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(54) **VERTICAL TAKE-OFF AND LANDING AIRCRAFT**

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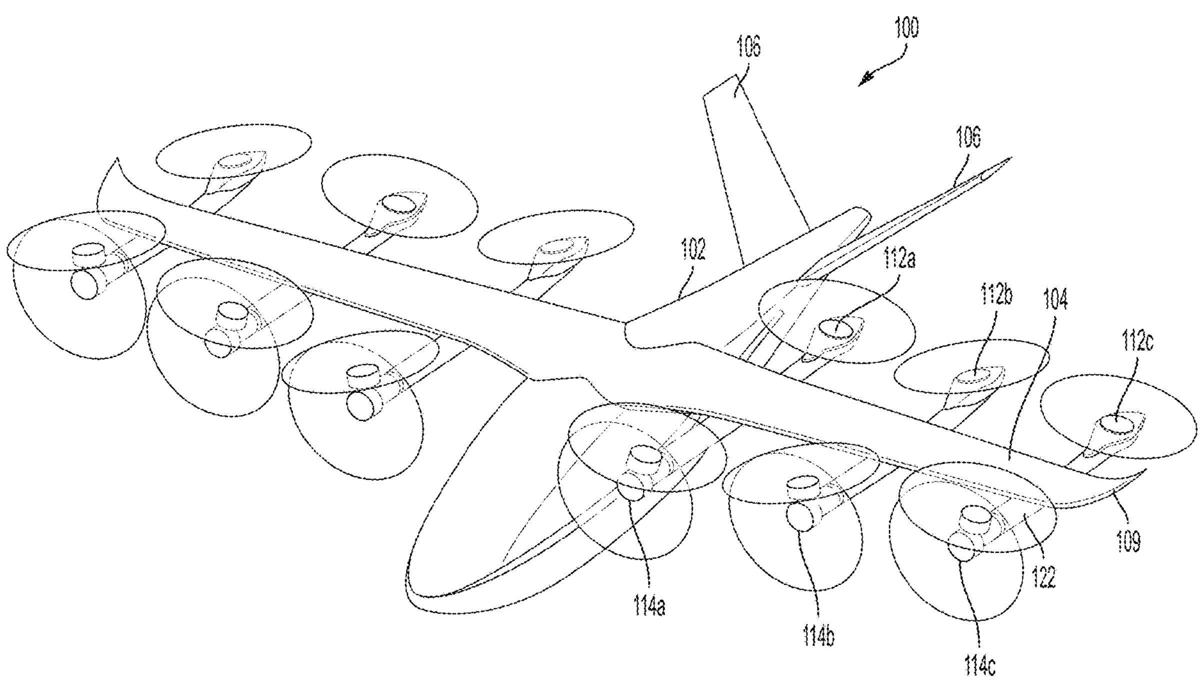
(57) **ABSTRACT**

A vertical take-off and landing aircraft includes a fuselage, at least one wing connected to the fuselage, a plurality of rotors connected to the at least one wing for providing lift for vertical take-off and landing of the aircraft and a plurality of proprotors connected to the at least one wing and tiltable between lift configurations for providing lift for vertical take-off and landing of the aircraft and propulsion configurations for providing forward thrust to the aircraft



