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(54) Title: MULTI-COPTER LIFT BODY AIRCRAFT WITH TILT ROTORS

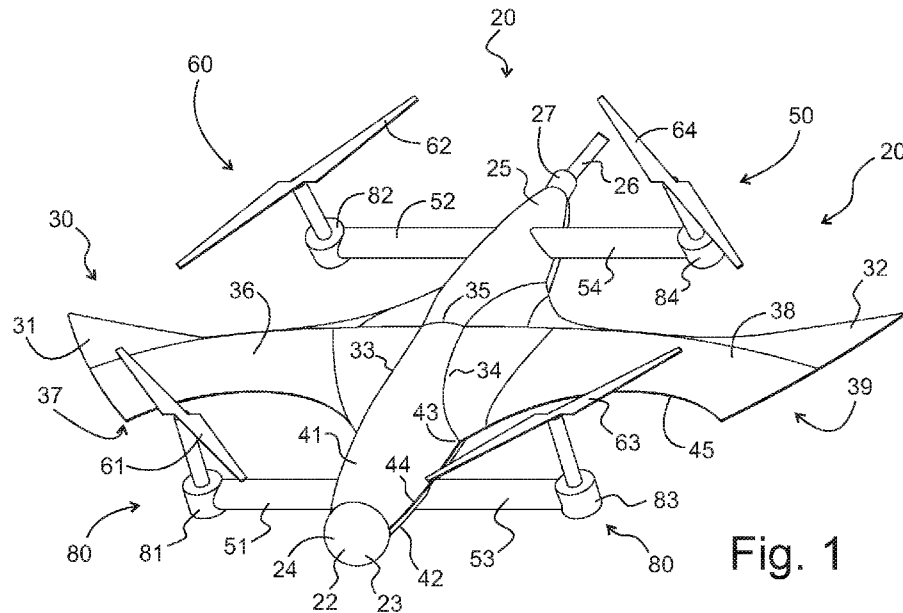


Fig. 1

(57) Abstract: A multi-copter lift body aircraft has a lift body that has a first airfoil shape on a front to rear cross-section. The lift body has a nose and a tail. A multi-copter propeller is attached to the lift body. The multi-copter propellers provide a lift at low speeds, and the lift body provides a lift at high speeds. The multi-copter propeller is mounted to a shaft. A shaft angle is formed on the multi-copter propeller, and the shaft angle provides a forward thrust. The shaft angle is angled upward and forward and the shaft angle is not perpendicular to a chord line of the lift body. Avionics are stored in a hollow cavity of the lift body. The avionics include a control circuit, batteries, and a radio receiver.



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MULTI-COPTER LIFT BODY AIRCRAFT WITH TILT ROTORS

FIELD OF THE INVENTION

5 The present invention is in the field of multicopter aircraft.

DISCUSSION OF RELATED ART

10 In U.S. patent publication 20060016930A1, entitled Sky Hopper and published on January 26, 2006, inventor Pak describes a vertical takeoff and landing (VTOL) aircraft design using counter rotating fan blades for stability. Separate horizontal and vertical tilting mechanisms are delivered to the fan units, the disclosure of which is incorporated herein by reference.

15 Inventor Walton also utilizes counter rotating fan blades in a set of four ducted fan units at the front, left, right, and rear of his VTOL aircraft. U.S. patent publication 20060226281, entitled Ducted fan vertical take-off and landing vehicle and published on October 12, 2006, states that the vertical force created by the fan units "are provided with such redundancy that the aircraft can hover with up to two thrusters inoperative." Furthermore, the fan units are movable between a vertical lift position and a horizontal thrust position through a set of servos and gears, the disclosure of which is incorporated herein by reference.

20 Four fan units pivoted on strakes via arms are intercoupled via chain drives or linkages on inventor Bryant's VTOL aircraft as illustrated in U.S. patent publication 20110001001, Flying-wing aircraft, published on January 6, 2011. The flying-wing shape of the aircraft may utilize fins, slats, flaps, and other control-surfaces for aerodynamic stability, the disclosure of which is incorporated herein by reference.

25 Similarly, the VTOL aircraft described in inventor Bothe's US patent 5,823,468, published on October 20, 1998 and entitled Hybrid Aircraft, uses turbo-electric driven propellers mounted on four outriggers, which are designed to distribute forces from the propellers to the hull. The lifting body hull creates aerodynamic lift and minimizes the need for panels of differing curvature in its construction, the disclosure of which is incorporated herein by reference.

30 Turbofan engines with separate core engines mounted on both sides of rear and front wings are described in U.S. patent publication 20030080242, published on May 1, 2003, by

inventor Kawai and entitled Vertical takeoff and landing aircraft. These fan engines are capable of biaxial rotation for the purpose of providing power to both cruise and hover, the disclosure of which is incorporated herein by reference.

5 Inventor Austen-Brown describes the use of tiltmotors on his VTOL in Personal hoverplane with four tiltmotors, U.S. publication 20030094537, published on May 22, 2003. These tiltmotors can be tilted vertically in order for the aircraft to maintain steep descent. All tiltmotors have a sideways cant when tilted in order to reduce engine side loads and are equipped with emergency electric motors, the disclosure of which is incorporated herein by reference.

10 In U.S. patent 3,181,810, entitled Attitude Control System For VTOL Aircraft and published by inventor Olson on May 4, 1965, an attitude control system for VTOL aircraft selectively adjusts the thrust of propellers, rotors, ducted fans, or jet engines through their gradual tilting from vertical to horizontal positions, the disclosure of which is incorporated herein by reference.

15 Selected angles of inclination of the thrust-generating devices improve the hovering stability of VTOL aircraft, as described by inventor Ducan in U.S. patent 5,419,514, entitled VTOL aircraft control method and published on May 30, 1995. Additionally, spars, mounted at a fixed angle to the centerline of the aircraft's fuselage, support the thrust-generating devices to achieve their desired inclination by the spars' simple rotation, the disclosure of which is incorporated herein by reference.

20 Mechanisms on two main propellers tilt around the pitch, roll, and yaw axes of inventor Raposo's invention, the disclosure of which is incorporated herein by reference. In U.S. publication 20100301168A1, entitled System and Process of Vector Propulsion with Independent Control of Three Translation and Three Rotation Axis and published on December 2, 2010, Raposo states that these tilting mechanisms can be used to perform lateral movements, upward or downward movements, and rotations around the vehicle yaw axis.

