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(54) **Title:** MULTICOPTER WITH IMPROVED PROPULSOR AND FAILSAFE OPERATION

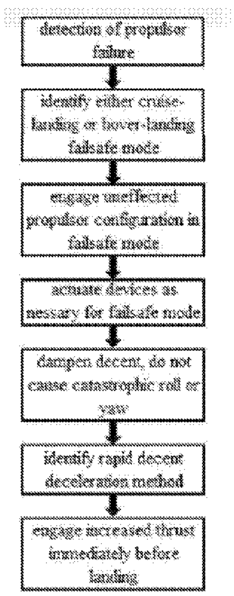

Fig. 10

(57) **Abstract:** A multicopter incorporates a front tiltwing, modular single-circuit motor, hybrid electric-fuel engine, modular injection-molded structures, and operational algorithms to reduce weight, increase efficiency, reduce greenhouse gas footprint, and improve safety. The multicopter has three failsafe modes of emergency landing with an engine have two modes of failsafe operation. The dicopter version of the multicopter has inherent flight stability from either propulsor with passive aerodynamic actuation.

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MULTICOPTER WITH IMPROVED PROPULSOR AND FAILSAFE OPERATION

CROSS REFERENCE TO RELATED APPLICATIONS

[1] This application is a continuation-in-part of Provisional Applications Ser. No 63/019,278 filed on May 2, 2020 entitled "Multicopter with Improved Propulsor and Failsafe Operation", Ser. No 63/016,362 filed Apr. 28, 2020 entitled "Multicopter with Improved Propulsor and Failsafe Operation", Ser. No 62/ 944,506 filed Dec. 6, 2019 entitled "Multicopter with Passively- Adjusting Tiltwing", Ser. No 62/879,003 filed Jul. 26, 2019 entitled "Passively-Adjusting Tiltwing", Ser. No 62/ 862,237 filed Jun. 17, 2019 entitled "High Speed Drone", and Ser. No 62/ 860,152 filed Jun. 11, 2019 entitled "High Speed Drone" and Non-Provisional Application 16/783,319 filed on Feb. 6, 2020 entitled "Multicopter with Improved Failsafe Operation". All of the above-listed applications are incorporated by reference in their entirety herein.

FIELD

[2] The present invention relates to vertical takeoff and landing (VTOL) aerial vehicles capable of transitioning to the equivalent of fixed-wing flight. More specifically this invention relates to multicopters with improved failsafe operation through use of a front tiltwing and to motors and structures useful for the aerial vehicles.

BACKGROUND

[3] This invention is a VTOL vehicle with significantly improved energy efficiency as compared to other VTOL vehicles. Benefits include lower cost vehicles, passive flight stability features, and reduced energy consumption. Additionally, use of light weight motors, structures, and jet engines further improves speed and efficiency.

[4] Preferred tiltwings of this invention include passively control and stability; often, passive control includes indirect control using a propeller to change vehicle velocity relative to air wherein the relative velocity of air controls tiltwing position. Baldwin (US Patent 7,059,562) performed early work on this topic and describes a wing "wherein the lift unit is freely rotatable". A tiltwing has both a propulsor and lift-generating wing-like surfaces.

SUMMARY OF THE INVENTION

[5] A transition VTOL tiltwing has a number of forces causing the tiltwing to transition from propulsor lift to propulsor thrust. Examples of torques acting on a tiltwing include torques from the center of gravity (CG), from aerodynamic forces, and from a propulsor motor (hereafter, "propulsor"). The tiltwing's pitch and respective propulsor force vector of this invention include passively-adjusting mechanisms such that increasing velocity leads to more thrust. Thrust is the horizontal vector of propulsor force; lift is the vertical vector. The

pitch of the fuselage may actively controlled by a number of methods, the most common of which is the rotational speed of a counterbalance propulsor (or propulsors). The pitch of the fuselage may be controlled by liftpath lift when cruising with a front tiltwing propulsor.

[6] A feature that distinguishes the embodiments of this invention from other art is a front tiltwing that can operate to land safely in the event of failure of all other vehicle propulsors.

BRIEF DESCRIPTION OF THE DRAWINGS

[7] Fig. 1 is an illustration of a dicopter version of a multicopter in VTOL position with a swaywing fuselage compartment.

[8] Fig. 2 is an illustration of a dicopter version of a multicopter in cruising position.

[9] Fig. 3 is an illustration of a dicopter version of a multicopter in failsafe pseudo-hovering position (10) using a front propulsor.

[10] Fig. 4 is an illustration of a dicopter version of a multicopter in cruising position with single truss airchassis; this is also a belly-landing failsafe configuration (11).

[11] Fig. 5 is an illustration of parts of a tricopter version of a multicopter.

[12] Fig. 6 is the tricopter with a freewing fuselage compartment in cruising position.

[13] Fig. 7 is the tricopter with the freewing in a loading (or unloading) position.

[14] Fig. 8 is a multicopter with a front tiltwing, lower swaywing, and control hardware.

[15] Fig. 9 illustrates three perspectives of a passively transforming rotary wing with passive twisting axis in radial direction and angular pivot to form a swept wing.

[16] Fig. 10 is a failsafe landing algorithm for "a-c failsafe modes".

[17] Fig. 11 is a quadcopter with a single front tiltwing in front of a single fuselage.

[18] Fig. 12 is an algorithm for changing steady-state velocity for a front tiltwing vehicle.

[19] Fig. 13 is an illustration of a bias torque electromagnet actuator.

[20] Fig. 14 is a tiltwing with a flap in position to bias the tiltwing to higher pitch.

[21] Fig. 15 is a tiltwing quadcopter a plurality of surfaces connecting to form a liftpath.

[22] Fig. 16 is an illustration of an aerial vehicle designed around a liftpath.

[23] Fig. 17 is an illustration of a pendular midsection propulsor with swaywing.

[24] Fig. 18 is a pendular midsection configured to approach airchassis for cruising.

[25] Fig. 19 is an illustration of a pendular midsection propulsor.

[26] Fig. 20 is a dicopter with arm connecting a swaywing where transforming of swaywing to cruising position lowers the midsection propulsor relative to the airchassis.

[27] Fig. 21 is a swept-wing cruising-position rotary wing on a multicopter.

[28] Fig. 22 illustrates slot on partial diagram of a stator disc.

[29] Fig. 23 is a single-circuit stator disc with a) outside and b) inside terminals (505).

[30] Fig. 24 a-c) are single-circuit stator discs having air (or water) cores and shielding, d) is a single-circuit stator disc with a solid core with holes for fluid flow, e) is a rotor disc having propeller baffles to induce flow, and f) is a rotor disc with a lip to reduce flux leakage.

[31] Fig. 25 is a paired configuration of single-circuit stator discs to achieve >1.5 loops.

[32] Fig. 26 is a stacked-disc stator hub connected to a vessel surface.

[33] Fig. 27 is a tricopter with a rear tiltwing in a) hover and b) cruise configurations.

[34] Fig. 28 a) is a stator comprising a fast stator stack and a slow stator stack with b) fast and slow rotors designed to engage the fast and slow stators.

[35] Fig. 29 illustrates a stator disc and rotor disc with larger inside:outside diameter ratio.

[36] Fig. 30 is a hybrid electric-fuel engine with a cross section of the scoop and nozzle.

[37] Fig. 31 is perspectives of a rotor-disc configuration for a hybrid electric-fuel engine with a larger propeller stator, relative to compressor stator, to provide higher propeller

[38] torque.

[39] Fig. 32 illustrates separate components of the Fig. 30 engine.

[40] Fig. 33 is an algorithm to optimally switch form electric to ramjet propulsion.

[41] Fig. 34 illustrates a structural body fabricated from two bodies showing a) the two bodies, b) cross sections of the two bodies, and c) and the structural body cross section.

[42] Fig. 35 is a fabricated male-component body with an alternative connector.

[43] Fig. 36 is a structural beam made by injection molding a body that contains a longitudinal tensile device showing a) the beam and b) a beam cross section.

DESCRIPTION OF INVENTION

[44] Figs. 1-4 illustrate a multicopter comprising a multicopter airchassis 2; a forward tilting body 3 pivotably connected [bearing 4] to the airchassis 2 and configured to pivot between a first position 5 associated with a hover flight mode and a second position 6 associated with a forward flight mode. A forward propulsor 7 is part of the front tiltwing 8; wherein the forward propulsor 7 is configured to aerodynamically actuate through a range of motion along with the forward tilting body 3 due to aerodynamics about the front tiltwing 8. The forward propulsor 7 is configured for failsafe operation to vertically land without lift from other propulsors such as a midsection propulsor 12 or second forward propulsor 13.

[45] A further embodiment of the multicopter comprises a second forward propulsor 13 coupled to the forward tilting 8 (see Fig. 2) wherein the forward propulsor 7 and the second forward propulsor 13 comprise a twin engine configuration 14 on the front tiltwing 8. A VTOL vehicle of this invention uses a front tiltwing to transition from VTOL to cruising and to enable a failsafe/emergency landing method. The VTOL vehicles have an airchassis as a

support structure that may be part of a fuselage or a separate structure and embodiments apply to multicopters ranging from dicopters to vehicles with more than four propulsors.

[46] Figs 5-7 illustrate tricopter components including a freewings 18 for payloads.

[47] The preferred embodiment is a multicopter comprising: a) an airchassis; b) a front tiltwing pivotably coupled to the airchassis and configured to transition between a hovering configuration and a cruising configuration, the front tiltwing including: (i) a first propulsor configured to generate at least one of thrust or lift and (ii) an aerodynamic lift surface; c) a counterbalance propulsor system coupled to the airchassis, the counterbalance propulsor system configured to balance gravitational, aerodynamic, thrust and lift forces and torques caused by the front tiltwing, the counterbalance propulsor system including a second propulsor configured to generate at least one of thrust or lift; and d) a control unit.

[48] The aerodynamic lift surface of the front tiltwing 3 is configured to: a) approach a near-perpendicular position relative to the airchassis 2 (see Fig. 1) in the hovering configuration 5 and b) approach a near-parallel position relative to the airchassis 2 (see Figs. 2, 4, and 15) in the cruising configuration 6. The multicopter further comprises a power supply (110, Fig. 8) configured to control the thrust and lift by providing a variable amount of power to the front tiltwing wherein the control unit is in communication with the power supply, the control unit having at least one sensor, a processor, and memory storing instructions thereon. When executed by the processor, control unit calculates at least one of the rate of descent, yaw angle, roll angle, pitch angle or altitude of the front tiltwing based on data provided to the processor by the at least one sensor; and the control unit adjusts at least one of the rate of descent, yaw angle, roll angle, pitch angle or altitude by regulating the amount of power provided to the first propulsor by the power supply via a control signal.

[49] As illustrated by Fig. 8, the power supply (110 or 112) and control unit (111 or 113), may be on the tiltwing, on the airchassis 2, or on other locations including redundant and interconnected configurations. Example sensors include a GPS sensor, level indicator, and velocity indicator; it is common for the sensors to be built into the control unit (111 or 113).

[50] Propulsors may provide lift and thrust; lift is an upward force and thrust is a horizontal force. The total propulsor force is the vector sum of thrust and lift. During steady-state flight, total lift needed to sustain flight is equal to the total multicopter weight.

[51] In the hovering configuration, the first propulsor of the front tiltwing and the second propulsor of the counterbalance propulsor system are configured to counterbalance the gravitational force acting through the center of gravity of the multicopter. Here, a propulsor may be one or more of the group: propeller, fan, rotating blade, or exhaust nozzle. In the

cruising configuration, the front tiltwing's propulsor generates more thrust than lift, and the front tiltwing's aerodynamic lift surface generates lift.

[52] Preferably, the airchassis, front tiltwing, and counterbalance propulsor system are transitionable through passive actuation to a default failsafe descent configuration, the failsafe descent configuration is conducive to landing without catastrophic damage to at least one of the airchassis, front tiltwing, counterbalance propulsor system, and a payload. Typically, passive actuation is movement due to a balance of forces (and torques) including at least gravity acting on a center of gravity and aerodynamic forces (from velocity and descent). Optional passive actuation does not preclude use of actuators. Payloads include passengers. Catastrophic is defined in terms of passenger safety and highly expensive vehicle damage; by example, loss of human life is catastrophic and damage greater than 20% of the value of the vehicle would be catastrophic.

[53] Preferably, the multicopters of this invention have three failsafe modes of descent, including: a) mostly vertical powered by the front tiltwing, b) mostly vertical powered by a midsection rotor, and c) mostly horizontal powered by the front tiltwing ("a-c failsafe modes"). The failsafe descent is typically triggered by a failure of a propulsor, and so, power from propulsors other than the one power descent is negligible. Fig. 10 provides an algorithm for using the a-c failsafe modes; a key failsafe aspect is to "dampen" "a)" and "b)" vertical (pseudo-autorotation) descent modes where dampen means to slow done without overdoing propulsor lift which could lead to out of control roll, yaw, or pitch.