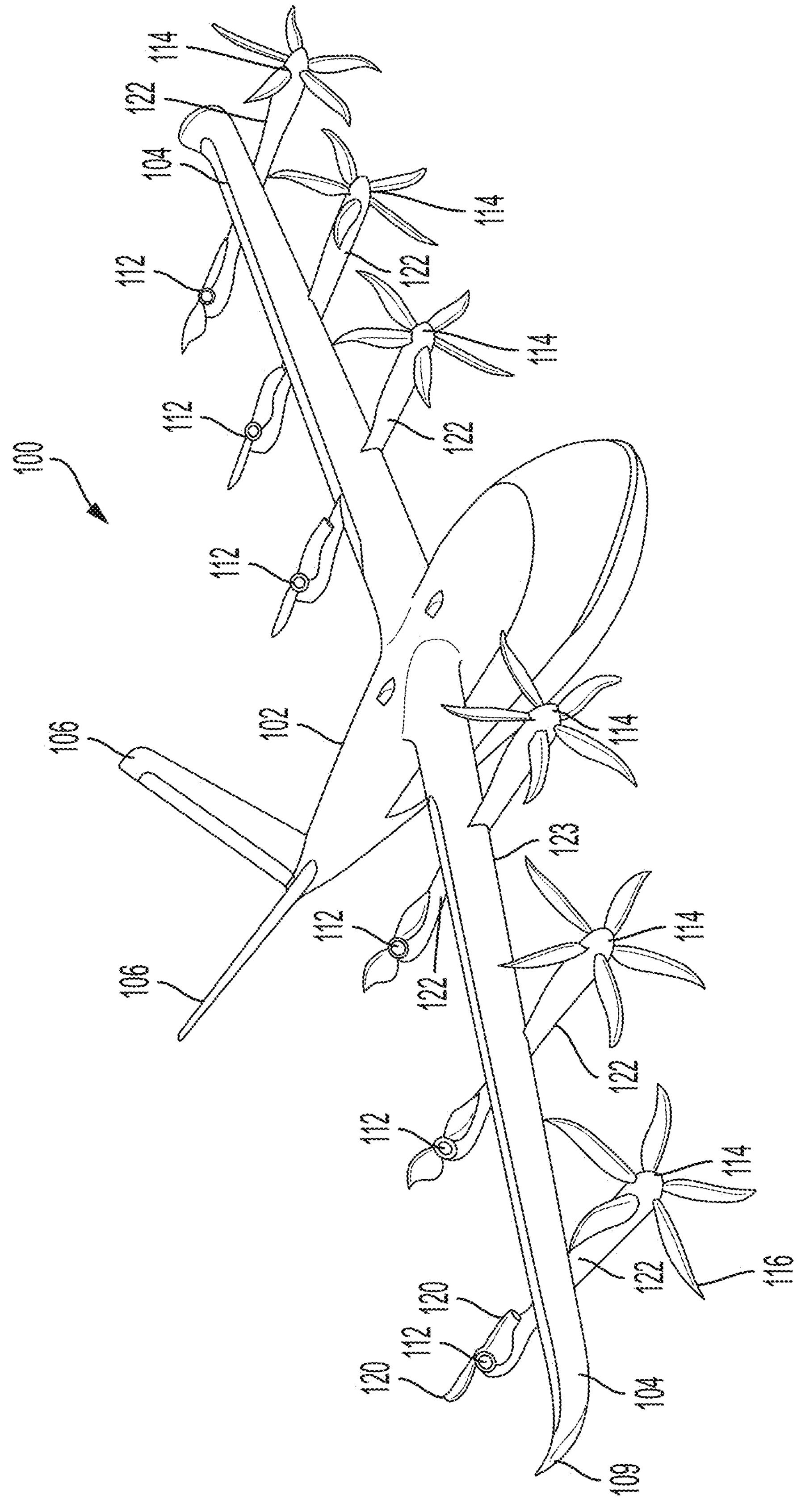

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FIG. 1

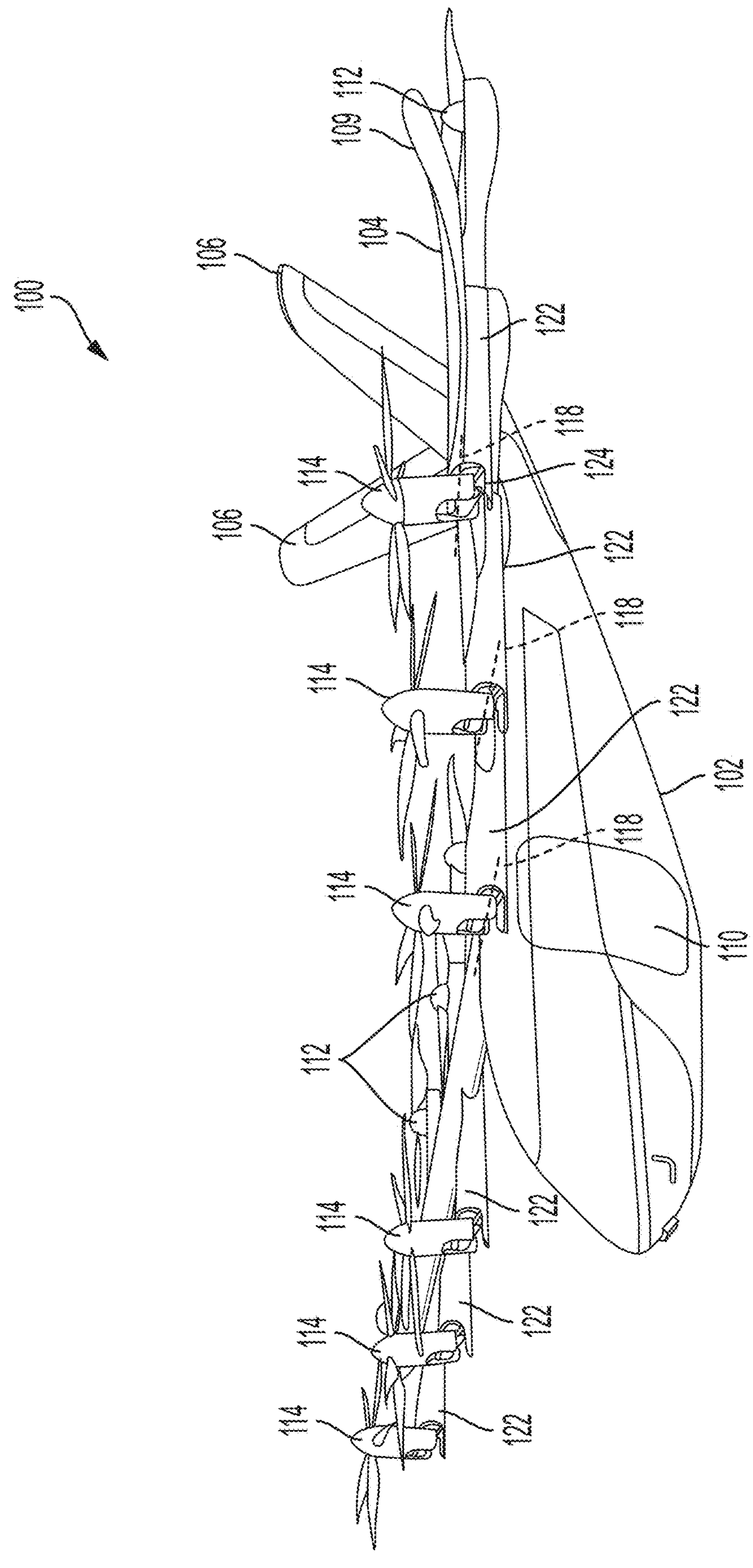

FIG. 2

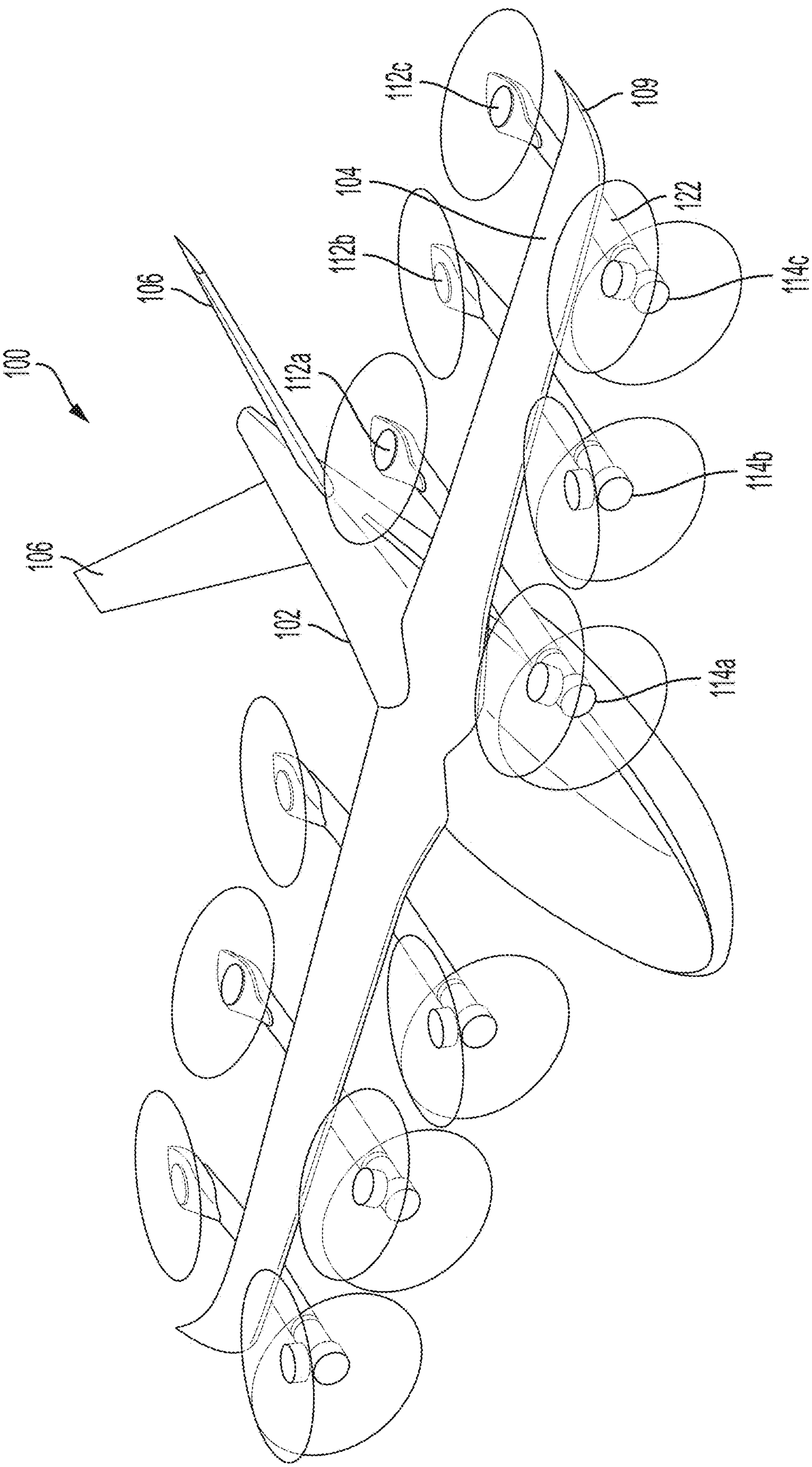

FIG. 3

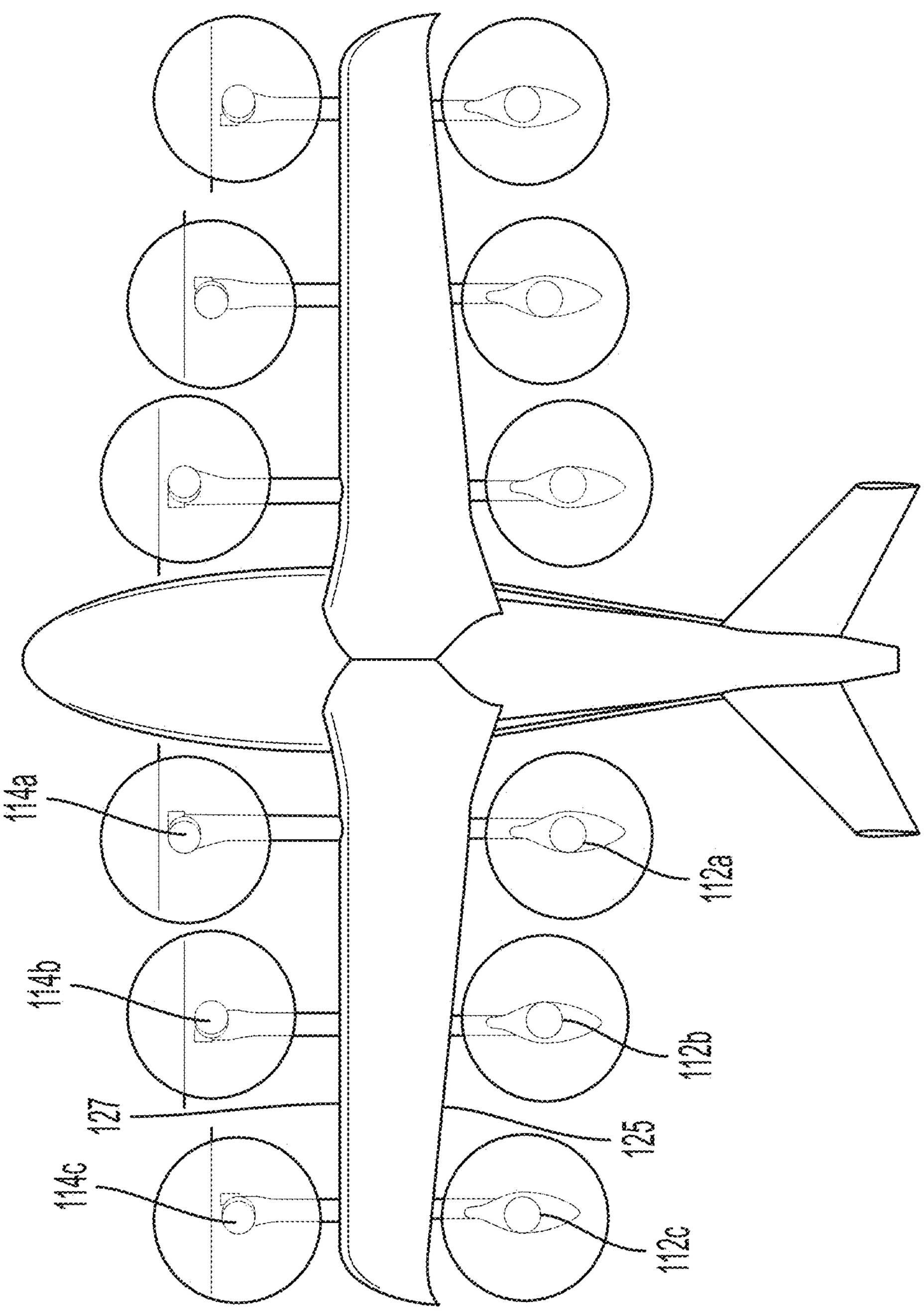

FIG. 4

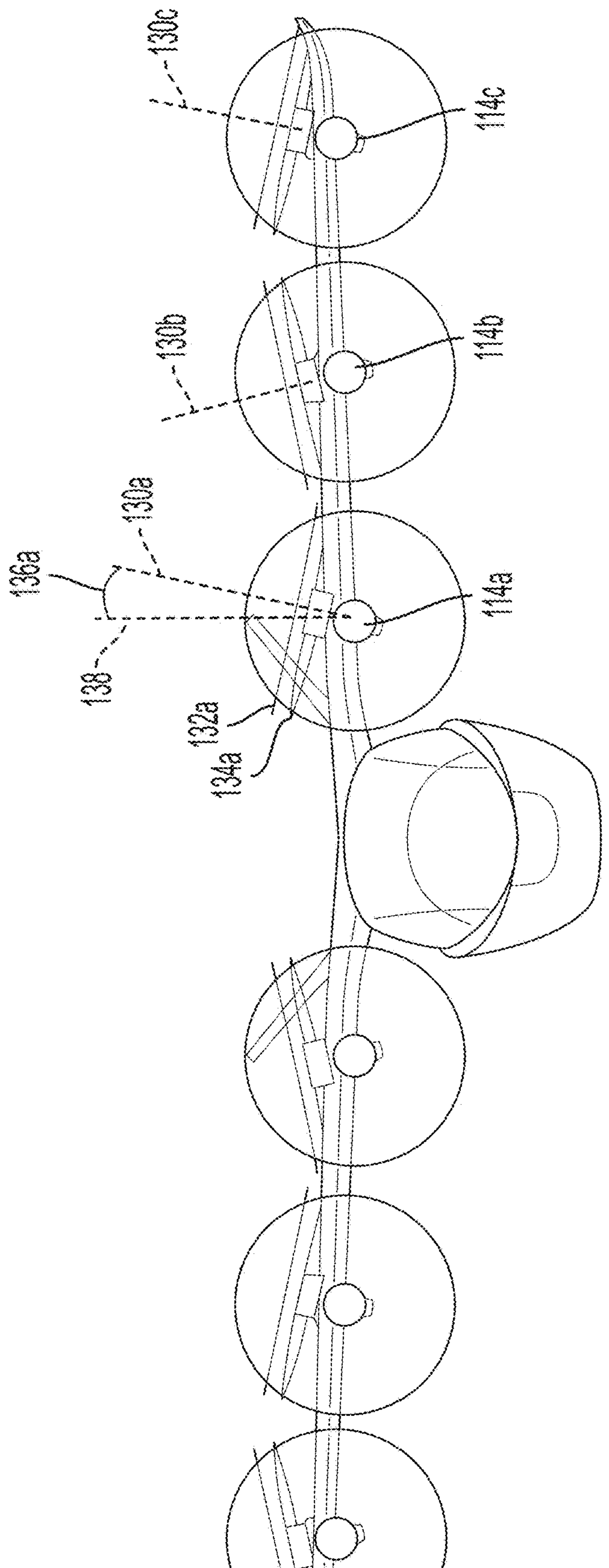

FIG. 5

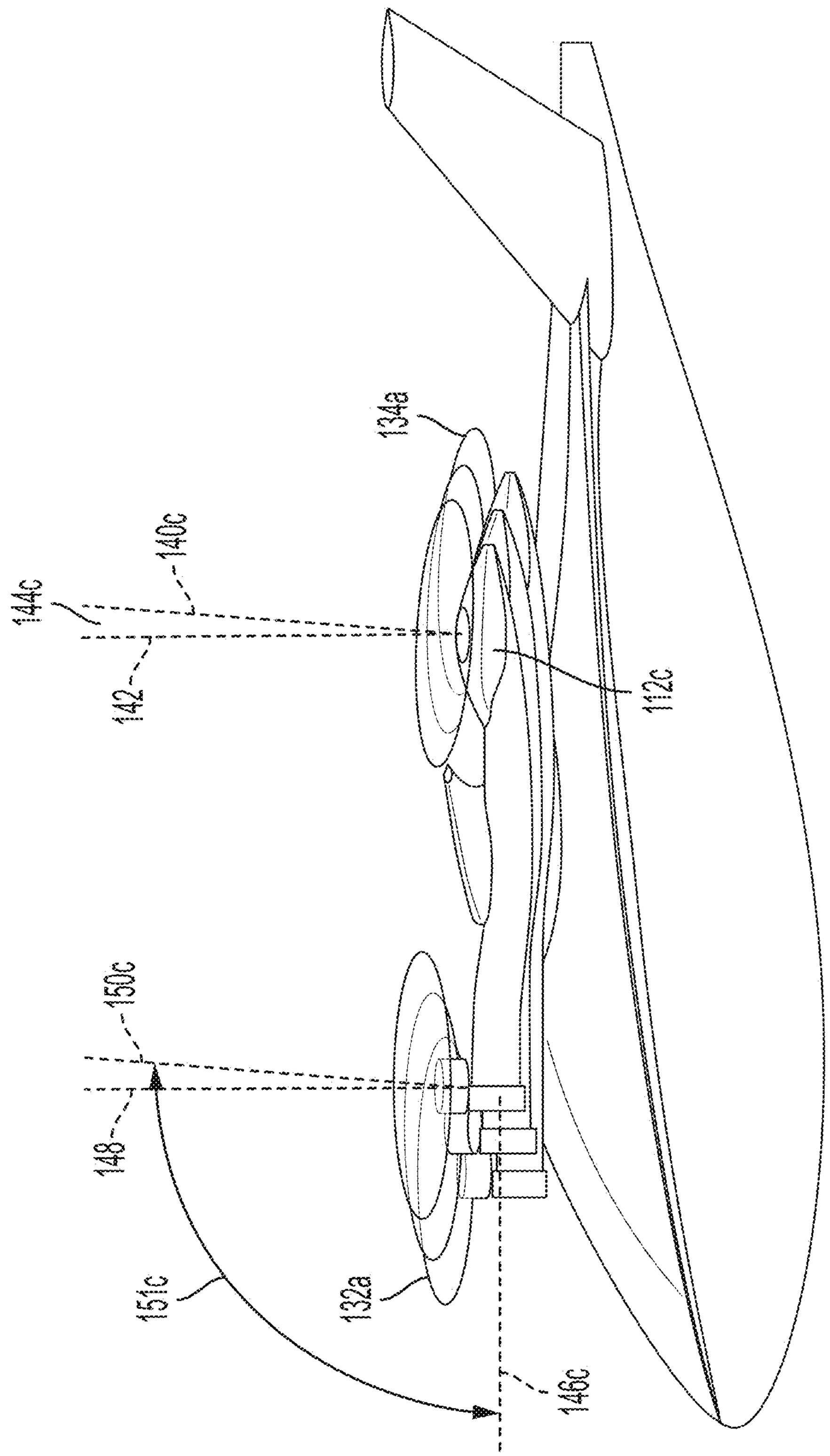

FIG. 6

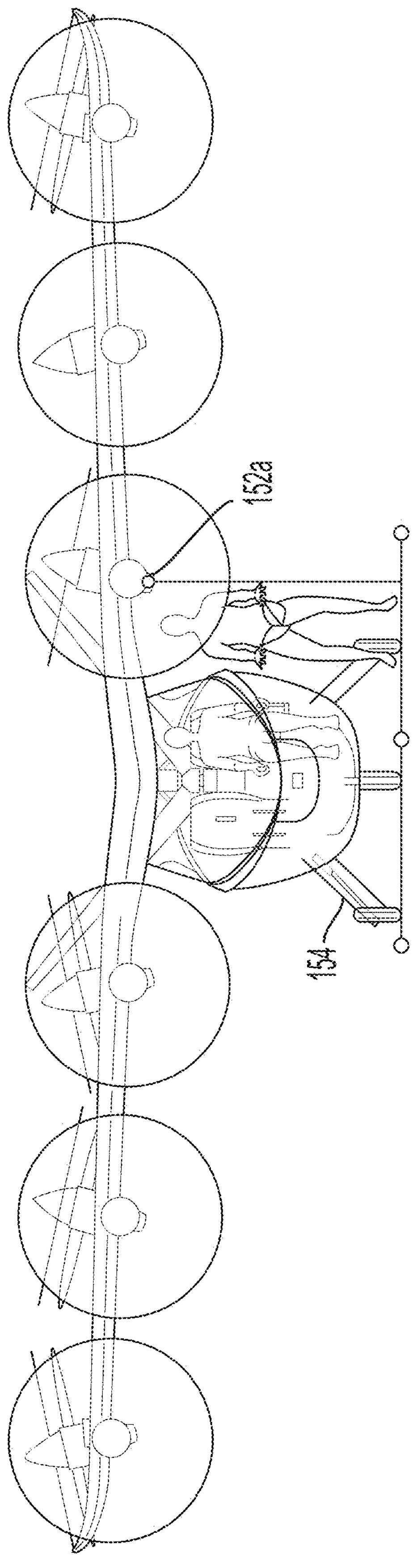

FIG. 7

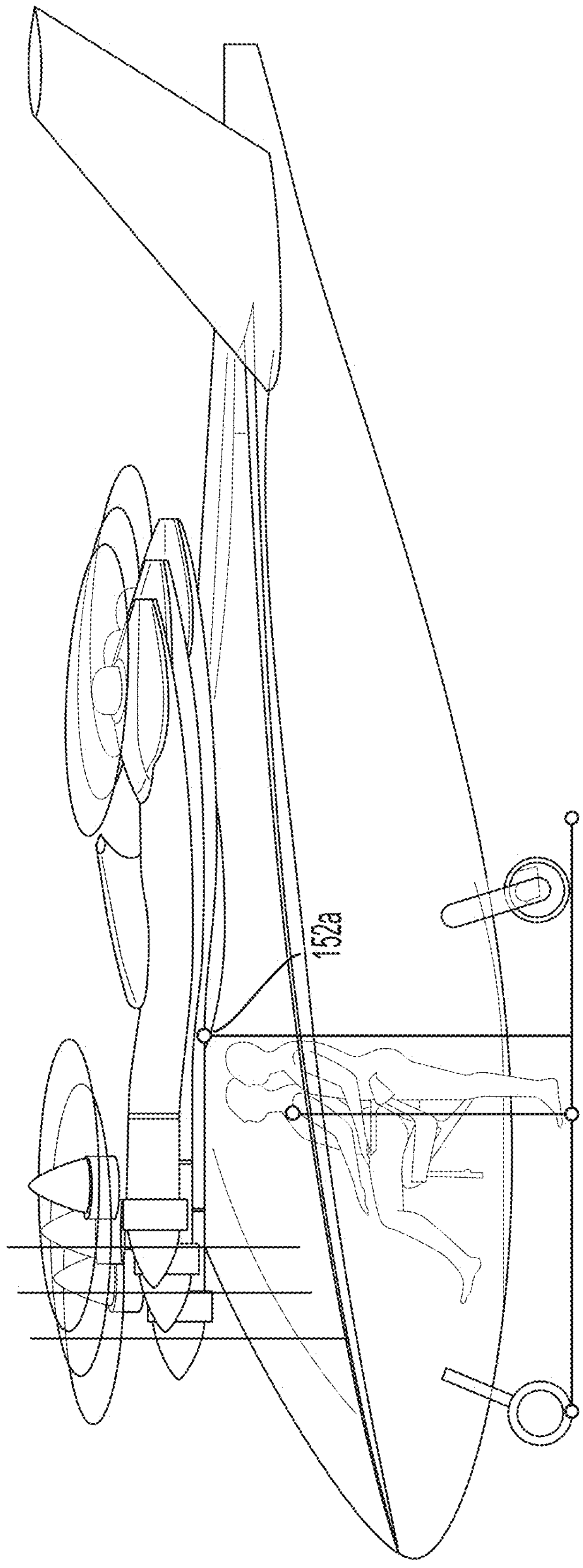

FIG. 8

VERTICAL TAKE-OFF AND LANDING AIRCRAFT

FIELD

[0001] This disclosure generally relates to vertical take-off and landing aircraft, and more specifically to fixed wing vertical take-off and landing aircraft.

BACKGROUND

[0002] Vertical take-off and landing (VTOL) aircraft are aircraft that can take-off and land vertically and hover, providing the ability to carry travelers directly to their destination. Helicopters are VTOL aircraft that generate lift entirely through their rotors. Some VTOL aircraft have wings and propulsion systems that enable the wings to provide the lift required during forward flight. Some winged VTOL aircraft use separate propulsion systems for vertical thrust for use during take-off and landing and forward thrust for use during cruising. Other winged VTOL aircraft use tiltable propulsion systems that tilt between vertical thrust and forward thrust positions.

SUMMARY

[0003] According to various embodiments, a vertical take-off and landing aircraft includes a fixed wing, a plurality of rotors for providing lift during vertical take-off and landing, and a plurality of proprotors that can tilt from lift configurations for providing lift during vertical take-off and landing to propulsion configurations for providing the forward air speed required for the aircraft to be supported by the fixed wing. By configuring the VTOL aircraft so that a portion of the propulsion system is dedicated to lift and a portion of the propulsion system is used during both lift and forward flight, the aircraft can be lighter and have lower drag than VTOL aircraft that have separate lift and propulsion systems and VTOL aircraft that use all propulsion for both lift and forward flight.

