AerForce Flight Vehicles

Legacy personal flight vehicles are limited by cost, safety, power density, and operating difficulty. AerForce technology provides means to produce personal flight vehicles that offer low cost, safety, high power density, and simple operation. See Appendix 1 “Why Fly”

AerForce flight vehicles are powered by arrays of microjets with propellants including compressed air, compressed air propelled water, compressed air/water mix, liquid air, hydrogen, hydrocarbons, alcohols, and steam.

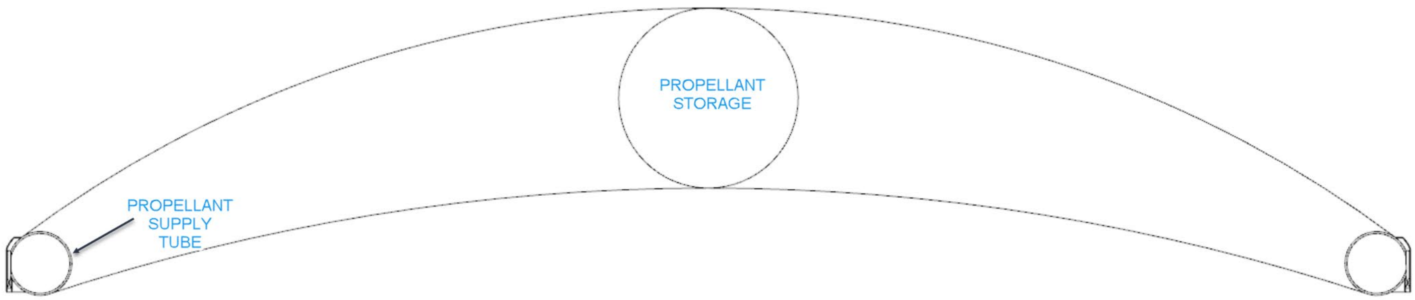

Fig.1

Fig.1 is a schematic cross-section of a lenticular VTOL flight vehicle powered and controlled by an annular array of microjets. The propulsive force is provided by the microjet exhaust directly, by the air entrained and accelerated by the microjet exhaust, by the directional change caused by the outer shroud, and by the reduction in pressure on the convex upper surface. Annular systems avoid end effects and as a consequence can achieve greater pressure reduction on a convex surface. The lenticular form provides lift in horizontal flight. AerForce technology can accommodate integrated and suspended cabins/cargo and a single craft can have multiple arrays.