25 The turbine fans used in the VTOL aircraft described by inventor Rowe in U.S. patent 3038683A, entitled VTOL Aircraft and published on June 12, 1962, are driven by separate generators and are symmetrically arranged about the longitudinal centerline of the aircraft. The fans pivot to provide thrust for both vertical lift and horizontal cruising. The fans are identical and interchangeable, the disclosure of which is incorporated herein by reference.

BRIEF SUMMARY OF THE INVENTION

A multi-copter lift body aircraft has a lift body that has a first airfoil shape on a front to rear cross-section. The lift body has a nose and a tail. A multi-copter propeller is attached to the lift body. Multi-copter propellers attached to the lift body provide a multi-copter propeller lift at low speeds, and the lift body provides a lift body lift at high speeds. The multi-copter propeller is mounted to a shaft. A shaft angle is formed on the multi-copter propeller, and the shaft angle provides a forward thrust. The shaft angle is angled upward and forward and the shaft angle is not perpendicular to a chord line of the lift body. Avionics are stored in a hollow cavity of the lift body. The avionics include a control circuit, batteries, and a radio receiver. As an airspeed increases, the multi-copter propeller lift decreases with increased lift body lift so that the aircraft maintains the same altitude at any speed up to a top speed. The shaft angle is not perpendicular to a chord line of the lift body. The shaft angle facilitates an F_x forward force and an F_y lifting force. The F_x forward force is the sine of the shaft angle.

The lift body is made from a pair of shells that have a structure, namely a top shell and a bottom shell, both of which can be made of plastic. The lift body has an optimum attack angle at a cruising speed, and the lift body provides a combined lift mode. The lift body includes a canard forward control surface. The center of gravity of the multi-copter mode is the center of gravity in airfoil mode, wherein the airfoil center of gravity is approximately 1/3 from the nose. Control surfaces mounted to the lift body includes a rudder, aileron and elevator. A locking means for multi-copter blades includes use of a hall sensor or encoder. The lift body has open concave curvatures. The lift body includes a camera in the nose of the lift body when a push propeller is mounted to the tail of the lift body.

BRIEF DESCRIPTION OF THE DRAWINGS

- Figure 1 is a perspective view of the present invention.
Figure 2 is a top view of the present invention.
Figure 3 is a rear view of the present invention.
Figure 4 is a front cross-section view of the present invention along the lateral line 29.
Figure 5 is a side view of the present invention.
Figure 6 is a side cross-section view of the present invention along the medial line.
Figure 7 is a diagram of the relative lift power of the lifting body to lifting rotor.

Figure 8 is a diagram of a four rotor lifting body.

Figure 9 is a diagram of a six rotor lifting body.

The following call out list of elements can be a useful guide when referencing the

5 elements of the drawings.

20 Main Body

21 Fuselage

22 Nose

23 Camera

10 24 Sensor

25 Tail

26 Tail Pusher Propeller

27 Tail Motor

28 Vertical Stabilizer

15 29 Rudder

30 Wings

31 Right-Wing

32 Left-Wing

33 Right-Wing Junction

20 34 Left-Wing Junction

35 Wing Junction Gap

36 Right Wing Upper Shell

37 Right Wing Lower Shell

38 Left Wing Upper Shell

25 39 Left Wing Lower Shell

41 Fuselage Upper Shell

42 Fuselage Lower Shell

43 Wing To Fuselage Junction

44 Fuselage Junction

30 45 Wing Junction

46 Joining Junction

- 47 Aileron
- 48 Canard
- 49 Elevator
- 50 Multi-Rotor System
- 5 51 Right Forward Extension Arm
- 52 Right Rear Extension Arm
- 53 Left Forward Extension Arm
- 54 Left Rear Extension Arm
- 55 Right Forward Extension Arm Connection
- 10 56 Right Rear Extension Arm Connection
- 57 Left Rear Extension Arm Connection
- 58 Left Front Extension Arm Connection
- 60 Lifting Propellers
- 61 Right Front Lifting Propeller
- 15 62 Right Rear Lifting Propeller
- 63 Left Front Lifting Propeller
- 64 Right Rear Lifting Propeller
- 65 Flight Controller
- 66 Power Supply
- 20 67 Tilt Sensor
- 68 Avionics And Transceiver
- 69 Antenna
- 70 Lifting Body
- 71 First Airfoil Profile
- 25 72 Second Airfoil Profile
- 73 Airfoil Profile Intersection
- 74 Center Of Gravity
- 75 Lifting Body Outside Leading Edge Line
- 76 Locked Propeller Leading-Edge Line
- 30 77 Leading Edge Concave Portion
- 78 Trailing Edge Concave Portion

- 79 Forward Tip
- 80 Motors
- 81 Right Front Motor
- 82 Right Rear Motor
- 5 83 Left Front Motor
- 84 Right Rear Motor
- 85 Outside Tip
- 86 Trailing Edge
- 87 Leading Edge Outside Portion
- 10 88 Halfway Point
- 90 Horizontal Line
- 91 Angle Of Attack
- 92 Airfoil Lower Surface
- 93 Airfoil Upper Surface
- 15 94 Chord Line
- 95 Lift Force
- 96 Airspeed
- 97 Lifting Propeller Force
- 98 Lifting Body Airfoil Force
- 20 99 Stall Speed
- 100 Hall Sensor
- 101 Encoder
- 194 Vertical Plane
- 195 Fixed Forward Angle
- 25 196 Fixed Forward Angle Junction Point
- 197 Rear Lifting Propeller Shaft Line
- 198 Front Lifting Propeller Shaft Line
- Fx Forward Force
- Fy Lifting Force

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention is a multirotor vertical lift off aircraft having a main body 20. The main body 20 includes a fuselage 21. The fuselage 21 has a nose 22 and a tail 25. A sensor 24 and a camera 23 can be mounted in the nose 22. A tail motor 27 can be mounted to the tail 25 to power a tail pusher propeller 26. The tail pusher propeller 26 can activate independently of the other propellers and can push the multirotor aircraft forward.

