US009981741B2

(12) United States Patent
Hutson

(10) Patent No.: US 9,981,741 B2
(45) Date of Patent: May 29, 2018

(54) UNMANNED AERIAL VEHICLE

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 300 days.

(21) Appl. No.: **14/858,973**

(22) Filed: **Sep. 18, 2015**

(65) **Prior Publication Data**

US 2016/0185454 A1 Jun. 30, 2016

Related U.S. Application Data

(60) Provisional application No. 62/096,829, filed on Dec. 24, 2014.

(51) **Int. Cl.**
B64C 27/08 (2006.01)
B64C 39/02 (2006.01)

(52) **U.S. Cl.**
CPC ***B64C 39/024*** (2013.01); *B64C 2201/027* (2013.01); *B64C 2201/042* (2013.01); *B64C 2201/127* (2013.01)

(58) **Field of Classification Search**
CPC B64C 39/024; B64C 2201/027; B64C 2201/042; B64C 2201/127; B64C 2201/108; B64C 2201/088
See application file for complete search history.

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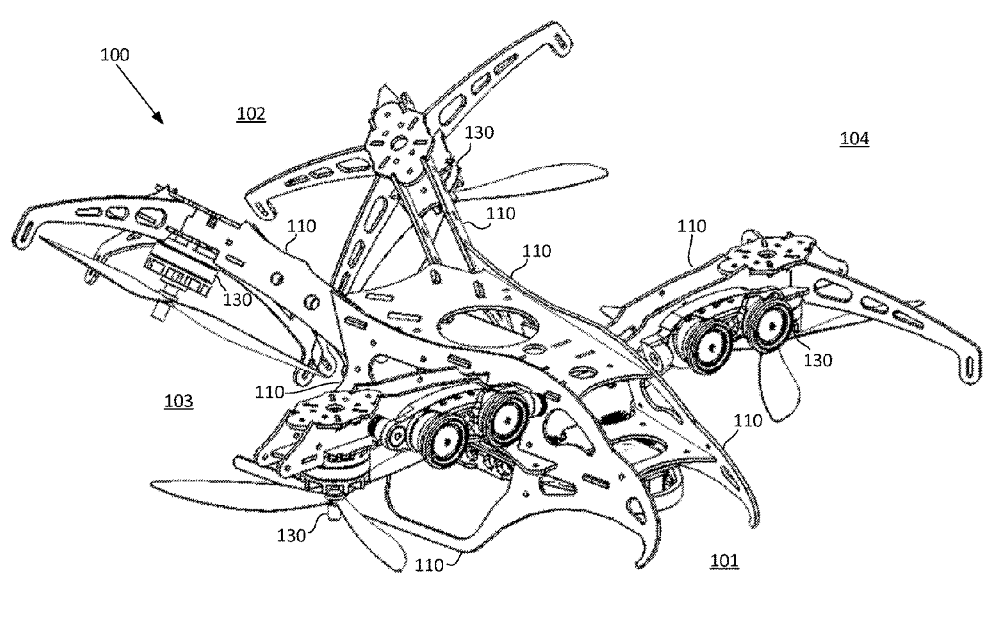
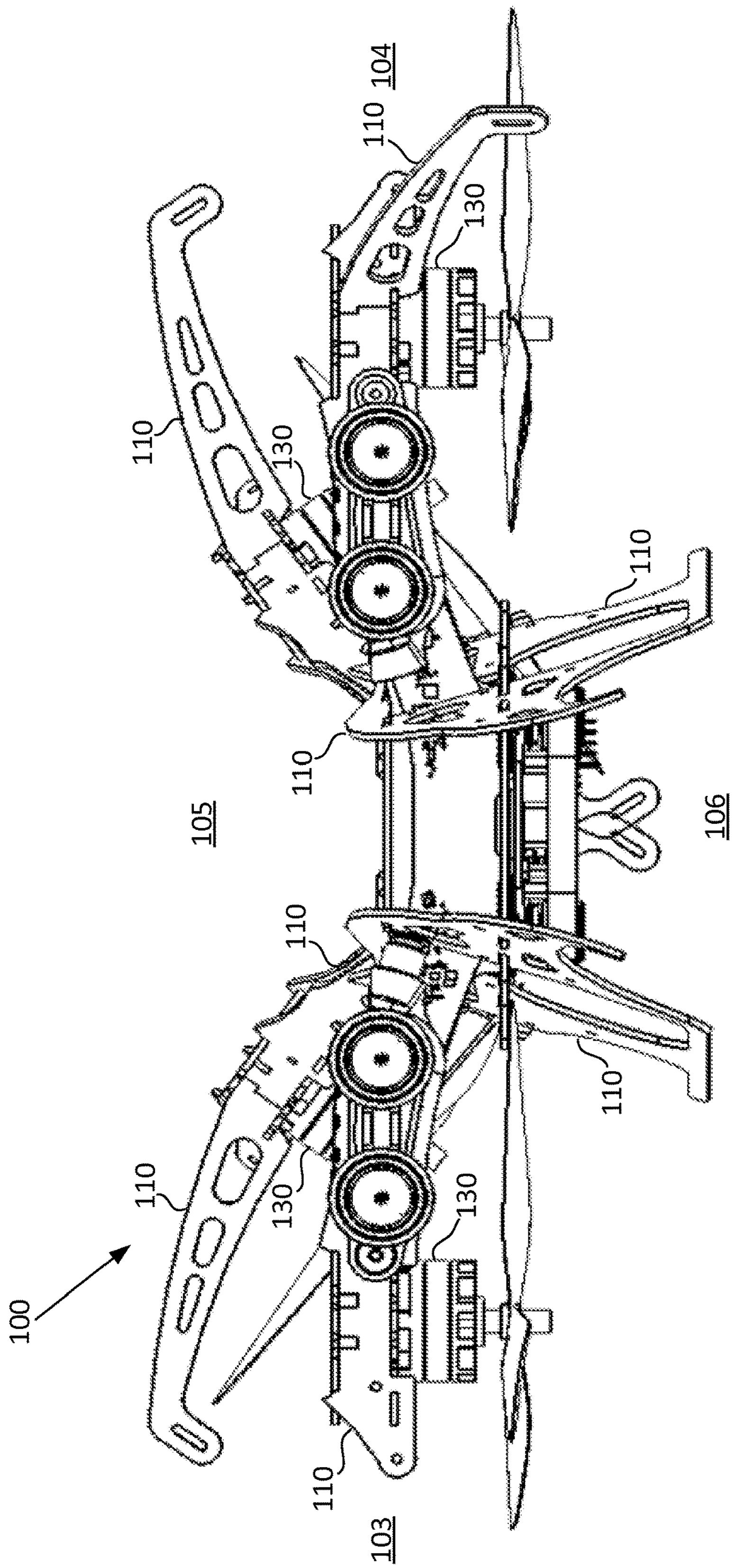
(74) *Attorney, Agent, or Firm* — Paradice and Li LLP

(57) **ABSTRACT**

Systems and methods are described herein related to an unmanned aerial vehicle, the unmanned aerial vehicle includes: a frame portion, two rear arms extending away from the frame portion, and at least one rear air propulsion device arranged on each of the rear arms at an orthogonal angle relative to a vertical axis. The at least one rear air propulsion device has an axis of rotation for both lift and rotation based on the angle. The unmanned aerial vehicle has two front arms arranged along a horizontal axis. The vertical axis is perpendicular to the horizontal axis. The unmanned aerial vehicle also includes at least one camera arranged on at least one of the front arms. The at least one camera faces a front direction.

28 Claims, 34 Drawing Sheets

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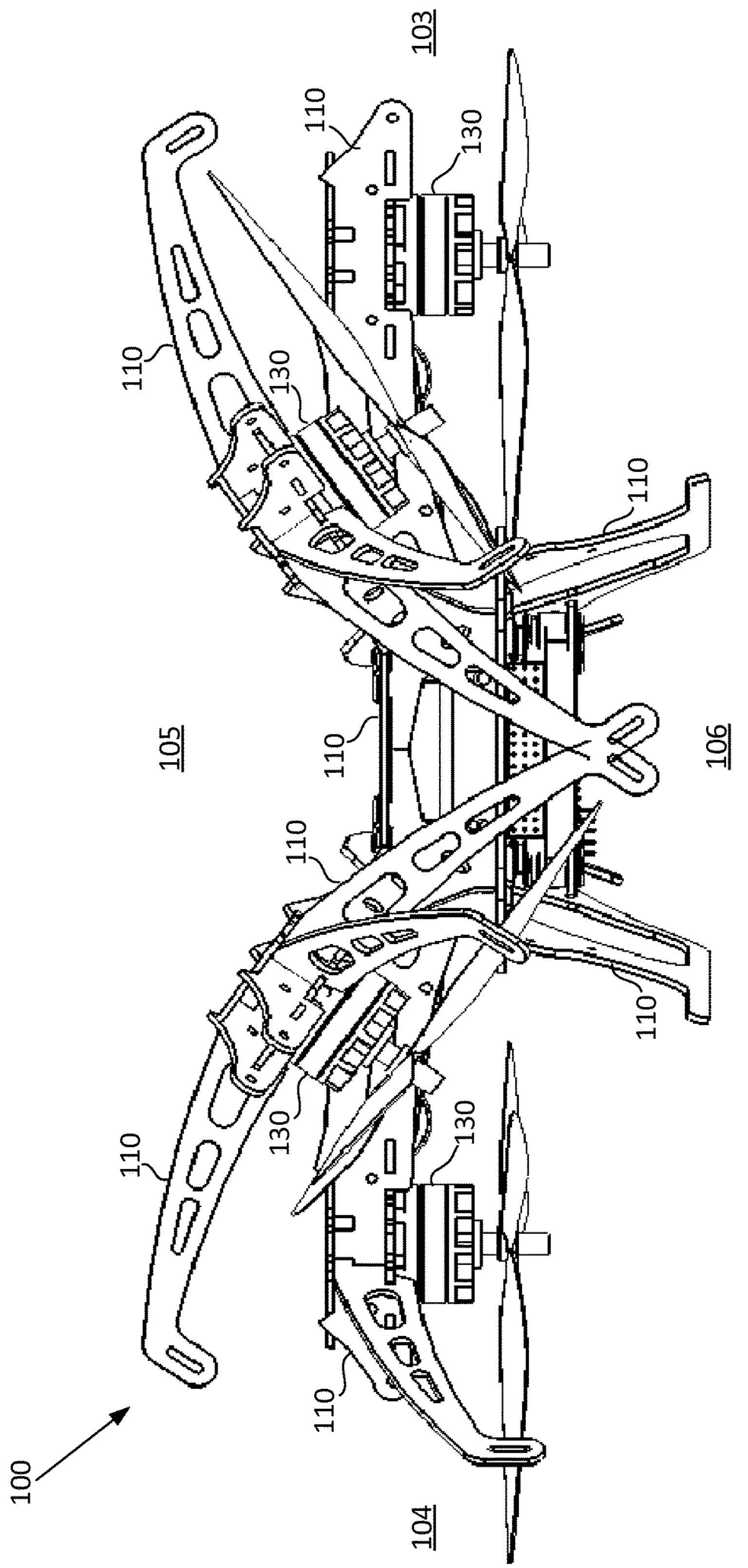
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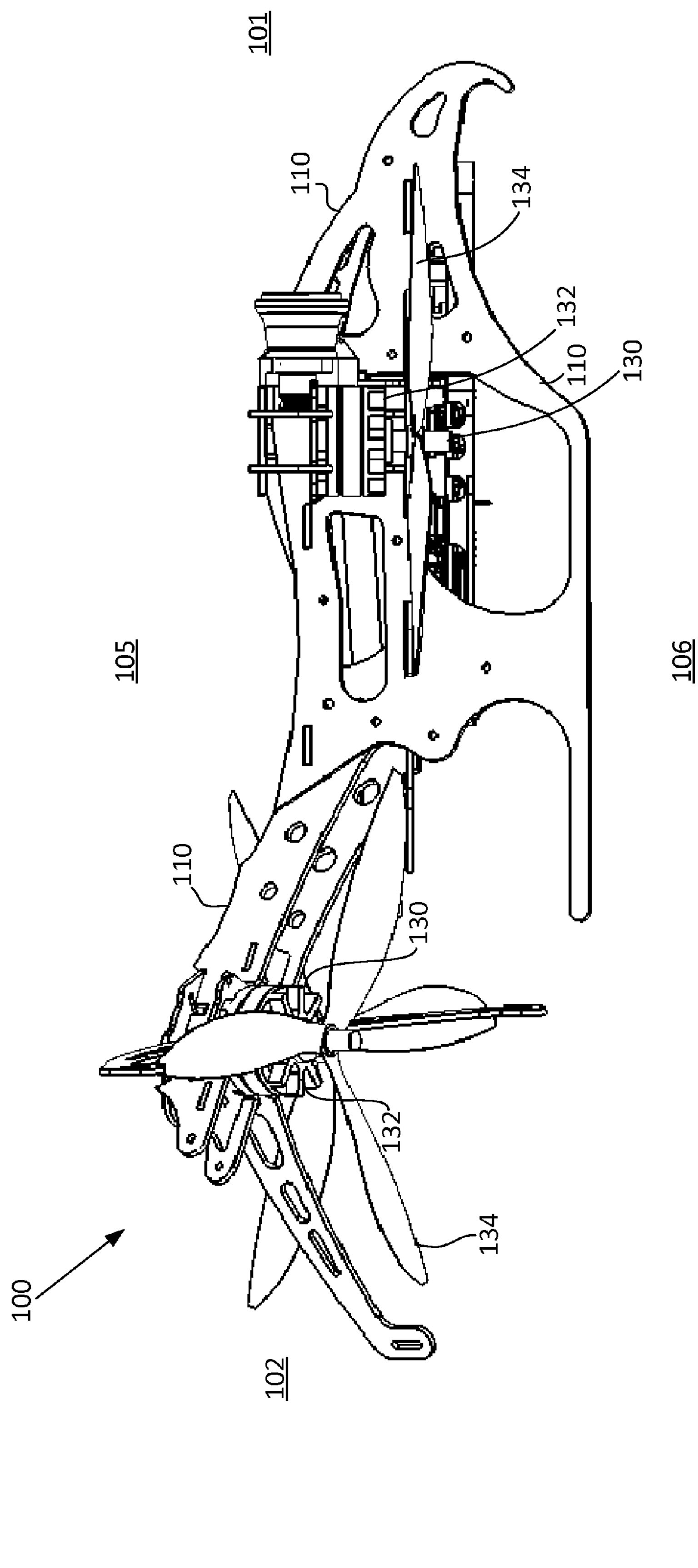

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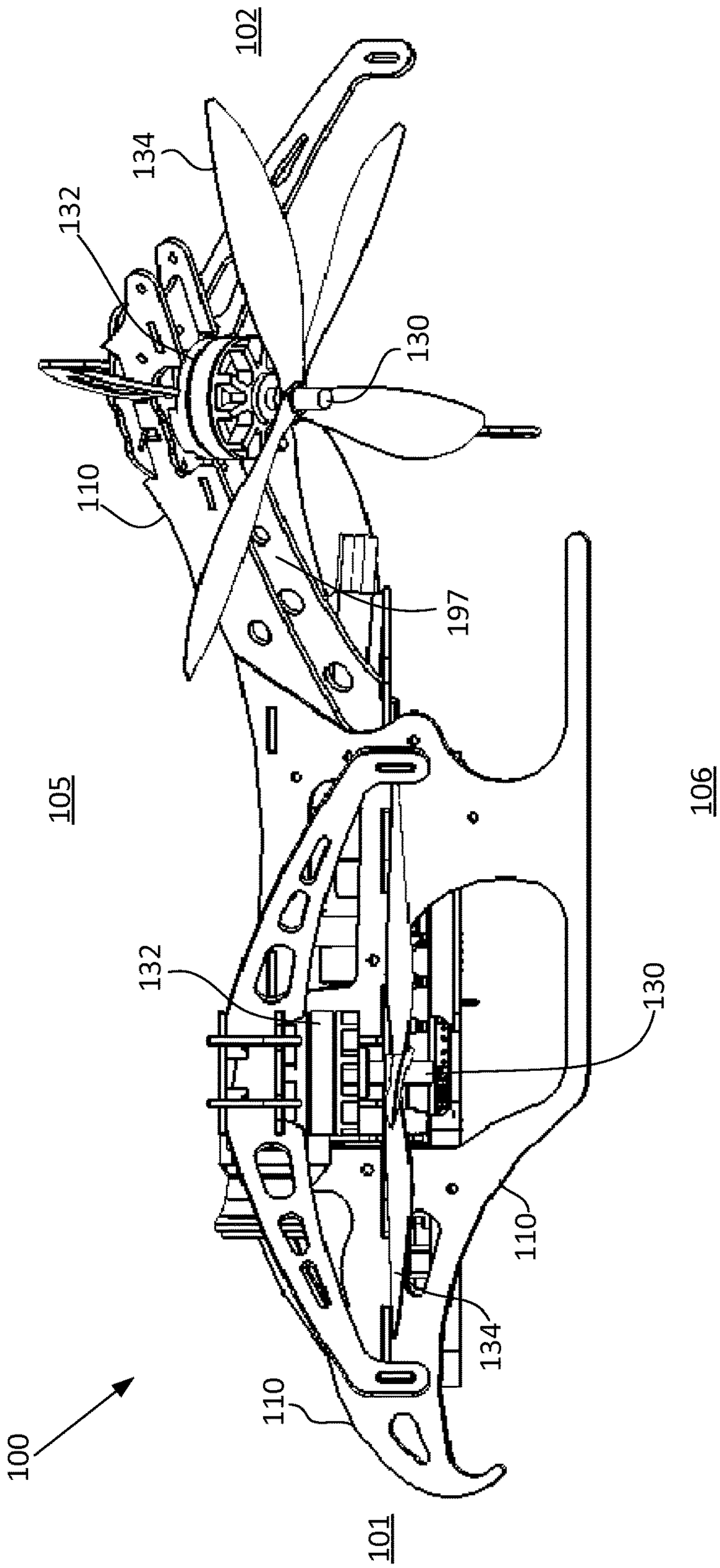