[0004] A vertical take-off and landing aircraft includes a fuselage; at least one wing connected to the fuselage; a plurality of rotors connected to the at least one wing for providing lift for vertical take-off and landing of the aircraft; and a plurality of proprotors connected to the at least one wing and tiltable between lift configurations for providing lift for vertical take-off and landing of the aircraft and propulsion configurations for providing forward thrust to the aircraft.

[0005] In any of these embodiments, the plurality of rotors can be rearward of the at least one wing and the plurality of proprotors can be forward of the at least one wing. In any of these embodiments, a plurality of booms can be mounted to the at least one wing, each boom mounting one rotor and one proprotor to the at least one wing.

[0006] In any of these embodiments, a first proprotor can be forward of a second proprotor that is adjacent to the first proprotor.

[0007] In any of these embodiments, a first proprotor can be mounted at a higher position on the aircraft than a second proprotor that is adjacent to the first proprotor.

[0008] In any of these embodiments, each rotor can have only two blades. In any of these embodiments, each rotor can be configured to fix the two blades in position during forward flight. In any of these embodiments, each proprotor can have greater than two blades.

[0009] In any of these embodiments, a first rotor of the plurality of rotors can be canted relative to a second rotor of the plurality of rotors such that a rotational axis of the first rotor is non-parallel with a rotational axis of the second rotor. In any of these embodiments, a cant angle of any rotor or proprotor is such that a respective burst disc cannot intersect with passengers or a pilot. In any of these embodiments, a cant angle of any rotor or proprotor is such that a respective burst disc cannot intersect with any flight-critical component.