The wings 30 are integrated to the fuselage 21. A right-wing 31 and a left-wing 32 are connected to the fuselage 21 at a right-wing junction 33 and a left-wing junction 34. Between the right-wing junction 33 and the left-wing junction 34 there can be a wing junction gap 35. The wing junction gap 35 forms an airfoil profile along the lateral line 29 and the medial line 28. The construction of the main body 20 is preferably in a pair of pieces, namely an upper shell and a lower shell. The upper shell may have various portions and the lower shell may have various portions. For example, the upper shell can have a right-wing upper shell 36 and a left-wing upper shell 38. Similarly, the lower shell can have a right-wing lower shell 37 and a left-wing lower shell 39. The fuselage of the main body 20 can have a fuselage upper shell 41 and a fuselage lower shell 42. The fuselage upper shell 41 can be integrally formed with the right wing upper shell 35 and the left-wing upper shell 38. A wing junction 45 can join a wing upper shell to a wing lower shell. The junctions can be snap fit, or joined by adhesive. The pair of shells can be plastic injection molded or made of laminate materials.

The upper shell portions can be joined to the lower shell portions at a joining junction 46. The joining junction 46 can have a wing to fuselage junction 43 where the joining junction of the wing connects to the joining junction of the fuselage. Also, the joining junction can have a fuselage junction 44 where the fuselage upper shell 41 joins to the fuselage lower shell 42. The multirotor system 50 has lifting propellers 60 mounted on extension arms. A right forward extension arm 51 extends from the main body 20 at a right forward extension arm connection 55. A right rear extension arm 52 extends from the main body 20 at a right rear extension arm connection 56. A left forward extension arm 53 extends from the main body 20 at a left front extension arm connection 58. A left rear extension arm 54 extends from the main body 20 at a left rear extension arm connection 57.

The lifting propellers 60 are mounted on the motors 80. The right front lifting propeller 61 is mounted to the right front motor 81 which is mounted to the right forward extension arm 51.

The right rear lifting propeller 62 is mounted to the right rear motor 82 which is mounted to the right rear extension arm 52. The left front lifting propeller 63 is mounted to the left front motor 83 which is mounted to the left forward extension arm 53. The left rear lifting propeller 64 is mounted to the left rear motor 84 which is mounted to the left rear extension arm 54.

5 The upper shell portions and the lower shell portions of the main body 20 form a cavity. The cavity can retain avionics and electronics, for example a flight controller 65, a power supply 66, a tilt sensor 67 and other avionics and transceiver 68. Additionally, an antenna 69 can be installed in the cavity of the main body 20. The power supply 66 can be a battery such as a rechargeable battery or an internal combustion engine for charging a rechargeable battery. The flight controller 65 is preferably a multicopter controller for controlling the motor output, receiving transceiver signals and otherwise maintaining the stability and control of the aircraft. The main body 20 has an airfoil shape in more than one orientation such that it forms a lifting body 70. The lifting body 70 has a first airfoil profile 71 along a medial line 28, then has a second airfoil profile 72 along a lateral line 29. The first airfoil profile 71 and the second airfoil profile 72 intersect at an airfoil profile intersection 73. The airfoil profile intersection 73 is behind a center of gravity 74. The center of gravity 74 is between the nose 22 and the airfoil profile intersection 73.

 The aircraft has a takeoff mode and a cruising mode. In the cruising mode, the tail pusher propeller 26 propels the aircraft forward and the lifting propellers 60 are in a locked position. The locked propellers have a lock propeller leading-edge line 76 that generally continues to a lift body outside leading-edge line 75. The propellers can be locked with a latch, a servo, using stepping motors, or other motors that can hold a position. The multi-copter blades can be spinning in a spinning mode and locked in a locked mode such as by use of a hall sensor 100 or encoder 101.

25 The lifting body 70 includes a leading edge concave portion 77 opposite a trailing edge concave portion 78. The leading edge concave portion 77 preferably terminates at a forward tip 79. An outside tip 85 can define a transition between the leading-edge and the trailing edge 86. The leading-edge has a leading-edge outside portion 87 that transitions to the trailing edge 86 at the outside tip 85. The leading-edge outside portion 87 transitions to the leading edge concave portion 77 at the forward tip 79. Preferably, the leading-edge concave portion 77 and is the trailing edge concave portion 78 are open to airflow.

When taking a side view of the present invention, the lifting propellers 60 are preferably parallel to a horizontal line 90. The airfoil lower surface 92 of the lift body 70 opposes the airfoil upper surface 93. The airfoil lower surface 92 and the chord line 94 are both angled relative to the horizontal line 90 such as at an angle of attack 91. As seen in Fig. 3, the fixed forward angle creates an Fx Forward Force and a Fy Lifting Force. The Fx forward force is the sine of the shaft angle

The flight controller 65 maintains an appropriate angle of attack 91 while the multicopter lifting propellers 60 are providing most of the lift power. As the aircraft increases in speed, the lifting body 70 provides more of the lift power relative to the lifting propellers 60. When the airspeed 96 is low, the lift force 95 is 100% lifting propeller force 97 during vertical takeoff. As the airspeed 96 increases, the lifting body 70 has a lifting body airfoil force 98 that surpasses the lifting propeller force 97. At higher speed, when the lifting propeller force 97 is smaller relative to the lifting body airfoil force 98, the flight controller 65 can turn off the lifting propellers 60 and lock them into cruising mode position. At a halfway point 88, the lifting force 95 is half due to the lifting body airfoil force 98 and half due to lifting propeller force 97 such that the lifting force 95 due to the lifting body airfoil is equivalent to the lifting force 95 due to the lifting propeller force. The halfway point 88 is at a speed that is higher than a stall speed 99 of the lifting body 70. To improve performance while getting past the stall speed 99 of the lifting body 70, additional control and stability surfaces such as ailerons 47, a canard 48, an elevator 49, and a rudder 29 can improve control and stability.