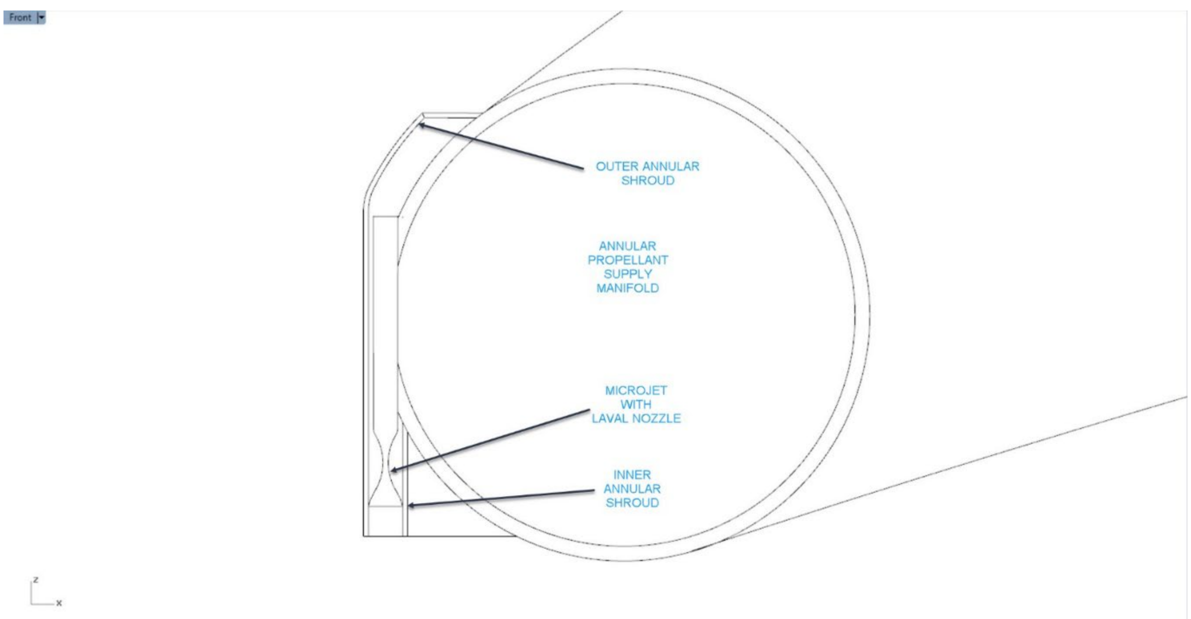

Fig.2

Fig.2 is a schematic cross-section of an annular propellant supply manifold and a typical microjet. Air from the domical region is ducted into the annular shroud due to the microjets atmospheric air entrainment. The microjets are made from stainless steel hypodermic tubing with typical internal radius from 0.05-0.75mm and spaced to optimize entrainment and convert the microjets high velocity, low mass flow rate into a lower velocity higher mass flow rate via entrainment.

Propellant supply manifolds can be primary structural elements.

Annular propellant supply manifolds can be fluidynamically divided into several radial sections for safety via parallelism and for thrust vector control.

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 and boost glide schemes are attractive. Compressed air can be charged and discharged at much greater rates than batteries and air is much cheaper than batteries.

Compressed air can be provided by 300 Bar carbon fiber tank types currently used by firefighters and divers.

Compressed air VTOL drones attractions include low cost, high power density, instant operation, rapid climb, high speed, and extreme control via thrust vectoring. Compressed air storage does not degrade with time.

Liquid air offers much greater range and endurance, 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. The microjet tube array, the annular supply manifold, and the neighboring shrouds can provide high rate heat exchange for liquid air systems. Liquid air fliers experience weight loss with travel vs. batteries and boost glide schemes are attractive. See Appendix 2 “A Liquid Air Economy”

Thrust is proportional to pressure. Liquid propellant feed pumps allow high pressure operation with low mass propellant storage vessels and liquid compression requires very little work. Automotive cam operated piston fuel pumps can provide 1,500 Bar.

Compressed and liquid air can be rapidly recharged in the air or on the ground.

Combustion can take place within shrouds to heat propellant in jet tubes with catalysts and wire cloth as aids.

Uses

Personal flight vehicles. Avoiding the massive wheelsets required by surface vehicles and the abuse that requires them is one reason that flight vehicles require less cost and less mass per person.

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 vertically suspended bifacial thin film 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. A hybrid airship eye in the sky. Liquid air can be used for lift, propulsion, and ballast control. Liquid air can also provide refrigeration, air-conditioning, and cooling of electronics and sensors.

Indoor flight. Low noise, small footprint, and lack of rotating blades brings flight indoors for warehousing, patrolling, inspecting, manufacturing, and general travel for people and goods.

AerForce microthruster propulsion systems can be used for surface vehicles, water vehicles, and underwater vehicles. Waterborne vehicles experience surface drag which can be reduced by an air layer between the surface and the water. Aerforce microthruster propulsion systems can provide drag reduction in addition to propulsion.

Tethered applications include manufacturing robots suspended from the ceiling with a wide range of motion.

Short haul applications are many. Crossing the river, escape pods, and package delivery via disposable delivery drones powered by compressed air are examples.

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.

Firefighting, painting, window washing,

Agriculture uses include watering, weeding, fertilizing, crop monitoring, planting, harvesting, security, and tree trimming.

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

Actuators.

Epilog

Microfluidics and microthermodynamics are the future of propulsion. Power density accrues on the small; a flea can jump hundreds of times its size, an elephant not at all. The divide and rule rule.

The importance of scale in propulsion systems cannot be overemphasized. We often go big when the benefits accrue on the small. There really is plenty of room at the bottom.

Transport phenomena final stage, “where the action is”, favors the small and the many. Capillaries, gills, and alveoli are examples. A high degree of end stage parallelism is attractive for overall effectiveness and beneficial for safety.

Power density is proportional to1/L. Efficiency i.e., range and endurance are proportional to $L^{2/3}$. Transport phenomena end stage “where the action is” favors the small and the many i.e., gills, alveoli, and capillaries. A high degree of end stage parallelism is attractive for overall effectiveness and beneficial for safety. Mixing length and time are reduced with scale reduction as diffusion is an L^2 phenomena i.e., doubling the distance quadruples the time required for similar mass, momentum, or energy transport. A large population of small jets allows increased coupling with the neighboring atmosphere for mass, momentum, and energy transport. Gas expansion causes a reduction in temperature that can be mitigated by close association with the neighboring atmosphere.