[0010] In any of these embodiments, a first proprotor of the plurality of proprotors can be canted relative to a second proprotor of the plurality of proprotors such that a rotational axis of the first proprotor is non-parallel with a rotational axis of the second proprotor.

[0011] In any of these embodiments, the aircraft further includes a control system configured to actively alter a tilt of at least one proprotor to generate yawing moments during hover.

[0012] In any of these embodiments, attack angles of blades of the proprotors can be collectively adjustable during flight.

[0013] In any of these embodiments, propulsion can be provided entirely by the proprotors.

[0014] In any of these embodiments, a range of tilt of the proprotors can be greater than ninety degrees.

[0015] In any of these embodiments, the at least one wing can provide the lift required during cruising.

[0016] In any of these embodiments, the at least one wing can be a high wing mounted to an upper side of the fuselage.

[0017] In any of these embodiments, the at least one wing has control surfaces.

[0018] In any of these embodiments, all of the rotors and proprotors are mounted to the at least one wing.

[0019] In any of these embodiments, the aircraft is electrically powered.

[0020] In any of these embodiments, the aircraft is manned.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] The invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

[0022] FIG. **1** shows a VTOL aircraft in a forward flight configuration, according to various embodiments;

[0023] FIG. **2** shows a VTOL aircraft in a takeoff and landing configuration, according to various embodiments;

[0024] FIG. **3** is a perspective view of a VTOL aircraft illustrating the rotor and proprotor positions in the lift and forward flight configurations, according to various embodiments;

[0025] FIG. **4** is a top view of the VTOL aircraft of FIG. **3**;

[0026] FIG. **5** is a front view of the VTOL aircraft of FIG. **3**;

[0027] FIG. **6** is a side view of the VTOL aircraft of FIG. **3**; and