The rear lifting propellers are mounted at a fixed forward angle 195 to the vertical plane 194. The rear lifting propeller shaft line 197 is the axis of rotation of the rear lifting propeller shaft. The rear motors are mounted at a fixed angle in the fixed angle is angled forwardly to provide a forward thrust. The vertical plane 194 intersects the rear lifting propeller shaft line 197 at a fixed forward angle junction point 196, which is below the airfoil lower surface 92. Preferably, the front lifting propellers have a front lifting propeller shaft line 198 which is generally vertical rather than angled forward like the rear lifting propellers. The front lifting propellers being at a different angle than the rear lifting propellers allows the aircraft to adjust a pitch and angle of attack. The fixed forward angle 195 generates a forward thrust so that a tail pusher propeller is not necessary and can be omitted. The forward thrust of the fixed forward angle 195 generates a lifting body airfoil force 98 that increases according to a speed of the

lifting body 70. As the lifting body 70 increases in speed, the lifting propeller force 97 is decreased as well as the energy consumption attributable to the lifting propeller force 97. On the other hand, the lifting body airfoil force 98 increases as speed increases so that it surpasses the lifting propeller force 97. The forward thrust of the fixed forward angle 195 is configured to provide an optimal angle of attack for the lifting body 70.

The aircraft can maintain a stable flight at the halfway point 88. Although lifting body airfoil force 98 is more energy efficient, the aircraft can still save substantial energy by having at least a partial lifting body airfoil force 98. For example, the lifting body airfoil force 98 can be 50%, 80% or 100%. The present invention can be implemented as a three rotor, four rotor, five rotor, or more. For example, Fig. 8 is a diagram of a six rotor lifting body. The six rotor lifting body can also have a stable mixed mode cruising state with the lifting body airfoil force 98 as a fraction of the total lifting force.

As seen in the figures, the extension arms can be connected at the extension arm connections to the wings or to the fuselage. The extension arms can be oriented perpendicular or parallel to the fuselage. The lifting body 70 can have lift in a forward direction and also in a direction that is lateral to the forward direction due to the lifting body having an airfoil profile in a forward direction as well as in a lateral direction perpendicular to the forward direction.

The airfoil profile in both the forward and lateral direction allows the lift body to generate lift from airflow arriving from the front, front left, front right, left or right for example. This maintains lift during sudden changes in relative airspeed such as due to changes in the wind or aircraft direction. The combination of the lifting body and lifting rotors provides a steady lift force throughout a full range of airspeed from a variety of different directions.

The number of rotors can be varied. As seen in Fig. 8, a six rotor lifting body provides six rotors instead of just four. A variety of different numbers of rotors can be used.

When carrying cargo, the center of gravity might be shifted caused by the cargo center of gravity not being centered. The lifting propeller speed can be varied to accommodate the shifted center of gravity due to non-centered cargo. For example, if the cargo is forward shifted, the forward propellers can spin faster to create more lift to compensate for the excessive forward center of gravity. For example, in this case the rear propellers may operate as usual.

During forward flight, for controlling attitude, instead of using control surfaces, the various lifting propellers can spin at varied speeds for controlling the flight of the aircraft. The