A large population of small jets can be beneficial on any size craft. Larger craft can have increased range and endurance i.e., doubling propellant mass does not double craft mass or surface area. A mothership can increase range and endurance while delivering smaller craft. Multiple stages can be used to increase range and endurance. The potential for laminar flow increases with decreasing scale and this is attractive since laminar drag is proportional to velocity while turbulent drag is proportional to the square of velocity. Thermal mass is reduced with reducing scale allowing increased response speed. External heating benefits increase with decreasing tube radius as reducing wall thickness reduces thermal resistance, increases surface area per unit flow, and allows more effective extended surface heat transfer.

AerForce flight vehicle technology has patent pending status.

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Appendix 1

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 more even 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 is 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 ($46m^2$). 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 is time to rise above it.

Appendix 2

A Liquid Air Economy

Why Liquid Air?

A liquid air economy has many benefits. Liquid air can be made anywhere, no need to mine it, no need to refine it, it is non-polluting, relatively safe, and it can be made at low cost with SuperHero Claude cycle liquefiers.

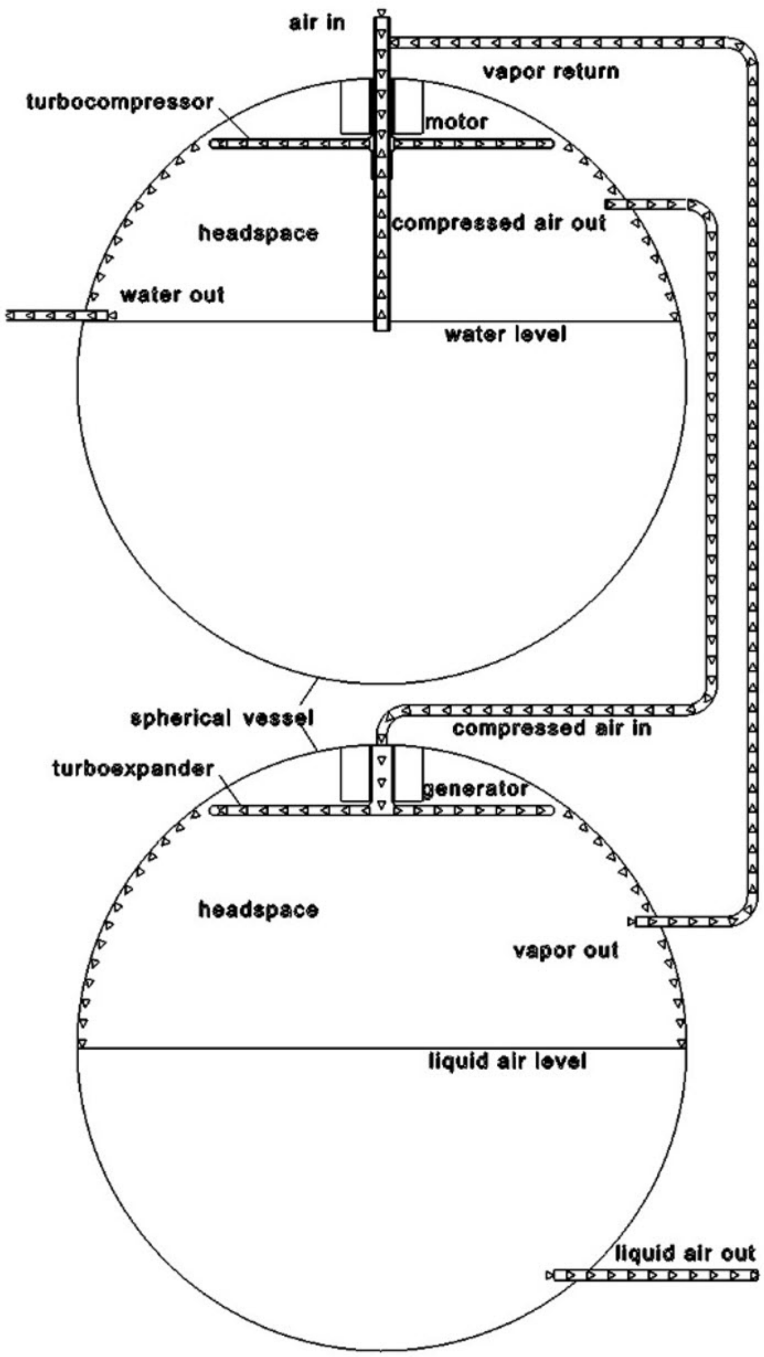

Fig. 1 SuperHero Claude Cycle Compressor and Liquefier Schematic

The motor driven SuperHero turbomachine in the upper spherical container in Fig.1 uses recirculating water as a periodic liquid piston to provide near isothermal air compression.