[0028] FIGS. **7** and **8** are front and side views, respectively, of a VTOL aircraft illustrating the size of the aircraft relative to a standing person, according to various embodiments.

DETAILED DESCRIPTION

[0029] According to various embodiments, VTOL aircraft described herein include at least one fixed wing, a plurality of rotors that are fixed for providing lift during take-off, landing, and hover, and a plurality of proprotors that are tiltable from lift configurations for providing lift to propulsion configurations for providing the forward thrust needed for the at least one fixed wing to provide the lift to the aircraft. By configuring the VTOL aircraft so that a portion of the propulsion system is dedicated to lift and a portion of the propulsion system is used during both lift and forward flight, the aircraft can be lighter and have lower drag than VTOL aircraft that have separate lift and propulsion systems and VTOL aircraft that use all propulsion for both lift and forward flight. Winged VTOL aircraft that have separate propulsion systems for vertical propulsion and forward propulsion essentially waste the forward propulsion system during vertical take-off and landing and hover. In contrast, aircraft according to the principles described herein utilize the forward propulsion system during vertical take-off and landing, which can results in a relatively light propulsion system overall. Winged VTOL aircraft that tilt all of their rotors have limited places to position the rotors (rotors must be positioned forward and rearward of the center of gravity but their positioning is limited by the other rotors and the wings), which often results in relatively fewer, and therefore larger, rotors. In contrast, propulsion systems according to the principles described herein can be have relatively smaller, lighter weight, and lower drag rotors. Thus, aircraft according to various embodiments described here have an ideal balance between a dedicated lift propulsion system and a tiltable propulsion system.