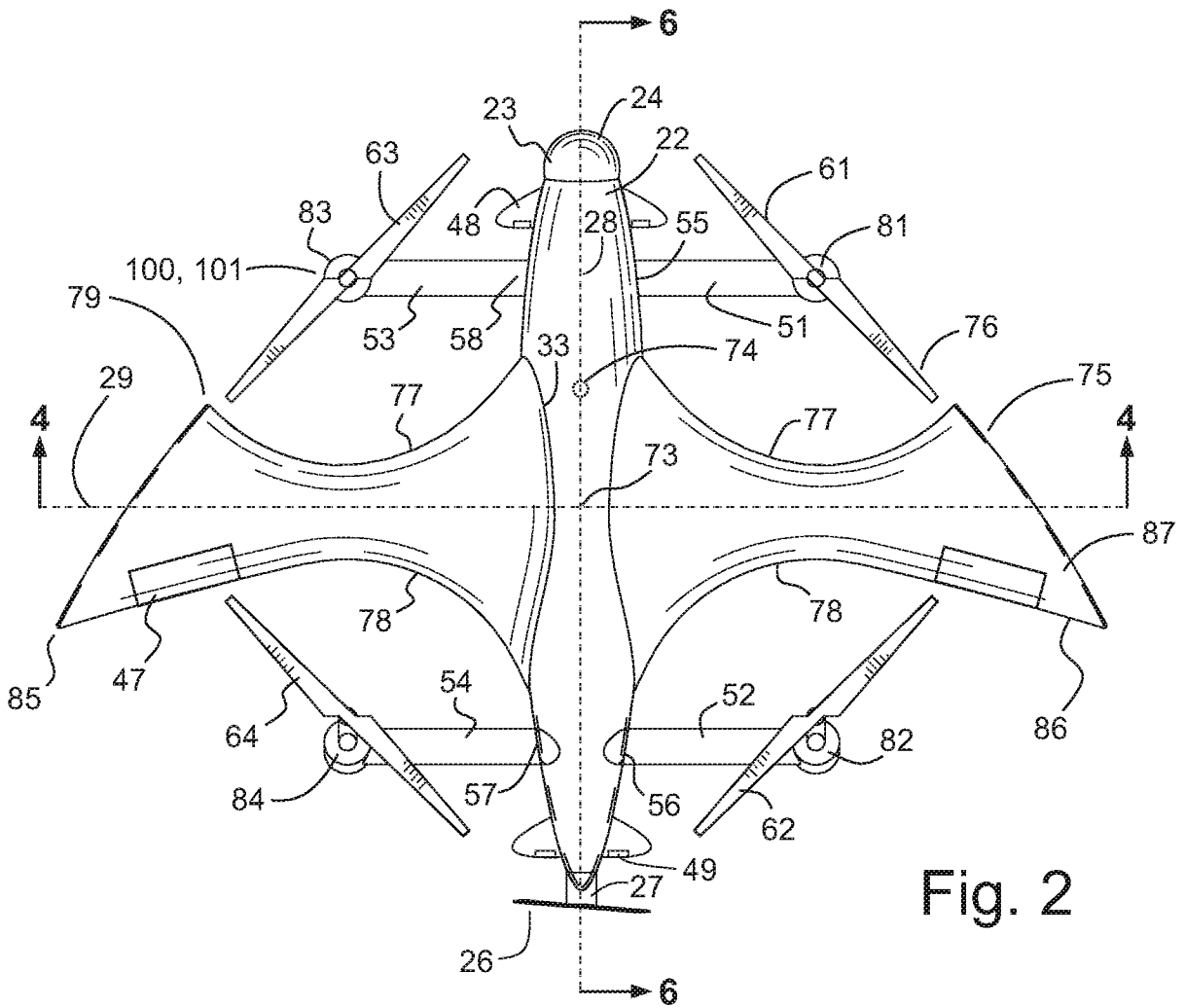
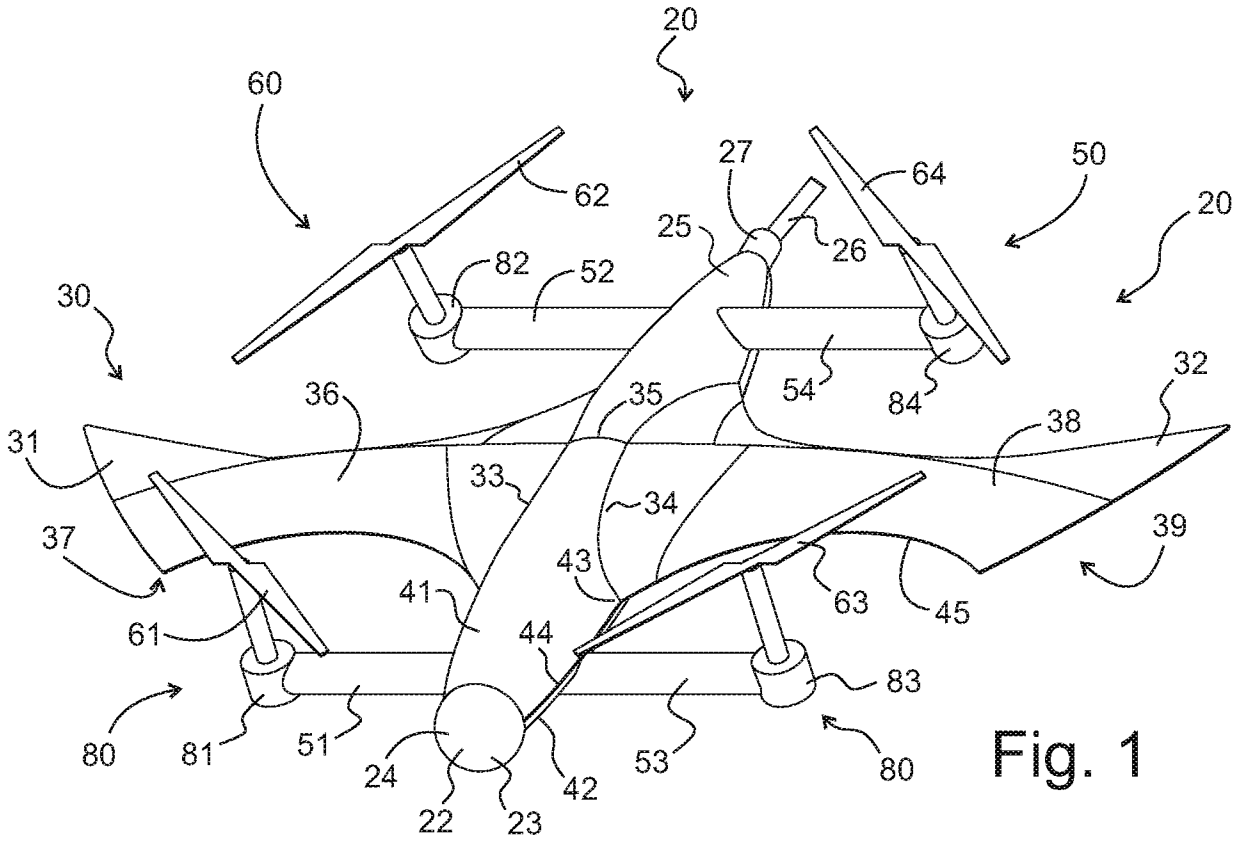
lifting body need not have any control surfaces. The lifting propellers can spin at low RPM for attitude control when most of the lift is being generated by the lifting body. The lifting propellers can idle at about 200-500 RPM so that they can speed up when necessary. This occurs when the lifting body generates a majority of the lift.

CLAIMS

1. A multi-copter lift body aircraft comprising:
 - a. lift body that has a first airfoil shape on a front to rear cross-section, wherein the lift body has a nose and a tail;
 - b. multi-copter propellers attached to the lift body, wherein the multi-copter propellers provide a multi-copter propeller lift at low speeds, wherein the lift body provides a lift body lift at high speeds, wherein the multi-copter propeller is mounted to a shaft, wherein the multi-copter propellers include front multi-copter propellers and rear multi-copter propellers;
 - c. a shaft angle formed on the rear multi-copter propellers, wherein the shaft angle provides a forward thrust, wherein the shaft angle is fixed and angled upward and forward, wherein the shaft angle is not perpendicular to a chord line of the lift body, wherein the shaft angle facilitates an F_x forward force and an F_y lifting force, wherein the F_x forward force is the sine of the shaft angle; and
 - d. avionics stored in a hollow cavity of the lift body, wherein the avionics includes a control circuit, batteries, and a radio receiver, wherein during a forward flight when the lift body generates a majority of the lift, the lifting propellers spin at varied speeds for controlling attitude, wherein the lift body does not have control surfaces, wherein lift body lift increases as an airspeed increases and a multi-copter propeller lift decreases so that the aircraft maintains the same altitude at any speed up to a top speed.
2. The multi-copter of claim 1, wherein the lifting propellers spin at varied speeds for assisting in controlling the flight of the aircraft, wherein when carrying cargo, a lifting propeller speed is varied to accommodate a shifted center of gravity due to non-centered cargo.
3. The multi-copter of claim 1, wherein the lift body has an optimum attack angle at a cruising speed, wherein the lift body provides a combined lift mode.
4. The multi-copter of claim 1, wherein the lift body includes a canard.
5. The multi-copter of claim 1, wherein the center of gravity of the multi-copter mode is the center of gravity in airfoil mode.

