steam is an attractive propellant. Heaters can be distributed and provide vectored thrust. Propane is an attractive fuel. AerForce microthrusters can provide high power density upstream heaters.

Air breathing heat engines. Microthruster arrays can be placed in the walls or interior of ramjet ducts to introduce gaseous fuel at high velocity for thrust and to entrain air for combustion. Heat from combustion can be used to heat and vaporize liquid propellants, allowing ramjets with stasis power. Low energy density propellants such as alcohol/water blends can be used to increase thrust by allowing greater use of combustion energy to heat propellants. Rounded intake lips can be used to further increase thrust.

Reactive propellant systems (rockets) can use inner tube/s for coreactant/s with reaction in space between inner and outer tubes. Inner tube/s can be scrolls. Liquid air with hydrogen, propane, or CNG are attractive combinations.

AerForce Microthrusters are especially attractive for marine application via the introduction of air along wetted surfaces to reduce drag in addition to providing propulsion.

Microthrusters can be used as motors with microthrusters normal to axis/axle/manifold or normal to radial tube/s.

Microthermodynamic check ball pump arrays for throttling and vectored thrust can be created from thinwall hypodermic tube arrays electrically heated with short pulses to vaporize a portion of the contained liquid causing rapid downstream pressurization. The pumps can also be produced by additive manufacturing. Microthermodynamic piston pumps are also possible.

Air/water mix. Water vapor can be used to reduce the cooling of expanding exhaust gas. Water evaporation can contribute additional power. Water can be heated.

Electricity can be used for compressors, pumps, controls, navigation, communication, lighting, and heaters via batteries, supercapacitors, photovoltaics, and tethers.

Flow Organization

Laminar flow is attractive as drag is proportional to velocity in laminar flow vs. the square of velocity in turbulent flow. Means to maintain laminar flow in AerForce microthrusters include small passage size and causing the fluid to follow the concave surface of the propulsive arc allowing laminar flow to be maintained at high Reynolds numbers via inertial confinement. The lesser the radius, the greater the inertial confinement to the concave surface and laminar flow is quieter than turbulent flow.

Noise is proportional to velocity with a large exponent i.e., 7+ and curvature acceleration allows greater force for a given fluid velocity.

The smaller the radius, the lesser the resistance path length, the thinner the boundary layer and the lesser energy required to accelerate it, and thinner boundary layers can support greater pressure gradients.

The thin jet sheet/microjet exhaust provides high mass, momentum, and heat transfer with the local environment, with benefits including reducing the cooling of expanding exhaust gases.

Microthruster exhaust paths can be linear convergent-divergent (C-D) nozzles for increased velocity.

Arcs can be equiangular spirals.

Supersonic flow can be achieved with compressed air at 1 atmosphere. Firefighters and divers use compressed air at 300 atmospheres. Liquid air and other propellants can be supplied at much greater pressures via pumps. The force yielded by AerForce microthrusters is proportional to supply pressure.

High power density can counter the effect of wind.

AerForce microthrusters do not require atmospheric air and thus suffer no altitude limitations. High altitudes offer reduced air resistance.

Murray's rule branching can be used to minimize the work of circulation i.e., r^3 of the parent tube equals the sum of the r^3s of the daughter tubes ($r_p^3=r_d^3+r_d^3+r_d^3+$).

The saddle type connections between the parent tube and the daughter tubes allow improved fluid dynamics via reduced restrictions in parent tubes, closer tube spacing, and improved manufacturability. Parent tubes have upper surface subatmospheric pressure from microthruster exhaust.

Lenticular disc forms are attractive for translation with the convex surface providing lift.

The propulsive passages can include annular corrugations to control passage cross-section, even flow rates along the length of the parent supply tube, form micro C-D nozzles, and provide connections such as weldments. Daughter tubes can have hole arrays rather than slots.

Micropumps can be used for pressure and control. Solenoid and thermally operated piston pumps and thermally actuated ball check pumps. Thermal actuation can be used for pressurization, control, and phase change. Electrically heating the space between ball checks can vaporize a portion of the liquid in the space with the resulting increase in pressure causing the outlet ball to open. Heating means include resistive heating of the tubular container or internal element/s. Pulsatile pumping can vary in frequency and power and pulsating flow may be more efficient, especially for entrainment. A large population of micropumps can reduce cost, mass, and volume.

Micropumps can be composed of thinwall hypodermic tubing with conductors on exterior. Conductors may be closely spaced to minimize resistance and thermal time constant. Capacitors can be used to store energy for powerful impulse.

Micropumps can be made via additive manufacturing.

Additive manufacturing offers optimization of both fluidynamics and structure in AerForce microthruster arrays. Direct Laser Writing (DLW) is one technique capable of small internal manifolds and abrasives can be pumped through manifolds for smoothing.

Applications

Electric aviation becomes much more attractive. Sources include batteries, super capacitors, photovoltaics, generators, and tethers.