[0030] According to various embodiments, the proprotors are mounted to wing(s), forward of the leading edge, and the rotors are mounted to the wing(s), rearward of the trailing edge. The proprotors and rotors can be mounted to the wings via booms. In some embodiments each boom supports a proprotor at its front end and a rotor at its rear end.

[0031] According to various embodiments, the proprotors are staggered in the forward and rearward direction to prevent broken blades of one proprotor from hitting the blades of the adjacent proprotor. According to some embodiments, the rotors and/or proprotors are positioned and canted so that their blades do not intersect one another and to enhance yaw control authority. In some embodiments, the rotors and/or proprotors are positioned and canted so that the planes of rotation of their blades do not intersect passengers and/or critical system components to minimize the potential damage resulting from a blade breaking during flight.

[0032] According to some embodiments, the wings are located high on the fuselage for easy passenger ingress and egress. The aircraft can be configured so that the bottom of the booms supporting the rotor and proprotors are above the head of an average sized person, which also contributed to ease of ingress and egress.

[0033] In the following description of the disclosure and embodiments, reference is made to the accompanying drawings in which are shown, by way of illustration, specific embodiments that can be practiced. It is to be understood that other embodiments and examples can be practiced, and changes can be made, without departing from the scope of the disclosure.

[0034] In addition, it is also to be understood that the singular forms "a," "an," and "the" used in the following description are intended to include the plural forms as well, unless the context clearly indicates otherwise. It is also to be understood that the term "and/or"," as used herein, refers to and encompasses any and all possible combinations of one or more of the associated listed items. It is further to be understood that the terms "includes, "including," "comprises," and/or "comprising," when used herein, specify the presence of stated features, integers, steps, operations, elements, components, and/or units, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, units, and/or groups thereof.

[0035] As used herein, the term "proprotor" refers to a variable pitch propeller that can provide thrust for vertical lift and for forward propulsion by varying the pitch of the propeller.

[0036] FIGS. **1** and **2** illustrate a VTOL aircraft **100** in a cruise configuration and a vertical take-off and landing configuration, respectively, according to various embodiments. The aircraft **100** includes a fuselage **102**, wings **104** mounted to the fuselage **102**, and one or more rear stabilizers **106** mounted to the rear of the fuselage **102**. A plurality of rotors **112** are mounted to the wings **104** and are configured to provide lift for vertical take-off and landing. A plurality of proprotors **114** are mounted to the wings **104** and are tiltable between lift configurations in which they provide a portion of the lift required for vertical take-off and landing and hovering, as shown in FIG. **2**, and propulsion configurations in which they provide forward thrust to the aircraft **100** for horizontal flight, as shown in FIG. **1**. As used herein, a proprotor lift configuration refers to any proprotor orientation in which the proprotor thrust is providing primarily lift to the aircraft and proprotor propulsion configuration refers to any proprotor orientation in which the proprotor thrust is providing primarily forward thrust to the aircraft.

[0037] According to various embodiments, the rotors **112** are configured for providing lift only, with all propulsion being provided be the proprotors. Accordingly, the rotors **112** may be in fixed positions. During take-off and landing, the proprotors **114** are tilted to lift configurations in which their thrust is directed downwardly for providing additional lift.

[0038] For forward flight, the proprotors **114** tilt from their lift configurations to their propulsion configurations. In other words, the pitch of the proprotors **114** is varied from a pitch in which the proprotor thrust is directed downward to provide lift during vertical take-off and landing and during hover to a pitch in which the proprotor thrust is directed rearward to provide forward thrust to the aircraft **100**. The proprotors tilt about axes **118** that are perpendicular to the forward direction of the aircraft **100**. When the aircraft **100** is in full forward flight, lift may be provided entirely by the wings **104**, and the rotors **112** may be shut-off. The blades **120** of the rotors **112** may be locked in low drags positions for aircraft cruising. In some embodiments, the rotors **112** each have two blades **120** that are locked for cruising in minimum drag positions in which one blade is directly in front of the other blade as illustrated in FIG. **1**. In some embodiments, the rotors **112** have more than two blades. In some embodiments, the proprotors **114** include more blades **116** than the rotors **112**. For example, as illustrated in FIGS. **1** and **2**, the rotors **112** may each include two blades and the proprotors **114** may each include five blades. According to various embodiments, the proprotors **114** can have from 2 to 5 blades.

[0039] According to various embodiments, the aircraft includes only one wing **104** on each side of the fuselage **102** (or a single wing that extends across the entire aircraft) and at least a portion of the rotors **112** are located rearward of the wings **104** and at least a portion of the proprotors **114** are located forward of the wings **104**. In some embodiments, all of the rotors **112** are located rearward of the wings **104** and all of the proprotors are located forward of the wings **104**. According to some embodiments, all rotors **112** and proprotors **114** are mounted to the wings—i.e., no rotors or proprotors are mounted to the fuselage. According to various embodiments, the rotors **112** are all located rearwardly of the wings **104** and the proprotors **114** are all located forward of the wings **104**. According to some embodiments, all rotors **112** and proprotors **114** are positioned inwardly of the wing tips **109**.

[0040] According to various embodiments, the rotors **112** and proprotors **114** are mounted to the wings **104** by booms **122**. The booms **122** may be mounted beneath the wings **104**, on top of the wings, and/or may be integrated into the wing profile. According to various embodiments, one rotor **112** and one proprotor **114** are mounted to each boom **122**. The rotor **112** may be mounted at a rear end of the boom **122** and a proprotor **114** may be mounted at a front end of the boom **122**. In some embodiments, the rotor **112** is mounted in a fixed position on the boom **122**. In some embodiments, the proprotor **114** is mounted to a front end of the boom **122** via a hinge **124**. The proprotor **114** may be mounted to the boom **122** such that the proprotor **114** is aligned with the body of the boom **122** when in its propulsion configuration, forming a continuous extension of the front end of the boom **122** that minimizes drag for forward flight.

[0041] According to various embodiments, the aircraft **100** may include only one wing on each side of the aircraft **100** or a single wing that extends across the aircraft. According to some embodiments, the at least one wing **104** is a high wing mounted to an upper side of the fuselage **102**. According to some embodiments, the wings include control surfaces, such as flaps and/or ailerons. According to some embodiments, the wings can have curved wing tips **109** for reduced drag during forward flight.

[0042] According to some embodiments, the rear stabilizers **106** include control surfaces, such as one or more rudders, one or more elevators, and/or one or more combined rudder-elevators. The wing(s) may have any suitable design. In some embodiments, the wings have a tapering leading edge **123**, as shown for example, in the embodiment of FIG. **1**. In some embodiments, the wings have a tapering trailing edge **125** as shown in the embodiment of FIG. **3**. In the embodiment of FIG. **3**, the wings have a substantially straight leading edge **127** in the central section of the wings **104**.

[0043] Aircraft **100** may include at least one door **110** for passenger entry and exit. In the illustrated embodiment, the door **110** is located beneath and forward of the wings **104**.