6. The multi-copter of claim 1, further including a locking means for multi-copter blades including use of a hall sensor or encoder.
7. The multi-copter of claim 1, wherein the lift body has open concave curvatures.
8. The multi-copter of claim 1, wherein the lift body includes a camera in the nose of the lift
5 body when a push propeller is mounted to the tail of the lift body.
9. A multi-copter lift body aircraft comprising:
 - e. lift body that has a first airfoil shape on a front to rear cross-section, wherein the lift body has a nose and a tail;
 - f. multi-copter propellers attached to the lift body, wherein the multi-copter
10 propellers provide a multi-copter propeller lift at low speeds, wherein the lift body provides a lift body lift at high speeds, wherein the multi-copter propeller is mounted to a shaft;
 - g. a shaft angle formed on the multi-copter propeller, wherein the shaft angle provides a forward thrust, wherein the shaft angle is fixed and angled upward and
15 forward, wherein the shaft angle is not perpendicular to a chord line of the lift body, wherein the shaft angle facilitates an F_x forward force and an F_y lifting force, wherein the F_x forward force is the sine of the shaft angle; and
 - h. avionics stored in a hollow cavity of the lift body, wherein the avionics includes a control circuit, batteries, and a radio receiver, wherein during a forward flight
20 when the lift body generates a majority of the lift, the lifting propellers spin at varied speeds for controlling attitude, wherein the lift body has control surfaces which are active, wherein lift body lift increases as an airspeed increases and a multi-copter propeller lift decreases so that the aircraft maintains the same altitude at any speed up to a top speed.
- 25 10. The multi-copter of claim 9, wherein the lift body is made from a top shell and a bottom shell.
11. The multi-copter of claim 9, wherein the lift body has an optimum attack angle at a cruising speed, wherein the lift body provides a combined lift mode.
12. The multi-copter of claim 9, wherein the lift body includes a canard forward control
30 surface.

13. The multi-copter of claim 9, wherein the center of gravity of the multi-copter mode is the center of gravity in airfoil mode, wherein the airfoil center of gravity is approximately 1/3 from the nose.
14. The multi-copter of claim 9, further including control surfaces mounted to the lift body including a rudder, aileron and elevator.
15. The multi-copter of claim 9, further including a locking means for multi-copter blades including use of a hall sensor or encoder.
16. The multi-copter of claim 9, wherein the lift body includes a camera in the nose of the lift body when a push propeller is mounted to the tail of the lift body.
17. The multi-copter of claim 9, further comprising a second multi-copter propeller angled toward the multi-copter propeller.
18. The multi-copter of claim 9, further comprising a second multi-copter propeller parallel to the multi-copter propeller.
19. The multi-copter of claim 9, further comprising a second multi-copter propeller angled away from the multi-copter propeller.