The compressed air from the upper spherical container can be expanded in the lower spherical container by a SuperHero expander turbine to liquify the air in a Claude cycle.

Heat from integrated motors and generators can be used to prevent bearing freezing in liquid air systems.

Liquid air systems can be hermetically sealed, like modern refrigeration systems.

Combined cycle via conventional high temperature topping cycle and liquid air bottoming cycle.

Liquid air can provide short-term and long-term storage for intermittent sources including photovoltaics and wind. Liquid air storage does not require pressurization.

Liquid air is attractive as a "utility." It is cheaper to distribute liquid air in a district or a building for air-conditioning, air make up, compressed air, refrigeration, electricity production, fan operation, electronics cooling, and electronics powering, than to provide these services individually. Liquid air can be supplied via a recirculating loop manifold. Personalized cool, clean fresh air can be provided at low cost and with low noise. Heat can be added via electricity from SuperHero liquid air turbogenerators.

Compressed air is an attractive utility and would enjoy greater use with greater access. Superhero turbomachines can provide quiet compressed air at low cost. Compressed air can be provided by SuperHero liquid piston recirculating water air compressors, by liquid air ported to a storage vessel, closed off from the liquid air supply vessel and heated by the local atmosphere to evaporate and thereby pressurize the air in a compressed air storage vessel, by a pump made from a pair of check balls with a heat exchanger between, and by liquid air pumps with downstream heat exchangers.

Liquid air can be transported by pipelines, trucks, trains, planes, and ships. Storage can be refilled as needed.

Liquid air allows existing fuel stations to become liquid air stations. Existing tanks can be internally insulated for liquid air storage. Liquid air is storable without pressurization. Oil and gasoline storage tanks can be converted to liquid air storage tanks. Liquid air can be stored in underground cavities,

Liquid air offers fast fill vs. the long waits associated with battery systems.

Liquid air controls require less cost, mass, and volume than electrical controls, including those required for automotive battery systems.

Liquid air storage vessels can be used as structural elements for mobile and stationary systems. Car, truck, train, plane, and ship structures can be made of tubes that can be used for liquid air storage. Truck and train chassis are very attractive candidates for tubular structures. Building structures can be formed from tubes used for cryogenic liquid storage.

Energy efficient buildings often suffer from poor air quality as a consequence of reduced communication with the local atmosphere and liquid air can provide clean air in these applications. Clean makeup air can be especially valuable in hospitals. Operating rooms lamps can be designed to emit clean air to displace room air and operating team emissions in addition to liquid airs ability to provide cooling for the light sources and associated electronics.

Energy is proportional to pressure and liquid air at high pressure can have energy densities ~200Whr/kg, less than Li-Ion, but greater than Lithium Iron Phosphate, which Tesla and other EV mfrs. are transitioning to due to the reduced cost and increased safety. Electric vehicle batteries require costly heating, cooling, and control systems that further reduce their useful energy density. **Liquid air powered vehicles have reduced mass with travel, especially important with aircraft.**

Liquid air SuperHero atmospheric source heat engines can provide power densities 10-100 times as great as electric motors and without the concern of overheating.

In server farms Superhero liquid air turbogenerators can both power and cool the electronics. Electronics can operate at much higher power densities and with better efficiency, reliability, and durability via lower operating temperatures and modularity. Cryogenic cooling allows the use of lower bandgap semiconductors such as Germanium.

A liquid air economy will use liquid nitrogen and liquid oxygen. Liquid oxygens reactive potential makes it much more valuable than liquid nitrogen. Liquid oxygen can be used for combustion to greatly improve power density and to prevent oxides of nitrogen, it can be used for breathing, it can be used for high altitude operation, including rockets for point to point and space travel, and it is useful in many chemical processes. Liquid oxygen can be used for a SuperHero combustion engine topping cycle and liquid nitrogen can be used for a SuperHero cryogenic engine bottoming cycle.