[0044] According to various embodiments, the rotors **112** and proprotors **114** are positioned and configured to minimize the damage that may occur due to blade failure (commonly referred to as rotor burst). FIG. **3-6** show the relative locations and orientations of the rotor and proprotor blades during use, according to some embodiments. The blade positions over full rotations are illustrated by discs. The proprotors each have two discs—one for the lift configuration and one for the propulsion configuration. The rotor and proprotor configurations on the left and right of the aircraft are mirror images, and therefore, the configurations of the rotors and proprotors of only one side of the aircraft are discussed below.

[0045] As illustrated in the top view of FIG. **4**, the proprotors **114** may be staggered in the forward-rearward direction such that the plane of rotation of the proprotors in their propulsion configurations are non-coplanar. In the illustrated embodiments, the innermost proprotor **114*a*** is forward of the other proprotors. In some embodiments, the innermost proprotors **114*a*** are forward of the passenger compartment or the forward-most location of passengers in the passenger compartment to ensure that a broken blade cannot enter the passenger compartment and injure a passenger. In some embodiments, at least two proprotors on the same side of the aircraft are aligned such that their blade rotation planes are coplanar.

[0046] According to some embodiments, the rotors **112** are in staggered forward-rearward positions. In some embodiments, the innermost rotors **112*a*** are positioned rearward of the other rotors. In some embodiments, at least a portion of the rotors **112** are aligned in the forward rearward direction.

[0047] According to some embodiments, at least one of the rotors **112** and/or proprotors **114** is canted relative to at least one other rotor **112** and/or proprotor **114**. As used herein, canting refers to a relative orientation of the rotational axis of the rotor/proprotor about a line that is parallel to the forward-rearward direction, analogous to the roll degree of freedom of the aircraft. Canting of the rotors and/or proprotors can help minimize damage from rotor burst by orienting the rotational plane of the rotor/proprotor discs (the blades plus the rotor portion onto which the blades are mounted) so as to not intersect critical portions of the aircraft (such areas of the fuselage in which people may be positioned, critical flight control systems, batteries, adjacent rotors/proprotors, etc.) or other rotor discs and may provide enhanced yaw control during flight. In some embodiments, a cant angle of any rotor or proprotor is such that a respective burst disc will not intersect with passengers or a pilot. In some embodiments, a cant angle of any rotor or proprotor is such that a respective burst disc will not intersect with any flight-critical component. (As used herein, a critical component is any component whose failure would contribute to or cause a failure condition that would prevent the continued controlled flight and landing of the aircraft.) The front view of FIG. **5** best illustrates the canting of the rotors and proprotors, according to some embodiments. A rotation axis **130*a*** for the innermost proprotor **114*a*** in its lift configuration is provided to illustrate the cant angle of the proprotor **114*a***. The canting of the proprotors **114** results in the rotation planes of their blades being angled relative to horizontal, as illustrated, for example, by disc **132*a*** being non-horizontal. The illustrated cant angle **136*a*** measured from vertical **138** is about 12 degrees, but can range from 0 to 30 degrees in either direction. In the illustrated embodiment, the outermost proprotor **114*c*** is canted the same amount and in the same direction as the innermost proprotor **114*a*** and the middle proprotor **114*b*** is canted by the same amount but in the opposite direction as the innermost and outermost proprotors **114*a,c*** such that the rotational axis

130*a* of proprotor **114***a* is parallel to the rotational axis of the rotational axis **130***c* of proprotor **114***c* but non-parallel to the rotational axis **130***b* of proprotor **114***b*. However, this is merely one example of the relative canting of the proprotors and it will be understood to a person of skill in the art that any suitable combination of proprotor canting (inclusive of no canting) may be used according to the desired performance characteristics of the aircraft.

[0048] The rotors **112** may also be canted in any suitable manner and combination. In some embodiments, the rotors **112** are canted according to a corresponding proprotor. For example, innermost rotor **112***a* is canted by the same amount and in the same direction as the innermost proprotor **114***a* as can be seen by comparing the innermost rotor blade disc **134***a* to the innermost proprotor blade disc **132***a*. Similarly, rotor **112***b* and **112***c* are canted similarly to the corresponding proprotor **114***b* and **114***c*, respectively. Note that in FIG. **5**, the innermost rotor blade disc **134***a* is not depicted as a straight line due to the innermost rotor **112***a* being oriented with a rearward tilt as discussed further below. Any suitable combination of canting and/or non-canting of the rotors relative to one another and relative to the proprotors can be used to achieve desired performance characteristics.

[0049] The side view of FIG. **6** illustrates the relatively small rearward tilt of the outermost rotor **112***c*, according to the illustrated embodiment. The rotational axis **140***c* of the rotor **112***c* is tilted rearward from vertical **142** by an angle **144***c*, which can range from 0 to 15 degrees in either direction. The slight rearward tilt of the rotor **112***c* can help with aircraft stability and yaw control. FIG. **6** also illustrates the range of tilt at least the outermost proprotor **114***c*, according to some embodiments. The outermost proprotor **114***c* can tilt from a straight-ahead position illustrated by the horizontal rotational axis **146***c* of the proprotor **114***c* in its propulsion configuration to a position just past (for example, less than 10 degrees past) vertical **148** as illustrated by rotational axis **150***c* of the proprotor **114***c* in its lift configuration, such that the proprotor **114***c* has a range of tilt **151***c* of about 100 degrees. According to various embodiments, each of the proprotors **114** has a range of greater than 90 degrees.

[0050] FIGS. **7** and **8** illustrate the locations of the wings, rotors, and proprotors relative to a person on the ground, according to some embodiments. The aircraft **100** may be configured so that the bottom **152***a* of the innermost proprotor **114***a* is located above the head of a person standing on the ground next to the fuselage (for example, preparing to enter the aircraft) when the aircraft **100** is supported by its landing gear **154** on the ground. Locating the wings in high positions on the upper portion of the fuselage **102** can ensure maximum head room for people entering and exiting the aircraft. FIGS. **7** and **8** also show a person sitting in the cabin of the fuselage to illustrate the relative size of the aircraft, according to some embodiments.

[0051] According to some embodiments, the rotors **112** and proprotors **114** are all electrically powered. Batteries for powering the rotors **112** and proprotors **114** can be located in any suitable locations of the aircraft, including in the fuselage and/or the wings. The number and power of the rotors and proprotors can be selected according to the desired performance parameters (e.g., target payload, airspeed, and altitude). According to some embodiments, the maximum power rating of one or more of the rotors and proprotors is 500 kilowatts or less, preferably 200 kilowatts or less, more preferably 150 kilowatts or less. According to some embodiments, the maximum power rating of one or more of the rotors and proprotors is at least 10 kilowatts, preferably at least 20 kilowatts, more preferably, at least 50 kilowatts. The number of proprotors can range from as little as 2 (one on each side of the aircraft) to a maximum of 24 (**12** on each side of the aircraft). Preferably, the number of proprotors is in the range of 4 to 8. The number of rotors can range from 2 to 24, and is preferably in the range of 4 to 8. The aircraft can have an equal number of rotors and proprotors, a greater number of proprotors, or a greater number of rotors.

[0052] Aircraft according to the principles discussed above can be configured to carry up to 10 people, preferably up to 6 people, and more preferably up to 4 people. According to some embodiments, the aircraft is configured to be piloted and includes piloting controls. In some embodiments, the aircraft is configured to operate autonomously without any onboard pilot.