[54] Preferred embodiments include a swaywing or freewing which positions at a location that both a) provides for easier loading and b) reduces resistance to hovering aerodynamics of propulsors producing lift. Figs. 1-4, 8, 17, and 20 illustrate swaywings 26.

[55] "Liftpath" is a term used to define efficient lift surfaces other than traditional airfoils; it is described and defined in U.S. Patent 10,589,838 B 1 and provisional applications cited therein. Liftpaths include surfaces having air angle of attacks from 0 to 3 degrees (leading-edge up surfaces of low pitch) on relatively flat surfaces that are longer than wide. A preferred swaywing has a total wetted surface area and a swaywing total liftpath area where the swaywing total liftpath surface area is greater than one third the swaywing wetted surface area. The swaywing is located below the airchassis and pivotably coupled to the airchassis.

[56] A midsection rotor is the preferred counterbalance propulsor due to failsafe landing configurations and due to the ability to of the rotary wing to fold to a fixed wing configuration with a conversion mechanism illustrated by Fig. 9 and a fixed-wing position on a vehicle illustrated by Fig. 21. Preferred midsection rotor transition is by aerodynamic

actuation where a stopped rotor leads to the fixed-wing position and rotation leads to the rotary wing configuration. A catch 84 may lock a first blade 69 in position relative to the fuselage (or airchassis) when aerodynamic forces cause rotation in a direction reverse that for lift generation; where after, the aerodynamic forces twist the second blade 70 about a radial axis 88 from the rotary wing position 89 to a fixed wing position 90. Movement of the second blade 70 in the angular direction 85 forms a swept wing. Preferably, the midsection rotor is of a design without a swashplate, and failsafe landing is in a pseudo-autorotation method with a pseudo-hovering configuration. Pseudo-autorotation method means "sort of autorotation method" and refers a moderate power supply to the rotor during descent with an increased in power five to fifteen seconds before landing to dampen landing soften the landing. The pseudo-hovering configuration is one in which a rotary wing or propulsor of a high ratio of upward force relative to weight (e.g. the high ratio is >0.4) passively positions above a fuselage of a lower ratio of upward force relative to weight. The upward force is a sum of lift and drag vertical vectors. A front tiltwing is located in front of the fuselage center of gravity, and the passive stability features of a front tiltwing causes formation of the auto-hovering configuration at forward velocities less than 50 miles per hour (mph) when there is negligible lift from the counterbalance propulsor and when lift-path lift is inadequate to maintain a cruising configuration. The front tiltwing is blocked from having a lower pitch (more nose up is more positive) than the airchassis by devices such as the airchassis 2 of Figs 1-8.

[57] Characteristics of these failsafe landings include one or more of: a) the thrust generated by the first propulsor is increased to a value greater than the pseudo-hovering lift prior to landing, b) the control unit (or pilot) maintains the roll angle between about -20 degrees to about 20 degrees from horizontal, and c) a slight forward velocity during the pseudo-autorotation failsafe (see Fig. 3) to facilitate control/stability.

[58] Preferably the multicopter comprises a plurality of longitudinally-extending lift-generating surfaces 327 forming a total aerodynamic lift surface area (see Fig. 15), the plurality of longitudinally-extending lift-generating surfaces comprising [a]the fuselage, the front passively-adjusting tiltwing, and an arm mechanically connecting the front passively-adjusting tiltwing to the fuselage. The plurality of longitudinally-extending lift-generating surfaces forms a liftpath 121 in a cruising configuration with the front tiltwing being a single front tiltwing in front of a single fuselage Typically, lift provided by the front passively-adjusting tiltwing is less than half the lift provided by the total aerodynamic lift surface area. The plurality of surfaces align to form liftpath.

[59] Swaywings and freewings of this invention are types of fuselages. For vehicles

without a swaywing or freewing, the airchassis is part of the fuselage.

[60] **Three Failsafe Modes and Midsection Rotary Wing** - The afore-mentioned a-c failsafe modes are a plurality of failsafe methods for landing a multicopter where the multicopter comprises a front tiltwing, a vehicle center of gravity, a front tiltwing propulsor thrust, a front tiltwing propulsor lift, a front tiltwing propulsor force, a ratio of tiltwing propulsor thrust to lift, a front tiltwing propulsor lift, a total multicopter lift, a total multicopter thrust, a first failsafe method, and a second failsafe method. The first failsafe method comprises transitioning the front tiltwing to a position wherein the total multicopter lift is more than four times greater than the front tiltwing propulsor lift and the tiltwing propulsor thrust is at least eighty percent of the total multicopter thrust. The second failsafe method comprises transitioning the front tiltwing to a position where the front tiltwing propulsor lift is greater than one third of the total multicopter lift and the tiltwing propulsor lift is greater than the total multicopter thrust. Preferably, passive aerodynamic actuation transitions the tiltwing for the first failsafe method and second failsafe method. The passive aerodynamic actuation is a result of the inherent stability of the front tiltwing against stall where tiltwing propulsor thrust induces the failsafe mode.

[61] The third failsafe method comprises transitioning a midsection rotary wing from a fixed wing position to a rotary position where the midsection rotary wing is coupled to and extends above an airchassis, and the midsection rotary wing is coupled to a power supply and a control unit. Preferred pseudo-autorotation increases and maintains lift from a propulsor or blade to >70%, preferably >80%, of the multicopter weight at least one second before impact.

[62] The Pseudo-autorotation method increases power to propulsor just prior to landing, the rate of descent is decreased while the yaw/roll/pitch increase has not had adequate time to catastrophically roll, flip, or spin the vehicle. Just prior to landing is about 8 seconds prior to landing, but could be greater or less depending on the specific situation. Preferably, yaw is controlled by aerodynamic forces acting on vanes 114 of a duct 115 surrounding the midsection rotary wing or a tiltwing propeller, whereby the vanes 114 are configured such that aerodynamic forces on the vanes 114 provide partial yaw control.

[63] Fig. 4 illustrates a configuration for the first failsafe method while Fig. 3 illustrates a configuration for the second failsafe method. For a vehicle without a swaywing (e.g. Fig. 15), the configuration for the first and second failsafe methods are the same with the vehicle point upward in the tiltwing's hover failsafe landing configuration.

[64] The second failsafe method is enabled by a front tiltwing propulsor force vector that provides a minimum torque about that center of gravity. In general, minimum torque

corresponds to the closest distance of approach of the extended force vector being less than half the median width of the aircraft fuselage.

[65] **A Most-Preferred Multicopter** - Fig. 10 illustrates a multicopter. Preferably, the tiltwing power supply (110) and control unit(l 11) are in addition to a airchassis power supply (112) and control unit (113) so as to provide for redundancy power, control, and propulsion therein allowing either the tiltwing or midsection rotary wing to land to land the multicopter. Preferably, propulsor ducts (114) have counter-torque duct vanes (115) along inner surfaces oriented to bend downwash air in a direction opposite the direction of travel of the rotor or propellor blade passing adjacent to the vanes (115). A vertical stabilizer (116) provides stability on a location to mount a rudder (117). Most preferably, the stabilizer (116) and rudder (117) are attached to an aft swaywing arm (40) in a manner that provides primarily roll control in the hovering configuration and primarily yaw control in the cruising configuration. Similarly, a stabilizer (116) with rudder (117) may be attached to the upper surface of the front tiltwing (8) to provide roll and yaw control.

[66] Preferably at least one aileron (118) is on the front tiltwing (8) configured to provide roll control, most preferably including enabling of yaw control from propeller downwash. A flap (362) on the front tiltwing (8) may also be used to bias pitch.

[67] Fig. 10 also identifies hardware for failsafe algorithm control comprised of: a) an airchassis (2); b) a single front tiltwing (8) extending in front of the airchassis (2) said front tiltwing (8) comprising a tiltwing propulsor configuration (7), an aerodynamic lift surface (347), a tiltwing power supply (110), and a tiltwing control unit (111) said control unit (111) comprising a control signal to control the tiltwing thrust such as a speed control system controlling power to the propulsor and communication by hard wire or transmitter-receiver communication.

[68] More preferred operation is a) wherein the hovering configuration (5) comprises a balancing of downward force on the center of gravity, lift from the front tiltwing (8), and lift from the counterbalance propulsion configuration.

[69] **Biased Actuator** - Fig. 13 illustrates a preferred actuator to provide position control; it is preferred since the electromagnet coil 364 creates a force but does not lock the actuator in position which is important in event of coil 364 failure for a system with passive control. The actuator is comprised of: a) an electromagnetic coil 364 with control system said coil connected to the fuselage and b) a internal electromagnet core rod 365 said rod having a first end attached to a device for positioning and a second end attached to a spring (or functional equivalent of the spring) and a section of continuously increasing ferromagnetic strength

from a first end to a maximum before continuously decreasing to the second end.

[70] Optionally, the spring may be removed or reduced in tensile force from the preferred actuator in an alternative actuator embodiment. The actuator acts as a damper, the rod 365 is a moving component that moves within a stationary electromagnetic coil 364. The first end 366 of the core rod is mechanically connected to provide torque on, by example, the tiltwing shaft 312. This optional configuration can be used both to dampen and to bias the tiltwing pitch. In this embodiment, application activation of the magnetic coil while at a vertical thrust position biases the tiltwing with negative torque toward a position with a forward thrust vector useful for initial acceleration. When the tiltwing is at or near its minimum angle/pitch, activation of the coil will bias the tiltwing with a positive torque force useful to pull out of a nose-down loss of forward lift. The control system is a feedback control system based on a set point such as rate of change of altitude relative to rate of velocity change.

[71] **Pendular Midsection Rotary Wing -** The optional configuration has the front tiltwing pivotably connected to a forward portion of the airchassis, and the counterbalance propulsor system pivotably connected rearward of where the front tiltwing is pivotably connected to the airchassis. A passive roll control embodiment comprises a midsection propulsor 12, such as a rotary wing 53, and a pendular connection 101. By example, a socket 102 and ball 103 form a pendular connection 102 which is mechanically connected to a vehicle with an arm 96 and a flexible arm 104. The motor 105 of the midsection rotor may serve as both a pendular weight and part of the structure. Here, the weight of the motor 105 may create a pendular movement in the spanwise direction. Either the Fig. 19 air chassis 2 or Fig. 18 arm 96 may connect to the socket 102; the socket may be donut shaped.

[72] Hinge joints 107, see Fig. 17, may connect the airchassis 2 or arm 96 to other vehicle components. A pendular hinge joint 108 may also provide an alternative pendular connection 101 that only has pendular action in a single plane.

[73] **Swaywing Positioning -** Passive activation of the optional swaywing may be configured to complement the tiltwing's inherent stability for these a-c failsafe modes. Here, the methods include transitioning a swaywing from a cruising position to a hovering position where the swaywing is configured to transition between a cruising configuration and a hovering configuration. The swaywing includes a fuselage compartment, a swaywing arm, and a lifting body surface; and the swaywing is located below the airchassis and mechanically connected to the airchassis through at least one lateral axis bearing by the swaywing arm. Fig. 4, Fig 3, and Fig. 1 illustrates the swaywing positions consistent with the first, second, and third failsafe methods, respectively.

[74] The swaywing may be connected to the front tiltwing at a location between a rearward end of the tiltwing's aerodynamic lift surface and a midpoint of the tiltwing's aerodynamic lift surface (see Figs. 1 and 8). The swaywing arm is a forward extension of the swaywing and the swaywing moves about the at least one lateral axis bearing. The swaywing further comprises a swaywing lateral-axis bearing connecting the swaywing to the swaywing arm where the swaywing is configured to swing in the aft and upward directions relative to the airchassis. Preferably, the swaywing arm is an aft swaywing arm and a forward swaywing arm is connected at one end to the swaywing via a lateral-axis bearing where the swaywing arm is connected at the other end to a) the airchassis via a lateral axis bearing (Figs. 3 and 4), or c) a front tiltwing via a lateral axis bearing (Figs. 1 and 10).

[75] **Plurality of Surfaces Forming Liftpath** - A preferred embodiment is a multicopter comprising a single front passively-adjusting tiltwing in front of a single fuselage, a tiltwing propulsor, at least one counterbalance propulsor, a plurality of longitudinally-extending lift-generating surfaces 327 (see Fig. 15), and a total multicopter weight. When transitioned to cruising, the plurality of longitudinally-extending lift-generating surfaces forms a liftpath wherein lift provided by the front passively-adjusting tiltwing is less than half total multicopter weight.