Figure 5

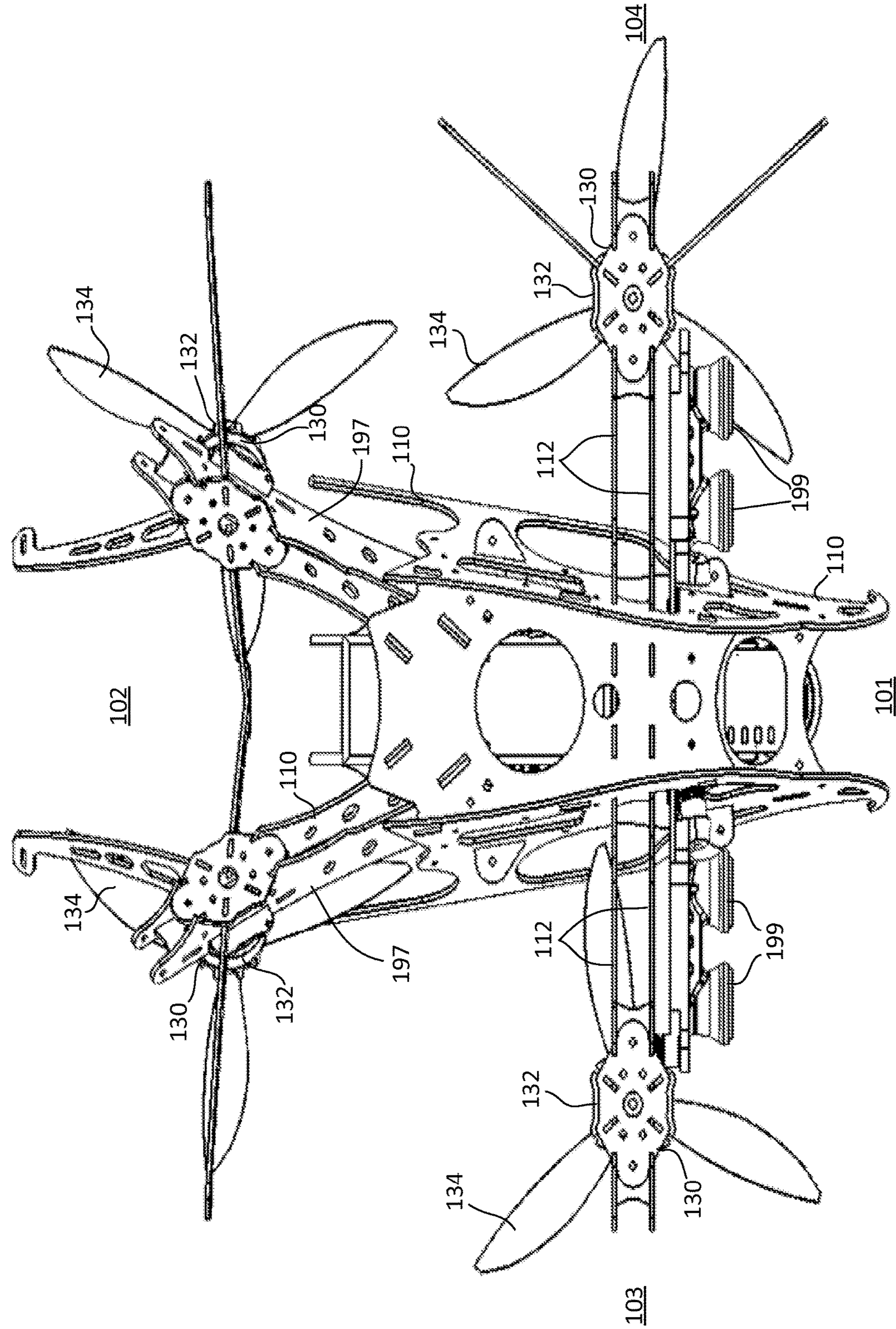

Figure 6

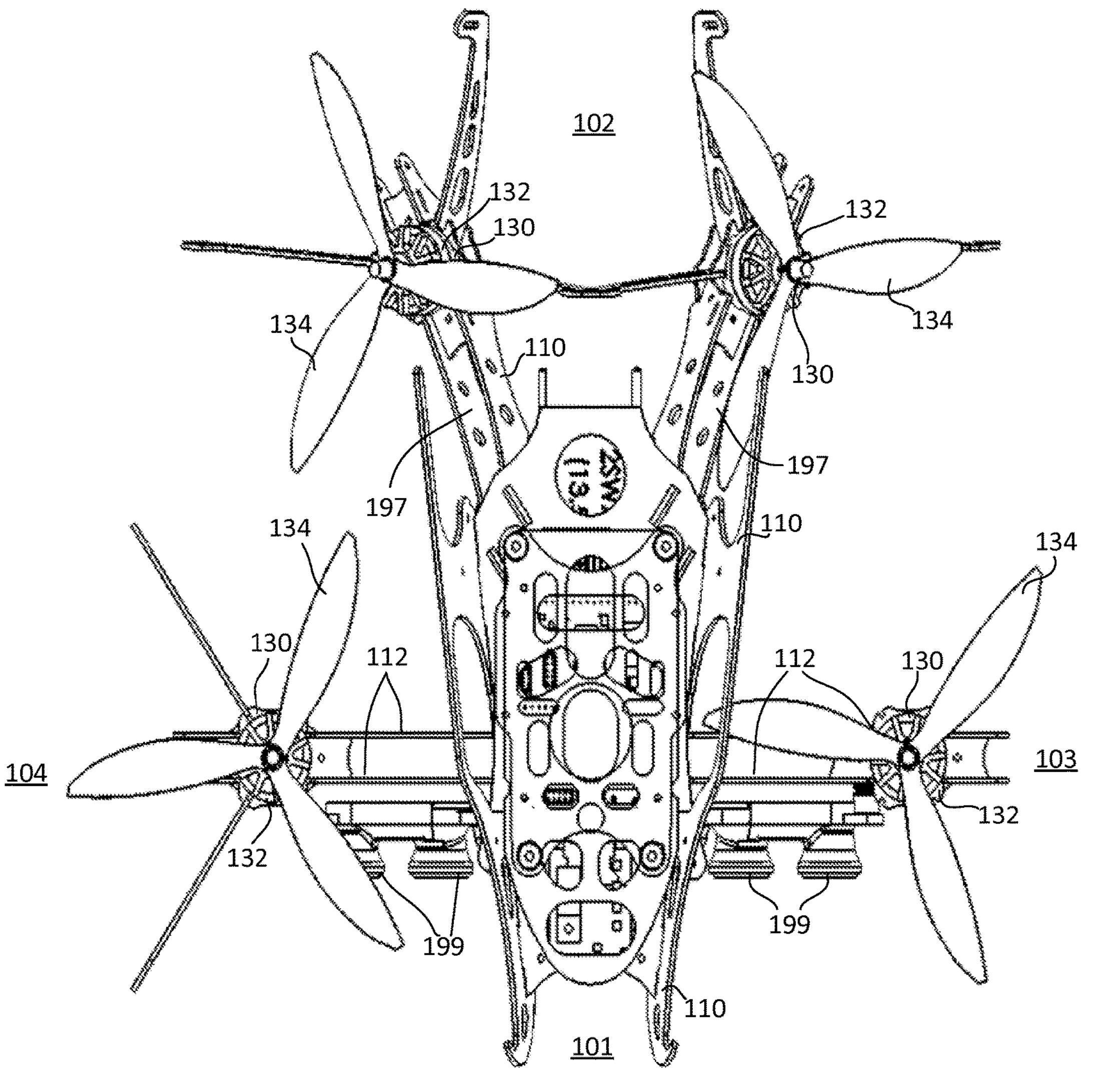
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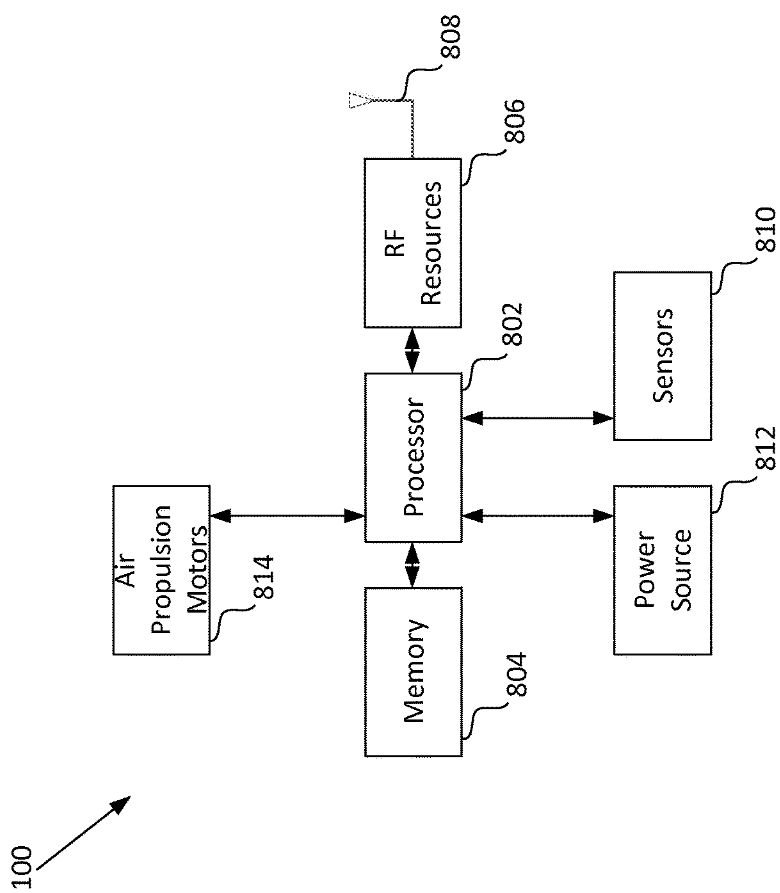
Figure 7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Power Source
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Figure 8

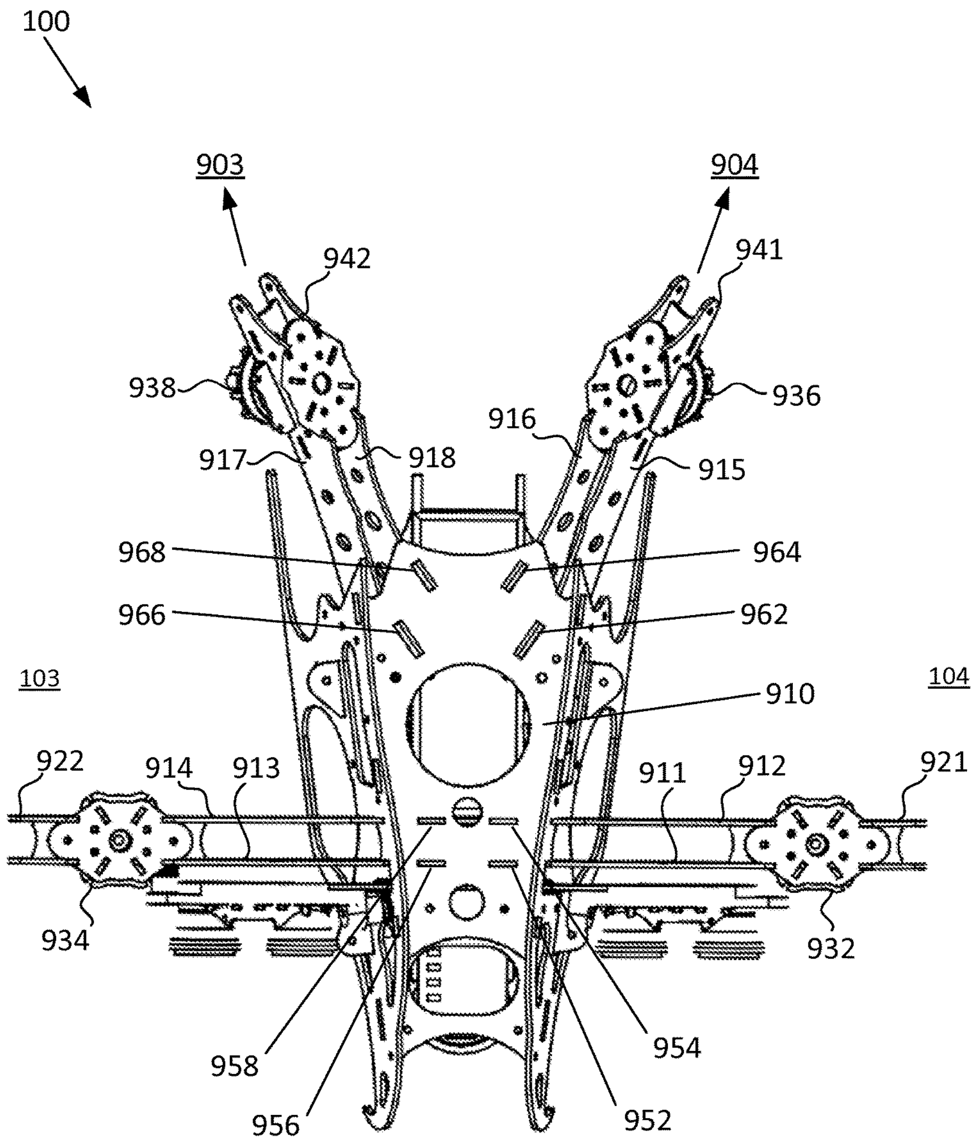

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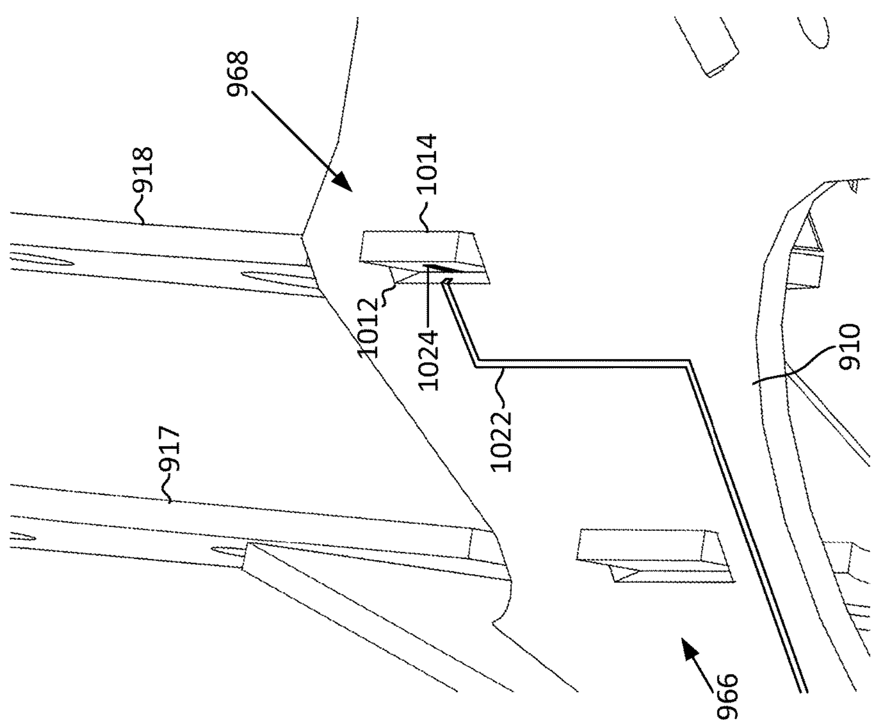
Figure 9



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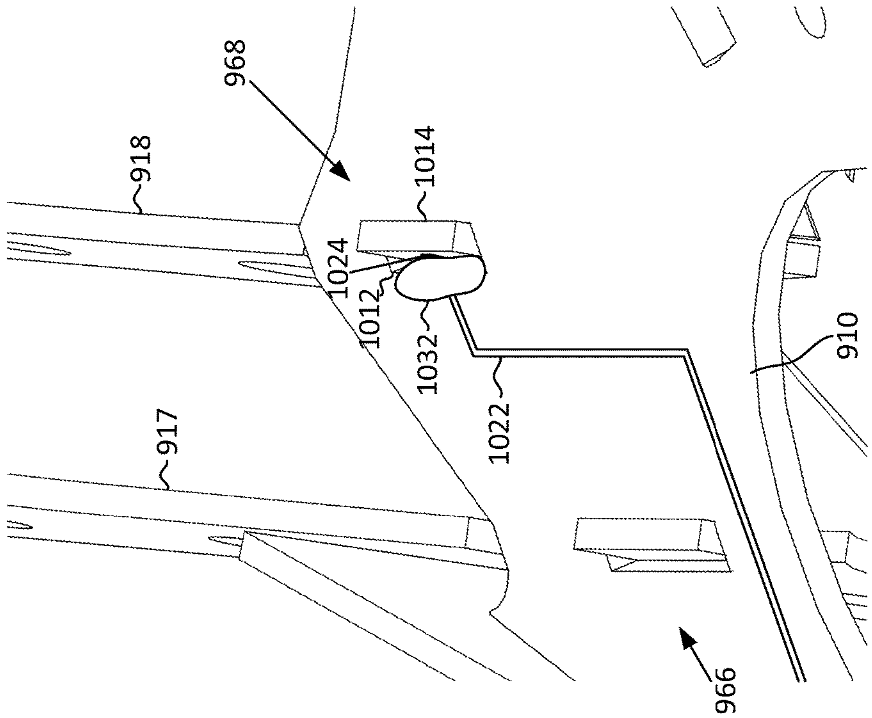

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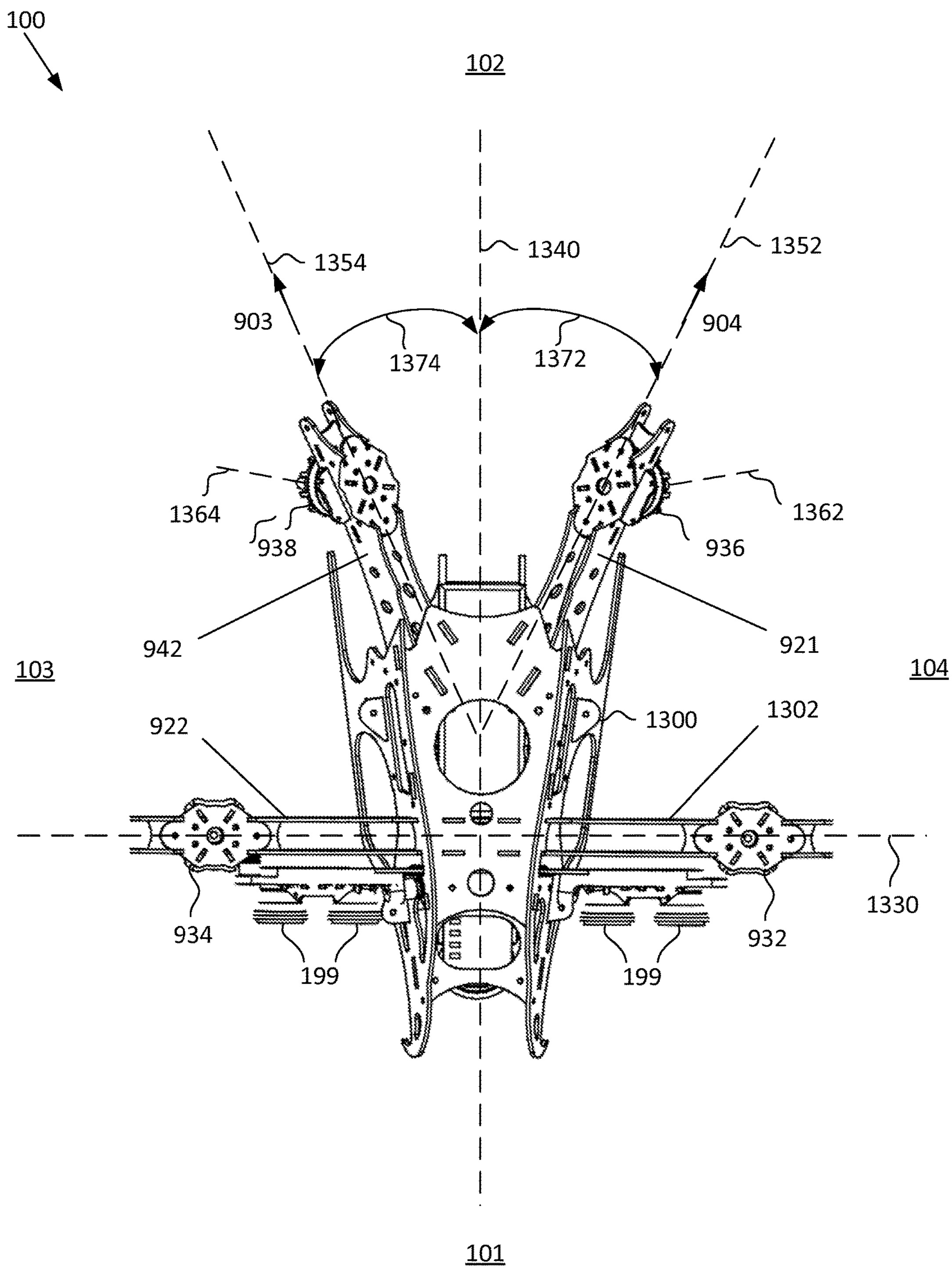
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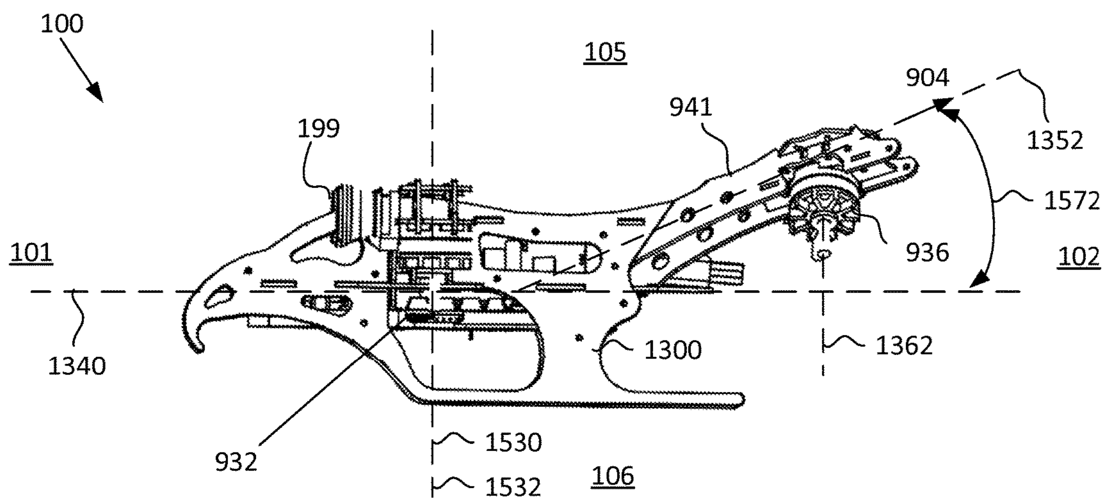
Figure 13



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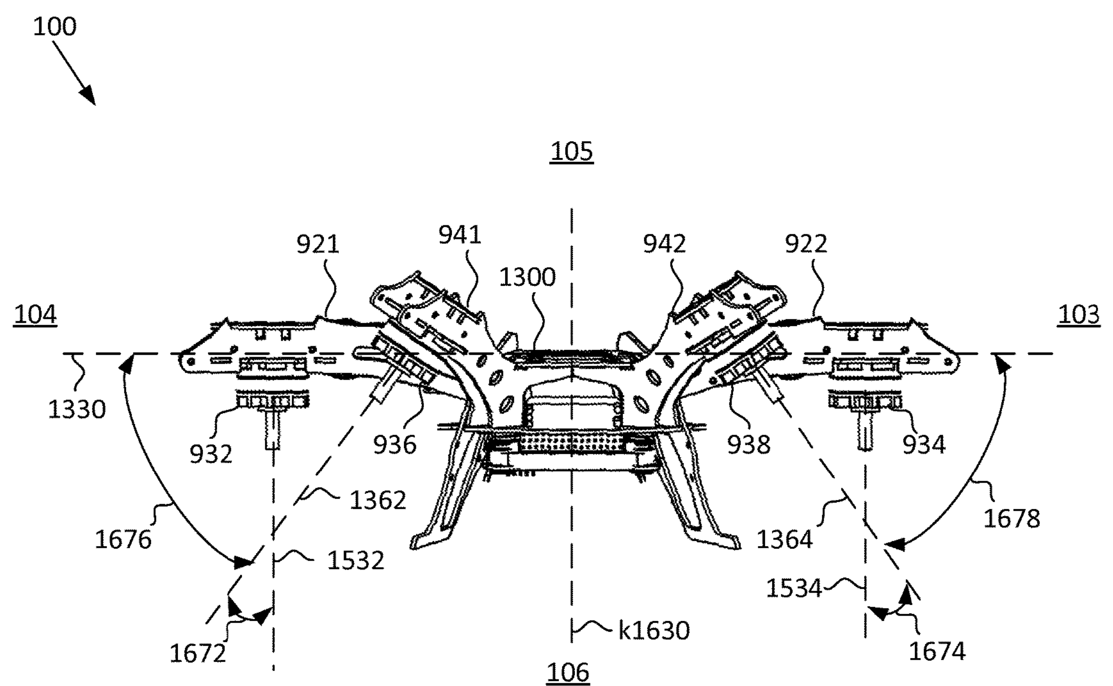
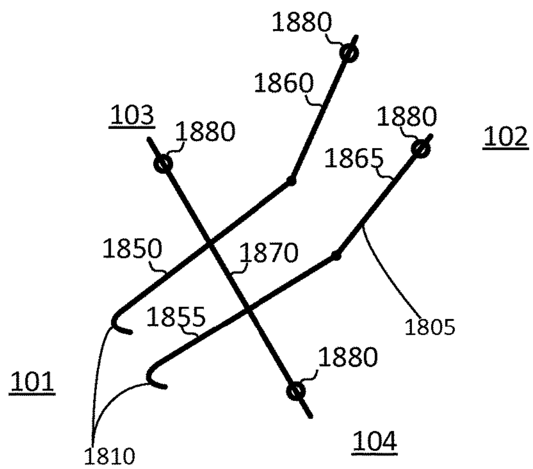