[0053] According to some embodiments, the aircraft is configured to carry up to 6 people (for example, a pilot and up to 5 passengers) up to 75 miles at a cruising speed of up to 150 miles per hour at an altitude of up to 3,000 feet above ground. In some embodiments, the aircraft is configured for 5 people, such as one pilot and four passengers. According to various embodiments, the maximum range on a single battery charge is 25 miles, 50 miles, 75 miles, 100 miles, or 200 miles.

[0054] According to various embodiments, the rotors **112** and/or proprotors **114** are configured to have relatively low tip speed to decrease the amount of noise generated by the aircraft. In some embodiments, the tip speed of the rotor blades is about 0.4 Mach in hover. According to various embodiments, the diameter of the rotor and/or proprotor blades is the range of 1 to 5 meters, preferably in the range of 1.5 to 2 meters.

[0055] According to various embodiments, the wingspan is in the range of 10 to 20 meters, preferably in the range of 15 to 16 meters. According to various embodiments, the length of the aircraft is in the range of 3 to 20 meters, preferably in the range of 5 to 15 meters, more preferably in the range of 6 to 10 meters.

[0056] According to various embodiments, the aircraft is operated during take-off and landing by positioning the proprotors in lift configurations and providing the required lift to the aircraft via the combined lift provided by the rotors and proprotors. According to various embodiments, during vertical take-off and landing and/or hover, the proprotors can be maintained in predetermined lift configurations that can be the same across all proprotors or different for different proprotors. According to various embodiments, the tilt of at least some of the proprotors can be actively adjusted during take-off and landing and/or hover to provide the required stability and/or maneuvering. According to some embodiments, the tilt of at least one proprotor is actively controlled by the flight controller during take-off, landing, and/or hover to generate yawing moments.

[0057] According to various embodiments, each rotor and/or each proprotor can be individually controlled by the flight controller according to the various operational degrees of freedom. According to various embodiments, the only degree of freedom of the rotor is the rotational speed of the rotor. In some embodiments, the angle of attack of the blades of the rotors can be collectively adjusted, providing an additional degree of freedom. According to various embodiments, the degrees of freedom of at least a portion of the proprotors includes the rotational speed of the proprotors, the collective attack angle of the blades, and the degree of tilt of the proprotors. According to various embodiments, any of these degrees of freedom can be actively controlled by the flight controller (either autonomously or in response to pilot commands) during take-off and landing in order to provide the appropriate stability and maneuvering.

[0058] Once the aircraft has achieved sufficient altitude to commence forward flight, the proprotors begin tilting forward toward their propulsion configurations such that their thrust provides a combination of lift and thrust, with a decreasing proportion of lift as the proprotors are tilted further toward their propulsion configurations. The rotors can remain active during at least a portion of the period in which the proprotors are tilted forward to continue to provide rotor-based lift. At any point after the forward airspeed is high enough that the wings provides sufficient lift to maintain the aircraft's altitude, the rotors can be deactivated. As discussed above, the rotor blades can be locked in a low-drag position.

[0059] During cruising, the rotors remain deactivated. The control surfaces of the wings and/or rear stabilizers can be used for aircraft maneuvering and stability in a conventional manner. According to some embodiments, the tilt of at least some of the proprotors can be actively controlled to provide additional stability and/or maneuverability control. In some embodiments, the tilt of at least some of the proprotors is actively controlled during take-off and landing and/or hover. In some embodiments, the tilt of the proprotors is fixed (i.e., non-varying) during cruise. According to some embodiments, the tilt of the outermost proprotors can be actively and independently controlled during vertical take-off and landing and/or hover to provide yawing moments as needed.

[0060] The foregoing description, for the purpose of explanation, has been described with reference to specific embodiments. However, the illustrative discussions above are not intended to be exhaustive or to limit the invention to the precise forms disclosed. Many modifications and variations are possible in view of the above teachings. The embodiments were chosen and described in order to best explain the principles of the techniques and their practical applications. Others skilled in the art are thereby enabled to best utilize the techniques and various embodiments with various modifications as are suited to the particular use contemplated.

[0061] Although the disclosure and examples have been fully described with reference to the accompanying figures, it is to be noted that various changes and modifications will become apparent to those skilled in the art. Such changes and modifications are to be understood as being included within the scope of the disclosure and examples as defined by the claims. Finally, the entire disclosure of the patents and publications referred to in this application are hereby incorporated herein by reference.

1. A vertical take-off and landing aircraft comprising:

a fuselage;

at least one wing connected to the fuselage;

a plurality of rotors connected to the at least one wing for providing lift for vertical take-off and landing of the aircraft; and

a plurality of proprotors connected to the at least one wing and tiltable between lift configurations for providing lift for vertical take-off and landing of the aircraft and propulsion configurations for providing forward thrust to the aircraft.

2. The aircraft of claim **1**, wherein the plurality of rotors are rearward of the at least one wing and the plurality of proprotors are forward of the at least one wing.

3. The aircraft of claim **2**, comprising a plurality of booms mounted to the at least one wing, each boom mounting one rotor and one proprotor to the at least one wing.

4. The aircraft of claim **1**, wherein a first proprotor is forward of a second proprotor that is adjacent to the first proprotor.

5. The aircraft of claim **1**, wherein a first proprotor is mounted at a higher position on the aircraft than a second proprotor that is adjacent to the first proprotor.

6. The aircraft of claim **1**, wherein each rotor has only two blades.

7. The aircraft of claim **6**, wherein each rotor is configured to fix the two blades in position during forward flight.

8. The aircraft of claim **6**, wherein each proprotor has greater than two blades.

9. The aircraft of claim **1**, wherein a first rotor of the plurality of rotors is canted relative to a second rotor of the plurality of rotors such that a rotational axis of the first rotor is non-parallel with a rotational axis of the second rotor.

10. The aircraft of claim **9**, wherein a cant angle of any rotor or proprotor is such that a respective burst disc cannot intersect with passengers or a pilot.

11. The aircraft of claim **9**, wherein a cant angle of any rotor or proprotor is such that a respective burst disc cannot intersect with any flight-critical component.

12. The aircraft of claim **1**, wherein a first proprotor of the plurality of proprotors is canted relative to a second proprotor of the plurality of proprotors such that a rotational axis of the first proprotor is non-parallel with a rotational axis of the second proprotor.

13. The aircraft of claim **1**, further comprising a control system configured to actively alter a tilt of at least one proprotor to generate yawing moments during hover.

14. The aircraft of claim **1**, wherein attack angles of blades of the proprotors are collectively adjustable during flight.

15. The aircraft of claim **1**, wherein propulsion is provided entirely by the proprotors.

16. The aircraft of claim **1**, wherein a range of tilt of the proprotors is greater than ninety degrees.

17. The aircraft of claim **1**, wherein the at least one wing provides the lift required during cruising.

18. The aircraft of claim **1**, wherein the at least one wing is a high wing mounted to an upper side of the fuselage.

19. The aircraft of claim **1**, wherein the at least one wing has control surfaces.

20. The aircraft of claim **1**, wherein all of the rotors and proprotors are mounted to the at least one wing.

21. The aircraft of claim **1**, wherein the aircraft is electrically powered.

22. The aircraft of claim **1**, wherein the aircraft is manned.

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