SuperHero Atmospheric Source Heat Engines

SuperHero Atmospheric Source Heat Engines can have high thermodynamic efficiency with cryogenic fluids. Additional benefits include safety, no need for ignition, no reaction time limits, no combustion space needed, drag heating utility, and boundary layer viscosity reduction via reduced temperature.

Atmospheric source heat engines are limited by atmospheric air mass flow rate and this can be increased by increasing travel speed, a positive feedback loop.

Bottom up Thermodynamics

Thermodynamic efficiency is limited by the absolute temperature ratio. Sadi Carnot gives us the thermal equivalent of height. If the temperature ratio is half, half of the thermal energy can be converted to work.

Maximum thermodynamic efficiency=1-$T_{low}/T_{high.}$ For liquid air T_{low} @78^{0}K and ambient temperature T_{high} @273^{0}K (1-78/273=0.71), or 71% maximum thermodynamic efficiency.

To achieve a similar thermodynamic efficiency with ambient temperature being T_{low}, T_{high} must be ~900^{0}K (1-273/900=0.7). The higher operating temperature requires costlier materials and implies heat loss to the environment rather than heat gain from the environment as is the case with liquid air.

SuperHero turbomachines with cryogenic propellants can convert sensible heat from atmospheric air and latent heat from atmospheric water vapor to rotational motion which can be used for electricity generation, shaft work, or thrust.

Atmospheric energy conversion. Air specific heat @300K=1kJ/kg.K. A liquid air powered vehicle travelling at 120k/h (33m/s) provides ~40kg/s of atmospheric air to a $1m^2$ aperture. 40kg/s X 100^0K ΔT X1kJ/kg.K =4MJ/s or $4Mw_t$. A portion of the thermal energy can be converted to rotational energy by SuperHero turbomachines and used to generate electricity, mechanical drive, or thrust.

Atmospheric energy conversion. Latent heat. Water liquid/gas latent heat of phase change energy =2.3kJ/gm. A vehicle travelling at 120k/h (33m/s) provides $33m^3$/s of air to a $1m^2$ aperture. Air at STP and 50% humidity contains $33m^3$/s X 11.5 gms H_2O/m^3 X 2.3kJ/gm=873kJ/sec or $0.87Mw_t$. 100% humidity doubles this figure. Cryogenic SuperHero turbo machines can provide freshwater from the atmosphere via condensation.

SuperHero cryogenic turbomachines are attractive for working in hot areas, foundries, metalworking, ceramics, and glass industries. SuperHero cryogenic liquid nitrogen turbomachines are attractive for working in flammable and explosive environments.

Cryogenic CO_2 Capture

SuperHero cryogenic turbomachines can benefit from the exhaust temperature from carbon containing fuel combustion and change the phase of CO_2 in the exhaust from a gas to a solid while delivering useful power. The CO_2 can be inertially separated at the source vs. trying to separate CO_2 from the atmosphere @400 parts per million.

LNG regasification facilities can be used to produce liquid air.

A thermos of liquid air and a small cryoturbine fan can provide a portable air conditioner without electricity.

Liquid air SuperHero turbomachines can power refrigerated delivery vans. Large numbers of refrigerated trucks spend their day in traffic with engine idling and with the refrigeration system operating to keep the food cold and with an air conditioner to cool the operator.

Liquid air can be used for projectile propulsion.

SuperHero cryogenic turbomachines can use heat from solar radiation, engine exhaust, industrial processes, and other sources to increase efficiency and power density.

Epilog

Liquid Air Vehicles (LAVs) can displace EVs due to lower overall cost, including lower overall environmental cost. Who thought that batteries would be cheaper than air.

You cannot create batteries with photovoltaics, but you can create liquid air. PV can be used to create liquid air directly vs. batteries.

The future is cool.

SuperHero Microturbines

Why microturbines?

Power density is inversely proportional to length (1/L). Small turbines have the potential to reduce the cost, mass, and volume per unit power output and they are more amenable to mass production.

SuperHero technology encompasses a family of microturbines that include relatives of Hero's Aeolipile.

SuperHero technology allows high power/cost, high power/mass, and high power/volume microturbines. The family includes atmospheric source heat engines, internal and external combustion heat engines, topping and bottoming cycle heat engines, boiler feed pumps, immersive self-propelled, self-cooled, liquid rocket turbopumps, thrusters, fans, condensers, expanders, liquefiers, mixed flow compressors, motors, generators, power convertors. centrifugal blowers, open and closed cycle air conditioners, dehumidifiers, and reactors.