[76] Preferably: a) the front passively-adjusting tiltwing is freely rotatable relative to the fuselage within a predetermined angular range around a tiltwing axis, b) the multicopter comprises two propulsors on the front passively-adjusting tiltwing, two arms mechanically connecting the fuselage to the front passively-adjusting tiltwing where the at least one counterbalance propulsor is two rear propulsors said two rear propulsors set at an angle relative to the fuselage, c) the fuselage comprises a swaywing pitotably connected to an air chassis pitotably connected to the sing front passively-adjusting tiltwing, and d) control system is capable of configuring the multicopter for a failsafe landing where greater than eighty percent of lift on the multicopter is generated by the tiltwing propulsor.

[77] **Forces, Torques, and Passive Activation** - A preferred embodiment may be defined in terms of designs that use inherent forces and torques for actuation. Here, a preferred multicopter comprises: a fuselage, a fuselage first propulsor, a wing 1, and a first tiltwing propulsor 2 statically connected to the wing 1 forming a passively-adjusting tiltwing 3, wherein a bearing mechanically couples the tiltwing and the fuselage said tiltwing freely rotatable relative to the fuselage within a predetermined angular range around a tiltwing axis (4), said tiltwing having i) a mass centroid, ii) an area centroid, iii) a mass centroid torque distance being the distance between the mass centroid and the tiltwing axis, iv) an area

centroid torque distance being the distance between the area centroid and the tiltwing axis, and v) a tiltwing centroid ratio said centroid ratio being the mass centroid torque distance divided by the area centroid torque distance, wherein the value of the tiltwing centroid ratio is between 0.2 and 5. Aerodynamic and gravitational forces produce torques about the tiltwing axis said torques comprising a positive tiltwing center of gravity force torque, a negative impacting air aerodynamic force torque, and a third positive torque, and wherein thrust of the fuselage first propulsor relative to thrust of the first tiltwing propulsor controls the pitch of the fuselage.

[78] Preferably: a) the third positive torque is one from a list comprising (i) torque resultant of force of the first tiltwing propulsor said first tiltwing propulsor having a motor axis of rotation below the tiltwing axis, (ii) torque resultant of a spring having a first end connected to the fuselage and a second end connected to the tiltwing, (iii) torque resultant of a variable force electromagnetic damper with a first end connected to the fuselage and a second end connected to the tiltwing, and (iv) torque resultant of tiltwing propulsor prop slipstream impacting a back-side concave surface of the wing 1; b) the multicopter comprises a total vertical takeoff thrust and a total multicopter weight wherein thrust from the tiltwing during vertical takeoff is less than half the total vertical takeoff thrust and lift force from the tiltwing is less than half the total multicopter weight; c) for multicopters with maximum cruising velocities is between 100 and 350 mph the tiltwing centroid ratio is between 0.5 and 3.0; d) the multicopter comprises a fuselage second propulsor wherein the fuselage first and second propulsors are set at an angle between 50 and 85 degrees relative to the median angle of the lower surface of the fuselage; e) said first tiltwing propulsor 2 has a motor axis center of rotation 9 and a tiltwing axis 4 center of rotation wherein the motor axis 9 is below the tiltwing axis 4 said passively-adjusting tiltwing having a center of gravity where in the vertical thrust configuration 5 said center of gravity is at or below the tiltwing axis 4, and wherein, a thrust of the tiltwing motor 2 produces a positive torque around the tiltwing axis 4 said positive torque producing force toward the vertical thrust configuration 5, gravity action on the center of gravity generates a zero to positive torque around the tiltwing axis 4, and the impacting air from horizontal flight produces a negative torque around the tiltwing axis 4; f) the multicopter comprises a fuselage second propulsor said first and fuselage second propulsors being electric motors turning propellers, and g) the plurality of longitudinally-extending lift-generating surfaces 327 forms a liftpath comprising: a cabin, said cabin having an average cabin length, a cabin average width, and a cabin average height; the lift path having a width greater than six tenths the cabin average width and said lift path having a

length greater than seven tenths the cabin average length; said lift path having a front third with a front average pitch, a back third with a back average pitch, and a middle third with a middle average pitch; wherein the back average pitch is 1 to 3 degrees less than the front average pitch.

[79] **Preferred Motor** - The preferred motor has a high power density and simple, inexpensive modular design. That preferred motor is based around a stator embodiment that may be used in both motor and generator applications. The stator discs 514 and stacked-disc configurations 521 or 523 may be used in generators in synchronous configurations.

[80] The preferred motor comprises a stator system. The stator system comprises a plurality of stator discs configured to rotate about a common axis. Each stator disc of the plurality of stator discs is spaced apart and defining gaps therebetween, and each stator disc of the plurality of stator discs includes an induction circuit wherein the induction circuit does not cross itself along the common axis. The induction circuit comprises a plurality of circuit radial-direction tracks, a plurality of angular-direction tracks, and a plurality of terminals. Example stator discs are provided by Figs. 23, 24, and 29. The term "stacked-disc configuration" is used to describe the preferred stator system will examples illustrated by Figs. 26, 28, 30, 31, and 32.

[81] A circuit busbar connects the plurality of stator discs to a controller. The circuit bus-bar provides electric power to the plurality of stator discs. A rotor system is axially aligned with the plurality of stator discs. The rotor system includes at least one rotor; the at least one rotor positioned in one of the gaps between each stator disc of the plurality of stator discs.

[82] Preferably: a) the circuit busbar further comprises a stationary shaft or a housing; b) a rotary device is one from a list comprising an electric motor, an electric generator, a pump, a propulsor, propeller, a hybrid jet engine, a rotating shaft, a synchronous electric motor, and an asynchronous electric motor; c) the rotary device includes a sensor, a source of electrical power, a control unit, and a flowing cooling fluid, and d) each stator disc of the plurality of stator discs includes a plurality of stator-disc cores through which at least one of ferromagnetic composite, ferromagnetic metal, air, and water may be housed. Example cooling fluids are ambient air or ambient water. A core material is simply that material through with an electromagnet induces magnetic flux. A core may be a ferromagnetic material, air, water, or essentially any material. The properties of the core impact the properties of the flux generated by an electromagnet. The rotary device's control unit and sensor with connection to the power supply may be combined in a motor control unit 513.

[83] Preferably: a) the motor comprises a plurality of induction circuits on each stator disc

of the plurality of stator discs of the stator system; b) the plurality of stator discs are fabricated by at least one of 3D printing, metal stamping, laser cutting of sheet metal, or pressing of a metal wire; c) two stators from the plurality of stator discs are adjacently mounted on the circuit busbar forming a 1.5 loop stacking, the 1.5 loop stacking having an induction circuit with four radial direction tracks, an inner angular direction track, and an outer direction track, and d) the motor comprises a 1.5 loop stacking 528 (see Fig. 25) said 1.5 loop stacking 528 comprising two of the each stator discs 502 adjacently mounted on the circuit busbar 506 forming adjacently-mounted sections cumulatively forming an induction circuit 510 comprising four radial-direction tacks 503, an inner conductive angular-direction track 504, and an outer conductive angular-direction track 504.

[84] Several options exist for the at least one rotor system. The rotor system may include: a conductive metal disc, a primary coil coupled to a rotating secondary coil and attached to a housing, an induction circuit (a continuous conductive track from connector to connector), a permanent magnet and a magnetic bearing through interaction with stator induction circuits 510. The preferred rotor system is configured to be turned via electromagnetic induction forces. Preferred stator disc configurations include: a three phase configuration comprising three angular orientations of the stator discs 502 aligned along the common axis 507, a six phase configuration comprising six angular orientations of the stator discs (#02) aligned along the common axis, a two phase configuration comprising two angular orientations of the stator discs aligned along the common axis 507, and a four phase configuration comprising four angular orientations of the stator discs 502 aligned along the common axis.

[85] Preferably: a) the induction circuit further comprises multiple circuit sections 516, each circuit section including two radial-direction tracks 503, one angular-direction track 504, and a stator-disc core 515 and b) at least one of the circuit sections of the induction circuit includes a conductive track extension 518 and a conductive discontinuity 519 adjacent the conductive track extension. The conductive track extension, two of the radial direction tracks, one of the angular direction tracks and the conductive discontinuity form a perimeter that surrounds a the stator-disc core. Also, a conduction lip 554 on a rotor disc may be used to provide flux shielding (see Fig. 24f). Fig. 24 b-c illustrates the conductive track extensions 518 and discontinuities 519. The conductive discontinuity 519 may be between conductive track extensions 518 from the two radial-direction tracks 503 or between outer ends of radial-direction tracks 503 and a conductive track adjacent to the stator disc's outer perimeter.

[86] The circuit tracks are preferably conductive metal (e.g. copper) strips where electrical insulation is applied to the outer surface of the metal as known in the science to prevent

electric current flow outside the metal strips. An example fabrication method is comprised of: a) laser cutting the induction circuit 510 from sheet metal, b) dip coating of the induction circuit 510 in a resin that forms an insulating layer, and c) injection molding of the stator-disc core 515between the sides of the induction tracks at locations where it is desired to have electromagnet core material (often referred to as a composite core).

[87] As common in the science, symmetry is preferred in design such as disc sections being axially symmetric around the axis of rotation 507. Also, a constant change/interval in angular orientations is preferred for the induction motor phase configurations. Figs. 26 and 28 illustrate stacked-disc configurations with changes in disc angular orientations to facility phased induction motor operation.

[88] **Motor Torque and Speed** - Certain applications require rotary device power of different torque or speed, where optimal applications match torque and power curves with applications. Embodiments of this invention can use the same busbar and axis of rotation to drive stators that engage rotors operating at different speeds and torques.

[89] Preferred motors comprise a slow grouping and a fast grouping , each of the slow 521 and fast groupings 523 including at least one stator disc of the plurality of stator discs and at least one rotor of the rotor system wherein the rotor system further includes at least two rotors, wherein the at least one stator disc of the slow grouping has a different number of circuit sections within the induction circuit than the number of circuit sections within the induction circuit of the at least one stator disc of the fast grouping, and wherein the at least one rotor of the slow grouping rotates at a different speed than the at least one rotor of the fast grouping. From a torque perspective, preferred motors comprise a slow grouping and a fast grouping, each of the slow 521 and fast groupings 523 including at least one stator disc of the plurality of stator discs and at least one rotor of the rotor system wherein the rotor system further includes at least two rotors. The at least one stator disc of the slow grouping has a larger average outside diameter than the average outside diameter of the at least one stator disc of the fast grouping, and the at least one rotor of the slow grouping generates a greater torque than the at least one rotor of the fast grouping.

[90] As the outside radius of the slow grouping 521 increases, the inside diameter may also increase with an outsidebnside radii ratio decreasing as per the discs of Fig. 29.

[91] **Hybrid Fuel-Electric Engine** - A hybrid electric-fuel engine is enabled by the motor torque embodiments of the previous paragraph. That engine provides speed and weight advantages for the preferred multicopter embodiments.

[92] Here, the preferred motor comprises a hybrid electric-fuel engine 530, the hybrid

electric-fuel engine 530 connected to a fuel tank 537 containing fuel 538. A fan or propeller is connected to the at least one rotor of the slow grouping. A compressor is connected to the at least one rotor of the fast grouping, the compressor including: a) an air entrance and an air exit, b) the air exit being in fluid communication with a combustion chamber, c) a combustion chamber configured to allow air to mix with fuel to produce flue gas in the combustion chamber, and d) a nozzle configured to allow the flue gas to exit the hybrid electric-fuel engine with expansion under pressure against inside surfaces of the nozzle.

[93] The circuit busbar 506 may be a shaft connected to an aerial vehicle. The preferred high-torque stator busbar 206 is an annulus with air flowing through the hole of the annulus as illustrated by Fig. 31 with preferred stator discs of Fig. 29. An example of a housed compressor 533 is an axial compressor turning inside a scoop. Preferably, a continuous internal surface progresses from the hole of the busbar annulus to the scoop to the combustor and through the nozzle to an exit from the motor. Thrust is transferred across the inside surface of the nozzle; a design method reduced to practice by heuristics of rocket, jet, and ramjet designs. Combustion enables jet propulsion by increasing the temperature of an air mixture under pressure, therein creating a larger volume of air at the combustion pressure for aerodynamic propulsion power than the power required to compress the air into the combustor. The preferred size and shape of the nozzles is bell-shaped and of an exit size so as to discharge the flue gas at a pressure between 1.0 and 1.2 times ambient pressure.

[94] The hybrid fuel-electric engine comprises a propulsion mechanism, the propulsion mechanism providing thrust by an electric-powered rotating blade, combustion-enabled nozzle jet propulsion, or the combination of electric-powered rotating blade and combustion-enable nozzle jet propulsion. The preferred compressor is a turbine compressor. A turbine expander may be used where the turbine expander is mechanically connected to the turbine compressor. More preferred is a hybrid electric-fuel ramjet engine mechanism absent an expander where compression is by a scoop 541 located in front of the combustion chamber.