FIGURE 16



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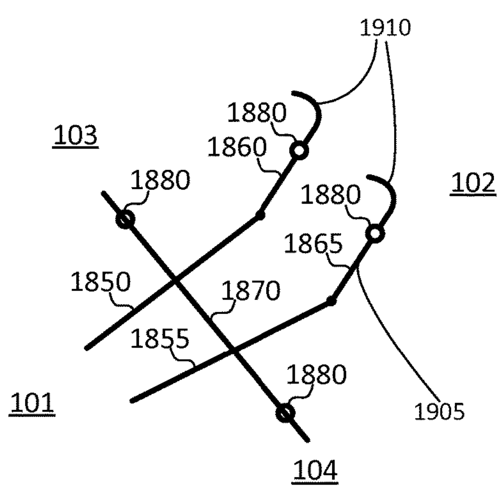

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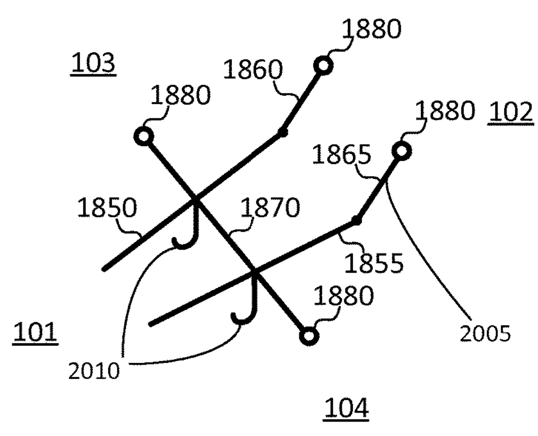

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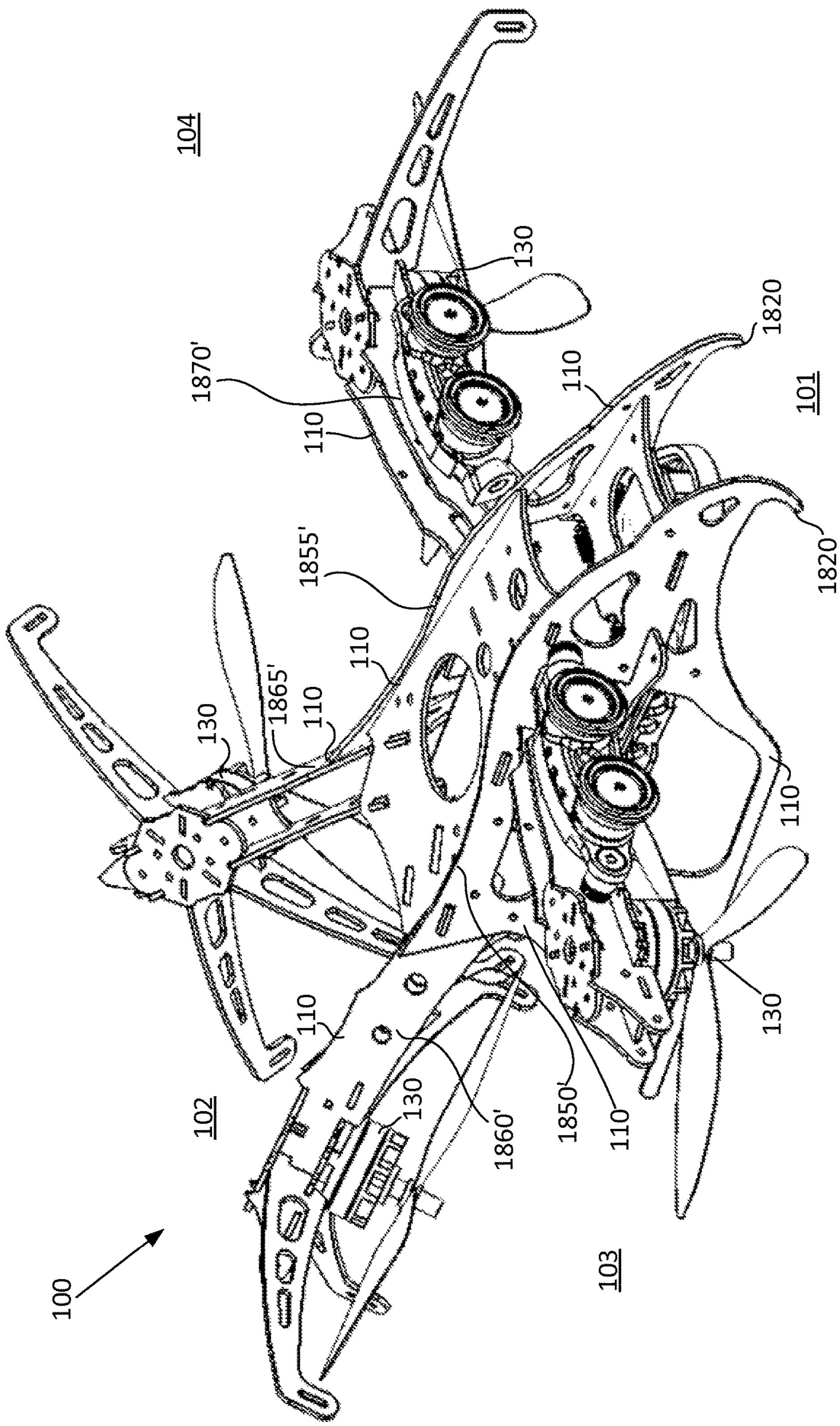
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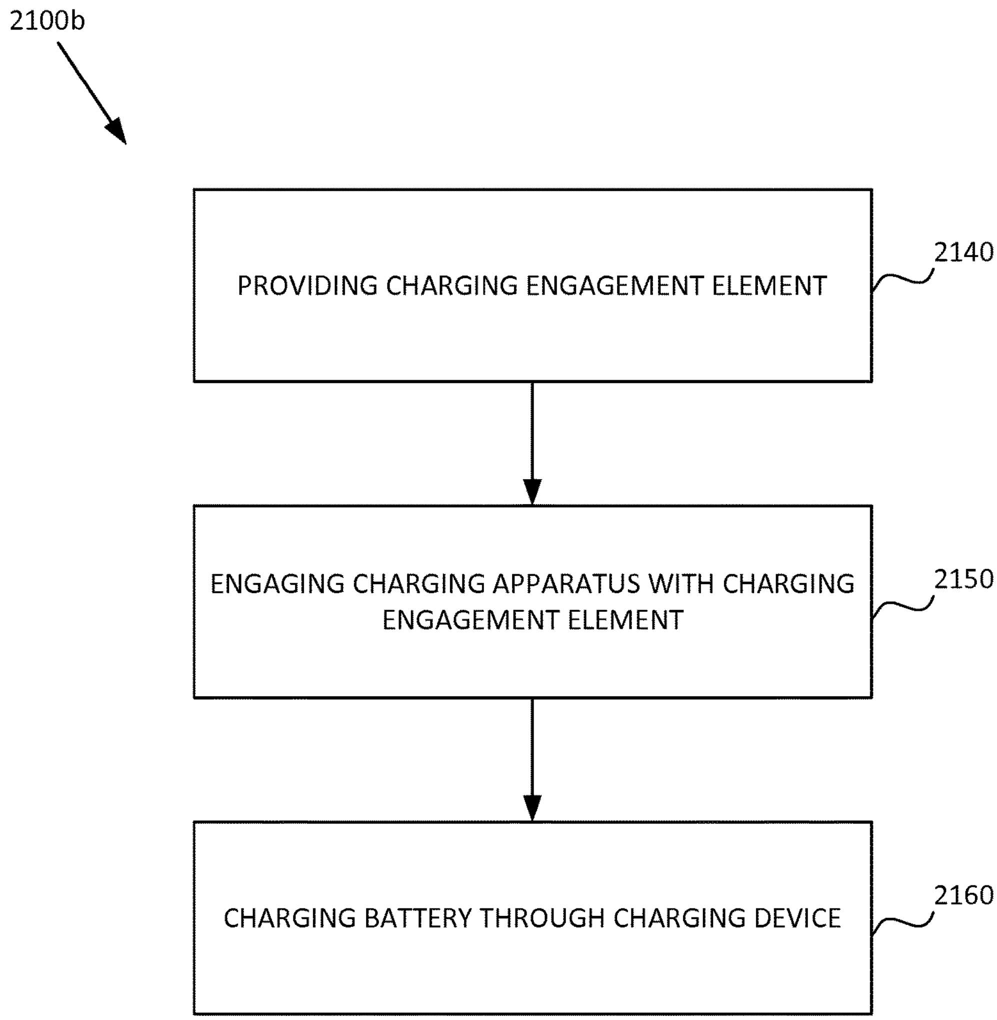
Figure 18B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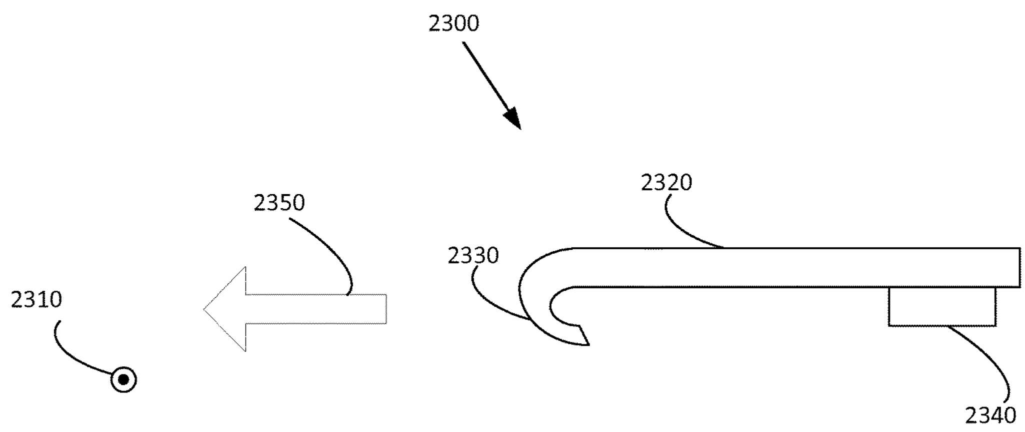
ENGAGING CHARGING APPARATUS WITH CHARGING ENGAGEMENT ELEMENT
2150
CHARGING BATTERY THROUGH CHARGING DEVICE
2160

Figure 21B



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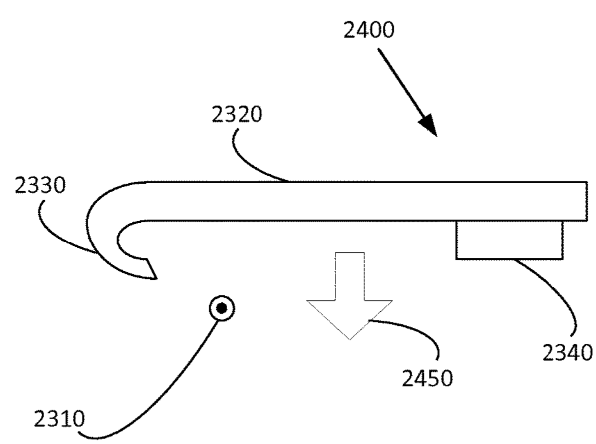

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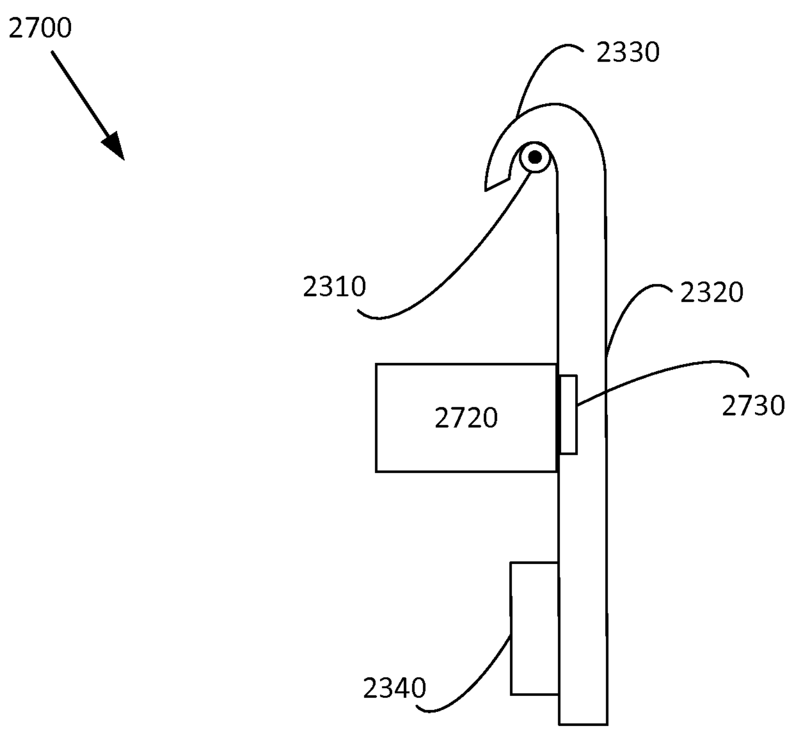

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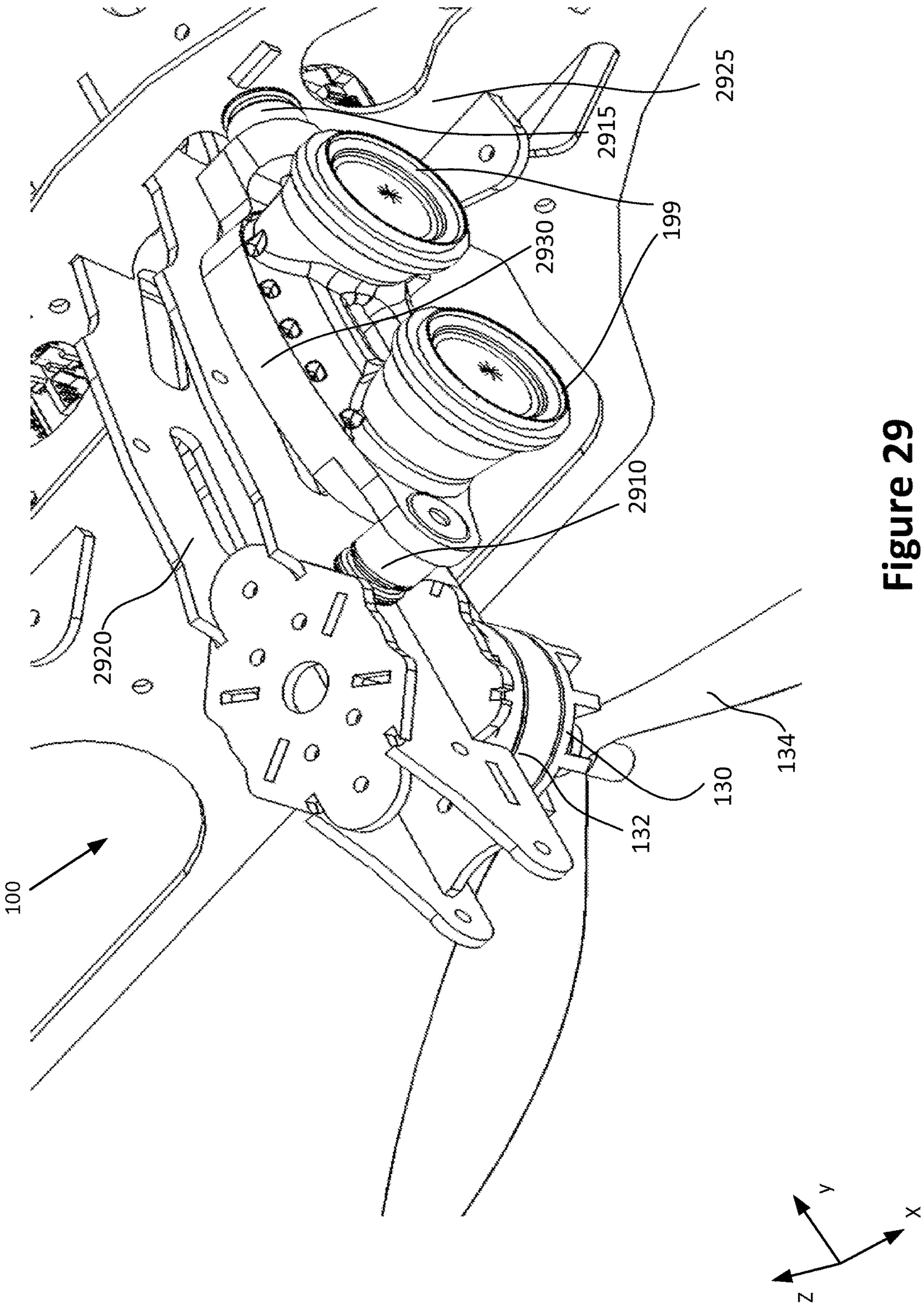

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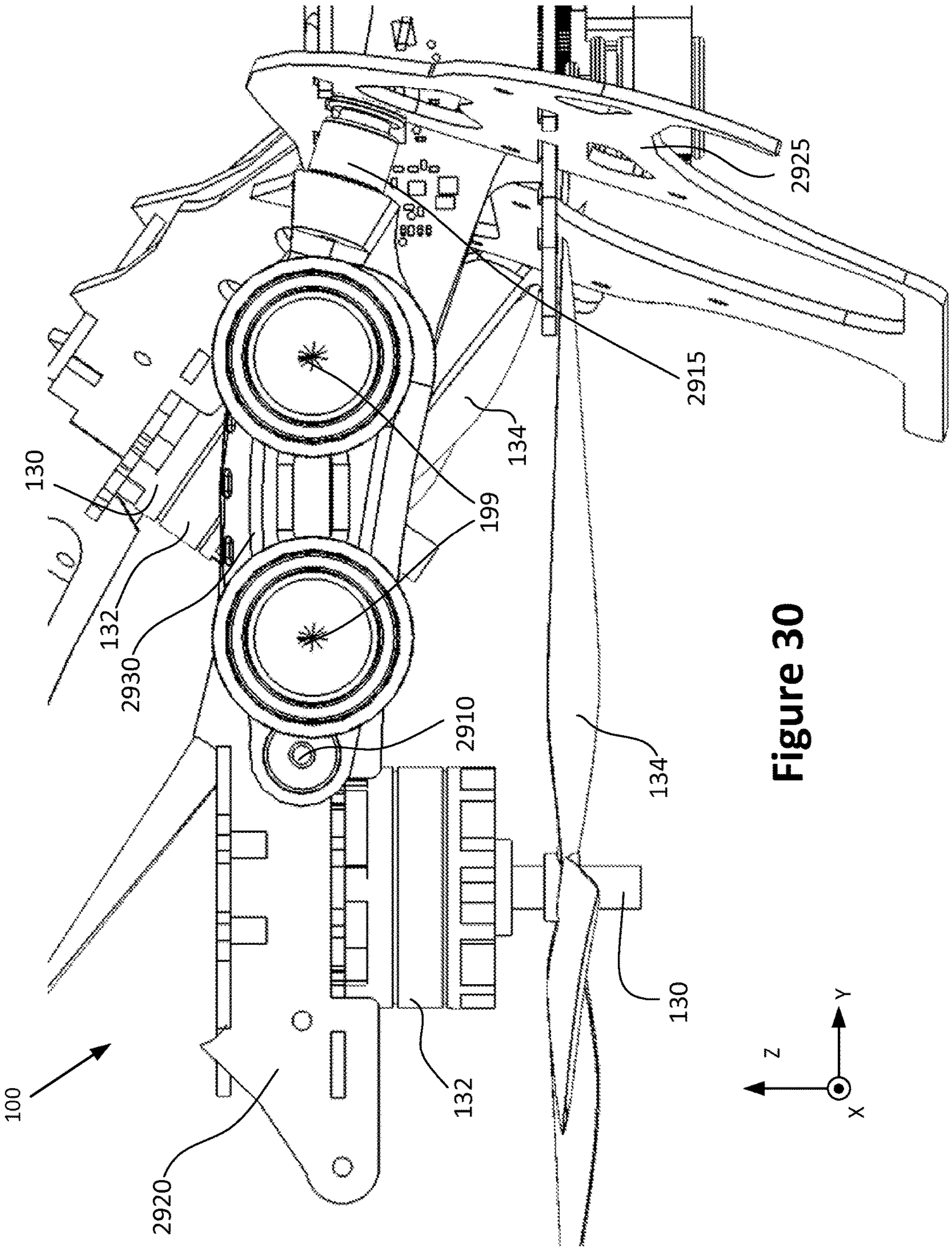

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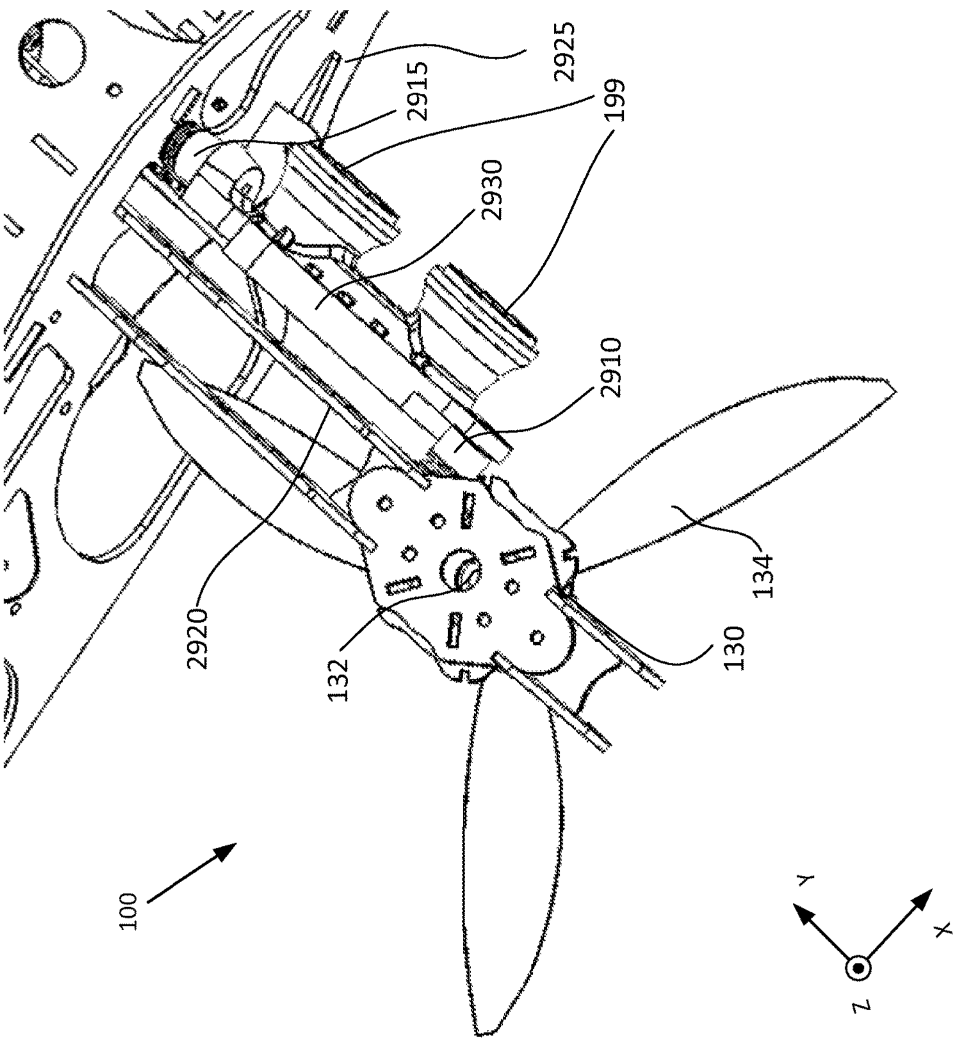