Superhero microturbines can provide power on a scale appropriate for homes, vehicles, and persons.

SuperHero microturbines can provide power as needed, when needed, where needed, and with the voltage/current ratio needed via modularity and without the long construction times associated with legacy power plants.

Superhero microturbines can provide reliability, maintainability, and throttleability by modularity.

Superhero microturbines can provide combined heat and power (CHP). ~60 million U.S. homes have natural gas supply. A SuperHero microturbogenerator with exhaust heat used for space heating and water heating can have >90% overall efficiency, provide reliable low-cost electricity and reduce grid dependence. Natural gas is less costly than electricity and less subject to outage.

SuperHero microturbogenerators are attractive for uninterruptible power supplies and emergency power production.

SuperHero backpack microturbogenerators can provide electricity and compressed air for construction and landscaping tools. SuperHero microturbine driven machine tools can provide high power density and cooling.

Why haven't microturbines been more successful, despite the potential benefits?

Large turbomachines dominate in commercial air transport and electricity generation, but when the size of legacy turbomachines is reduced, some of the beneficial characteristics are reduced, often to a degree that render them unable to compete with other means.

Cost: the cost of legacy turbomachines is due in large part to the manufacturing processes associated with complex blading and the cost of materials able to operate with high thermal and mechanical loads. SuperHero microturbines incorporate manufacturing simplicity and commodity materials.

Efficiency: efficiency is proportional to $L^{2/3}$ (square/cube law), but the loss mechanisms associated with scale reduction in turbomachines are mitigated in SuperHero microturbines by using enclosed passages to avoid rotor to stator leakage, by the use of liquid working fluids, and by advantageous heat exchange with the environment associated with increased surface/volume, especially with cryogenic fluids.

SuperHero microturbines use rotating tube arrays as compressors and the rotor drag can also be useful thermodynamically, especially in the case of cryogenic liquid propellants.

Shear force: the reduction in passage size associated with scale reduction in microturbines implies increased shear force per unit fluid flow (<Re) and this increase in the ratio of shear force to inertial force is associated with increased drag. The relative shear force increase may be inevitable, but not inevitably bad. Small passages allow increased heat transport rates and SuperHero microturbines can be designed to operate with laminar flow where drag is proportional to velocity rather than the square of velocity associated with turbulent flow. Laminar flows also produce less noise.

A classic argument against tip jets is that efficient operation requires unrealistic tip speeds.

SuperHero microturbines combine modern materials and proprietary design to allow much higher tip speeds than legacy reaction turbines and the technology provides several means to use the energy downstream of the jets, including rockets, concentric contrarotating radial outflow impulse turbines, contrarotating tipjet rotors, entrainment, volutes, blown wings, and deswirl vane arrays.

Fig.1 SuperHero Tipjet Reaction Microturbine

The radial tubes in the arrays of Fig.1 are composed of 1.5mm OD X 0.1mm wall thickness (17Ga) 304 stainless steel hypodermic tubing. Superhero microturbines can generate higher pressures in a single stage than multistage legacy microturbines via the use of liquid propellants.

The rotating tube arrays in SuperHero microturbines cause fluids introduced through a central hollow axle to be accelerated in the tubes and ejected tangentially at the tube ends or returned to the hollow axle via “U” tubes.

The tube arrays can be configured as centrifugal, axial, or mixed flow compressors and blowers.

SuperHero microturbines are rotating high power density heat exchangers capable of extremely high pressures i.e., thousands of atmospheres. The extreme pressures are confined to small regions which also serve as high-rate heat exchangers. Torque can be additive and/or subtractive.

A large population of small jets allows increased coupling with the neighboring atmosphere for mass, momentum, and heat transfer. Jet expansion causes a reduction in temperature that can be mitigated by close association with the neighboring airstream. The neighboring airstream may be at atmospheric temperature or preheated.

SuperHero microturbines can have many rotating tube arrays and bilateral entry.