[95] Ramjets cannot operate at zero vehicle velocity, and so, this embodiment uses an electric-powered propulsor (e.g. propeller connected to a high-torque rotor) at lower velocity. Fig. 33 illustrates an algorithm for beneficial operation of the hybrid electric-fuel engine.

[96] A Bernoulli tube is an example of how a scoop and nozzle can connect to efficiently compress then expand a gas. Changing pressure of air is a vital step in ramjet and jet operation, with the goal being compression at a lower temperature than expansion.

[97] Preferred is for the scoop to surround at least part of the compressor forming a housed compressor 539 having a turbine with blades 542 of larger radial length at the compressor

entrance and blades of smaller radial length at the compressor exit.

[98] The hybrid fuel-electric engine may use other motors than the motor embodiments of this invention. A preferred hybrid electric-fuel engine comprises an at least one electric motor, a propeller, a compressor, and a ramjet system. The motor preferably has a fast stator, a fast rotor, a slow stator, a slow rotor and a longitudinal axis of rotation; the engine further comprising: a) the at least one electric motor comprising; b) the slow rotor rotating the propeller around the longitudinal axis of rotation; c) the fast rotor rotating the compressor around the longitudinal axis of rotation; d) the hybrid electric-fuel engine 530 connected to a fuel tank 537 containing fuel 538; e) the ramjet system comprising a scoop, a combustion chamber, and a nozzle; f) the compressor including an air entrance 534 and an air exit 535, the air exit 535 in fluid communication with the scoop to form an air flow path; and g) the air flow path flowing from the scoop to the combustion chamber to the nozzle to an ambient environment exit. The combustion chamber is configured to allow air to mix with fuel to produce flue gas in the combustion chamber, where no shaft connects a rotating expander to the axial-flow compressor. Optionally: a) the compressor is an axial-flow compressor, b) the compressor is a turbine compressor preferably with blades of the turbine compressor project from an outer rotating surface inward, c) the propeller comprising a plurality of propeller blades connected to the slow rotor said propeller blades extending radially outward from the slow rotor, d) the propeller is a fan, and e) the slow stator in an annulus configuration with the propeller blades extending radially outward from the annulus configuration with air flowing through the annulus configuration to the scoop.

[99] An advantage of this design is minimal restriction of air flow which enables reducing of compressor compression of the feed to the ramjet system at higher velocities. Methods known in the art to control combustion and expansion in a ramjet may be directly applied herein to allow one familiar with the art to reduce this embodiment to practice. This embodiment uses electric-power compression and a scoop inlet as the entrance to the ramjet combustion chamber at lower velocities, such as velocities between 100 and 450 mph. At lower velocities, ramjet operation is inefficient and at higher velocities the supplementing of compression with electrical power is not needed.

[100] At higher velocities the momentum of impacting air will compress air to enable the ramjet propulsion mechanism. The optimal balance of compressor compression versus air-momentum compression progresses from only compressor compression at zero velocity to mostly, or totally, air-momentum compression at higher velocity (e.g. >450 mph). Control of optimal operation of the hybrid electric-fuel engine may be reduced to a control algorithm.

[101] The hybrid electric-fuel engine preferably comprises a control algorithm and a sensor, the sensor providing an electrical input to the controller with the electrical input functionally related to the second derivative of the propulsion thrust relative to axial compressor (or propeller) power input. The algorithm (see Fig. 33) comprises the progressive steps of a) engage the propeller, b) engage the compressor, c) ignite the ramjet burner, d) shut down the propeller, e) balance compressor versus scoop compression, and f) optionally to convert to 100% ramjet thrust. The velocity set points for progressing through the steps varies with details of the design, but can be determined the afore-mentioned second derivative function.

[102] Specifying in greater detail, the hybrid electric-fuel engine comprises a propeller backwash average velocity, a compressor backwash average velocity, a ramjet startup velocity, a propeller shutdown velocity, and a maximum velocity with an algorithm sequence of: the propeller is engaged as the primary thrust for takeoff, the compressor is engaged until the compressor backwash average velocity is about equal to the propeller backwash average velocity, the velocity is increased, the ramjet burner is ignite at the startup velocity, the velocity is increased, the propeller is shut down at the propeller shutdown velocity, velocity is increased wherein the compressor duty/power is adjusted based on proximity to the minimum of the second derivative of the propulsion thrust relative to axial compressor power input, the velocity is increased, and the compressor is shut down at the compressor shutdown velocity therein feeding air into the ramjet only through scoop aerodynamics.

[103] This algorithm is summarized by Fig. 33. Here, shutdown is further defined as a) setting power input to zero and allowing free rotation, b) providing only sufficient power so as to eliminate the longitudinal drag component, or c) braking of rotation with folding of blades reward about a hinge connection to a hub of rotation.

[104] The ramjet version (no turbine expansion) of the hybrid fuel-electric engine has advantages of simplicity (reduced cost) and potential for reduced lost work. A second law analysis of engine operation directly relates lost work to irreversible processes. Turbine and compressor operation have definitive and significant lost work while Bernoulli-tube type of compression and expansion has minimum lost work. The optimization of the ramjet version of this invention includes optimizing the nozzle shape and size to reduce the lost work of mixing of exhaust with ambient air where exhaust port size is increased to be greater than but approaching a targeted vehicle velocity; wherein, the exhaust area will tend to be larger than the air intake area. If is preferred to distribute, to some extent, the exhaust area along the back side of a wing or fuselage, and it is preferred for that area to have a width greater than height to facilitate lifting body surfaces on the upper and lower portions of an engine housing

(which may be part of a wing or fuselage). A preferred option is to have the hybrid engine at the rear of a vehicle such as the propeller of Fig. 27; wherein, the high-torque stator driving the propeller may be at the aft of the engine with exhaust gases exiting through the hole of high-torque stator annulus.

[105] In a pandemic environment, commercial flights can be highly impacted by spreading of a virus. The embodiments of this invention have advantage for energy and cost effective jet-speed flights of smaller passenger payload. It is possible to use the air handling system of a aircraft to spread vaccine through airborne water droplets. In a highly evolved species, the species has a defense against a virus where transmitted fluids (e.g. airborne droplets) that unavoidably contain biological information to spread a virus, also have biological information to fight the virus. Here the transmitted virus biological information acts as a catalyst to stimulate production of the virus-fighting biological information. Such biological information would be in the fluids of these highly evolved species, and the air handling system could circulate actual airborne fluids from species or replicated airborne fluid compositions.

[106] **Fluid Propulsion Devices** - In addition to aerial propulsion, embodiments of this invention are useful to induce fluid flow. An alternative motor embodiment is a fluid propulsion device. The preferred motor is where: a) each stator disc of the plurality of stator discs includes stator disc cores, b) the circuit busbar is a shaft connected to a surface, c) the rotor system includes a stacked-disc rotor with at least partially open core discs with the stacked disc rotor is inductively coupled to the shaft and configured to rotate around the shaft, d) a fluid flows axially through the stator-disc cores of the plurality of stator discs, and e) the fluid flows through the at least partially open core discs of the stacked-disc rotor. Flow is induced by the stacked-disc rotor 544 by deflective surfaces that are substantially built-in rotor blades 550 to induce propulsion. Fig. 26 illustrates a stacked-disc stator as a hub for mounting a propeller on a naval vessel.

[107] Preferably: a) at least partially open-core discs of the stacked-disc rotor induce fluid flow through the stator disc cores of the plurality of stator discs where the disc have built-in propulsor surfaces 550; b) the fluid propulsion device is a propulsor for a naval vessel; c) a housing surrounds the propulsion blades with a housing entrance end, a housing exit end, and with propulsor blades connected to the stacked-disc rotor; d) the stacked-disc rotor further comprises a stator-disc stator water pump; e) the stator-disc stator water pump is in an electric appliance such as a washing machine or dishwasher; and f) the stator disc stator water pump is configured to produce a hydraulic force, wherein the hydraulic force is capable of turning a water sprayer in a dishwasher.

[108] Preferred rotor discs have both passages through the core 515 for fluid to flow and blades 550 to induce the flow. Its design is a compromise between a) a flat surface that minimizes clearance and median gap between induction coils of the stator 501 and the rotor surface and b) turbine-type blades with curvature designed to cause flow.

[109] Fluid flow through the cores 515serves multiple purposes, including cooling and reducing viscous forces due to movement of a rotor next to a stator. Also, the air/liquid/fluid "pump" of this embodiment may resemble an axial-flow turbine-type pump or centrifugal pumps connected in series through a common rotary shaft.

[110] **Assembly and Fabrication** - Assembly of the stacked-disc axial-flow embodiments of this invention can be performed by a number of methods. One method is to have the outer unit hinge together to encase the shaft 531 and discs of the center unit. Another method is to slip stator discs through the gaps of a rotor, align the rotor with the stator discs about an axis of rotation, slip a busbar shaft 531 through the holes of the discs where the holes have slots 553 (see Fig. 22) through which connective clips on the busbar fit. A matching key of on the connective clips allows a twisting action (same direction as rotor rotation) to friction fit the connective clips to the disc's terminals 505. The connection clips are designed to connect the disc terminals 505 to appropriate live controller circuits on the busbar.

[111] The busbar may connect the disc circuits in series or in parallel. Preferably, the busbar connects the disc circuits in series by alternating the ground and live wire connection along the busbar's axial length and at locations of connectivity to the discs. Washers may be used as a locking device. By example, an eighth turn latch mechanism latching with a turn in the direction of motor rotation (e.g. a partial thread).

[112] A method for joining 3D-printed smaller structures to form a structural body may be used to produce multicopter surfaces at larger scales. A preferred structural body is comprised of a first body 250 and a second body 251 with a connector 252 having a duct 253 for flow of thermoset resin between body mold cavities 254 said cavities 254 open to an injection port 255, said duct 253 open to flow between the first body 250, and second body 251. This is illustrated by Fig. 34.

[113] Fabrication steps required to make the structural body include: a) fabricating the first body 250 and second body 251 by a method such as 3D printing, b) connecting the bodies with the connector, c) injecting a curing-type resin (e.g. thermoset resin) into the injection part with flow of the resin through the cavities 254 and duct, and d) allowing the resin to set forming a polymer in the cavities 254 which are a mold for the resin.

[114] Examples of connectors 252 include a ferrule connector (Fig. 34) and male inserts

held in place by friction (Fig. 35). A slot 256 may be used to facilitate slipping a male connector of the first body 250 into the female counterpart of the second body 251. The female counterpart comprises a space conforming to the male connector 252 as is common in the art. Also, the female counterpart must be open to the cavity in the second body.

[115] Preferably, the structural body contains at least one vent port 257 at an upper portion of the a mold cavity 254 to allow gases to escape therein allowing resin to more-effectively fill the cavities 254. The joining surface of connecting bodies may have multiple connectors; and the connectors may have shapes and locations that better enable 3D printing. Vent ports 257 should be located at mold locations distant from the injection port 255.

[116] 3D printing of multicopter components provides for rapid prototyping and easy CAD modification with iterations in prototyping; however, the structural properties of most 3D print filaments and resins are inferior to high performance thermoset polymers. A preferred method to realize the benefits of high performance thermoset polymers is to incorporate injection ducts and cavities in the 3D-printed components wherein the cavities are strategically placed at locations and shapes to provide extra strength where needed and wherein the ducts connect the cavities to an entrance and vent port for injecting a reacting thermoset resin. The vent port 257 is smaller (e.g. 0.2 to 1.5 mm dia.) than the injection port 255 (e.g. 2 to 5 mm dia.) so as to accommodate exiting air rather than exiting resin.

[117] A further embodiment is a structural body wherein a longitudinal tension device 258 is in the cavity 254 and the thermoset polymer forms around the tension device 258. Preferably, the tension device 258 is in a deflected position from end-to-end of the structural body. Here, "deflected position" may be created by a vertical bar 259 near the longitudinal midsection of the cavity 254.

[118] Tension may be provided by clips or nuts 260 attached to the tension device 258 that push against the ends of the shell of the mold 254; preferably, an auxiliary structure is used to place tension on the tension device 258 when a resin is injected and cures. Example tension devices 258 are a cable and a belt. For lighter-density foams, use of a belt is advantageous to reduce localized compression forces that could crush the foam. The structural body is configured to form an injection mold around the tension device 258, similar to the first body 250 and a second body 251 as previously described. The polymer or concrete that forms in the mold 254 supplements longitudinal compression strength that vectors into reduced vertical deflection by encasing the tension device 258 in a rigid matrix. Application of this technology is to make stronger and larger parts from smaller 3D printed parts including use to 3D print multicopters and to make light-weight structural beams.