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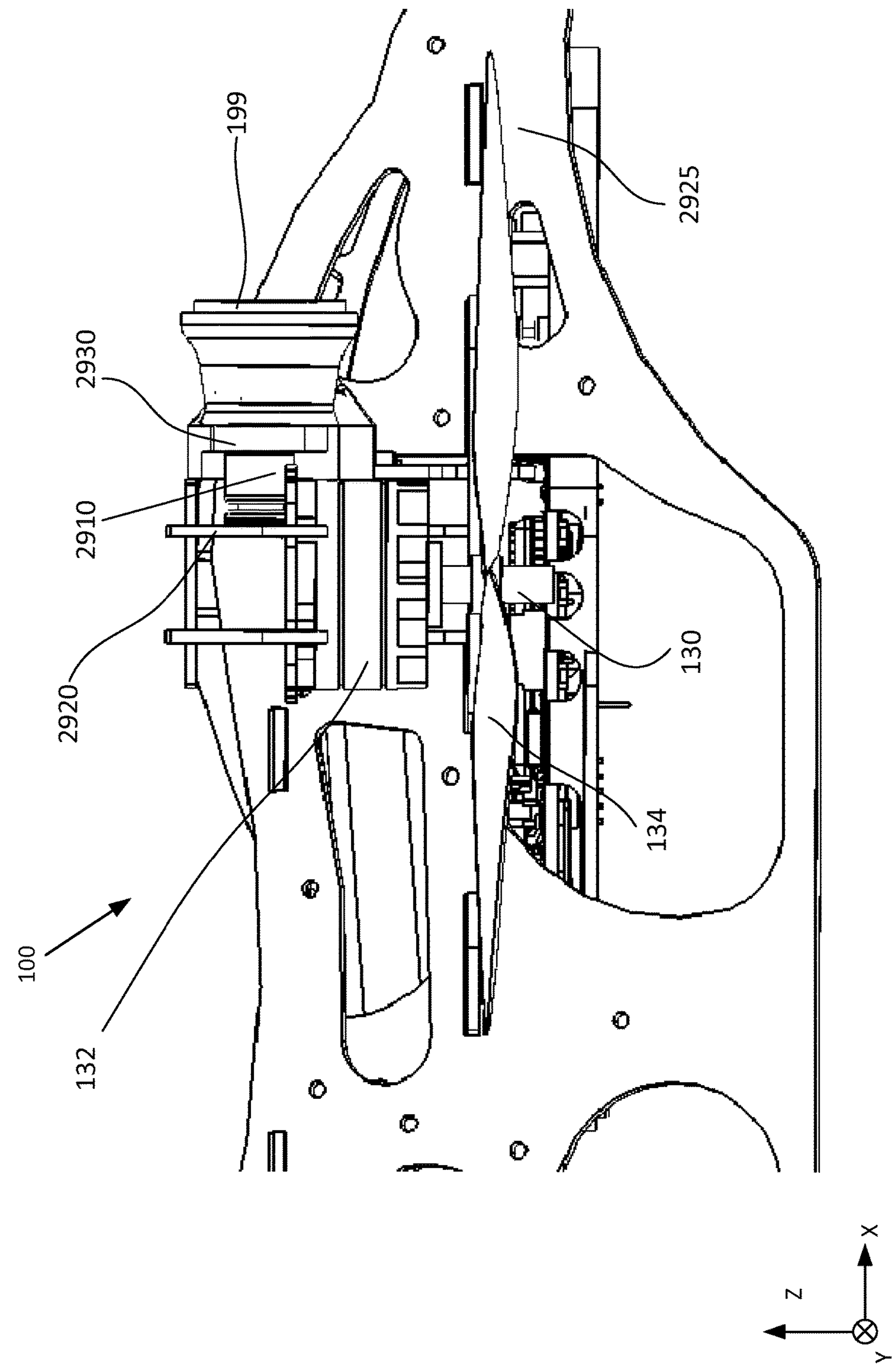

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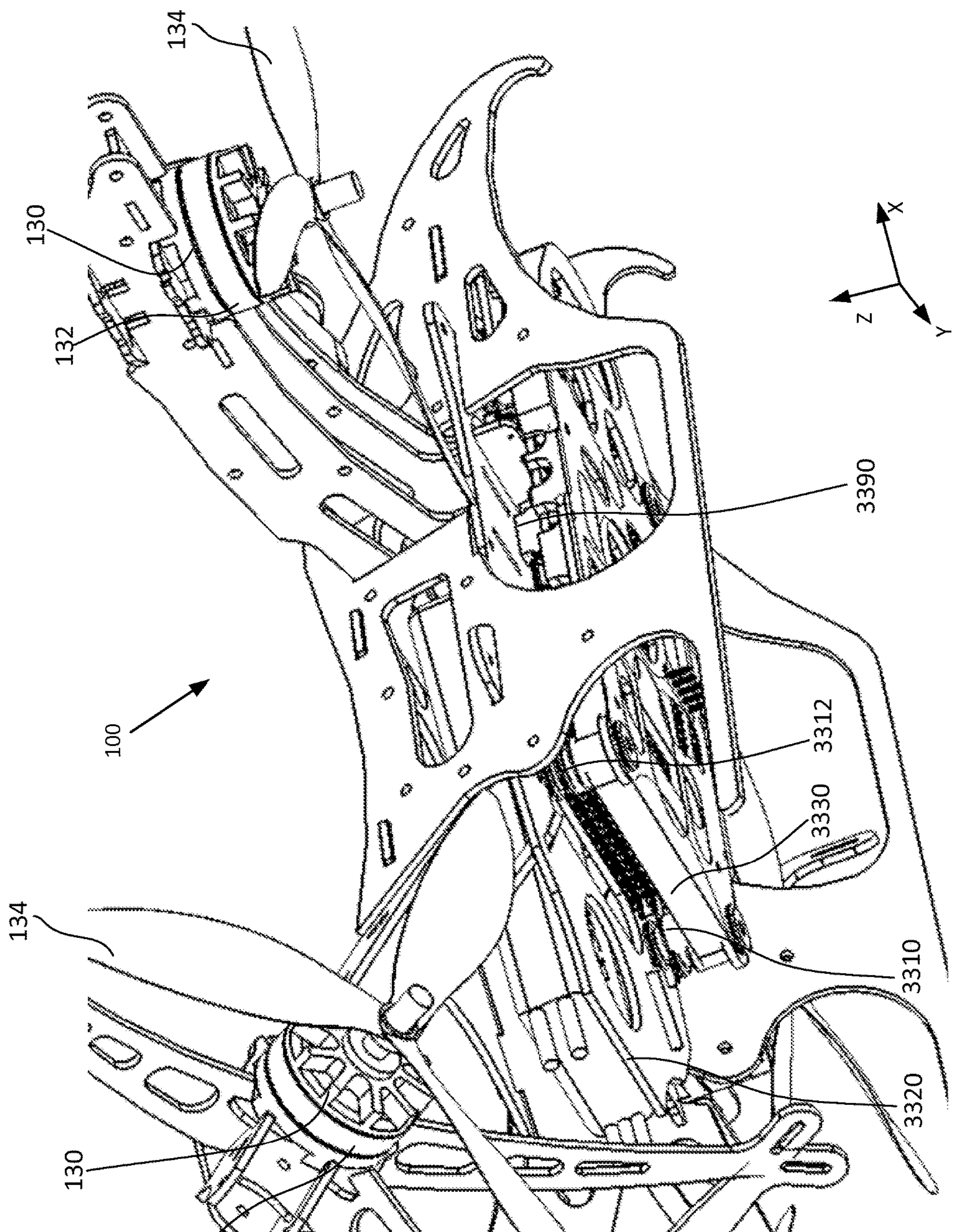

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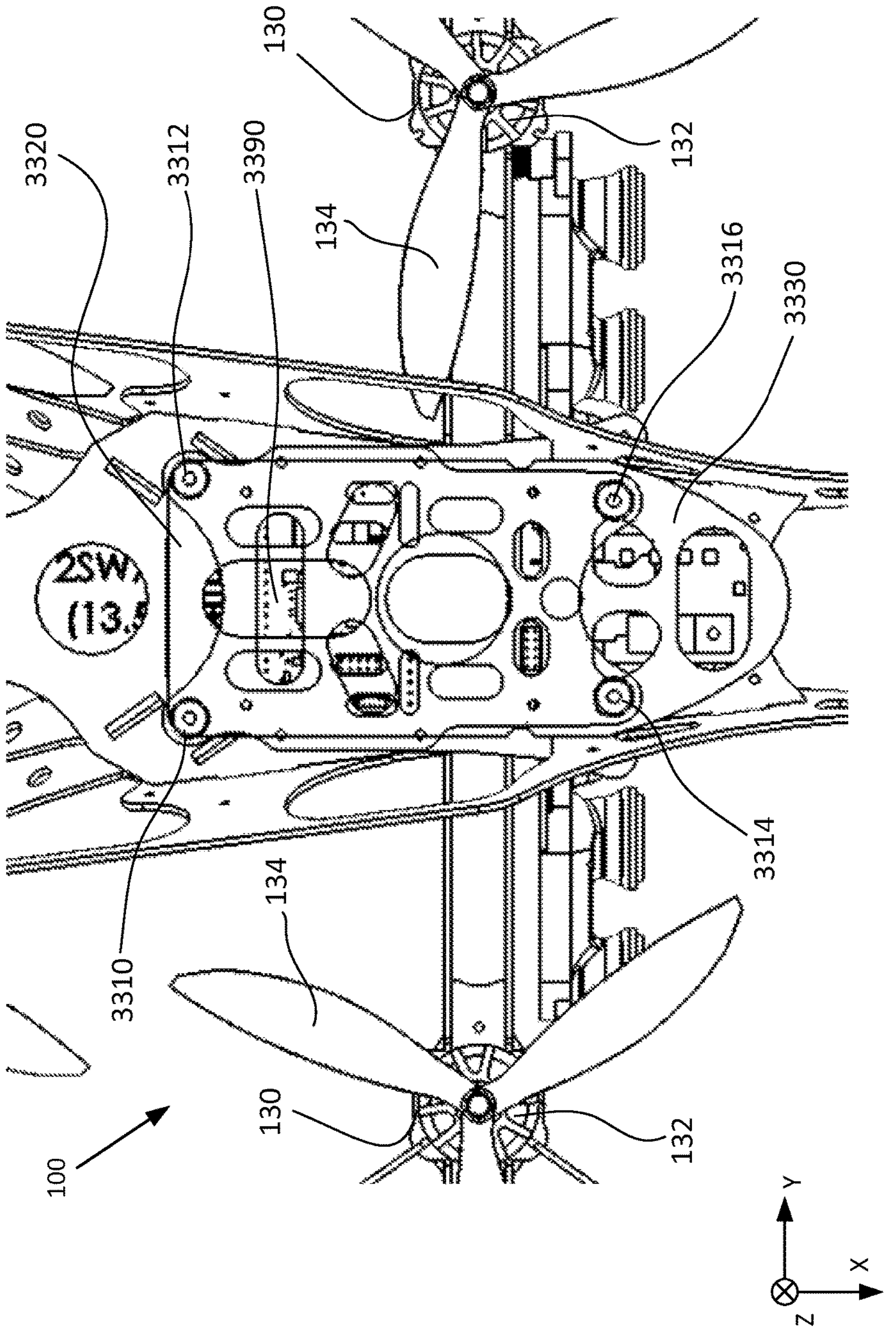
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Figure 34

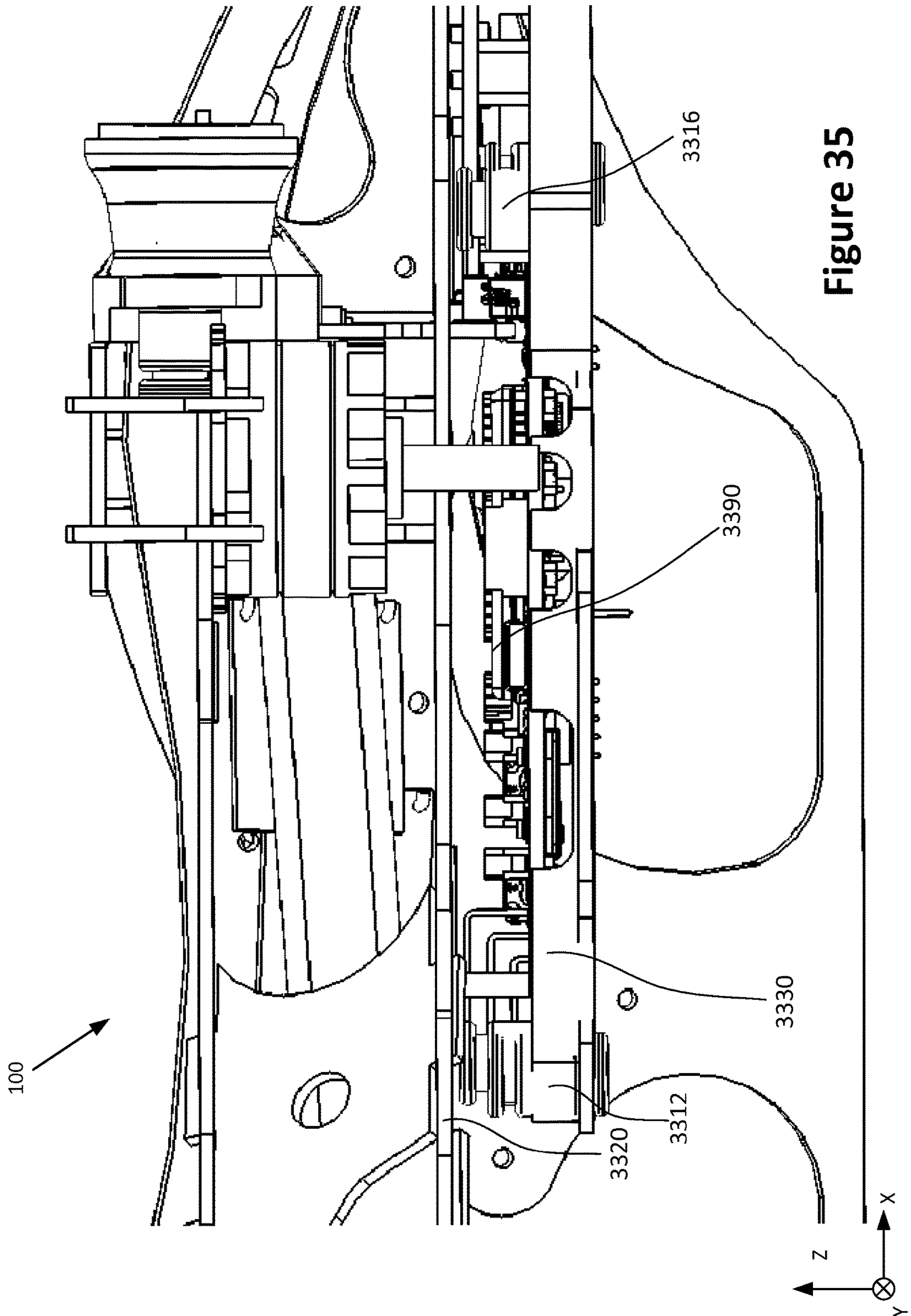


Figure 35

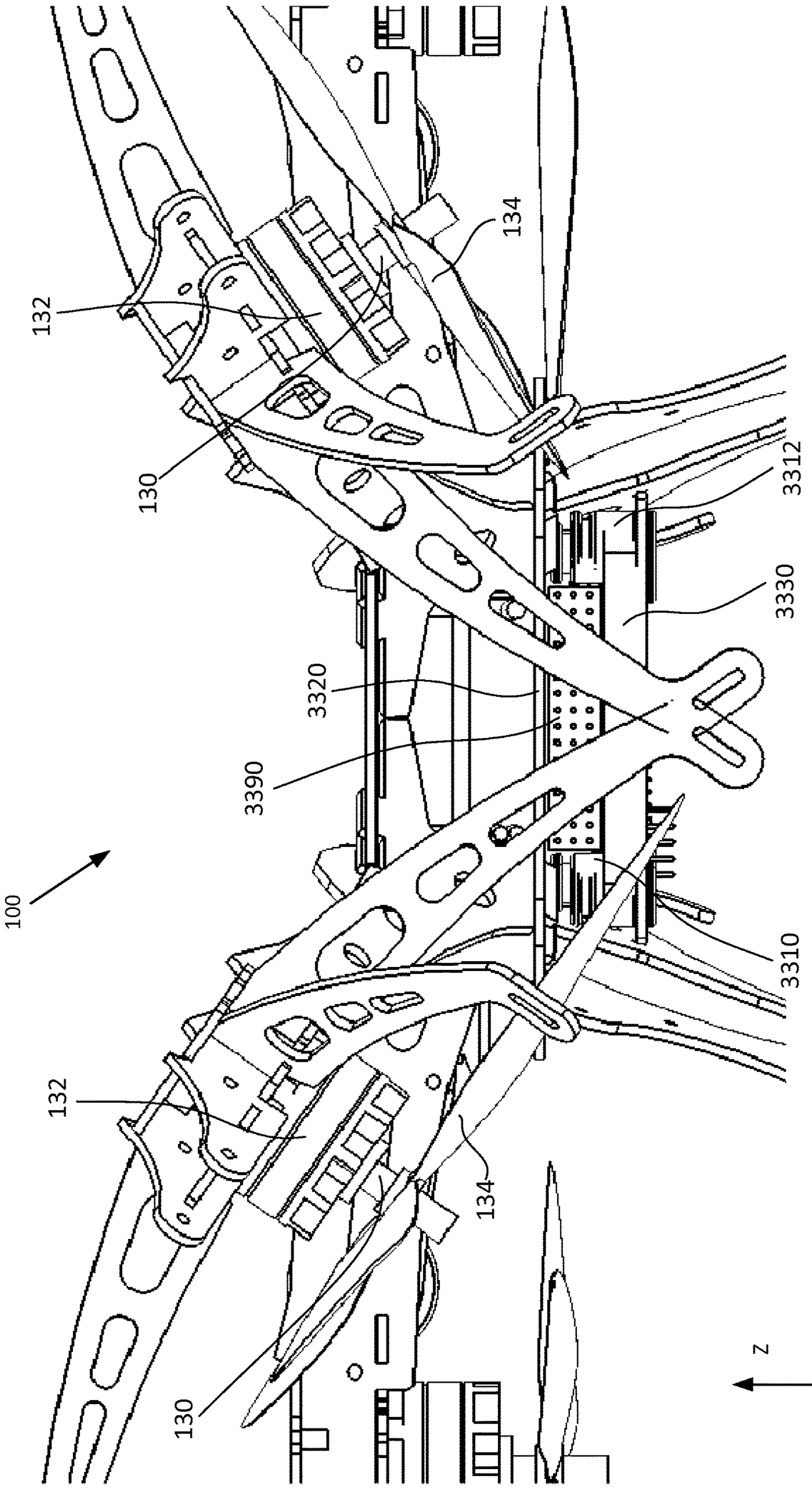


Figure 36

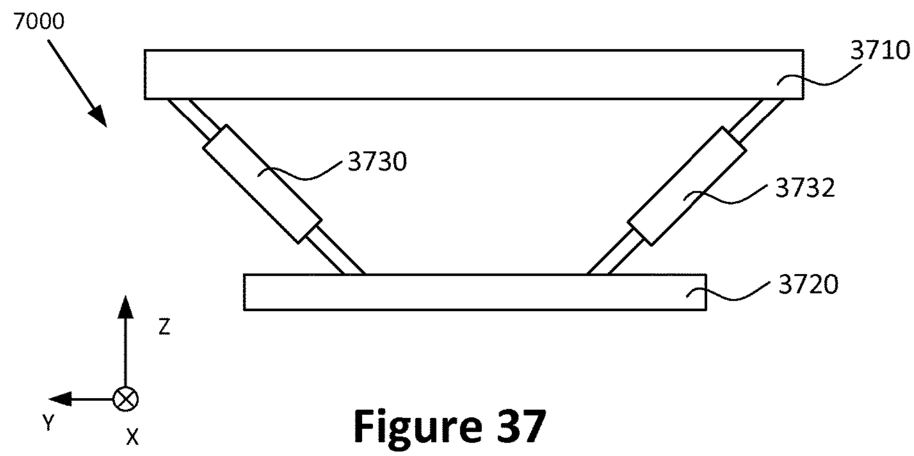


Figure 37

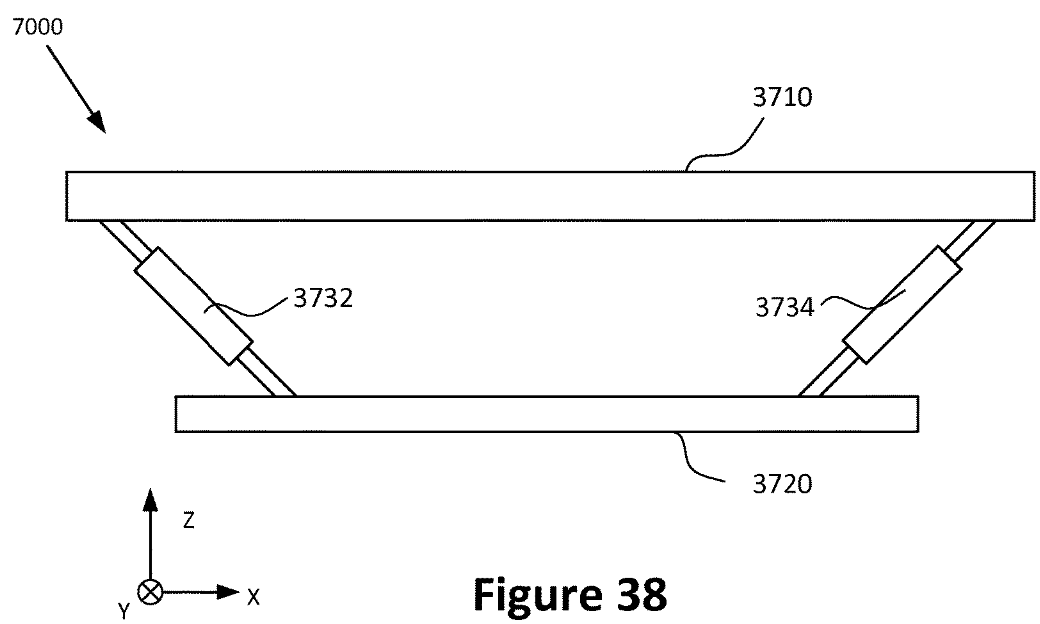


Figure 38

UNMANNED AERIAL VEHICLE

CROSS-REFERENCE TO RELATED PATENT APPLICATIONS

This application claims priority from Provisional Application U.S. Application 62/096,829 filed Dec. 24, 2014, incorporated herein by reference in its entirety.