A human flier can use a single overhead array with the ability to vary flow to the left and right side of an array for directional control and vertical control via overall flow rate. Propulsion can be via backpack supply, the simplest being compressed air.

An annular array can power a single place aircraft composed of a vertical cylinder topped by a transparent polycarbonate hemisphere surrounded by an annular array of microthrusters.

The annular propellant supply tubes can be divided into segments for vectored thrust and safety. The user can stand up or be aided by a bicycle seat. Propellant can be stored in the bottom of the cylinder and the region can provide crush space. A rear cusp in the cylinder below the polycarbonate dome improves aerodynamics, provides storage, and a wing can be added.

Eye in the sky. A low cost eye in the sky for communications, police, fire, and traffic management with a real time gods eye view for automated vehicles.

Arrays of low cost AerForce eyes in the sky can be tethered, inflight refueled, periodically replaced, and/or powered by suspended vertical bifacial photovoltaic arrays.

Long term hover is attractive for many applications. Cameras, communications, radar, advertising, and lighting where and when you want it via remote control.

Airships can benefit from a lightweight lift and propulsion means. Hybrid airship Eye in The Sky. Quiet, Low radar and IR signature. Liquid air can provide lift, propulsion, and ballast control. Liquid air can also provide refrigeration, air-conditioning, and cooling of electronics and sensors.

Indoor flight. Reduced noise and footprint along with the lack of rotating blades bring flight indoors for warehousing, patrolling, inspecting, manufacturing, and general travel for people and goods.

Hoverboards for personal and goods transport.

Vacuum platen.

Propulsive force and subatmospheric pressure can be used maintain contact with surfaces for maintenance i.e., ceilings and walls.

Tethered applications include manufacturing robots suspended from the ceiling with a wide range of motion, window cleaning, painting, firefighting, and agriculture use.

Short haul applications are many. Crossing the river and package delivery via disposable delivery drones powered by compressed air, especially with parent aircraft to reduce propellant needs.

Hierarchal drones. The mothership. 2/3 Law augers for a large flight vehicle to carry and disperse smaller vehicles for increased range and reduced cost.

Sky crane. Construction aid.

Agriculture. Watering, spraying, crop monitoring, planting, harvesting, security, and tree trimming.

Self-propelled air heater powered by propane or natural gas.

HVAC. AerForce technology can provide quiet, personalized, temperature controlled airflow and the supply of makeup air can be clean with humidity control and personalized scent if desired. Compressed air can become a common household and business utility. HVAC uses include fan, ventilator, heater, cooler, and humidifier. A compressed air supply can provided clean temperature and humidity controlled air to arrays. Expansion cooling can be a significant contributor to air conditioning.

AerForce arrays are attractive for lighting, signage, and display. The arrays can be colored, illuminated, made into displays signage, billboards, and art.

Transparent polymer arrays can transport light via Total Internal Reflection (TIR) within the walls to emission regions.

AerForce arrays can be easily stored for parking, for other flight modes, and can be flat packed for shipping

Epilog

Microfluidics and microthermodynamics are the future of propulsion and transportation.

Personal flight has been limited by cost, safety, power density, and operating difficulty. AerForce Propulsion Technology provides extraordinary reductions in the cost, mass, and volume of propulsion systems and offers safety through simplicity, parallelism, and controllability. The lack of rotating blades, VTOL, and the ability to stop in flight are further benefits.

A high thrust/mass allows a large propellant mass to be flown for increased duration and range, making a low cost propellant with low energy density viable. Liquid air is a low cost propellant that can be made anywhere via photovoltaics. Pumps can be used to pressurize liquid air for increased efficiency, provide throttling, and to allow unpressurized liquid air storage. Gasification of liquid air can be via additive manufactured metal arrays acting as heat exchangers.

Power density scales with 1/L, A flea can jump hundreds of times its size, an elephant not at all. Benefits accrue on the small as capillaries, alveoli, and gills demonstrate, where mass, momentum and energy are exchanged at small scale and with a high degree of parallelism for optima. The thin jet sheet exhaust/microjet array provides high mass, momentum, and heat exchange rate with the local atmosphere and the benefits include compact systems and reduced expansion cooling of exhaust gases.

Stealth benefits with polymer construction include low radar signature, low thermal signature, low visual signature with transparent polymers, and low acoustic signature via laminar flow. PET film construction allows propulsors with very low cost, low mass, and low volume. Stainless steel foil construction is attractive for cryogenic and high temperature systems.

AerForce Propulsion Technology has wide applicability and is a killer app for additive manufacturing.

We are indebted to Leonard Euler for the realization of a force proportional to fluid density times the square of the velocity, divided by the radius ($P=\rho V^2/r$).

AerForce Propulsion Technology is the property of John Popovich and has patent pending status.