CLAIMS

1. A multicopter comprising:

an airchassis;

a front tiltwing pivotably coupled to the airchassis and configured to transition between a hovering configuration and a cruising configuration, the front tiltwing including: a) a first propulsor configured to generate at least one of a tiltwing propulsor thrust or a tiltwing propulsor lift and b) an aerodynamic lift surface;

a counterbalance propulsor system coupled to the airchassis, the counterbalance propulsor system configured to balance gravitational, aerodynamic, thrust and lift forces and torques caused by the front tiltwing, the counterbalance propulsor system including a second propulsor configured to generate at least one of thrust or lift; and a control unit.

2. The multicopter of claim 1, wherein the first propulsor is configured to generate the tiltwing propulsor lift at least twice the tiltwing propulsor thrust in the hovering configuration, and wherein the first propulsor is configured to generate the tiltwing propulsor thrust at least twice the tiltwing propulsor lift in the cruising configuration.

3. The multicopter of claim 1, wherein the airchassis, front tiltwing, and counterbalance propulsor system are transitionable through passive actuation to a default failsafe descent configuration, the failsafe descent configuration conducive to landing without catastrophic damage to at least one of the airchassis, front tiltwing, counterbalance propulsor system, and a payload.

4. The multicopter of claim 3, wherein the counterbalance propulsor system provides negligible thrust while the airchassis, front tiltwing, and counterbalance propulsor system are in the failsafe descent configuration and wherein the counterbalance propulsor system is aft the front tiltwing.

5. The multicopter of claim 1, further comprising a swaywing, a swaywing total wetted surface area, and a swaywing total liftpath surface area,

the swaywing located below the airchassis and pivotably coupled to the airchassis and the swaywing total liftpath surface area is greater than one third the swaywing wetted surface area.

6. The multicopter of claim 1, the counterbalance propulsor system further includes a midsection rotary wing.

7. The multicopter of claim 6, wherein the midsection rotary wing is configured to transition between a fixed wing position and a rotary position.

8. The multicopter of claim 1, wherein the front tiltwing is configured to be aerodynamically actuated to a pseudo-hovering configuration to provide a dampened descent by a pseudo-hovering upward force said pseudo-hovering upward force a combination of lift and drag.

9. The multicopter of claim 1 comprising a plurality of longitudinally-extending lift-generating surfaces forming a total aerodynamic lift surface area; the plurality of longitudinally-extending lift-generating surfaces comprising a fuselage, the front passively-adjusting tiltwing, and an arm mechanically connecting the front passively-adjusting tiltwing to the fuselage;
the plurality of longitudinally-extending lift-generating surfaces forms a liftpath; and
the front tiltwing is a single front tiltwing in front of a single airchassis; wherein
lift provided by the front passively-adjusting tiltwing is less than half the lift provided by the total aerodynamic lift surface area.

10. A multicopter comprising a single front passively-adjusting tiltwing in front of a single fuselage, a tiltwing propulsor, at least one counterbalance propulsor, a plurality of longitudinally-extending lift-generating surfaces, and a total multicopter weight;

the plurality of longitudinally-extending lift-generating surfaces comprising the fuselage, the front passively-adjusting tiltwing, and an arm mechanically connecting the front passively-adjusting tiltwing to the fuselage; wherein the plurality of longitudinally-extending lift-generating surfaces forms a liftpath wherein lift provided by the front passively-adjusting tiltwing is less than half total multicopter weight.

11. The multicopter of claim 10 wherein the front passively-adjusting tiltwing is freely rotatable relative to the fuselage within a predetermined angular range around a tiltwing axis.

12. The multicopter of claim 10 comprising two propulsors on the front passively-adjusting tiltwing, two arms mechanically connecting the fuselage to the front passively-adjusting tiltwing, and wherein the at least one counterbalance propulsor is two rear propulsors said two rear propulsors set at an angle relative to the fuselage.

13. The multicopter of claim 10 the fuselage comprising a swaywing pitotably connected to an air chassis pitotably connected to the sing front passively-adjusting tiltwing.

14. The multicopter of claim 10 comprising a control system capable of configuring the multicopter for a failsafe landing where greater than eighty percent of lift on the multicopter is generated by the tiltwing propulsor.

15. A landing method for landing a multicopter comprising a plurality of failsafe methods;

the multicopter comprising a front tiltwing, a vehicle center of gravity, a front tiltwing propulsor thrust, a front tiltwing propulsor lift, a front tiltwing propulsor force said front tiltwing propulsor force being a vector sum of the front tiltwing propulsor thrust and the front tiltwing propulsor lift, a ratio of tiltwing propulsor thrust to lift, a front tiltwing propulsor lift, a total multicopter lift, a total multicopter thrust, a first failsafe method, and a second failsafe method;

the second failsafe method comprising transitioning the front tiltwing to a position wherein the front tiltwing propulsor lift is greater than one third of the total multicopter lift and the tiltwing propulsor lift is greater than the total multicopter thrust; and

the first failsafe method comprising transitioning the front tiltwing to a position wherein the total multicopter lift is more than four times greater than the front tiltwing propulsor lift and the tiltwing propulsor thrust is at least eighty percent of the total multicopter thrust.

16. The landing method of Claim 15, wherein passive aerodynamic actuation performs at least one of the first failsafe method and the second failsafe method.

17. The landing method of Claim 15 including a third failsafe method, the third failsafe method comprising transitioning a midsection rotary wing from a fixed wing position to a rotary position, the midsection rotary wing coupled to and extending above an airchassis, the midsection rotary wing also coupled to a power supply and a control unit and increasing power supplied by the power supply to the midsection rotary wing prior to landing; wherein the rotary wing produces over eighty percent of the total multicopter lift one second before landing.

18. The landing method of Claim 17 comprising transitioning a swaywing from a cruising position to a hovering position, the swaywing configured to transition between a cruising configuration and a hovering configuration, the swaywing including a fuselage compartment, a swaywing arm, and a lifting body surface, the swaywing located below the airchassis and mechanically connected to the airchassis through at least one lateral axis bearing by the swaywing arm, the swaywing configured to transition between the cruising configuration and the hovering configuration.

19. The landing method of Claim 18, wherein a front tiltwing is coupled to the airchassis and swaywing.

20. The landing method of Claim 17, further comprising controlling a yaw angle via aerodynamic forces acting on a duct having vanes surrounding the midsection rotary wing.

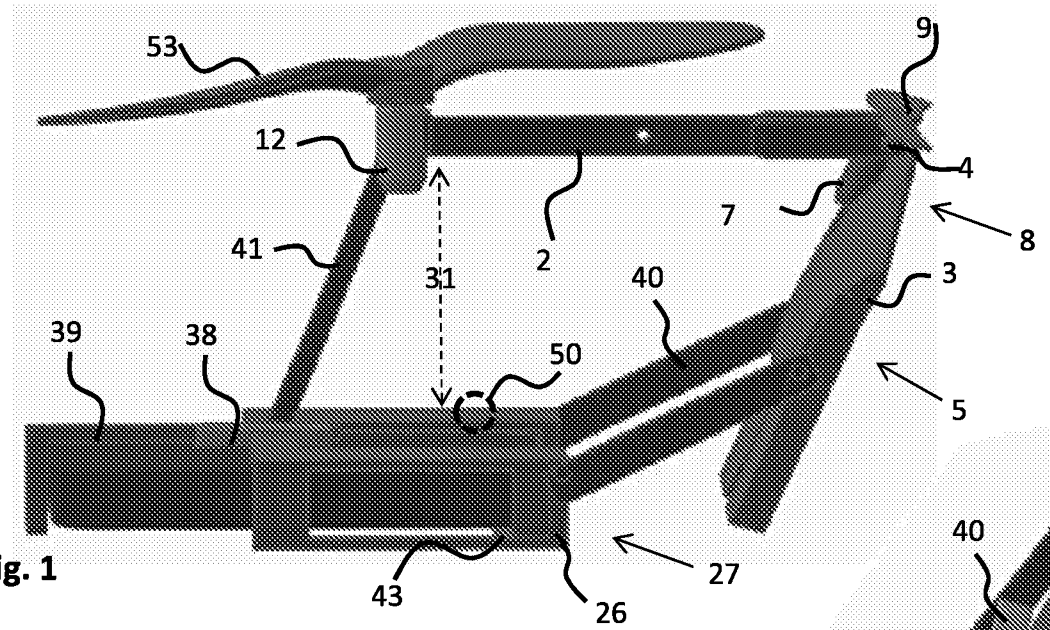


Fig. 1

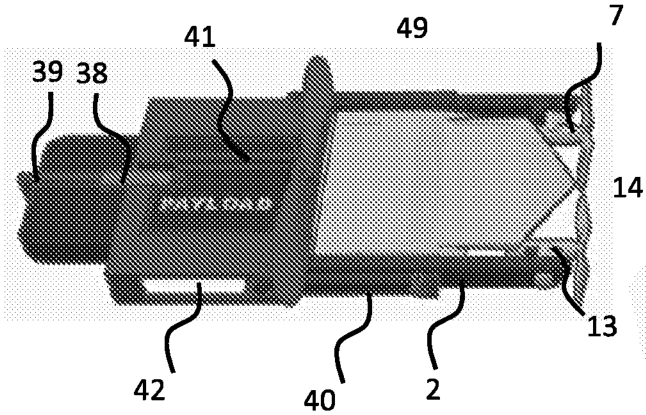


Fig. 2

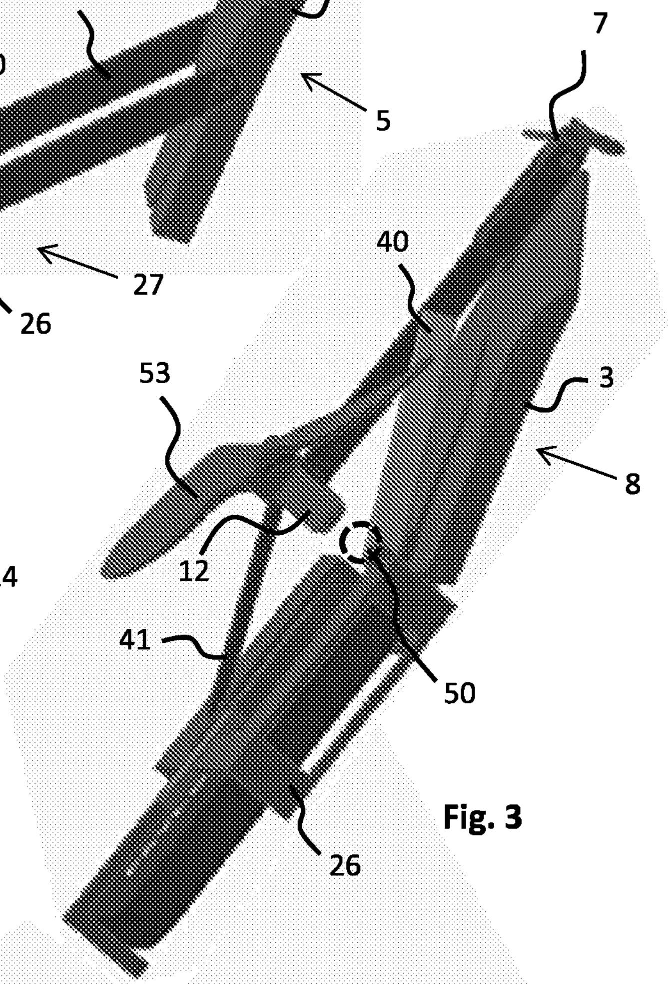
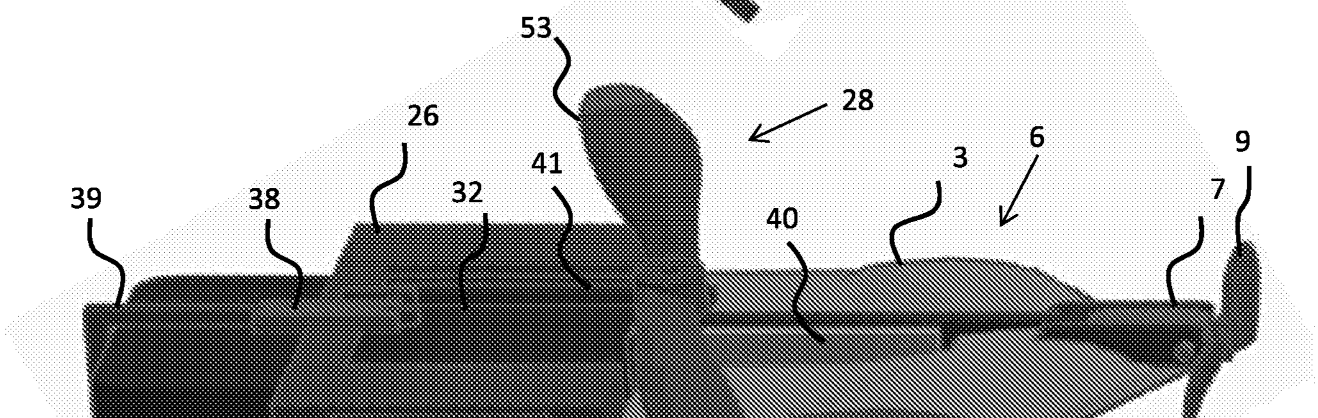