BACKGROUND

A variety of unmanned aerial vehicles have been developed, including Remote Control (RC) planes for the hobbyists, and more advanced "drones" or UAVs for military and commercial applications. Various UAV configurations and features, including for example, various "quadcopter" or four-rotor configurations, have been developed for various hobby, commercial or military applications.

SUMMARY

According to some embodiments, an unmanned aerial vehicle includes a frame portion, two rear arms extending away from the frame portion, and at least one rear air propulsion device arranged on each of the rear arms at an orthogonal angle relative to a vertical axis. The at least one rear air propulsion device having an axis of rotation for both lift and rotation based on the orthogonal angle. The unmanned aerial vehicle further includes two front arms extending away from the frame portion along a horizontal axis of the frame portion, the vertical axis is perpendicular to the horizontal axis. The unmanned aerial vehicle further includes at least one camera arranged on at least one of the front arms to face a front direction of the frame portion.

In some embodiments, the rear arms extend from the frame portion in a "V" shape.

In some embodiments, the rear arms extend from the frame portion to form an angle relative to one another, the angle being acute.

In various embodiments, the unmanned aerial vehicle further includes at least one front air propulsion device arranged on each of the two front arms to face a bottom direction of the frame portion.

In various embodiments, ends of the rear arms are elevated in a top direction as compared to the front arms, the top direction being opposite to the bottom direction. Each of the rear arms is arranged along the top direction with respect to the at least one rear air propulsion device.

In some embodiments, the axis of rotation includes a component of the bottom direction for lift.

In various embodiments, the axis of rotation includes a component of a side direction for rotation. The side direction is perpendicular to both the bottom direction and the front direction.

In various embodiments, the at least one front air propulsion device is arranged in the bottom direction of the front arms.

In some embodiments, the at least one camera is vibration isolated from the at least one front air propulsion device.

According to various embodiments, the at least one of the front arms includes a frame and a panel. The at least one camera is arranged on the panel. The at least one front air propulsion device is arranged on the frame.

In some embodiments, the unmanned aerial vehicle further includes a vibration dampener between the panel and the frame.

In various embodiments, the front arms extend from the frame portion to form a straight angle.

In various embodiments, the at least one camera includes a stereo camera.

According to some embodiments, a method for providing an unmanned aerial vehicle includes providing a frame portion and two rear arms extending away from the frame portion. The method further includes providing at least one rear air propulsion device arranged on each of the rear arms at an orthogonal angle relative to a vertical axis. The at least one rear air propulsion device having an axis of rotation for both lift and rotation based on the orthogonal angle. The method further includes providing two front arms extending away from the frame portion along a horizontal axis of the frame portion. The vertical axis is perpendicular to the horizontal axis and at least one camera arranged on at least one of the front arms to face a front direction.

In some embodiments, the method further includes arranging the rear arms to extend from the frame portion in a "V" shape.

In various embodiments, the method further includes arranging the rear arms to extend from the frame portion to form an angle relative to one another, the angle being acute.

In various embodiments, the method further includes arranging at least one front air propulsion device on each of the two front arms to face a bottom direction of the frame portion.

According to some embodiments, the method further includes elevating ends of the rear arms in a top direction as compared to the front arms. The top direction is opposite to the bottom direction. The method further includes arranging each of the rear arms along the top direction with respect to the at least one rear air propulsion device.

In some embodiments, the axis of rotation includes a component of the bottom direction for lift.

In some embodiments, the axis of rotation includes a component of a side direction for rotation. The side direction is perpendicular to both the bottom direction and the front direction.

In various embodiments, the method further includes arranged the at least one front air propulsion device in the bottom direction of the front arms.

According to various embodiments, an unmanned aerial vehicle includes a frame portion, two front arms extending away from the frame portion in side directions with respect to the frame portion, at least one camera, and at least one front air propulsion device arranged on each of the front arms to face a bottom direction of the frame portion. The unmanned aerial vehicle further includes two rear arms extending away from the frame portion in a "V" shape. The at least one rear air propulsion device arranged on each of the rear arms. The unmanned aerial vehicle further includes at least one rear air propulsion device having an axis of rotation having a component in both one of the side directions and the bottom direction.

In various embodiments, the at least one camera is arranged to face a front direction. The front direction is perpendicular to the side directions and the bottom direction.

In some embodiments, the at least one camera is arranged on the at least one of the front arms to maximize a field of view around the unmanned aerial vehicle.

In some embodiments, the at least one camera is arranged on a first component of each of the front arms. The first component is vibration isolated from the at least one front air propulsion device.

In various embodiments, the at least one camera is provided between the frame portion and the at least one front air propulsion device.

In various embodiments, the two rear arms extend from the frame portion to form an angle, the angle being acute.

In some embodiments, the at least one rear air propulsion device is elevated in a top direction of the frame portion as compared to the at least one front air propulsion device, the top direction being opposite to the bottom direction. Each of the rear arms is arranged along the top direction with respect to the at least one rear air propulsion device.

According to various embodiments, a method for providing an unmanned aerial vehicle, includes providing a frame portion and two front arms that extend away from the frame portion in side directions with respect to the frame portion. The method further includes arranging at least one camera and at least one front air propulsion device on each of the front arms to face a bottom direction. The method further includes providing two rear arms that extend away from the frame portion in a "V" shape. The method further includes arranging at least one rear air propulsion device on each of the rear arms. The at least one rear air propulsion device having an axis of rotation having a component in both one of the side directions and the bottom direction.

In some embodiments, the at least one camera is arranged to face a front direction. The front direction is perpendicular to the side directions and the bottom direction.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a perspective view of an unmanned aerial vehicle according to some embodiments.

FIG. **2** shows a front view of an unmanned aerial vehicle according to some embodiments.

FIG. **3** shows a rear view of an unmanned aerial vehicle according to some embodiments.

FIG. **4** shows a left view of an unmanned aerial vehicle according to some embodiments.

FIG. **5** shows a right view of an unmanned aerial vehicle according to some embodiments.

FIG. **6** shows a top view of an unmanned aerial vehicle according to some embodiments.

FIG. **7** shows a bottom view of an unmanned aerial vehicle according to some embodiments.

FIG. **8** shows a schematic diagram of various components of an unmanned aerial vehicle according to some embodiments.

FIG. **9** shows a top view of an unmanned aerial vehicle according to some embodiments.

FIG. **10**A shows a top view of an unmanned aerial vehicle and connection components according to some embodiments.

FIG. **10**B shows a top view of an unmanned aerial vehicle and connection components according to some embodiments.

FIG. **11**A shows a top view of an unmanned aerial vehicle and connection components according to some embodiments.

FIG. **11**B shows a top view of an unmanned aerial vehicle and connection components according to some embodiments.

FIG. **12**A shows a top view of an unmanned aerial vehicle and connection components according to some embodiments.

FIG. **12**B shows a top view of an unmanned aerial vehicle and connection components according to some embodiments.

FIG. **13** shows a top view of an unmanned aerial vehicle and various axes according to some embodiments.

FIG. **14** shows a bottom view of an unmanned aerial vehicle and various axes according to some embodiments.

FIG. **15** shows a right side view of an unmanned aerial vehicle and various axes according to some embodiments.

FIG. **16** shows a rear view of an unmanned aerial vehicle and various axes according to some embodiments.

FIG. **17** shows a flow diagram of a general method for charging the unmanned aerial vehicle according to various embodiments.

FIG. **18**A is a conceptual diagram in perspective views of the unmanned aerial vehicle according to various embodiments.

FIG. **18**B is a perspective view of the unmanned aerial vehicle in various embodiments.

FIG. **19** is a conceptual diagram in perspective views of the unmanned aerial vehicle according to various embodiments.

FIG. **20** is a conceptual diagram in perspective views of the unmanned aerial vehicle according to various embodiments.

FIG. **21**A shows a flow diagram of a method for charging the unmanned aerial vehicle according to various embodiments.

FIG. **21**B shows a flow diagram of a method for charging the unmanned aerial vehicle according to various embodiments.

FIG. **22** shows a flow diagram of a method for positioning the unmanned aerial vehicle for charging according to various embodiments.

FIGS. **23-27** are conceptual diagrams illustrating examples of the method for positioning the unmanned aerial vehicle (illustrated by the representative) for charging according to various embodiments.

FIG. **28** shows a schematic diagram of various components of the unmanned aerial vehicle according to various embodiments.

FIG. **29** is a perspective view of a portion of the unmanned aerial vehicle according to various embodiments.

FIG. **30** is a front view of a portion of the unmanned aerial vehicle according to various embodiments.

FIG. **31** is a top view of a portion of the unmanned aerial vehicle according to various embodiments.

FIG. **32** is a side view of a portion of the unmanned aerial vehicle according to various embodiments.

FIG. **33** is a perspective view of a portion of the unmanned aerial vehicle according to various embodiments.

FIG. **34** is a bottom view of a portion of the unmanned aerial vehicle according to various embodiments.

FIG. **35** is a side view of a portion of the unmanned aerial vehicle according to various embodiments.

FIG. **36** is a rear view of a portion of the unmanned aerial vehicle according to various embodiments.

FIG. **37** shows a rear view of a portion of a schematic representation of a damping system according to various embodiments.

FIG. **38** is a side view of a portion of the schematic representation of the damping system according to various embodiments.

DETAILED DESCRIPTION

Embodiments relate to apparatuses, systems, and methods for unmanned aerial vehicles (UAVs). Particular embodiments relate to unmanned aerial vehicles having certain configurations and features relating to support frames, inductive charging, motion control, and/or structural design.

The detailed description set forth below in connection with the appended drawings is intended as a description of various configurations and is not intended to represent the only configurations in which the concepts described herein may be practiced. The detailed description includes specific details for providing a thorough understanding of various concepts. However, it will be apparent to those skilled in the art that these concepts may be practiced without these specific details. In some instances, well-known structures and components are shown in block diagram form in order to avoid obscuring such concepts.

The embodiments described herein can provide various benefits over conventional unmanned aerial vehicles. Some embodiments described herein may provide an unmanned aerial vehicle with greater maneuverability than conventional unmanned aerial vehicles. For example, certain camera location placements and V-tail configurations allow the unmanned aerial vehicle to turn within a relatively small circle or in place, to provide improved camera direction stability. Some embodiments described herein may provide an unmanned aerial vehicle with greater modularity of its component parts than conventional unmanned aerial vehicles. Some embodiments described herein may provide an unmanned aerial vehicle with better payload hauling capabilities than conventional unmanned aerial vehicles. Some embodiments described herein may provide an unmanned aerial vehicle with efficient and convenient charging mechanisms. Some embodiments described herein may provide an unmanned aerial vehicle with improved sensor stability and output accuracy. Some embodiments described herein may provide an unmanned aerial vehicle with dual-purpose structural and electrical connections. Further embodiments described herein may include various combinations of two or more (or all) of those embodiments.

FIG. **1** shows a perspective view of an unmanned aerial vehicle **100** according to some embodiments. The unmanned aerial vehicle **100** is shown with respect to various reference directions. A front direction **101**, a rear direction **102**, a left direction **103**, and a right direction **104** are shown. Top and bottom directions are not shown for the sake of clarity but will be identified in other figures.

The unmanned aerial vehicle **100** may have a frame or frame portion **110**. The phrases "frame" and "frame portion" are used synonymously in the present description. The frame **110** may be a substantially fixed structure (or combination of structures) on which other elements of the unmanned aerial vehicle **100** may be mounted and supported.

The unmanned aerial vehicle **100** may have one or more aerial propulsion devices **130**. The aerial propulsion devices **130** are illustrated as propeller assemblies in the drawings. The aerial propulsion devices **130** may each include a rotor/propeller assembly. The aerial propulsion devices **130** may each include a propeller guard. Each of these elements is illustrated in greater detail in other figures. The unmanned aerial vehicle **100** may have four pairs of rotor/propeller assemblies. While embodiments may employ aerial propulsion systems having a rotor/propeller assembly, other embodiments may employ other suitable types of aerial propulsion systems. Also, while embodiments may employ a four rotor/propeller assemblies, other embodiments may employ fewer or more rotor/propeller assemblies (or other aerial propulsion systems).

FIG. **2** shows a front view of the unmanned aerial vehicle **100** according to some embodiments. FIG. **3** shows a rear view of the unmanned aerial vehicle **100** according to some embodiments. With reference to FIGS. **1-3**, the unmanned aerial vehicle **100** is shown with respect to various reference directions. A top direction **105**, a bottom direction **106**, the left direction **103**, and the right direction **104** are shown.

In some embodiments, the unmanned aerial vehicle **100** may have a first payload interface (not shown). In particular embodiments, the first payload interface may be or be arranged on a portion of the unmanned aerial vehicle **100** provided towards the bottom direction **106** or any other suitable portion of the unmanned aerial vehicle **100**. The first payload interface may be designed to engage with various payload objects. Engaging with payload objects may include gripping the payload objects in order to lift them up and carry them away. Engaging with payload objects may include releasing the payload objects in order to leave the objects where released. The first payload interface may have various gripper fingers (not shown). The gripper fingers may be individually articulating fingers driven by one or more motors in order to control engaging with payload objects. In other embodiments, other suitable payload interfaces may be used.

In some embodiments, the unmanned aerial vehicle **100** may have a second payload interface (not shown) with gripper fingers (not shown). The second payload interface may be provided in a similar manner as just described for the first payload interface, except that the second payload interface is configured to engage payload objects positioned above the unmanned aerial vehicle **100**. In other embodiments, other suitable payload interfaces may be used for the second payload interface.

FIG. **4** shows a left view of the unmanned aerial vehicle **100** according to some embodiments. FIG. **5** shows a right view of the unmanned aerial vehicle **100** according to some embodiments. FIG. **6** shows a top view of the unmanned aerial vehicle **100** according to some embodiments. FIG. **7** shows a bottom view of the unmanned aerial vehicle **100** according to some embodiments.

With reference to FIGS. **1-7**, the unmanned aerial vehicle **100** may have rotor motors **132**, included as a part of aerial propulsion devices **130**. Each rotor motor **132** may drive a propeller **134** (propeller blade(s)) in order to provide aerial propulsion to the unmanned aerial vehicle **100**. The speed of revolution of the rotor motors **132** may be controlled by a central processor (e.g., **802** in FIG. **8**) provided as part of the unmanned aerial vehicle **100**. The central processor may use differences in rotational speeds of the various rotor motors **132** in order to control the motion of the unmanned aerial vehicle **100** in the air. Techniques similar to those used with quadcopters or the like may be used with the rotor motors **132** in order to control motion of the unmanned aerial vehicle **100** through the air.

In some embodiments, one rotor motor **132** may be provided on each arm, for example on a bottom surface of a rear arm **197**. The rotor motor **132** may include an interface with the propeller **134**. The rotor motor **132** may be arranged such that the propeller **134** (and the interface of the rotor motor **132**) is pointed (at least substantially) toward the bottom direction **106**. Configuration of the rotor motors **132** (and/or propellers **134**) different than that shown may be used in other embodiments.

In some embodiments, a total of three propellers **134** are shown for each rotor motor **132**. Configuration of propellers different than such may be used in other embodiments. In some embodiments, the unmanned aerial vehicle **100** may have propeller guards (not shown). The propeller guards may be a substantially rigid structure that prevents the propeller **134** of the various aerial propulsion devices **130** from striking objects to one or more sides (e.g., the left direction and right direction) of the unmanned aerial vehicle **100**.

In various embodiments, the unmanned aerial vehicle **100** is shown as having one or more frame fixtures **112**. The frame fixtures **112** may be components of the frame **110**. The frame fixtures **112** may be designed to allow the attachment of various components or devices (e.g., sensor devices **199**, such as cameras) to the unmanned aerial vehicle **100**. For example, a first frame fixture **112** provided towards the front direction **101** of the unmanned aerial vehicle **100** may allow the connection of a vision sensor (e.g., the sensor devices **199**), such as a (stereo) camera, LIDAR, or other vision system. As another non-limiting example, a second frame fixture may be provided towards the rear direction **102** of the unmanned aerial vehicle **100** to allow the connection of an audio sensor, such as a microphone or other audio system not shown. Configuration of frame fixtures and sensor attachment points other than that shown may be used in other embodiments.

FIG. **8** shows a schematic diagram of various components of the unmanned aerial vehicle **100** according to some embodiments. With reference to FIGS. **1-8**, the unmanned aerial vehicle **100** is shown as having a processor **802** and a memory **804**. The processor **802** and the memory **804** may be effective together to store and run software related to controlling the operation of the unmanned aerial vehicle **100**. The processor **802** may process software related to controlling speed of rotation of air propulsion motors **814** (which may correspond to and/or be associated with the rotor motors **132** of the aerial propulsion devices **130**). The processor **802** may process software related to storing or processing data received from sensors **810**. The processor **802** may process software related to performing wireless communications with another device using one or more RF resources **806** and antenna **808**. The processor **802** along with other components of the unmanned aerial vehicle **100** may receive electrical power from power source **812** (e.g., one or more batteries).

FIG. **9** shows a top view of the unmanned aerial vehicle **100** according to some embodiments. With reference to FIGS. **1-9**, the unmanned aerial vehicle **100** may include elements that provide both electrical functionality and structural functionality. The unmanned aerial vehicle **100** may include at least a right-front arm **921** and a left-front arm **922**. The right-front arm **921** may extend from the frame portion **910** in the right direction **104**. The left-front arm **922** may extend from the frame portion **910** in the left direction **103**. In some embodiments, the right-front arm **921** and left-front arm **922** may be a unitary component. In other embodiments, the right-front arm **921** and left-front arm **922** may be two separate components.

The unmanned aerial vehicle **100** may include at least a right-rear arm **941** and a left-rear arm **942**. The right-rear arm **941** may extend from the frame portion **910** in a first extension direction **904**. The left-rear arm **942** may extend from the frame portion **910** in a second extension direction **903**. In some embodiments, the right-rear arm **941** and left-rear arm **942** may be a unitary component. In other embodiments, the right-rear arm **941** and left-rear arm **942** may be two separate components. The first extension direction **904** and the second extension direction **903** may be orthogonal. In various embodiments, the first extension direction **904** and second extension direction **903** may extend along and correspond to axes **1352** and **1354** (of FIG. **13**), respectively.

The unmanned aerial vehicle **100** may include frame portion **910**, frame portion **911**, frame portion **912**, frame portion **913**, frame portion **914**, frame portion **915**, frame portion **916**, frame portion **917**, and frame portion **918**. One or more of the frame portions **910-918** may be parts of the frame portion **110**. The frame portion **910** may be a top plate on a box-frame main body section of the unmanned aerial vehicle **100**.

The right-front arm **921** may be formed, for example, but not limited to, the frame portions **911** and **912**. The left-front arm **922** may be formed, for example, but not limited to, the frame portions **913** and **914**. The right-rear arm **941** may be formed, for example, but not limited to, the frame portions **915** and **916**. The left-rear arm **942** may be formed, for example, but not limited to, the frame portions **917** and **918**.

In some embodiments, the frame portions **910-918** may be constructed of printed circuit board material. In such embodiments, one or more of the frame portions **910-918** may have conductive lines provided as part of the frame portions **910-918** for transmission of electrical signals between various components of the unmanned aerial vehicle **100**. In other embodiments, the unmanned aerial vehicle **100** may include external wires or other devices for the transmission of electrical signals between various components of the unmanned aerial vehicle **100**.

The unmanned aerial vehicle **100** may include propulsion device **932**, propulsion device **934**, propulsion device **936**, and propulsion device **936**. Each of the propulsion devices **932**, **934**, **936**, and **938** may be provided as described with respect to the aerial propulsion device **130**. The propulsion device **932** may be mounted near a distal end of the right-front arm **921**. The propulsion device **934** may be mounted near a distal end of the left-front arm. The propulsion device **936** may be mounted near a distal end of the right-rear arm **941**. The propulsion device **938** may be mounted near a distal end of the left-rear arm **942**.