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Addendum

Why Fly

Flight is “innately” cheaper, safer, faster, and more enjoyable than surface travel.

Flight is cheaper

Birds travel an order of magnitude faster than their earthbound brethren with equal mass and metabolic rate and therefore use 1/10 the energy to transport a given mass a given distance ("A sparrow, which is identical in mass and metabolic rate to a mouse, flies an order of magnitude faster than a mouse runs, and so has a minimum cost of transport an order of magnitude lower than that of a mouse" Proceedings of the National Academy of Sciences USA, Volume 95, pages 5448-5455, May 1998 Engineering). And sparrows are on the low efficiency end for birds, with soarers like the albatross at the top.

Birds are also able to travel more directly between two points and to exploit favorable air motions. There are many instances where surface vehicles have to travel great distances to access a nearby region because of water or mountains. The San Francisco Bay Area is a typical example where hours can be spent in traffic to access a region a few miles distant. Surface travel in these circumstances can be hundreds of times costlier and more time consuming than flight.

Maintaining a flight infrastructure is much less costly and disruptive than maintaining a system of roads, rails, and streams. Flight transport can reduce road traffic and has no road, rail, or stream width limitations. Surface (2D) transportation requires an enormous amount of time and resources for construction and operation.

Everyone on Earth is connected by air, flight joins people separated by mountains, oceans, and hostile intermediaries. Flight can greatly reduce the resources needed for transportation.

Why should aircraft cost more than cars? Flight vehicles can have much more structural loading. Automobiles have four small contact patches and must be strong enough to suffer indignities like hitting a pothole while braking. Roadable aircraft have been poor cars. Aircraft can be lighter than cars per person or per unit payload, Consider the vehicle mass per person in planes, cars, trains, and ships.

Flight is Safer

Flight allows for greater distance from surface obstacles and between vehicles. Roads represent a small portion (~1%) of the Earth's surface and are restricted to the surface. Flight vehicles can cover 100% of the Earth's surface and access a large number of flight levels via 3D rather than 2D travel. The distance between vehicles can be much greater via increased surface coverage, additional flight levels, straighter paths, and shorter trips. Flight vehicles can travel at steady and predictable speeds and air transport can be more automated. Reduced blocking from surface obstructions aids cameras, RADAR, LIDAR, SONAR, vehicle to vehicle, vehicle to ground, and vehicle to satellite communication. We also have much more experience with automated flight.

The safety of legacy flight vehicles is compromised by the need to take off and land at high speed, the proximity of other vehicles at the takeoff and landing sites, the need to maintain a certain speed to be airborne, and the lack of passive safety features.

Flight vehicles with thrust greater than mass can provide increased utility, including the ability to stop in midair, change direction rapidly to prevent collisions, easily refuel inflight, and takeoff and land in dense urban environments.

Flight vehicles also can be designed to have stable high drag descent and controlled structural deformability, making collisions, and forced landings less dangerous. Ballistic parachutes can provide additional safety.

Multiple technological advancements have increased our ability to develop low cost, robust, integrated control, communication, and navigation systems that can provide greatly increased travel safety and convenience while reducing resource expenditure.

Flight is Faster

Flight paths are more direct and do not suffer the speed limitations associated with surface obstructions encountered by road, rail, and water vehicles.

Flight offers time saving for people and critical cargoes and capital cost can be reduced by more frequent flights.

Flight is More Enjoyable

Earth from above is more beautiful, our view of it is much greater and it yields a better understanding of our environment. Flight is typically smoother as it does not require the stopping and starting associated with surface travel and it allows much greater freedom of movement via the third dimension.

Epilog

This is the time in our history for the transition to flight. We need to reduce the cost and planform area for personal vehicles capable of vertical takeoff and landing (VTOL).

Mass market personal air travel requires reductions in cost and increases in safety and power density. Entry level 2 place helicopters (Robinson R22) start at ~$300,000.00, 20X the cost of a car and require large rotor swept areas (46m2). Power per unit plan area needs to be increased ~10X for compact VTOL vehicles. Helicopters also require skilled operators.

Progress in computers, artificial intelligence, radio communication, GPS, cameras, LIDAR, RADAR, SONAR, and inertial sensors, have the potential to greatly increase safety and efficiency, while reducing necessary operator skills.

Much of the area of a city is taken away by roads and parking regions. Personal aerial vehicles do not require roads and can park from above, thereby reducing parking space access roadways. They can park on roofs to greatly reduce the need for a retailer/homeowner/+, to have a parking region. They also increase security and allow our cities to be walkable, bikeable, and livable. All of a sudden, a lot more room is available in cities. Apartments, cafes, markets, parks, amphitheaters, + seem a better choice than parking lots. Upward mobility is the future.

Ford felt the automobile could free people from the vagaries of the mass transit system. We now need to be freed from the vagaries of the automobile. The wheeled cart has been very useful but it’s time to rise above it.