Fig. 3



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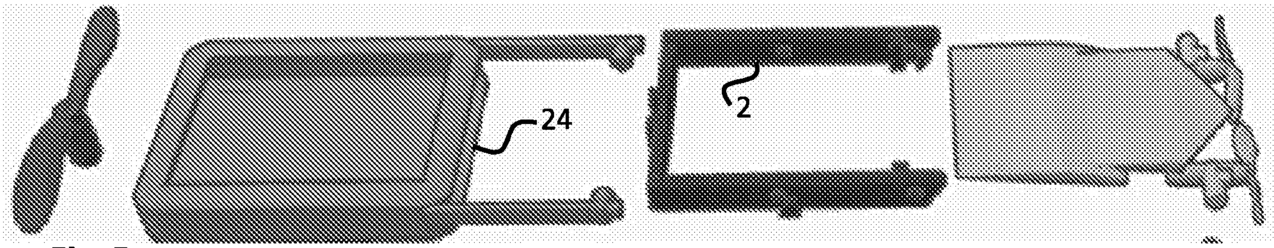

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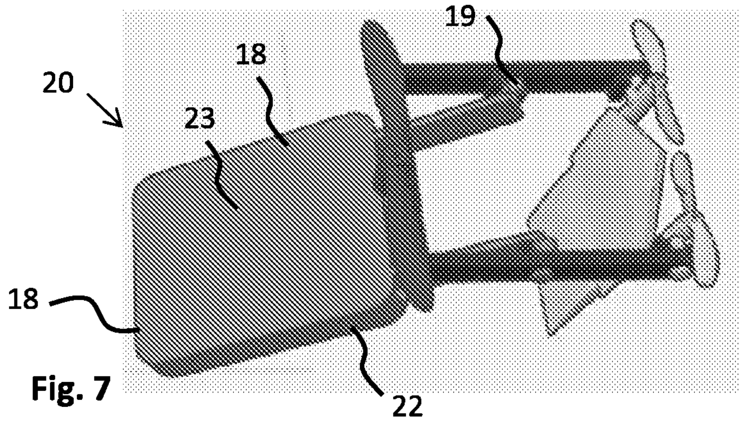

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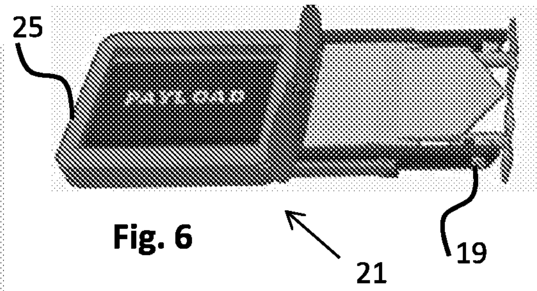

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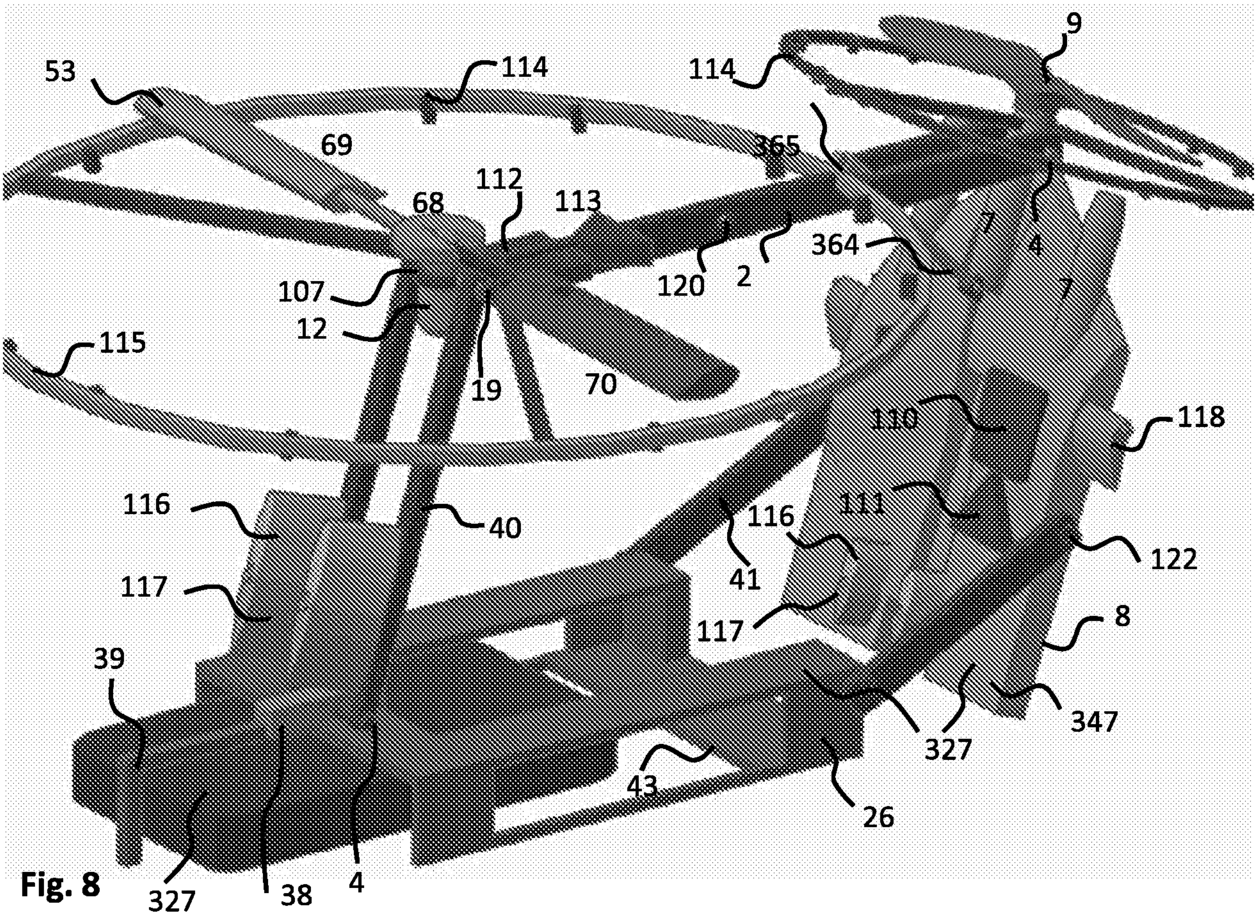
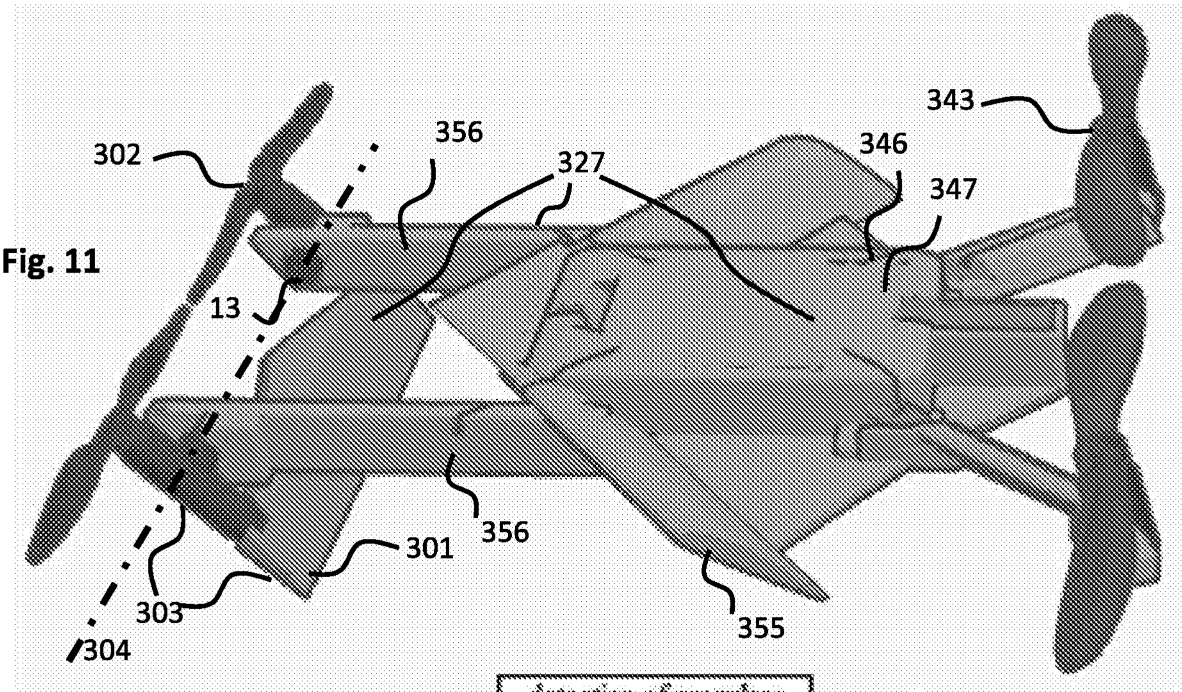


Fig. 8



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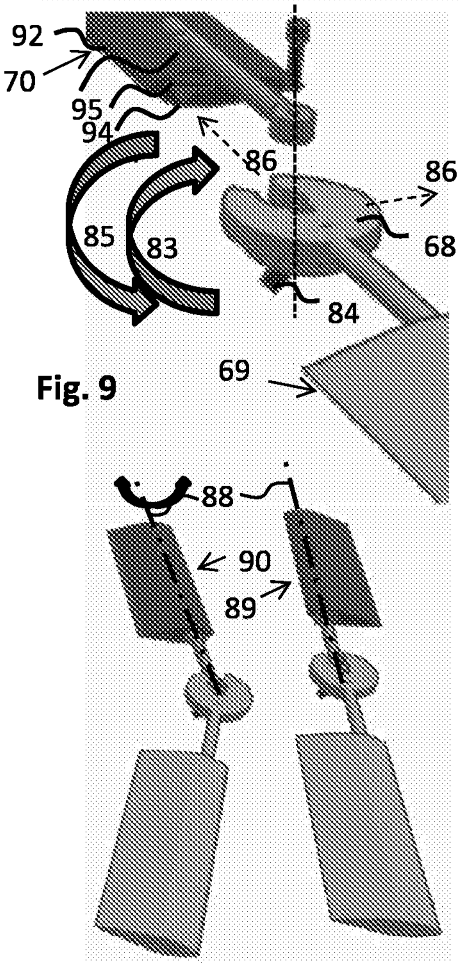

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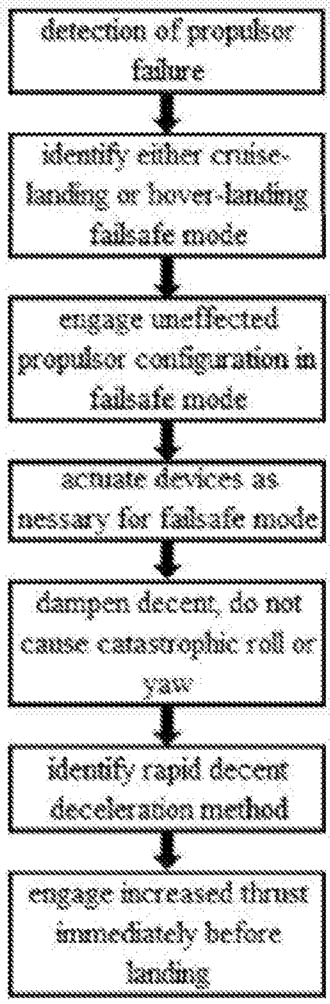

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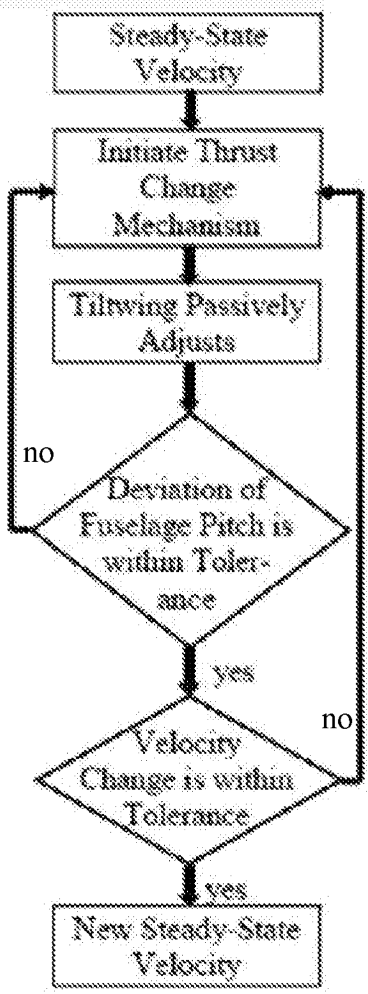