The unmanned aerial vehicle **100** may include various connections, such as, but not limited to, connection **952**, connection **954**, connection **956**, connection **958**, connection **962**, connection **964**, connection **966**, and connection **968**. In various embodiments, each of the connections connection **952**, **954**, **956**, **958**, **962**, **964**, **966**, and **968** may form both a structural connection and an electrical connection between the frame portion **910** and a respective component. For instance, the connection **952** may form both a structural connection and an electrical connection between the frame portion **910** and the frame portion **911**. The connection **954** may form both a structural connection and an electrical connection between the frame portion **910** and the frame portion **912**. The connection **956** may form both a structural connection and an electrical connection between the frame portion **910** and the frame portion **913**. The connection **958** may form both a structural connection and an electrical connection between the frame portion **910** and the frame portion **914**. The connection **962** may form both a structural connection and an electrical connection between the frame portion **910** and the frame portion **915**. The connection **964** may form both a structural connection and an electrical connection between the frame portion **910** and the frame portion **916**. The connection **966** may form both a structural connection and an electrical connection between the frame portion **910** and the frame portion **917**. The connection **968** may form both a structural connection and an electrical connection between the frame portion **910** and the frame portion **918**.

In some embodiments, each of the connections **952**, **954**, **956**, **958**, **962**, **964**, **966**, and **968** may include a tongue and groove configuration wherein a tongue portion of one frame portion fits into a groove portion of another frame portion. In some embodiments, the tongue and groove configuration may then be soldered. The solder may serve to physically bind the tongue portion and the groove portion together, thereby providing a structural connection for the two connected frame portions. The solder may further serve to electrically connect an electrical input on the tongue portion to an electrical input on the groove portion, thereby providing an electrical connection for the two connected frame portions. In some embodiments, the connections **952**, **954**, **956**, **958**, **962**, **964**, **966**, and **968** may provide a structural connection using other configuration, e.g., a bolting connection, a riveting connection, or otherwise. The connections **952**, **954**, **956**, **958**, **962**, **964**, **966**, and **968** may be provided in other configurations in various embodiments.

FIGS. **10**A-B and FIGS. **11**A-B show a top view of the unmanned aerial vehicle **100** and connection components according to some embodiments. With reference to FIGS. **1-11**B, the unmanned aerial vehicle **100** may include the connection **968** with slot portion **1012**, tab portion **1014**, and solder portion **1032**. The slot portion **1012** may be an opening in the frame portion **910** through which the tab portion **1014** is configured to be received. The tab portion **1014** may be a protrusion from a proximal end of the frame portion **918** that is shaped so as to be received in the slot portion **1012**. When the tab portion **1014** engages the slot portion **1012**, the frame portion **918** is secured to the frame portion **910**.

In various embodiments, the unmanned aerial vehicle **100** may include conductive track **1022** and conductive track **1024**. The conductive track **1022** may be provided in a printed circuit board material of the frame portion **910**. The conductive track **1022** may pass along or within the frame portion **910** up to the opening formed by the slot **1012**. On the end not terminating at the slot portion **1012**, the conductive track **1022** may be electrically connected to electronic components of the unmanned aerial vehicle, such as the processor **802** or the power source **812**. The conductive track **1024** may be provided in a printed circuit board material of the frame portion **918**. The conductive track **1024** may pass along or within the frame portion **918** up to and onto the tab portion **1014**. On the end not terminating at the tab portion **1014**, the conductive track **1024** may be electrically connected to electronic components of the unmanned aerial vehicle, such as the air propulsion motors **814** or the sensors **810**.

The solder portion **1032** may be a solid element of a conductive metal alloy used to bind electrical components, generally referred to as "solder." The solder portion **1032** may be formed by applying the molten metal alloy to the point where the tab portion **1014** engages the slot portion **1012**. The solder portion **1032** may physically bind the tab portion **1014** to the slot portion **1012**. For example, the solder portion **1032** may physically obstruct the tab portion **1014** from sliding out of the slot portion **1014**. Where the solder portion **1032** physically binds the frame portion **918** to the frame portion **910**, the connection **968** may be considered to form a structural connection between frame portions of the unmanned aerial vehicle **100**.

The solder portion **1032** may form an electrical connection between the conductive track **1022** and the conductive track **1024**. For example, the solder portion **1032** may be an electrically conductive metal alloy that forms an unbroken physical connection between the conductive track **1022** and the conductive track **1024**. Based on the electrical connection between the conductive track **1022** and the conductive track **1024**, the solder portion **1032** may allow the electrical components to which the conductive track **1022** is connected (e.g., the processor **802** or the power source **812**) to communicate with the electrical components to which the conductive track **1024** is connected (e.g., the air propulsion motors **814** or the sensors **810**). For example, the electrical connection formed by the connection **968** may allow the processor **802** to send control signals to the air propulsion motors **814**, such as the propulsion device **938** mounted at a distal end of the frame portion **918**.

FIGS. **12**A-B show a top view of the unmanned aerial vehicle **100** and connection components according to some embodiments. With reference to FIGS. **1-12**B, the connection **968** may provide multiple electrical connections for the unmanned aerial vehicle **100**.

According to some embodiments, the slot portion **1012** and the tab portion **1014** may terminate more than one conductive track each. In some embodiments, the frame portion **910** may include both the conductive track **1022** and a conductive track **1026**, which both pass along or within the frame portion **910** up to the opening formed by the slot **1012**. In some embodiments, the frame portion **918** may include the conductive track **1024** and a conductive track **1028**, which both pass along or within the frame portion **918** up to and onto the tab portion **1014**. The conductive track **1026** may be connected to the same or different electrical components as the conductive track **1022**. For example, the conductive track **1022** may be connected to the processor **802**, while the conductive track **1026** may be connected to the power source **812**. As another example, the conductive track **1022** may be connected to the processor **802** for transmitting a first signal, while the conductive track **1024** may be connected to the processor **802** for transmitting a second signal. The conductive track **1024** may be connected to the same or different electrical components as the conductive track **1028**. For example, the conductive track **1024** may be connected to the air propulsion motors **814**, while the conductive track **1028** may be connected to the sensors **810**. As another example, the conductive track **1024** may be connected to the air propulsion motors **814** for receiving a first signal, while the conductive track **1028** may be connected to the air propulsion motors **814** for receiving a second signal. Other configurations of the conductive tracks **1022**, **1024**, **1026**, and **1028** are possible in various embodiments.

According to embodiments where the slot portion **1012** and the tab portion **1014** may terminate more than one conductive track each, multiple solder portions may be included in the connection **968**. In such embodiments, the connection **968** may include the solder portion **1032** and a solder portion **1034**. The solder portion **1032** may provide a physical connection between the slot portion **1012** and the tab portion **1014**, and the solder portion **1032** may also provide an electrical connection between the conductive track **1022** and the conductive track **1024**. The solder portion **1034** may provide a physical connection between the slot portion **1012** and the tab portion **1014**, and the solder portion **1034** may also provide an electrical connection between the conductive track **1026** and the conductive track **1028**.

FIG. **13** shows a top view of the unmanned aerial vehicle **100** and various axes according to some embodiments. FIG. **14** shows a bottom view of the unmanned aerial vehicle **100** and various axes according to some embodiments. With reference to FIGS. **1-14**, the unmanned aerial vehicle **100** may contain a central body portion **1300**. The central body portion **1300** may be a structure containing various components of the unmanned aerial vehicle **100** (e.g., the processor

802, the memory **804**, the power source **812**, etc.). In some embodiments, the unmanned aerial vehicle **100** may be configured so that the center of mass of the unmanned aerial vehicle **100** is located within the central body portion **1300**.

According to some embodiments, the unmanned aerial vehicle **100** may be situated with respect to a first plane defined by axis **1330** and axis **1340**. The first plane defined by the axis **1330** and the axis **1340** may be a horizontal plane. The axis **1330** may pass in the left direction **103** and the right direction **104** across the central body portion **1300** and through each of the arms portions **921** and **922**. The axis **1340** may pass in the front direction **101** and the rear direction **102** through the central body portion **1300**.

In some embodiments, the front arms **921** and **922** may be provided parallel to the axis **1330**. In such configurations, the front-right arm **921** may extend directly out to the right direction **104** (a side direction) from the central body portion **1300**, while the front-left arm **922** may extend directly to the left direction **103** (another side direction) from the central body portion **1300**. In some embodiments, the aerial propulsion devices **932** and **934** may be provided in a downward facing direction (into the page with respect to FIG. **13**). The downward facing direction may be the bottom direction **106**. As such, an axis of rotation (**1432**, **1534** in FIGS. **15-16**, respectively) for each of the aerial propulsion device **932** and **934** may be perpendicular to the axis **1330**. Similarly, the axis of rotation for each of the aerial propulsion device **932** and **934** may be perpendicular to the axis **1330** if translated either left or right to intersect the axis **1330**.

According to some embodiments, the rear arms **941** and **942** may be arranged in a "V" shape. The right-rear arm **941** may be arranged along an axis **1352**, and the left-rear arm **942** may be arranged along an axis **1354**. The rear arms **941** and **942** may be connected to the central body portion **1300** in a narrow, close, or otherwise more proximate position to one another. The rear arms portions **941** and **942** may be angled outwards as they extend away from the central body portion **1300** to a wide, far, or otherwise less proximate position to one another. As such, the proximal ends (with respect to the central body portion **1300**) of the rear arms **941** and **942** may be a first distance apart, whereas the distal ends (with respect to the central body portion **1300**) of the rear arms **941** and **942** may be a second distance apart, with the second distance being larger than the first distance. The rear arms **941** and **942** form an acute angle with each other. The rear arms **941** and **942** may be orthogonal with respect to each other.

In some embodiments, the V shape of the rear arms **941** and **942** may be defined based on the position of the rear arms **941** and **942** to the horizontal (first) plane defined by the axes **1330** and **1340**. In some embodiments, the axis **1352** on which the right-rear arm **941** is arranged may be positioned at an angle **1372** away from the axis **1340**. Similarly, the axis **1354** on which the left-rear arm **942** is arranged may be positioned at an angle **1374** away from the axis **1340**. The angle **1372** and the angle **1374** may be provided so as to have the same magnitude as one another, but rotated in different directions with respect to the axis **1340**. As such, the axis **1352** and **1354** may be arranged with a same absolute angular separation from the axis **1340**, while the axis **1352** is arranged to the right side **104** of the axis **1340** and the axis **1354** is arranged to the left side **103** of the axis **1340**.

Numerous configurations of the angles **1372** and **1374** may be provided in various embodiments. In some embodiments, the angles **1372** and **1374** may be provided as greater than zero degrees and less than 90 degrees in absolute values (acute). In this way, the rear arms **941** and **942** may form a "V" shape facing the rear direction **102**. In some embodiments, the angles **1372** and **1374** may be provided as between 20 degrees and 30 degrees in absolute values. With the angles **1372** and **1374** provided as between 20 degrees and 30 degrees in absolute values, the rear arms portions **941** and **942** may be swept backwards to a large degree, while still avoiding collision of propellers driven by the aerial propulsion devices **936** and **938**. For any configuration where the angles **1372** and **1374** do not equal to zero degrees or 90 degrees (or some multiple thereof), the axes **1352** and **1354** will neither be parallel nor perpendicular to the axis **1340**. Similarly, if the axis **1330** is perpendicular to the axis **1340**, then the axes **1352** and **1354** will neither be parallel nor perpendicular to the axis **1330**.

In some embodiments, the aerial propulsion devices **936** and **938** may be provided in a substantially downward facing direction (a first direction). As such, an axis of rotation **1362** for the aerial propulsion device **936** may be perpendicular to the axis **1352**. Similarly, an axis of rotation **1364** for the aerial propulsion device **938** may be perpendicular to the axis **1354**. However, each of the axes of rotation **1362** and **1364** may be turned outwards to the side directions. That is, the axis of rotation **1362** may be directed partially in the right direction **104**. Similarly, the axis of rotation **1364** may be directed partially in the left direction **103**. As a result, the axes of rotation **1362** and **1364** may not be perpendicular to the axis **1340** even if the axes of rotation **1362** and **1364** are translated left or right to intersect the axis **1340**.

Numerous configurations of the outward angling of the axes **1362** and **1364** may be provided in various embodiments. In some embodiments, the axes **1362** and **1364** may be angled outwards at angles greater than zero degrees and less than 90 degrees (in absolute values relative to a reference directly downward into the page for FIG. **13**). In this way, the axes of rotation **1362** and **1364** may have both components in the top and bottom directions **103**, **106** as well as the side directions **103**, **104**. In particular, the axis of rotation **1362** (a direction in which the aerial propulsion device **936** faces) may be provided so that the aerial propulsion device **936** exerts a force vector with a component force vector in the down direction **106** (for lift) and a component force vector in right direction **104** (for rotation). Similarly, the axis of rotation **1364** (a direction in which the aerial propulsion device **938** faces) may be provided so that the aerial propulsion device **938** exerts a force vector with a component force vector in the down direction **106** (for lift) and a component force vector in left direction **103** (for rotation). At least in this way, the axes of rotation **1362** and **1364** may be provided with outward angling so that the aerial propulsion devices **936** and **938** are configured to provide both lifting force (downward force vectors) and side-to-side force (left/right force vectors). In some embodiments, the axes **1362** and **1364** may be angled outwards at angles between 30 degrees and 40 degrees (in absolute values relative to a reference directly downward into the page for FIG. **13**). With such a configuration, the aerial propulsion devices **936** and **938** may be configured to provide both lifting force and side-to-side force, but with slightly stronger force components for lifting force than side-to-side force, because the aerial propulsion devices **936** and **938** may face slightly more downwards than outwards. The outward angling of the axes **1362** and **1364** may be provided differently in various embodiments. The axes **1362** and **1364** coupled with the "V" tail configuration may allow the unmanned aerial vehicle **100** to turn in place while in flight. Alternatively, the configuration may allow turning in a small circle. The sensor devices **199** (e.g., stereo cameras) may be arranged on the front arms **921** and **922** facing the front direction **101**. Such arrangement maximizes a field of view of the sensor devices **199** around the unmanned aerial vehicle **100**.

FIG. **15** shows a right side view of the unmanned aerial vehicle **100** and various axes according to some embodiments. FIG. **16** shows a rear view of the unmanned aerial vehicle **100** and various axes according to some embodiments. With reference to FIGS. **1-16**, the unmanned aerial vehicle **100** may be situated with respect to axis **1530**. The axis **1530** may pass in the up direction **105** and the down direction **106** through the central body portion **1300**.

According to some embodiments, the aerial propulsion devices **932** and **934** may be configured so as to rotate around axes of rotation **1532** and **1534**, respectively. In particular, the aerial propulsion device **932** may rotate about the axis of rotation **1532**. Similarly, the aerial propulsion device **934** may rotate about the axis of rotation **1534**. The axes of rotation **1532** and **1534** may be provided perpendicular to the axis **1330**. Similarly, the axes of rotation **1532** and **1534** may be provided perpendicular to the axis **1330** if translated either left or right to intersect the axis **1330**. The axes of rotation **1532** and **1534** may be provided parallel to the axis **1530**. As such, the aerial propulsion devices **932** and **934** may be configured to generate force vectors with components only in the down direction **106**. Therefore, the aerial propulsion devices **932** and **934** may provide only a lifting force as a direct force on the surrounding environment. Nonetheless, when the unmanned aerial vehicle **100** is not situated flat on the horizontal plane, the force from the aerial propulsion devices **932** and **934** may provide components in other directions other than only the down direction **106**.

According to some embodiments, the outward angling of the axes of rotation **1362** and **1364** may be defined by the angles **1672**, **1674**, **1676**, and **1678**. As discussed, the aerial propulsion devices **936** and **938** may be provided as angled outwards relative to an up-down axis (e.g., the axis **1530**). The angle **1672** defines the angular difference between the axis of rotation **1362** (of the aerial propulsion device **936**) and the axis of rotation **1532** (of the aerial propulsion device **932**). The angle **1672** may be provided as discussed. In some embodiments, the angle **1672** may be provided greater than zero degrees and less than 90 degrees (in absolute values). In some embodiments, the angle **1672** may be provided between 30 degrees and 40 degrees (in absolute values). The angle **1676** is the complement of the angle **1672**. The angle **1674** defines the angular difference between the axis of rotation **1364** (of the aerial propulsion device **938**) and the axis of rotation **1534** (of the aerial propulsion device **934**). The angle **1674** may be provided as discussed. In some embodiments, the angle **1674** may be provided greater than zero degrees and less than 90 degrees (in absolute values). In some embodiments, the angle **1674** may be provided between 30 degrees and 40 degrees (in absolute values). The angle **1678** is the complement of the angle **1674**.

In some embodiments, the angles **1672** and **1674** may provide a benefit of allowing a more compact placement of the rear arms **941** and **942**. In particular, if the axes of rotation **1362** and **1364** were provided directly vertical (i.e., parallel to the axis **1530**) and the angles **1672** and **1674** were equal to zero, then the propellers driven by the aerial propulsion devices **936** and **938** may be more likely to collide due to rotation on a same horizontal plane. However, with the angles **1672** and **1674** provided greater than zero, the propellers driven by the aerial propulsion devices **936** and **938** do not rotate on a same plane. While the planes of rotation may intersect, the planes of rotation may intersect less often than would occur if the angles **1672** and **1674** were provided equal to zero. As such, because the angles **1672** and **1674** greater than zero reduce the collision space of propellers driven by the aerial propulsion devices **932** and **934**, the aerial propulsion devices **932** and **934** (and by consequence the rear arms **941** and **942**) may be placed in closer proximity. Stated in other terms, the use of non-zero angles for the angles **1672** and **1674** allow the use of smaller angles for the angles **1372** and **1374**. As discussed, the angles **1372** and **1374** may allow a composite angular separation of the rear arms **941** and **942** of 40 degrees (i.e., 20 degree configurations for each of **1372** and **1374**). Without the use of the outward angles **1372** and **1374**, the minimum composite angular separation of the rear arms **941** and **942** may be much greater than 40 degrees.

According to some embodiments, the rear arms **941** and **942** may be provided at angular separations relative to the axis **1340**. In some embodiments, the rear arm **941** may be provided on the axis **1353** at an angle **1572** relative to the axis **1340**. In some embodiments, the angle **1572** may be provided greater than zero degrees and less than 90 degrees (in absolute values). In some embodiments, the angle **1572** may be provided between 20 degrees and 30 degrees (in absolute values).

In some embodiments, the angle **1572** may not cause the axis of rotation **1362** to be directed in the rear direction **102**. In such embodiments, even though the angle **1572** causes the rear arm **941** to be positioned in the up direction **105** from the axis **1340**, the rear arm **941** may compensate for the angle **1572** so that the axis of rotation **1362** is directed strictly in an up and down direction (i.e., parallel to the axis **1530**).

In some embodiments, the angle **1572** may cause the axis of rotation **1362** to be directed in the rear direction **102**. In such embodiments, the axis of rotation **1362** may be provided perpendicular to the axis **1352**. As such, the axis of rotation **1362** may be provided relative to perfectly vertical (i.e., a translation of the axis **1530**) at an angle that is the complement of the angle **1572**. This may be the case based on the right triangle defined by the right angle at the intersection of the axis **1352** and the axis of rotation **1362**, the angle **1572**, and the angle of rearward deflection for the angle of rotation **1362**. In embodiments where the axis of rotation **1362** is directed in the rear direction **102**, the aerial propulsion device **936** may generate a force vector with a rearward force component in addition to the lifting force component and side-to-side force component discussed.

The distal ends (e.g., the aerial propulsion devices **936** and **938**) of the rear arms **941** and **942** may be elevated in the top direction **105** with respect to the aerial propulsion devices **932** and **934** and the front arms **941** and **942**. The aerial propulsion devices **932**, **934**, **936**, and **938** may be each provided below (in the bottom direction **106**) the distal end of the respective one of the arms **921**, **922**, **941**, and **942**.

The configurations described with respect to FIGS. **1-16** may provide numerous benefits in various embodiments. The unmanned aerial vehicle **100** may allow simplified controller design, improved maneuverability, improved sensor operation, and safer operation in addition to other benefits.

In some embodiments, the unmanned aerial vehicle **100** may allow simplified controller design due to the arrangement of the aerial propulsion devices **932**, **934**, **936** and **938**. First, because the aerial propulsion devices **936** and **938** may be configured to provide force vector components in multiple directions simultaneously (e.g., lifting force vector and side-to-side force vector), the unmanned aerial vehicle **100** may be able to perform maneuvers using the direct force vectors from the aerial propulsion device **936** and **938** in addition to using the angular velocity differentials of the aerial propulsion devices **932**, **934**, **936** and **938** as used in standard quadcopter devices. With the use of direct force components in multiple directions from the aerial propulsion devices **936** and **938**, the unmanned aerial vehicles **100** may be able to perform maneuvers without the use of angular velocity differentials or with less sensitivity required in the control of angular velocities of the aerial propulsion devices **932**, **934**, **936** and **938** when using angular velocity differentials.

In some embodiments, the unmanned aerial vehicle **100** may be configured to use only the aerial propulsion device **936** and **938** to provide rotational force. In such embodiments, the aerial propulsion devices **932** and **934** may only be used to provide the single direction force vector along the axis of rotation **1532**. As such, the controller may need to provide significantly fewer or less frequent control signals to the aerial propulsion devices **936** and **938**. This may allow a simplified controller design including reduced controller logic.

In some embodiments, the unmanned aerial vehicle **100** may allow improved maneuverability due to the arrangement of the aerial propulsion devices **932**, **934**, **936** and **938**. As discussed, the arrangement of the aerial propulsion devices **936** and **938** may produce force vectors with multiple force vectors of lifting force, side-to-side force, and/or rearward force. In addition, the unmanned aerial vehicle **100** may use angular velocity differentials to create angular velocity for the unmanned aerial vehicle as used in standard quadcopter devices. Therefore, the unmanned aerial vehicle **100** may be able to perform more maneuvers and more rapid maneuvers due to these additional force vectors, which may not be possible with standard quadcopter devices. Furthermore, the unmanned aerial vehicle **100** may rotate in place or in a small circle.