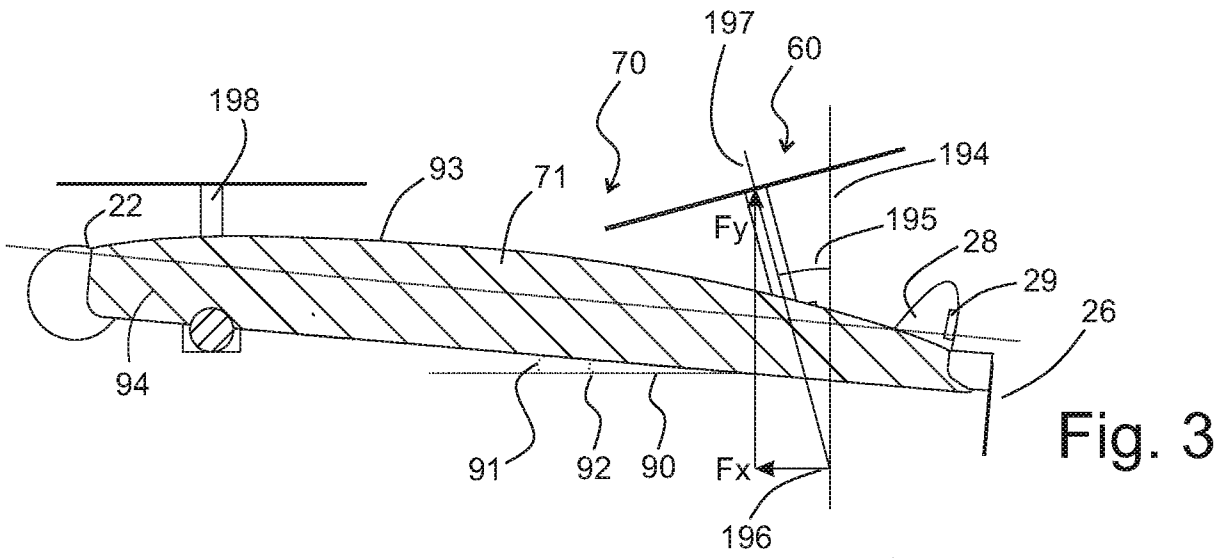


Fig. 3

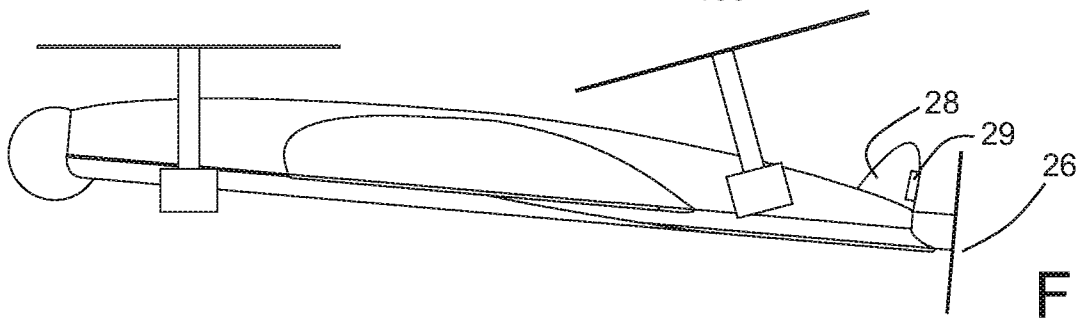


Fig. 4

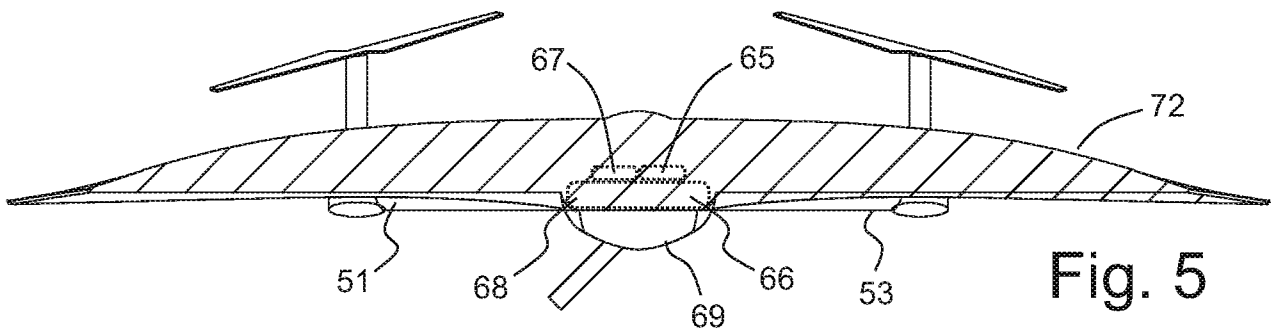


Fig. 5

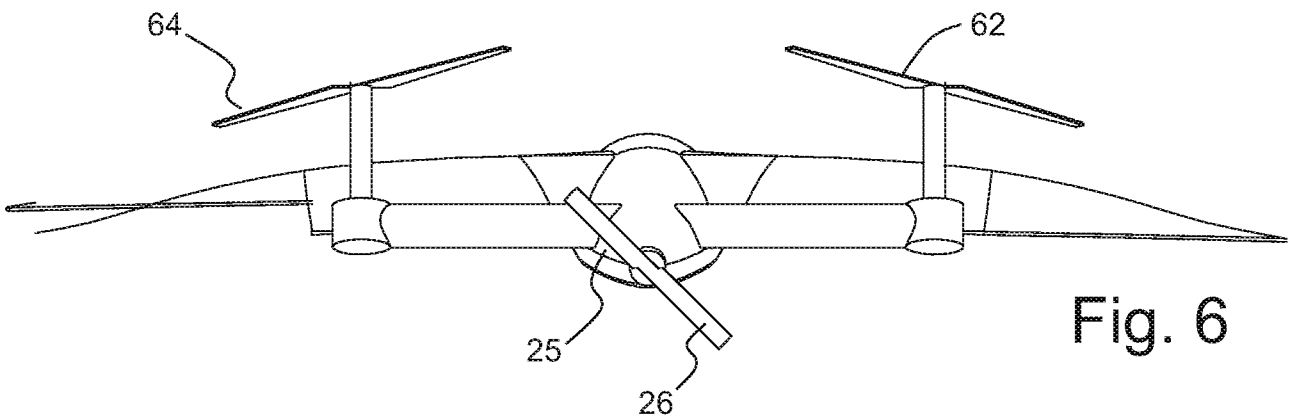


Fig. 6

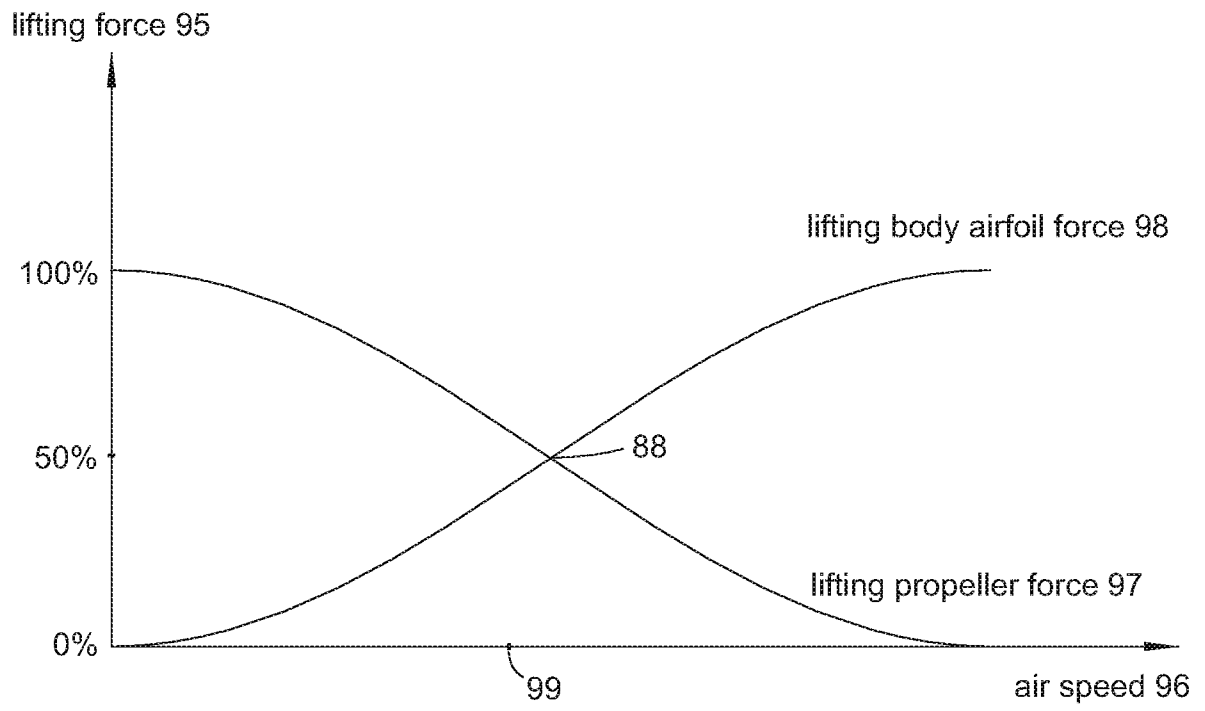


Fig. 7

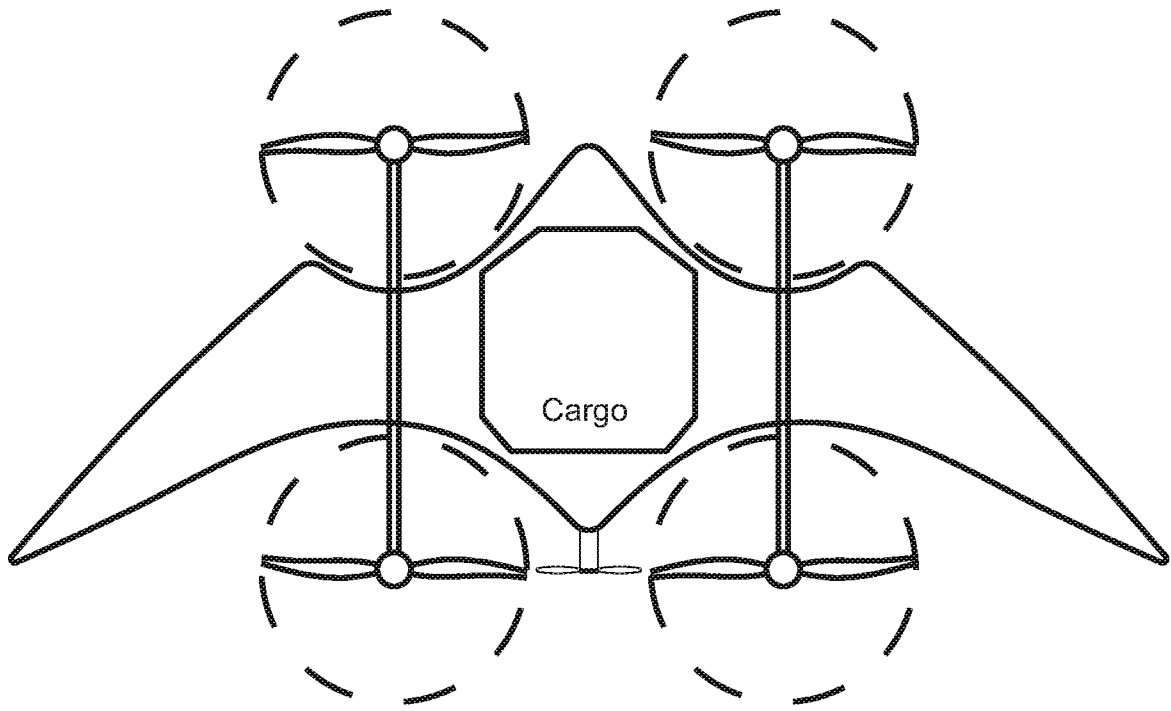


Fig. 8

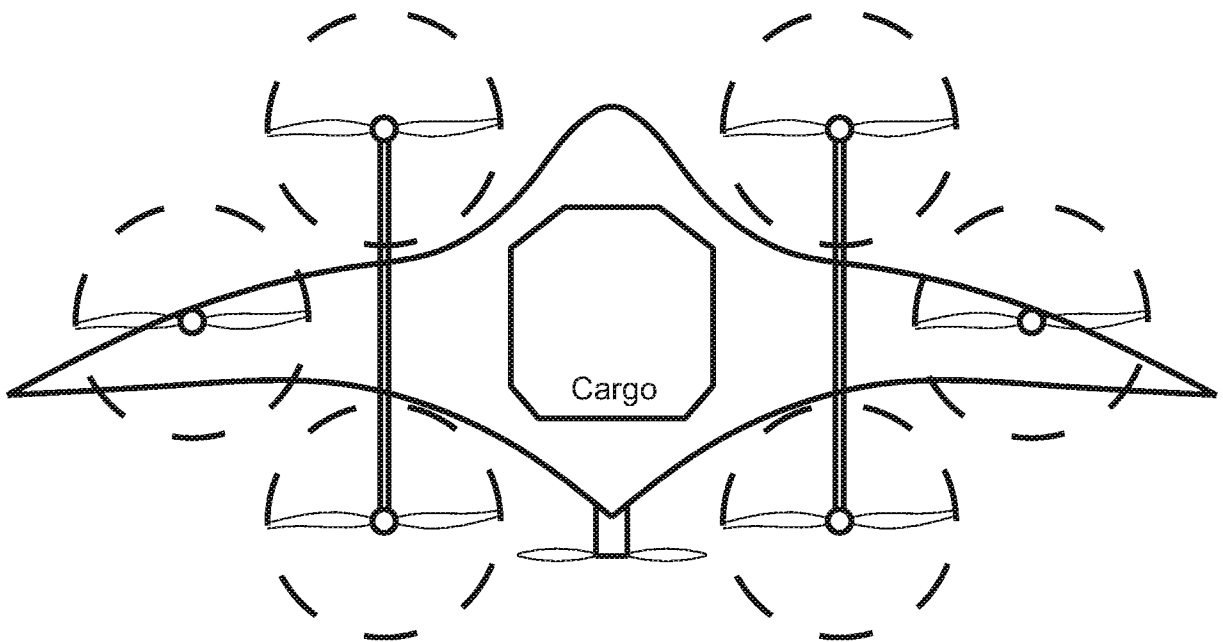


Fig. 9

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2018/031098

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - B64C 27/08; B64C 27/20; B64C 27/24; B64C 27/28; B64C 27/52; B64C 29/00 (2018.01)

CPC - B64C 27/08; B64C 27/26; B64C 27/28; B64C 29/0008; B64C 29/0033; B64C 39/00; B64C 2201/024 (2018.05)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

USPC - 244/6; 244/12.1; 244/12.4; 244/17.11; 244/17.23; 244/30; 701/3 (keyword delimited)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2016/0207625 A1 (AIRBUS DEFENCE AND SPACE GMBH et al) 21 July 2016 (21.07.2016) entire document	1, 4, 5, 7-10, 12-14, 16-19
Y	US 2010/0051740 A1 (YOELI) 04 March 2010 (04.03.2010) entire document	1, 4, 5, 7-10, 12-14, 16-19
Y	US 2015/0329204 A1 (NELSON) 19 November 2015 (19.11.2015) entire document	1, 4, 5, 7-10, 12-14, 16-19
Y	US 2014/0061367 A1 (EUROCOPTER DEUTSCHLAND GMBH) 06 March 2014 (06.03.2014) entire document	4, 12
Y	US 5,086,996 A (ROEDER et al) 11 February 1992 (11.02.1992) entire document	10
Y	US 2011/0248124 A1 (FRASER) 13 October 2011 (13.10.2011) entire document	14
A	US 2011/0266081 A1 (NOVIKOV-KOPP) 03 November 2011 (03.11.2011) entire document	1-19
A	US 2009/0008499 A1 (SHAW) 08 January 2009 (08.01.2009) entire document	1-19
A	US 2014/0084114 A1 (VALENTIN) 27 March 2014 (27.03.2014) entire document	1-19

 Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

26 June 2018

Date of mailing of the international search report

12 JUL 2018

Name and mailing address of the ISA/US

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