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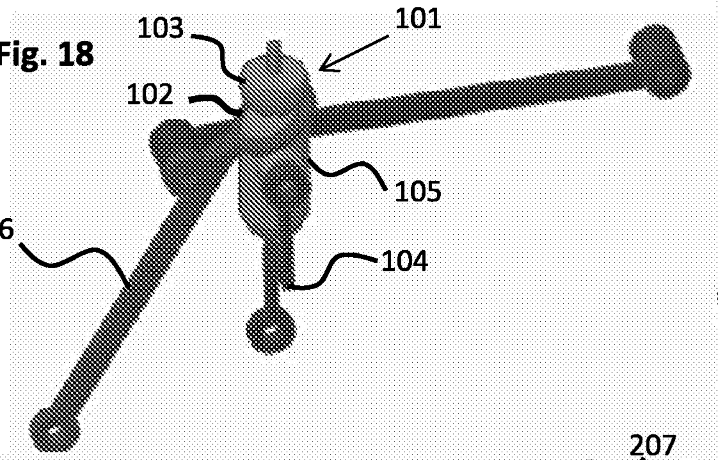


Fig. 18

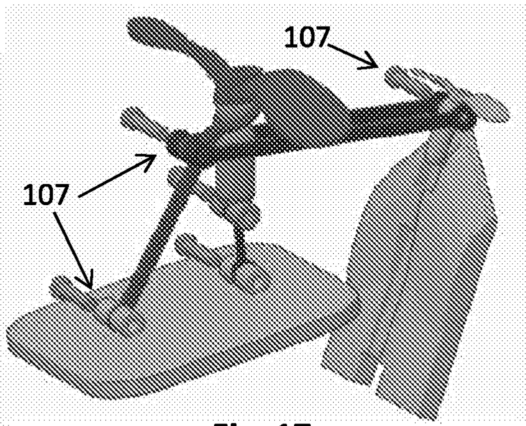


Fig. 17

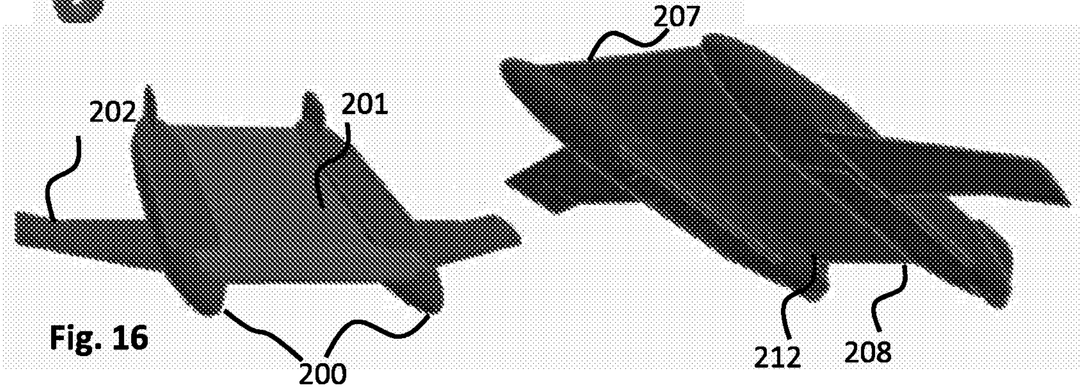


Fig. 16

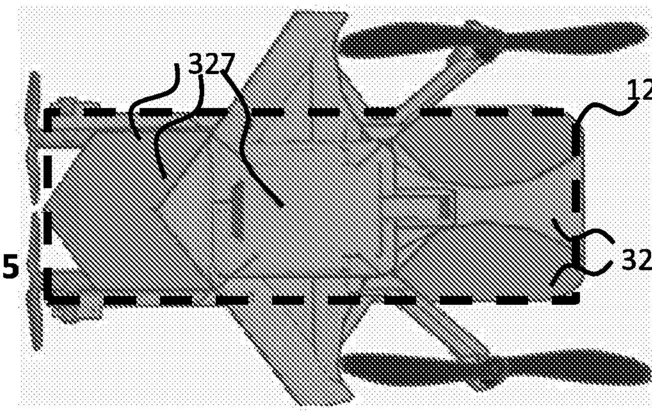
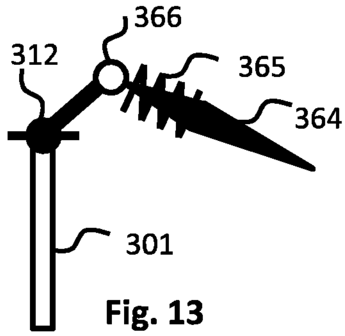


Fig. 15



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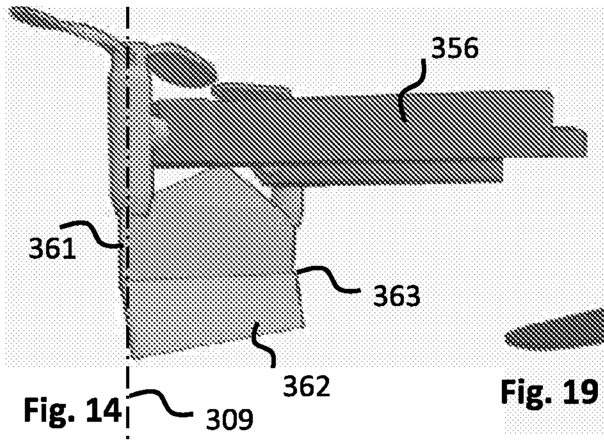
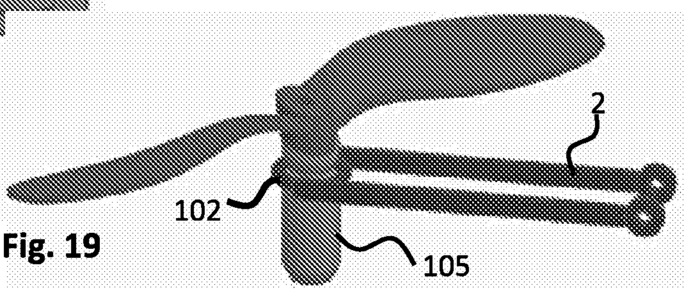


Fig. 14



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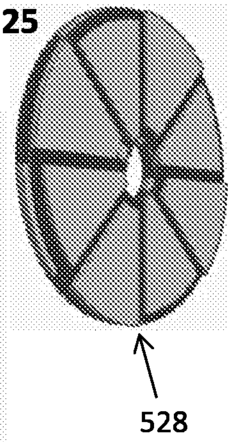

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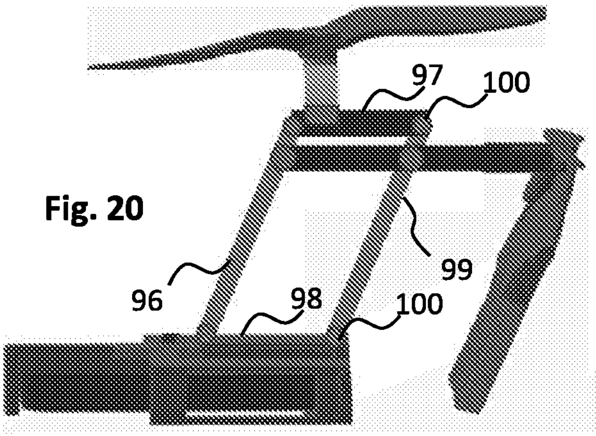


Fig. 20

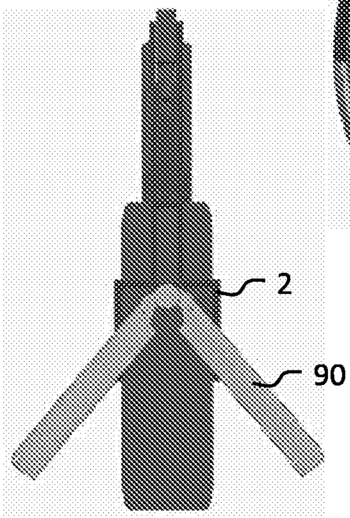
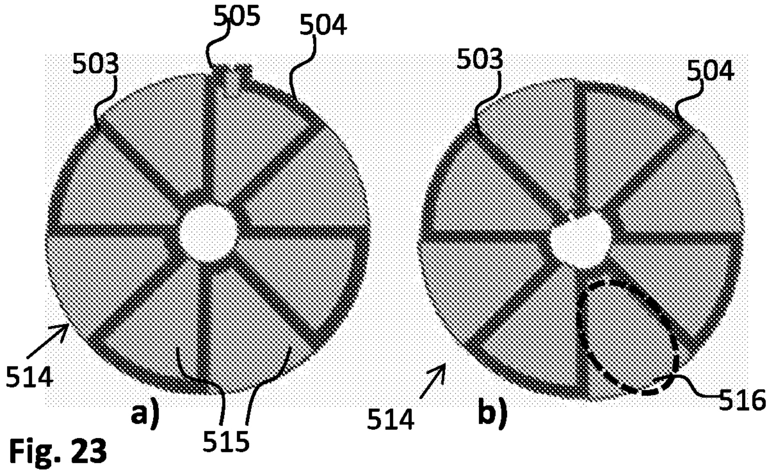


Fig. 21



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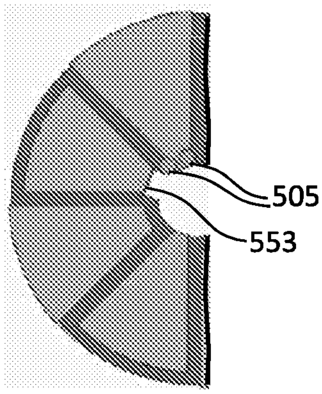