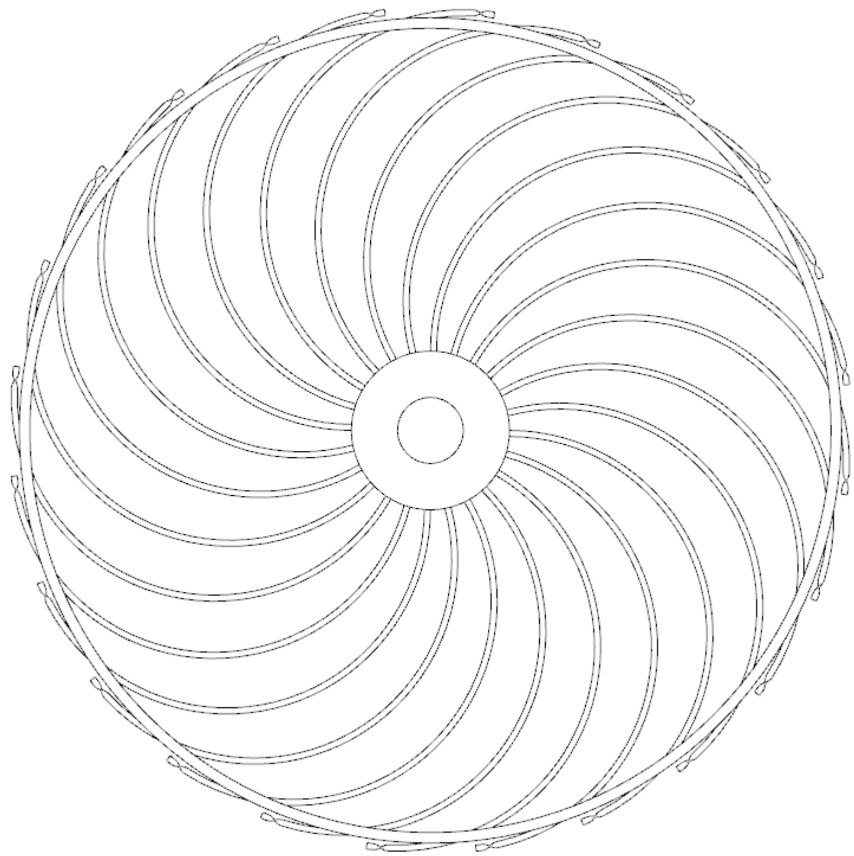

Fig. 2 SuperHero Tipjet Reaction Turbine with Backswept Passages

Fig. 2 is a SuperHero centrifugal microturbine rotor comprising a backswept stainless steel hypodermic tube array with C-D nozzles via plastic deformation and with brazed 4GPa tire cord wire supporting rings. Backswept tubes reduce drag and increase fill factor

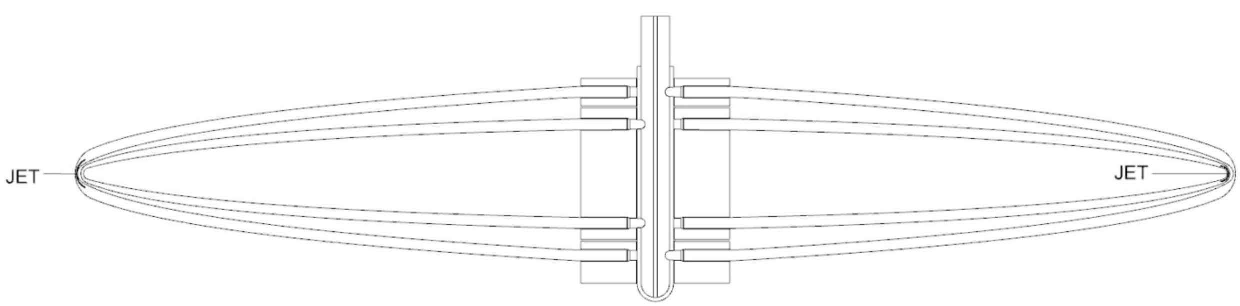

Fig.3 Contrarotating Parabolic Tube Array Schematic

Fig.3 is a pair of contrarotating radial reaction turbine arrays that can provide intense mixing and add torque to opposing turbine array. The jets from one rotor encounter opposing high velocity flows from neighboring rotors. The contrarotation can provide intense mixing, reacting, and combustion.