In some embodiments, the unmanned aerial vehicle **100** may be capable of improved sensor operation due to the arrangement of the aerial propulsion devices **932**, **934**, **936** and **938**. In particular, the unmanned aerial vehicle **100** may be capable of operating sensors (e.g., sensor devices **199**) more effectively due to the numerous force vectors produced by the aerial propulsion devices **932**, **934**, **936** and **938**. In some situations, the use of the sensor devices **199** (e.g., stereo cameras) may be complicated based on translational movement of the unmanned aerial vehicle **100**. The sensor devices **199** (which may correspond to the sensors **810**) or other devices (e.g., the processor **802**) may need to determine the precise movement of the unmanned aerial vehicle **100** in order to determine the field being sensed at any particular time by the sensor devices **199**. Velocity sensing components provided on the unmanned aerial vehicle **100** (e.g., an inertial measurement unit) may be highly effective at measuring angular changes in the position of the unmanned aerial vehicle **100**. However, these velocity sensing components may not be as effective at measuring translational changes in the position of the unmanned aerial vehicle (e.g., movement in any of the directions **101-106**). Because the aerial propulsion devices **932**, **934**, **936** and **938** may be capable of producing force vector components in multiple directions simultaneously, the unmanned aerial vehicle **100** may be configured to perform rotational movement without significant translational movement. For example, the unmanned aerial vehicle **100** may be capable of rotating about a point defined by the intersection of the axes **1340** and **1530** with little or no movement in any of the directions **101**, **102**, **105**, or **106**. This form of "rotation-in-place" may not be capable with standard quadcopter devices due to the limitation that force vectors are all provided in a single direction. As such, the unmanned aerial vehicle **100** may be capable of performing sensing with the sensor devices **199** while reducing the imprecise translation movement that would otherwise make interpretation of the sensor output more difficult.

In some embodiments, the unmanned aerial vehicle **100** may be capable of safer operation due to the arrangement of the aerial propulsion devices **932**, **934**, **936** and **938**. Because the aerial propulsion devices **936** and **938** may be configured to produce force vector components in numerous directions outward from the unmanned aerial vehicle **100**, the unmanned aerial vehicle **100** may be less likely to collide with objects in a surrounding environment. In particular, because a standard quadcopter device only produces force vectors in a single direction (nominally downward when flat on a horizontal plane), the standard quadcopter device may be prone to drifting into and colliding with objects positioned in numerous directions around the standard quadcopter device (e.g., to the side of the device). However, the unmanned aerial vehicle **100** may be configured to produce force vector components in downwards, side-to-side, and/or rearwards directions simultaneously. As such, the unmanned aerial vehicle **100** may be more likely to push away from objects positioned in numerous directions around the unmanned aerial vehicle **100** (e.g., to the side of the unmanned aerial vehicle **100**). As a result, the unmanned aerial vehicle may be capable of operation with fewer or less significant collisions with objects in the surrounding environment.

FIG. **17** shows a flow diagram of a general method **1700** for charging the unmanned aerial vehicle **100** according to various embodiments. With reference to FIGS. **1-17**, the method **1700** may be used for embodiments where a charging apparatus may be available to charge energy storage devices (e.g., batteries or capacitors) of the unmanned aerial vehicle **100**.

The charging apparatus may be a device fixed to a position close to the ground or elevated in the air above the ground. In other embodiments, the charging apparatus may be secured to a moving or movable object, such as, but not limited to a train, a plane, a boat, another drone, an automobile, a truck or other vehicle. The charging apparatus may include at least a power source, engagement device, and transfer unit. The power source may be any suitable power source containing power to be transferred to the unmanned aerial vehicle **100**. The engagement device may be any suitable device for engaging the unmanned aerial vehicle **100** (in particular, a charging engagement element of the unmanned aerial vehicle **100** as described). The engagement device may be a wire, a rod, a clutch, a clamp, a net, a hook, a combination thereof, and/or the like. The transfer unit may be any suitable device for wireless (e.g., inductive) or wired transfer of power stored in the power source to the energy storage devices of the unmanned aerial vehicle **100**. Examples of the transfer unit may include, but not limited to, a wire, inductive charging unit, coils, a combination thereof, and/or the like.

First at block B**1710**, the unmanned aerial vehicle **100** may engage the charging apparatus. For example, the charging engagement element of the unmanned aerial vehicle **100** may be mechanically or electromagnetically become coupled, linked, or connected to the engagement device of the charging apparatus. As such, the unmanned aerial vehicle **100** may become linked physically to the charging apparatus to allow charging of the unmanned aerial vehicle **100**.

Next at block B**1720**, the unmanned aerial vehicle **100** may be charged by the charging apparatus. The charging may be any suitable wireless (e.g., inductive) or wires charging by the transfer unit of the charging apparatus. In particular embodiments, the manner of charging may be depending on the configuration (e.g., position and orientation) of the unmanned aerial vehicle **100** as it becomes engaged with the charging apparatus at the engagement device of the charging apparatus.

FIGS. **18**A, **19**, and **20** are conceptual diagrams in perspective views of the unmanned aerial vehicle **100** according to various embodiments. In particular, FIGS. **18**A, **19**, and **20** are diagrams illustrating positions of the charging engagement element of the unmanned aerial vehicle **100** according to corresponding embodiments. One of ordinary skill in the art would appreciate that, while two hooks may be shown in the non-limiting examples shown herein, one, three, or more hooks (or other suitable charging engagement elements) may be provided to the unmanned aerial vehicle **100**.

The portions of the conceptual diagrams may correspond to components of the unmanned aerial vehicle **100** (a perspective view of which may be illustrated in FIG. **18**B). For example, a first representative line **1850** may correspond to a first axial dimension **2450'**. A second representative line **1855** may correspond to a second axial dimension **2455'**. A third representative line **1860** may correspond to a first tail axial dimension **2460'**. A fourth representative line **1865** may correspond to a second tail axial dimension **2460'**. A fifth representative line **1870** may correspond to a cross dimension **1870'**. And representative motors **1880** may correspond to the aerial propulsion devices **130**.

In particular, FIG. **18**A illustrates embodiments where the charging engagement element includes two front hook members **1810** provided at a front portion of the unmanned aerial vehicle **100** (as illustrated in a first simplified model **1805**). Referring to FIGS. **1-18**A, the front hook members **1810** may be a portion of the frame **110** of the unmanned aerial vehicle **100** made of the same material and having the same physical properties as the frame **110**. In other embodiments, the front hook members **1810** may be connected to or linked to the frame **110**. The front hook members **1810** may be provided in the front direction **101** as compared to the rest of the unmanned aerial vehicle **100** or the rest of the frame **110**. In other words, the front hook members **1810** may be provided at a front portion of the unmanned aerial vehicle **100**. The front portion is arranged in the front direction **101** as compared to the rest of the unmanned aerial vehicle **100** and the frame **110**.

In the non-limiting example shown in FIG. **18**A, base portions of the front hook members **1810** may extend from (the front portion of) the frame **110** of the unmanned aerial vehicle **100** in the front direction **101**. End (tip) portions of the front hook members **1810** may be curved with respect to the base portion and pointing at a different direction than the front direction **101**. For example, the end portion of each of the front hook members **1810** may be curved toward the bottom direction **106**, the rear direction **102**, a combination thereof, and/or the like. In some examples, the front hook members **1810** may curve in the top direction **105**, the rear direction **102**, a combination thereof, and/or the like. In some examples, each of the front hook members **1810** may curve, in the left direction **103** or the right direction **104** (in addition to any other directional component of curvature).

FIG. **18**B is a perspective view of the unmanned aerial vehicle **100** in various embodiments. The unmanned aerial vehicle **100** may include two hook members **1820** as the charging engagement element of the unmanned aerial vehicle **100**. The hook members **1820** may correspond to the front hook members **1810**. The front hook members **1820** may be a portion of the frame **110**. The hook members **1820** may be made of the same materials as the frame **110** and/or have the same physical properties as the frame **110**. In particular, the hook members **1820** may have the same conductive properties as the frame **110**. In the non-limiting example shown in FIG. **18**B, (an end portion of) each of the hook members **1820** may be curved in a direction having vector components in the rear direction **102** and the bottom direction **106**. In addition, (the end portion of) each of the hook members **1820** may be curved in a direction having vector components in either the right direction **103** or the left direction **104**.

FIG. **19** illustrates embodiments where the charging engagement element includes two rear hook members **1910** provided at a rear portion of the unmanned aerial vehicle **100** (as illustrated in a second simplified model **1905**). Referring to FIGS. **1-19**, the rear hook members **1910** may be a portion of the frame **110** of the unmanned aerial vehicle **100** made of the same material and having the same physical properties as the frame **110**. In other embodiments, the rear hook members **1910** may be connected to or linked to the frame **110**. The rear hook members **1910** may be provided in the rear direction **102** as compared to the rest of the unmanned aerial vehicle **100** or the frame **110**. In other words, the rear hook members **1910** may be provided at a rear portion of the unmanned aerial vehicle **100**. The rear portion (tip of the V-shaped tails) is arranged in the rear direction **102** as compared to the rest of the unmanned aerial vehicle **100** and the frame **110**.

In the non-limiting example shown in FIG. **19**, base portions of the rear hook members **1910** may extend from (the rear portion of) the frame **110** of the unmanned aerial vehicle **100** in the rear direction **102** and/or the top direction **105**. End (tip) portions of the rear hook members **1910** may be curved with respect to the base portion and pointing at a different direction than the rear direction **102** and/or the top direction **105**. For example, the end portion of each of the rear hook members **1910** may be curved in the front direction **101**, the bottom direction **106**, a combination thereof, and/or the like. In some examples, the rear hook members **1910** may curve in the top direction **105**, the rear direction **102**, a combination thereof, and/or the like. In some examples, each of the rear hook members **1910** may curve, in the left direction **103** or the right direction **104** (in addition to any other directional component of curvature).

FIG. **20** illustrates embodiments where the charging engagement element includes two bottom hook members **2010** provided at a bottom portion of the unmanned aerial vehicle **100** (as illustrated in a third simplified model **2005**). Referring to FIGS. **1-20**, the bottom hook members **2010** may be a portion of the frame **110** of the unmanned aerial vehicle **100** made of the same material and having the same physical properties as the frame **110**. In other embodiments, the bottom hook members **2010** may be connected to or linked to the frame **110**. The bottom hook members **2010** may be provided in the bottom direction **106** as compared to the rest of the unmanned aerial vehicle **100** or the frame **110**. In other words, the bottom hook members **2010** may be provided at a bottom portion (e.g., a slide portion or a payload interface) of the unmanned aerial vehicle **100**. The bottom portion may be arranged in the bottom direction **106** as compared to the rest of the unmanned aerial vehicle **100** and the frame **110**.

In the non-limiting example shown in FIG. **20**, base portions of the bottom hook members **2010** may extend from (the bottom portion of) the frame **110** of the unmanned aerial vehicle **100** in the bottom direction **106**. End (tip) portions of the bottom hook members **2010** may be curved with respect to the base portion and pointing at a different direction than the bottom direction **106**. For example, the end portion of each of the bottom hook members **2010** may be curved in the front direction **101**, the top direction **105**, a combination thereof, and/or the like. In some examples, the bottom hook members **2010** may curve in the top direction **105**, the rear direction **102**, a combination thereof, and/or the like. In some examples, each of the bottom hook members **2010** may curve, in the left direction **103** or the right direction **104** (in addition to any other directional component of curvature).

In various embodiments, two or more charging engagement elements (e.g., the front hook members **1810**, the hook members **1820**, the rear hook members **1910**, the bottom hook members **2010**, and/or the like) may be provided to allow the unmanned aerial vehicle **100** to be charged in various configurations. Thus, flexibility of charging the unmanned aerial vehicle **100** may accordingly be achieved.

FIG. **21**A shows a flow diagram of a method **2100***a* for charging the unmanned aerial vehicle **100** according to various embodiments. With reference to FIGS. **1-21**A, the method **2100***a* may be used for embodiments where the charging engagement element of the unmanned aerial vehicle **100** may be used as a charging device of the unmanned aerial vehicle **100**. As used herein, a charging device may be a device on the unmanned aerial vehicle **100** that receives power (stored in the power source of the charging apparatus) from the transfer unit of the charging apparatus and relay the power to the energy storage devices of the unmanned aerial vehicle **100**. In such embodiments, the engagement device in the charging apparatus may also be implemented as the transfer unit. Thus, charging may be completed by coupling of only the engagement device of the charging apparatus and the charging engagement element of the unmanned aerial vehicle **100**.

First at block B**2110**, a charging engagement element may be provided to the unmanned aerial vehicle **100**. For example, the charging engagement element may be suitable hooks (e.g., the front hook members **1810**, the hook members **1820**, the rear hook members **1910**, and the bottom hook members **2010**) as described. Two or more charging engagement elements may be provided to allow flexibility in charging methods.

Next at block B**2120**, the unmanned aerial vehicle **100** may engage (the engagement device) of the charging apparatus with the charging engagement element. In various embodiments, the engagement device may be at least one of a wire, a clutch, a net, a hook, a combination thereof, and/or the like. The charging engagement element may become connected, linked, hooked, clutched, captured, or otherwise contacted by at least a portion of the engagement device of the charging apparatus. In the non-limiting examples described herein, the engagement device may be a strip of wire, and the charging engagement element may be hooks. The hooks may be engaged to the wire by hooking onto the wire as described in further detail herein.

Next at block B**2130**, the unmanned aerial vehicle **100** may charge its batteries/capacitors (i.e., energy storage devices) through the charging engagement element of the unmanned aerial vehicle **100**. In the non-limiting examples provided, the wire, which is the engagement device, may also be the transfer unit used to transfer power from the power source of the charging device to the unmanned aerial vehicle **100**. The hooks may also be implemented as both the charging engagement element and the charging device. In other words, the hooks may physically position the unmanned aerial vehicle **100** in a charging position and receive power from the transfer unit of the charging apparatus. The power may be transferred from the power source, through the wire to the hooks; the hooks may, in turn, relay the power to the energy storage devices of the unmanned aerial vehicle **100**.

In some embodiments, the hooks (charging engagement element) of the unmanned aerial vehicle **100** is connected to the rest of the frame **110** and share material properties such as conductivity. The hooks may also server as the charging device in transferring power from the transfer unit of the charging apparatus to the energy storage of the unmanned aerial vehicle **100**. Thus, the hooks may use the frame **110** as conduits for transferring power to the energy storage. Components provided on the frame **110** that are not a part of the transfer conduit may be accordingly insulated.

FIG. **21**B shows a flow diagram of a method **2100***b* for charging the unmanned aerial vehicle **100** according to various embodiments. With reference to FIGS. **1-21**B, the method **2100***b* may be used for embodiments where the charging engagement element of the unmanned aerial vehicle **100** may be a separate device (portion of the unmanned aerial vehicle **100**) as the charging device of the unmanned aerial vehicle **100**. In such embodiments, the engagement device in the charging apparatus may a separate device as the transfer unit. Thus, charging may be completed by coupling of the transfer unit and the charging device. The engagement device of the charging apparatus and the charging engagement element of the unmanned aerial vehicle **100** may be implemented to position or orient the unmanned aerial vehicle **100** in an appropriate position such that the transfer unit and the charging device may be in contact (for wired or wireless charging) or within a desired proximity (for wireless charging).

First at block B**2140**, the charging engagement element may be provided to the unmanned aerial vehicle **100**. For example, the charging engagement element may be suitable hooks (e.g., the front hook members **1810**, the hook members **1820**, the rear hook members **1910**, and the bottom hook members **2010**) as described. Two or more charging engagement elements may be provided to allow flexibility in charging methods.

Next at block B**2150**, the unmanned aerial vehicle **100** may engage (the engagement device) of the charging apparatus with the charging engagement element. In various embodiments, the engagement device may be at least one of a wire, a clutch, a net, a hook, a combination thereof, and/or the like. The charging engagement element may become connected, linked, hooked, clutched, captured, or otherwise contacted by at least a portion of the engagement device of the charging apparatus. In the non-limiting examples described herein, the engagement device may be a strip of wire, and the charging engagement element may be hooks as described. The hooks may be engaged to the wire by hooking onto the wire.

Next at block B**2160**, the unmanned aerial vehicle **100** may charge its batteries/capacitors (i.e., energy storage devices) through the charging device of the unmanned aerial vehicle **100**. For example, the hooks and the wire may position the unmanned aerial vehicle **100** in a suitable charging position such that the transfer unit of the charging apparatus may transfer power to the charging device in any suitable wired or wireless fashion. Given that the engagement device and the transfer unit may be different devices, the engagement device and the transfer unit may be located at different portions of the charging apparatus. Similarly, given that the charging engagement element and the charging device may be different devices, the charging engagement element and the charging device may be located at different portions of the unmanned aerial vehicle **100**.

FIG. **22** shows a flow diagram of a method **2200** for positioning the unmanned aerial vehicle **100** for charging according to various embodiments. With reference to FIGS. **1-22**, the method **2200** may correspond to blocks B**1710**, B**2120**, and B**2220**. At block B**2210**, the unmanned aerial vehicle **100** may move toward a predetermine position and orientation with respect to the charging apparatus.

For example, a predetermined position may be one or a range of positions that the unmanned aerial vehicle **100** may be in prior to the coupling process of the charging engagement element of the unmanned aerial vehicle **100** and the engagement device of the charging apparatus. The predetermined orientation may be one or a range of orientations (e.g., angle) that the unmanned aerial vehicle **100** may be in prior to the coupling process of the charging engagement element of the unmanned aerial vehicle **100** and the engagement device of the charging apparatus.

In some embodiments, the unmanned aerial vehicle **100** may move to the predetermined position and orientation based on user controls by an operator of the unmanned aerial vehicle **100**. In other embodiments, the unmanned aerial vehicle **100** may move to the predetermined position and orientation automatically based on sensor information received from the sensors **810**. The processor **802** may accordingly calculate movement s of the unmanned aerial vehicle **100** needed to arrive at the predetermined position and orientation and cause the unmanned aerial vehicle **100** to do so.

Next at block B**2220**, it may be determined whether the unmanned aerial vehicle **100** has arrived at the predetermined position and orientation. In some embodiments, such determination may be made manually by the operator. In other embodiments, the processor **802** may make such determination based on information detected by the sensors **810**. Whereas it has been determined that the unmanned aerial vehicle **100** has not arrived at the predetermined position or orientation, the unmanned aerial vehicle **100** may be configured to move toward the predetermined position and orientation, for example, at block B**2210** (B**2220**: NO).

On the other hand, whereas it has been determined that the unmanned aerial vehicle **100** has arrived at the predetermined position and/or orientation, the unmanned aerial vehicle **100** may couple the charging engagement element to the (engagement device) of the charging apparatus at block B**2230** (B**2220**: YES). In the non-limiting examples described herein, coupling may include allowing at least a portion of the hooks of the unmanned aerial vehicle **100** to come into contact with the wire of the charging device. In other examples, the engagement device of the charging apparatus and the charging engagement element of the unmanned aerial vehicle **100** may be coupled in other suitable manners such as, but not limited to, connecting, linking, clamping, clutching, capturing (with the engagement device as a net), a combination thereof, and/or the like. When the coupling has occurred, the unmanned aerial vehicle **100** may be at a coupling position/orientation.

Next at block B**2240**, at least a part of the unmanned aerial vehicle **100** may be repositioned for charging by the charging apparatus. In some embodiments, the coupling position/orientation may be the same as the position/orientation (charging position/orientation) of the unmanned aerial vehicle **100** as it is charged by the transfer unit. In such embodiments, block B**2240** is moot.

In other embodiments, the unmanned aerial vehicle **100** may be repositioned to the charging position/orientation that is different from the coupling position/orientation, in the manner described. The charging position/orientation may be dependent on the structure of the unmanned aerial vehicle **100** as well as the charging apparatus. In particular, the manner in which the unmanned aerial vehicle **100** rests at the charging position/orientation may be different as compared to the manner in which the unmanned aerial vehicle **100** becomes coupled to the charging apparatus.

FIGS. **23-27** are conceptual diagrams illustrating examples of the process **2200** for positioning the unmanned aerial vehicle **100** (illustrated by the representative UAV **2320**) for charging according to various embodiments. Referring to FIGS. **1-27**, the representative UAV **2320** may be a simplified representation of the unmanned aerial vehicle **100** showing a charging engagement element **2330** (e.g., the front hooks **1810** and the hook members **1820**) and a coupling sensor **2340** (e.g., at least one of the sensors **810**). The coupling sensor **2340** may be any suitable sensor or cameras that determines the position/orientation of the unmanned aerial vehicle **100** with respect to the engagement device (e.g., a wire **2310**) of the charging apparatus. Other parts of the unmanned aerial vehicle **100** are not shown for the sake of brevity and clarity.

The wire **2310** may be the engagement device of the charging apparatus. The cross section of the wire **2310** may be shown in FIGS. **23-27**. The rest of the charging apparatus is not shown for the sake of brevity and clarity.

FIG. **23** illustrates the representative UAV **2320** in an initial position GX **5600** moving toward the predetermined position and orientation with respect to the charging apparatus (e.g., at block B**2210**). For example, the representative UAV **2320** may be moving in a first direction **2350** toward the wire **2310** initially. In some embodiments, the representative UAV **2320** may be moving in the first direction **2350** based on user input of the operator via suitable controls. In some embodiments, the representative UAV **2320** may be moving in the first direction **2350** based, at least in part, on the sensor output from the coupling sensor **2340**. For example, the coupling sensor **2340** may be a camera mounted on the representative UAV **2320** providing the operator with images or videos of objects in front of (in the front direction **101**) of the representative UAV **2320**. In other examples, the processor **802** may automatically determine the first direction **2350** based on output provided by the coupling sensor **2340**.

FIG. **24** illustrates the representative UAV **2320** being in the predetermined position and orientation GX **5700** with respect to the charging apparatus (e.g., B**2220**: YES). In the non-limiting example illustrated herein, the predetermined position and orientation of the representative UAV **2320** may include the representative UAV **2320** being directly above the wire **2310** after the charging engagement element **2330** of the representative UAV **2320** has passed over the wire **2310** in the first direction **2350**. In other words, the wire **2310** may be in the bottom direction **106** with respect to the representative UAV **2320**. The predetermined position and orientation of the representative UAV **2320** may also correspond to the charging engagement element **2330** (or at least the end portions of the charging engagement element **2330**) surpassing the wire **2310** in the first direction **2350**.