Fig. 22

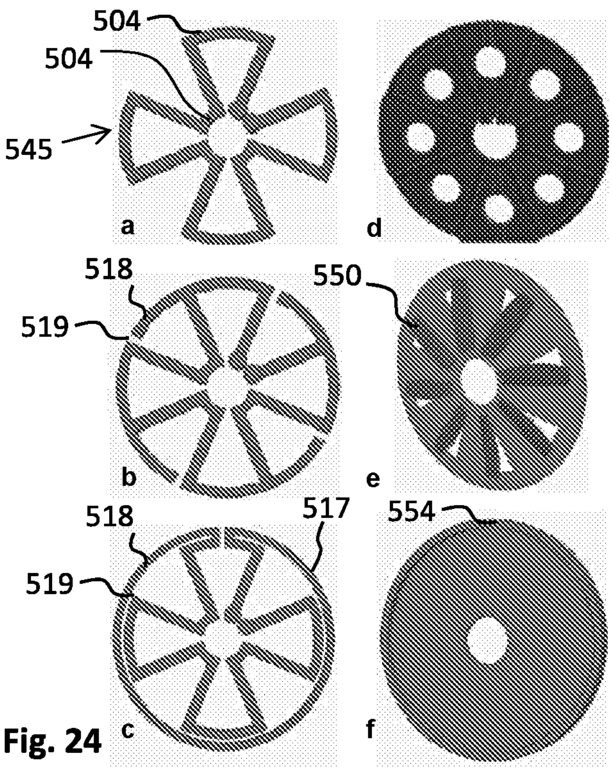


Fig. 24

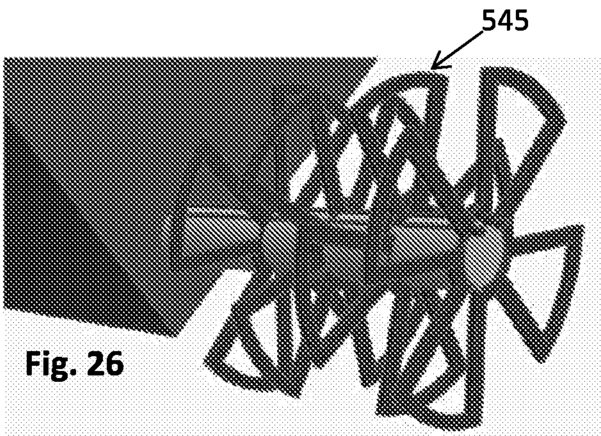


Fig. 26

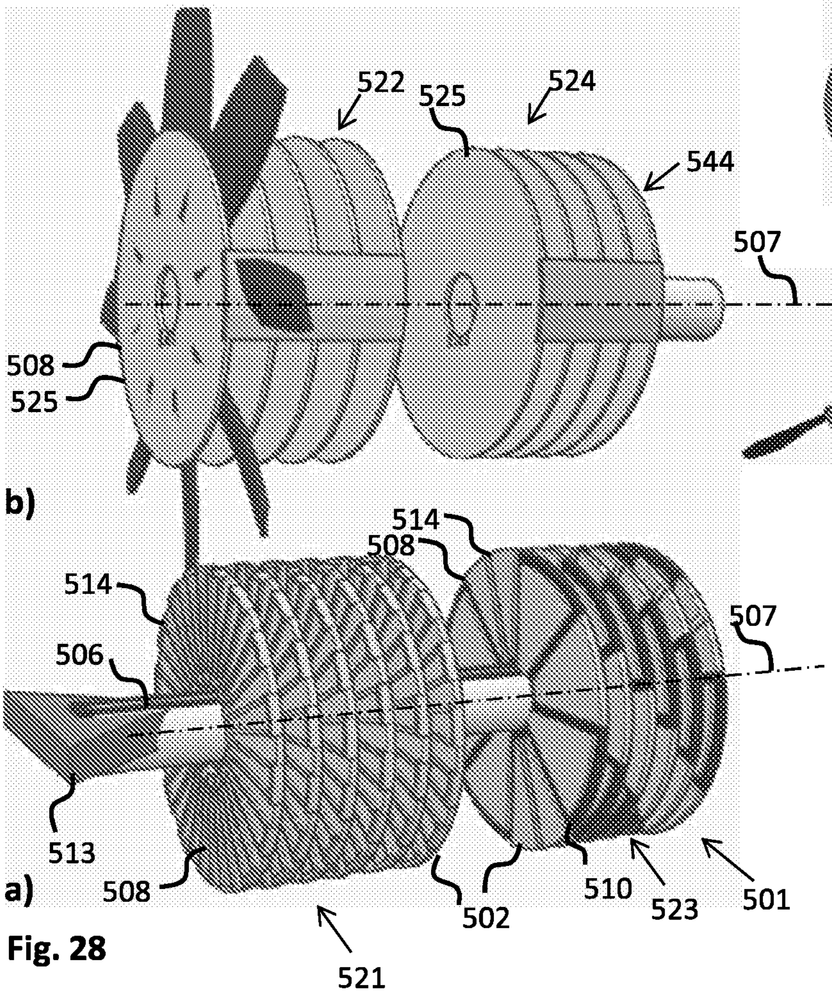
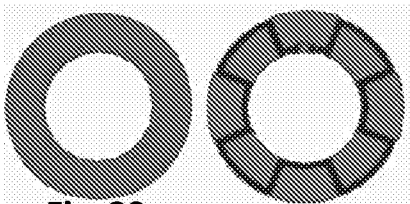


Fig. 28



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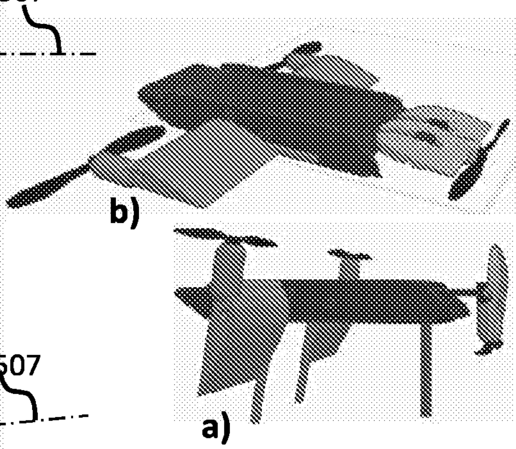

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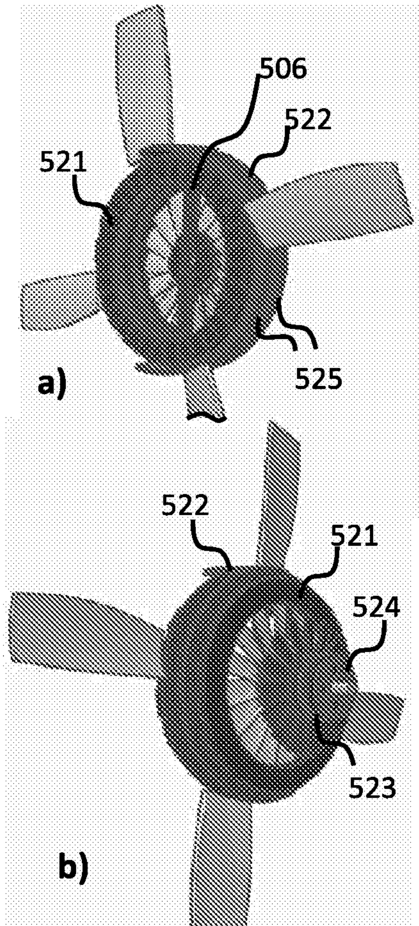

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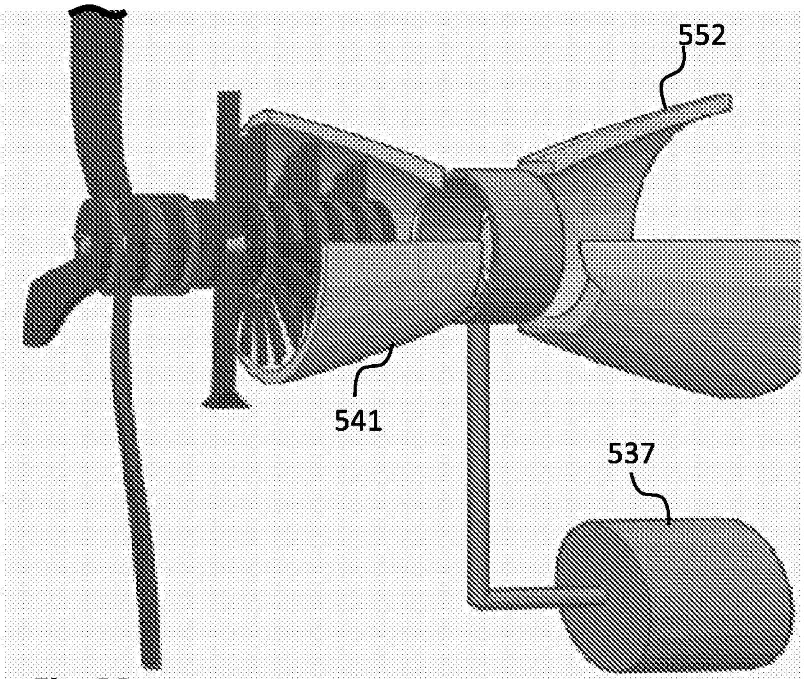
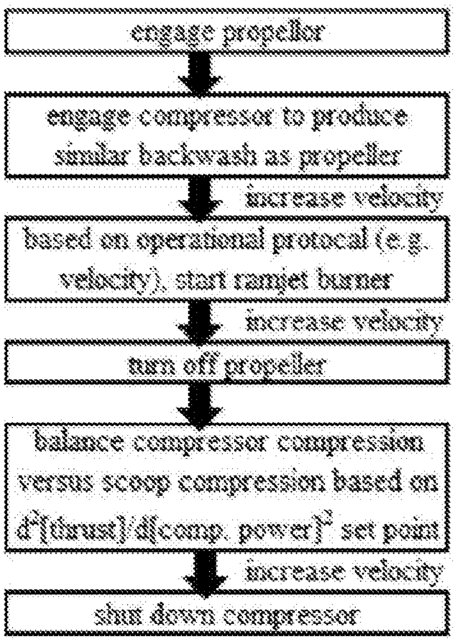


Fig. 30



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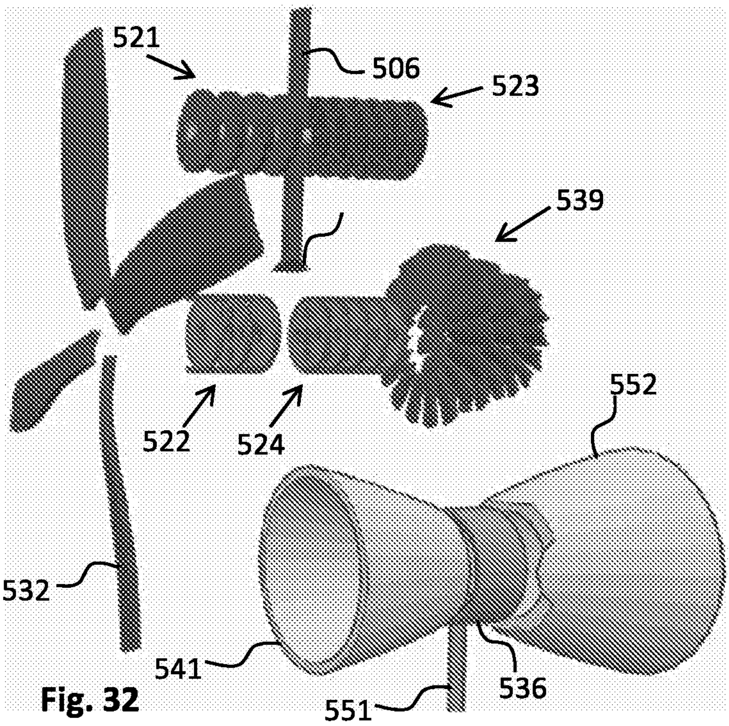

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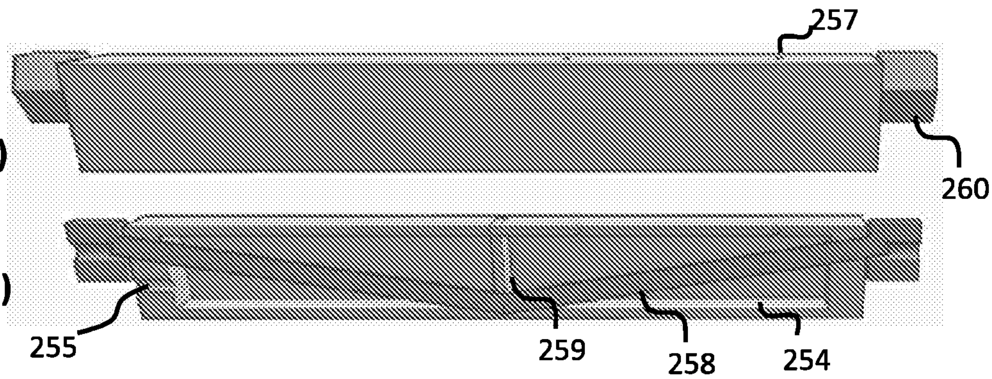

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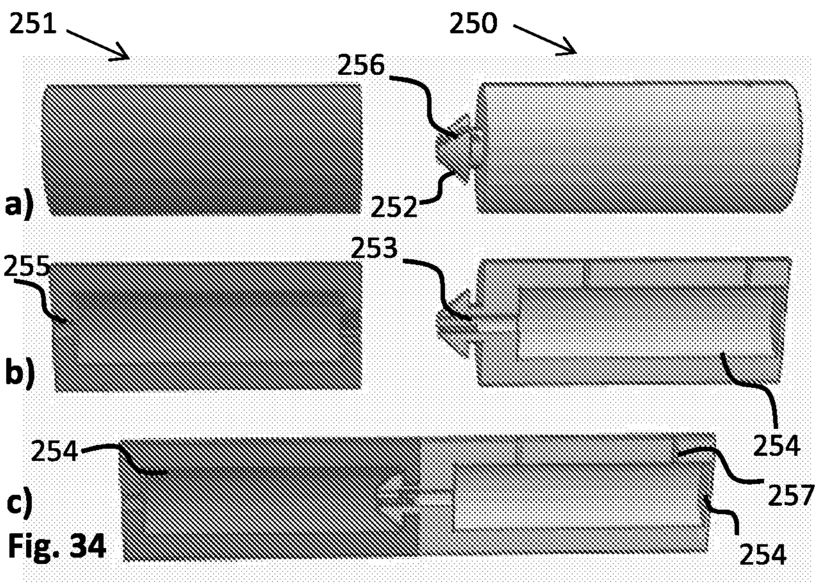

Fig. 34

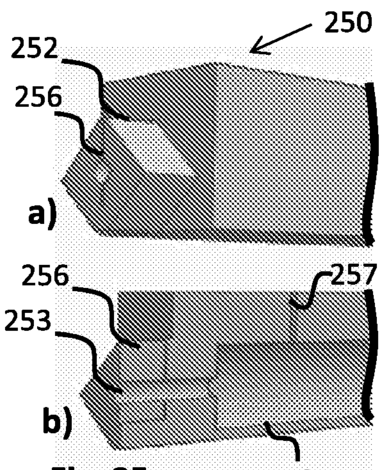

Fig. 35