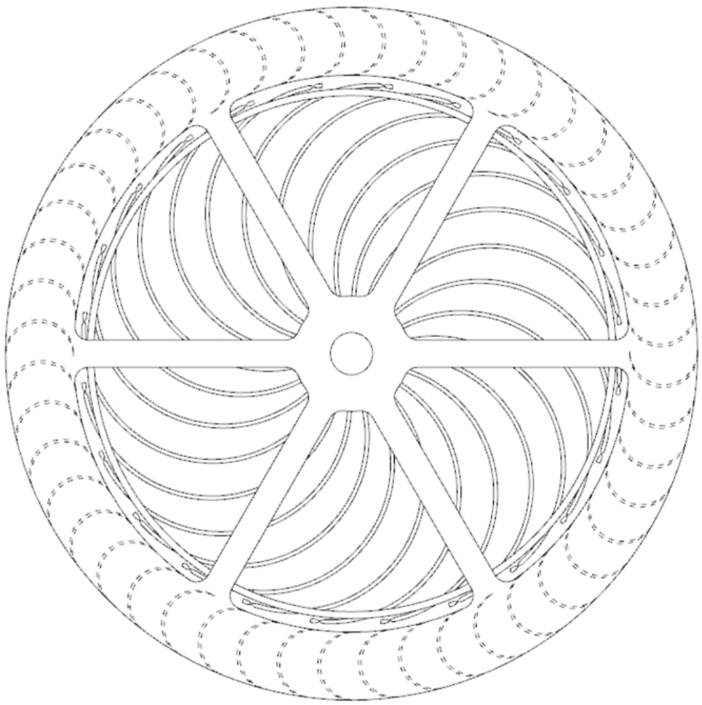

Fig. 4 SuperHero Tipjet Reaction Turbine with External Impulse Contrarotor

In Fig. 4 the SuperHero inner reaction turbine output drives a concentric contrarotating impulse turbine and the large number of nozzles provides high power density. One or more concentric contrarotating impulse turbine stages can be used in radially outflowing SuperHero microturbine systems to provide output power with increased efficiency, lower output rotational rate for connection to drives, reduced exhaust temperature, and reduced exhaust velocity.

Contrarotor spokes can be increased in number and used to induce air.

SuperHero microturbines can provide net positive suction head for pumping unpressurized propellants.

The incoming fluid passage between static axle and rotor can provide a hydrostatic journal bearing.

A rotor with 0.1m radial length liquid phase rotating at 45krpm will develop a centrifugal pressure equal to $(1/2\rho r^2\omega^2)$. A liquid air density ρ=870kg/m^3 X 0.5 X 0.1m^2 X ω4,710^2=9.65 X10^7N/m^2 or 965atm with an angular velocity of 471m/s.

17 Gauge thinwall 304 SS hypodermic tubing has an OD of 1.5mm, a wall thickness of 0.1mm, and a tensile yield strength of 944MPa. The hoop stress at 1,000 atmospheres (s=pr/t) is 650MPa, which yields a safety factor of ~1.5 at 1,000atm, and the high pressure is confined to a small region, allowing low wall mass and cost. 2GPa 301 stainless steel allows 2X pressure increase and 4GPa wire braided sleeve and helical bottlebrush inserts allows much greater pressures.

Low temperature and cryogenic SuperHero microturbines benefit from increased material strength at low temperature and the ability to use advanced nonmetallics such as carbon fiber and graphene.

A helical “Bottlebrush” internal structure can be used to provide an array of ties normal to the tube axis to resist outward pressure forces and provide extended surface area for heat exchange. The bottlebrush can use 4GPa wires and attach to the tube ID by brazing. Adding a helical moment counters the Coriolis force causing flow to follow the trailing edge of the tube wall and prevents Dean vortices due to tube curvature. 4GPa central twisted wire can provide increased axial tensile strength. The bottlebrush can be catalyzed to react with fluids in passage for combustion or operation as a chemical process reactor.

The thinwall tubes and high rotation rates in SuperHero microturbines provide high heat transfer rates, but extended surfaces such as wire cloth can be used to further increase heat transfer rates.

Wire cloth can be bias cut to equalize heat transfer for wires in both axes and to reduce edge affects. The wire cloth elements can be anchored at the hub and brazed to the tube arrays.

Wire arrays can use commercially available high strength copper clad steel wires (CCS) for increased heat transfer and brazing. The wire arrays can be brazed to the trailing edge of the tubes, making the tube arrays part of a hierarchal flow organization.

The rotating wire cloth arrays are somewhat analogous to crossflow filtration schemes. The high surface velocity parallel to the wire cloth arrays and the pressure difference across the wire cloth arrays provide very high heat transfer rates. The system can be designed for air to make a single pass through the capillary mesh.

SuperHero hierarchal microscale heat exchanger power density is due to the high surface/volume ratio associated with fine wire mesh, the related thin boundary layers, massive end stage parallelism, and laminar flow.