Once in the predetermined position and orientation, the representative UAV **2320** may be configured to move in a second direction **2450** to reach the coupling position and orientation (as shown in FIG. **25**). The second direction **2450** may be substantially perpendicular to the first direction **2350**. The second direction **2450** may be the bottom direction **106**. In response to reaching the predetermined position and orientation, the processor **802** may cause the representative UAV **2320** to descend into the coupling position/orientation in the second direction **2450**. In some embodiments, the processor **802** may cause the air propulsion motors **814** to decrease lift of the representative UAV **2320**. In other embodiments, the processor **802** may simply cause the air propulsion motors **814** to shut off, allowing the representative UAV **2320** to free fall onto the wire **2310** into the coupling position/orientation.

FIG. **25** illustrates the representative UAV **2320** in the coupling position/orientation **2500** with respect to wire **2310** of the charging apparatus (e.g., B**2230**). The representative UAV **2320** may fall onto the wire **2310** as it moves in the second direction **2450**. At least a portion of the representative UAV **2320** may contact the wire **2310**. Such portion may be a part of the charging engagement element **2330** or any other bottom portion that is positioned between the center of mass of the representative UAV **2320** and the charging engagement element **2330**. This allows the body of the representative UAV **2320** to move in the third direction **2550** into the charging position and orientation as shown in FIG. **26** in a falling motion, as the air propulsion motors **814** may be shut off. The charging engagement element **2330** may accordingly be engaged (e.g., hooked) on the wire **2310**.

FIG. **26** illustrates the representative UAV **2320** in a charging position and orientation **2600** with respect to wire **2310** of the charging apparatus (e.g., B**2240**). The representative UAV **2320** is shown to be at a perched position with the charging engagement element **2330** being hooked on the wire **2310**. In other words, the representative UAV **2320** may be hung on the wire **2310**.

The orientation of the representative UAV **2320** in the charging position and orientation **2600** may be substantially perpendicular to the representative UAV **2320** in the coupling position and orientation **2500**, the predetermined position and orientation **2400**, and/or the initial position and orientation **2300**. In some embodiments, the representative UAV **2320** may not be perched at an exact perpendicular angle, given the mass distribution of the representative UAV **2320**. The charging engagement element **2330** may serve as the charging device while the wire **2310** may be the transfer unit (e.g., including inductive coils or other elements for inductive or wired charging). Thus, power may be transferred from the wire **2310** to the charging engagement element **2330**, where the power may be relayed to the energy storage devices of the representative UAV **2320**. FIG. **26** may correspond to the process **2100***a*.

FIG. **27** illustrates the representative UAV **2320** in a charging position and orientation **2700** with respect to wire **2310** of the charging apparatus (e.g., B**2240**). The position and orientation of the representative UAV **2320** may the same or similar to shown with respect to FIG. **26**. The charging apparatus may include a transfer unit **2720** that is a separate element than the wire **2310**. The representative UAV **2320** may also include a charging device **2730** that is a separate element than the charging engagement element **2330**. FIG. **27** may correspond to the process **2100***b*.

When the representative UAV **2320** is in the charging position/orientation **2700** as shown, the transfer unit **2720** and the charging device **2730** may come into contact or within an acceptable proximity for wired or wireless charging. Thus, power may be transferred from the transfer unit **2720** to the charging device **2730**, where the power may be relayed to the energy storage devices of the representative UAV **2320**. Cushions or other motion dampers may be provided at the transfer unit **2720**, the charging device **2730**, or both to reduce or prevent impact damage as the representative UAV **2320** moves from the coupling position/orientation **2500** to the charging position/orientation **2700** in the third direction **2550**.

FIG. **28** shows a schematic diagram of various components of the unmanned aerial vehicle **100** according to various embodiments. With reference to FIGS. **1-28**, in some embodiments, the components of the unmanned aerial vehicle **100** may be reclassified based on motion, vibration, or other types of physical impact. The unmanned aerial vehicle **100** may include at least motion source elements **2810**, motion transfer elements **2820**, motion dampening elements **2830**, reference elements **2840**, and motion-sensitive elements **2850**.

The motion source elements **2810** may include components of the unmanned aerial vehicle **100** that may generate motion, vibration, or other types of physical displacement with respect to the rest of the unmanned aerial vehicle **100**. Such motion, vibration, or physical displacement may occur in addition to the motion of the unmanned aerial vehicle **100** as a whole. For example, the motion source elements **2810** may include the aerial propulsion devices **130**, rotor motors **132**, propellers **134**, a combination thereof, and/or the like.

The motion transfer elements **2820** may include components of the unmanned aerial vehicle **100** that transfer or relay the motion, vibration, or other types of physical displacement to other components of the unmanned aerial vehicle **100**. In some embodiments, the motion transfer elements **2820** may not generate motion by itself. In other embodiments, the motion transfer elements **2820** may itself be capable of motion generating as well as motion transfer. Examples of the motion transfer elements **2820** may include portions of the frame **110** (or any components) connected/linked to the motion source elements **2810**, where each of the motion transfer elements **2820** may have material properties (e.g., rigidity) that are capable of substantially transfer motion to other components.

The motion-sensitive elements **2850** may include components of the unmanned aerial vehicle **100** that are sensitive to internal motion, vibration, or other types of physical displacement within the unmanned aerial vehicle **100**. Such motion-sensitive elements **2850** may generally include motion-sensitive sensors (e.g., the sensor devices **199**). The motion-sensitive sensors may include, but not limited to, depth-determining cameras, stereo cameras, motion sensor, accelerometer, a combination thereof, and/or the like. Such motion-sensitive elements **2850** may also include fragile components that may be damaged by motion within the unmanned aerial vehicle **100**. In various embodiments, the motion-sensitive elements **2850** may be grouped together and installed on panels, sleds, plates, portions of the frame **110**. Such on panels, sleds, plates, portions of the frame **110** may be the reference elements **2840**.

The reference elements **2840** may include components of the unmanned aerial vehicle **100** connected or linked to the motion sensitive elements **2850**. The reference elements **2840** may be bases or foundations on which the motion sensitive elements **2850** are provided. The reference elements **2840** may also be motion transfer elements **2820** given that the reference elements **2840** may be composed of material that is capable of substantially transferring motion from the motion source elements **2810** to the motion-sensitive elements **2850**.

The motion dampening elements **2830** may be components of the unmanned aerial vehicle **100** that connect the motion transfer elements **2820** and the reference elements **2840**. In addition, the motion dampening elements **2830** may be configured to dampen the motion from the motion transfer elements **2820** or the motion source elements **2810** themselves. As such, the motion felt by the reference elements **2840** and the motion-sensitive elements **2850** may be substantially reduced. The motion dampening elements **2830** may be components having flexible or elastic properties. Examples of the motion dampening elements **2830** may include, but not limited to, spring configurations, rubber grommets, shock absorbers, a combination thereof, and/or the like.

FIG. **29** is a perspective view of a portion of the unmanned aerial vehicle **100** according to various embodiments. FIG. **30** is a front view of a portion of the unmanned aerial vehicle **100** according to various embodiments. FIG. **31** is a top view of a portion of the unmanned aerial vehicle **100** according to various embodiments. FIG. **32** is a side view of a portion of the unmanned aerial vehicle **100** according to various embodiments.

Referring to FIGS. **1-32**, the unmanned aerial vehicle **100** may include the motion source elements **2810** such as, but not limited to, the aerial propulsion devices **130**, rotor motors **132**, and propeller **134**. The unmanned aerial vehicle **100** may include the motion transfer elements **2820** such as, but not limited to, a first frame portion **2920** and a second frame portion **2925**. The first frame portion **2920** and/or the second frame portion **2925** may be a portion of the frame **110**.

The unmanned aerial vehicle **100** may additionally include the reference elements **2840** such as, but not limited to, the panel **2930**. The panel **2930** may be provided at a front portion (at either side) of the unmanned aerial vehicle **100**. A front surface of the panel **2930** may be facing in the front direction **101**. In some embodiments, a surface of the first frame portion **2920** may be parallel to the front surface (and/or a rear surface) of the panel **2930**. The unmanned aerial vehicle **100** may include the motion-sensitive elements **2850** such as, but not limited to the sensor devices **199**. The sensor devices **199** may be provided on the panel **2930** in suitable configurations (e.g., at the front surface of the panel **2930**).

In addition, the unmanned aerial vehicle **100** may be provided with the motion dampening elements **2830** including, but not limited to, a first damper unit **2910** and a second damper unit **2915**. Each of the first damper unit **2910** and the second damper unit **2915** may be a cylindrical rubber grommet. The first damper unit **2910** may be positioned between the first frame portion **2920** and the panel **2930**. The first damper unit **2910** may be provided at the rear surface of the panel **2930**, the rear surface being opposite to the front surface. The second damper unit **2915** may be positioned between the second frame portion **2925** and the panel **2930**. Given the flexible/elastic characteristics of the first damper unit **2910** and the second damper unit **2915**, the impact of the motion/vibration caused by the aerial propulsion devices **130**, rotor motors **132**, and propeller **134** may be substantially reduced.

A first end of the first damper unit **2910** may be in contact or otherwise provided to the first frame portion **2920**. A second end of the first damper unit **2910** may be in contact or otherwise provided to a first portion of the panel **2930**. A first end of the second damper unit **2915** may be in contact or otherwise provided to the second frame portion **2925**. A second end of the second damper unit **2915** may be in contact or otherwise provided to a second portion of the panel **2930**.

For example, the motion/vibration caused by the aerial propulsion devices **130**, rotor motors **132**, and propeller **134** may be felt by the first frame portion **2920** and the second frame portions **2925**. The first frame portion **2920** and the second frame portions **2925** may transfer the motion/vibration to the first damper unit **2910** and the second damper unit **2915**, respectively. The motion/vibration may then be attenuated due to the material properties of the first damper unit **2910** and the second damper unit **2915**. Accordingly, the panel **2930** and the sensor devices **199** received on the panel **2930** may receive only a fraction of the motion/vibration originally caused by the aerial propulsion devices **130**, rotor motors **132**, and propeller **134**.

In some embodiments, the first damper unit **2910** (extending along the x-direction) may be perpendicular to the surface of the first frame portion **2920** (extending along the y-z plane) and/or a surface of the panel **2930** (extending along the y-z plane). Thus, the first damper unit **2910** is adapt at attenuating the motion/vibration propagated through the first damper unit **2910** in the x-direction.

In some embodiments, the second damper unit **2915** (extending along a direction having a x-direction component, y-direction component, and z-direction component) may be substantially perpendicular to a surface of the second frame portion **2925** (extending along a direction having a x-direction component, y-direction component, and a z-direction component) and/or a surface of the panel **2930**. Thus, the second damper unit **2915** is adapt at attenuating the motion/vibration propagated through the second damper unit **2915** in the x-direction, y-direction, and z-direction.

One of the ordinary skill in the art would appreciate that various embodiments are illustrate non-limiting examples of the motion dampening elements **2830**. Further examples include the damper units (e.g., the first damper unit **2910**, the second damper unit **2915**, and/or the like) extending in two or more directional axes. This allows damping of momentum/force in multiple directions to allow improved stability as compared in damping in only one directional axis.

FIG. **33** is a perspective view of a portion of the unmanned aerial vehicle **100** according to various embodiments. FIG. **34** is a bottom view of a portion of the unmanned aerial vehicle **100** according to various embodiments. FIG. **35** is a side view of a portion of the unmanned aerial vehicle **100** according to various embodiments. FIG. **36** is a rear view of a portion of the unmanned aerial vehicle **100** according to various embodiments. FIGS. **33-36** illustrates embodiments in which motion/vibration impacts electronics **3390** (such as the sensors **199**, **810**, and/or electronic components) may be reduced by damper units **3310**, **3312**, **3314**, and **3316** in a sled configuration.

Referring to FIGS. **1-36**, the unmanned aerial vehicle **100** may include motion source elements **2810** such as, but not limited to, the aerial propulsion devices **130**, rotor motors **132**, and propeller **134**. The unmanned aerial vehicle **100** may include motion transfer elements **2820** such as, but not limited to, a base frame **3320**. The base frame **3320** may be a portion of the frame **110**. The unmanned aerial vehicle **100** may additionally include reference elements **2840** such as, but not limited to, a sled plate **3330**. The sled plate **3330** may be provided at a bottom portion of the unmanned aerial vehicle **100** and is in the bottom direction **106** as compared to the rest of the unmanned aerial vehicle **100**. A top surface of the sled plate **3330** may be facing in the top direction **105**. In some embodiments, a surface of the base frame **3320** may be parallel to the top surface (and/or a bottom surface) of the sled plate **3330**. The unmanned aerial vehicle **100** may include the motion-sensitive elements **2850** such as, but not limited to, the electronics **3390**. The electronics **3390** may be suitable sensors and may be provided on sled plate **3330** in suitable configurations.

In addition, the unmanned aerial vehicle **100** may be provided motion dampening elements **2830** including, but not limited to, a third damper unit **3310**, fourth damper unit **3312**, fifth damper unit **3314**, and sixth damper unit **3316**. Each of the third damper unit **3310**, fourth damper unit **3312**, fifth damper unit **3314**, and sixth damper unit **3316** may be a cylindrical rubber grommet. Each of the third damper unit **3310**, fourth damper unit **3312**, fifth damper unit **3314**, and sixth damper unit **3316** may be positioned between the base frame **3320** and the sled plate **3330**. For example, each of the third damper unit **3310**, fourth damper unit **3312**, fifth damper unit **3314** (or vice versa), and sixth damper unit **3316** may be provided at the top surface of the sled plate **3330**, the top surface being opposite to the bottom surface of the sled plate **3330**. Given the flexible/elastic characteristics of the third damper unit **3310**, fourth damper unit **3312**, fifth damper unit **3314**, and sixth damper unit **3316**, the impact of the motion/vibration caused by the aerial propulsion devices **130**, rotor motors **132**, and propeller **134** may be substantially reduced.

A first end of each of the third damper unit **3310**, fourth damper unit **3312**, fifth damper unit **3314**, and sixth damper unit **3316** may be in contact or otherwise provided to the base frame **3320**. A second end of the each of the third damper unit **3310**, fourth damper unit **3312**, fifth damper unit **3314**, and sixth damper unit **3316** may be in contact or otherwise provided to top surface of the sled plate **3330**.

For example, the motion/vibration caused by the aerial propulsion devices **130**, rotor motors **132**, and propeller **134** may be felt by the base frame **3320**. The base frame **3320** may transfer the motion/vibration to the third damper unit **3310**, fourth damper unit **3312**, fifth damper unit **3314**, and sixth damper unit **3316**. The motion/vibration may then be attenuated due to the material properties of the third damper unit **3310**, fourth damper unit **3312**, fifth damper unit **3314**, and sixth damper unit **3316**. Accordingly, the sled plate **3330** and the electronics **3390** received on the sled plate **3330** may receive only a fraction of the motion/vibration originally caused by the aerial propulsion devices **130**, rotor motors **132**, and propeller **134**.

In some embodiments, the third damper unit **3310**, fourth damper unit **3312**, fifth damper unit **3314**, and sixth damper unit **3316** may extend alone the z-direction. The third damper unit **3310**, fourth damper unit **3312**, fifth damper unit **3314**, and sixth damper unit **3316** may be perpendicular to the surface of the base frame **3320** (extending in the x/y plane) and/or the top surface (and/or a bottom surface) of the sled plate **3330** (extending in the x/y plane). Thus, the third damper unit **3310**, fourth damper unit **3312**, fifth damper unit **3314**, and sixth damper unit **3316** may be adapt at attenuating the motion/vibration propagated through each of the third damper unit **3310**, fourth damper unit **3312**, fifth damper unit **3314**, and sixth damper unit **3316** in the z-direction.

Loads such as the electronics **3390** may be carried at either the top surface or the bottom surface of the sled plate **3330**. In some embodiments, loads may be provided to be carried by the sled plate **3330** in any suitable manner to aggregate a weight of sufficient mass to stabilize flight and further dampen motions caused by the motion dampening elements **2830**. For example, heavy loads carried at the sled plate **3330** may cause higher inertia associated with the loads and the sled plate **3330**. Higher inertia will, in turn, further cause the loads and the sled plate **3330** to be resistant to movement. Therefore, heavier components such as batteries, PCDs, sensor, and/or the like may be provided as loads. In some embodiments, the loads, including the sled plate **3330**, may be detachable.

FIG. **37** shows a rear view of a portion of a schematic representation of a damping system **7000** according to various embodiments. FIG. **38** is a side view of a portion of the schematic representation of the damping system **7000** according to various embodiments. The schematic representation **7000** may be a simplified diagram of a portion of the unmanned aerial vehicle **100**. The FIGS. **37** and **38** may illustrate embodiments of the motion dampening elements **2830** (e.g., FIG. **28**) having components in three coordinate axes for dampening of motion and vibration in all directions.

With reference to FIGS. **1-38**, in some embodiments, a first plate **3710** may correspond to any motion transfer elements **2820** described herein. A second plate **3720** may correspond to any reference elements **2840** described herein. A first damper **3730**, a second damper **3732**, and a third damper **3734** may correspond to any motion dampening elements **2830** described herein.

In some embodiments, the first damper **3730**, second damper **3732**, and third damper **3734** may be angled at an angel with respect to each of the first plate **3710** and the second plate **3720** in the x-direction, the y-direction, and the z-direction. The angles may include, but not limited to, 30 degrees, 45 degrees, 60 degrees, and/or the like. By virtue of the first damper **3730**, second damper **3732**, and third damper **3734** having directional elements in all three axes, motion/vibration in any of the directions may be reduced.

The previous description is provided to enable any person skilled in the art to practice the various aspects described herein. Various modifications to these aspects will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other aspects. Thus, the claims are not intended to be limited to the aspects shown herein, but is to be accorded the full scope consistent with the language claims, wherein reference to an element in the singular is not intended to mean "one and only one" unless specifically so stated, but rather "one or more." Unless specifically stated otherwise, the term "some" refers to one or more. All structural and functional equivalents to the elements of the various aspects described throughout the previous description that are known or later come to be known to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed by the claims. Moreover, nothing disclosed herein is intended to be dedicated to the public regardless of whether such disclosure is explicitly recited in the claims. No claim element is to be construed as a means plus function unless the element is expressly recited using the phrase "means for."

It is understood that the specific order or hierarchy of steps in the processes disclosed is an example of illustrative approaches. Based upon design preferences, it is understood that the specific order or hierarchy of steps in the processes may be rearranged while remaining within the scope of the previous description. The accompanying method claims present elements of the various steps in a sample order, and are not meant to be limited to the specific order or hierarchy presented.

The previous description of the disclosed implementations is provided to enable any person skilled in the art to make or use the disclosed subject matter. Various modifications to these implementations will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other implementations without departing from the spirit or scope of the previous description. Thus, the previous description is not intended to be limited to the implementations shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

What is claimed is:

1. An unmanned aerial vehicle, comprising:

a frame portion oriented on a horizontal plane;

two rear arms extending away in fixed directions from the frame portion at an acute angle relative to one another to form a V-shape between the two rear arms;

two rear air propulsion devices, each coupled to a corresponding one of the rear arms and each having an axis of rotation including a component in a bottom direction perpendicular to the horizontal plane and including a component in a side direction coplaner with the horizontal plane;

two front arms parallel to each other and extending away in fixed directions from the frame portion along the horizontal plane, wherein ends of the two rear arms are elevated, relative to the two front arms, in a top direction; and

two front air propulsion devices, each coupled to a corresponding one of the front arms and each having an axis of rotation in the bottom direction.

2. The unmanned aerial vehicle of claim **1**, wherein each of the front air propulsion devices is configured to face the bottom direction.

3. The unmanned aerial vehicle of claim **1**, wherein:

the axis of rotation of a first of the rear air propulsion devices comprises a first direction forming an acute angle with the bottom direction; and

the axis of rotation of a second of the rear air propulsion devices comprises a second direction forming an acute angle with the bottom direction, wherein the first direction is different than the second direction.

4. The unmanned aerial vehicle of claim **1**, wherein the axis of rotation of each of the rear air propulsion devices is fixed.

5. The unmanned aerial vehicle of claim **1**, wherein the axis of rotation of each of the front air propulsion devices is fixed.

6. The unmanned aerial vehicle of claim **1**, wherein the axis of rotation component in the bottom direction is configured for lift, and the axis of rotation component in the side direction is configured for rotation.

7. The unmanned aerial vehicle of claim **1**, further comprising a charging engagement element.

8. The unmanned aerial vehicle of claim **1**, further comprising:

a camera configured to face a front direction and vibration isolated from the front air propulsion devices.

9. The unmanned aerial vehicle of claim **8**, wherein:

at least one of the front arms comprises a frame and a panel;

the camera is arranged on the panel; and

the at least one front air propulsion device is arranged on the frame.

10. The unmanned aerial vehicle of claim **9**, further comprising a vibration dampener between the panel and the frame.

11. The unmanned aerial vehicle of claim **7**, wherein the charging engagement element is configured to charge the unmanned aerial vehicle.

12. The unmanned aerial vehicle of claim **11**, wherein the charging engagement element includes a number of hook members.

13. The unmanned aerial vehicle of claim **12**, wherein the number of hook members are part of the frame portion.

14. The unmanned aerial vehicle of claim **13**, wherein each of the number of hook members extends from the frame portion in a different direction.

15. A method of providing an unmanned aerial vehicle, comprising:

providing a frame portion oriented on a horizontal plane;

providing two rear arms extending away in fixed directions from the frame portion at an acute angle relative to one another to form a V-shape between the two rear arms;

providing two rear air propulsion devices, each coupled to a corresponding one of the rear arms and each having an axis of rotation including a component in a bottom direction perpendicular to the horizontal plane and including a component in a side direction coplaner with the horizontal plane;

providing two front arms parallel to each other and extending away in fixed directions from the frame portion along the horizontal plane, wherein ends of the two rear arms are elevated, relative to the two front arms, in a top direction; and

providing two front air propulsion devices, each coupled to a corresponding one of the front arms and each having an axis of rotation in the bottom direction.

16. The method of claim **15**, wherein each of the front air propulsion devices is configured to face the bottom direction.

17. The method of claim **15**, wherein the axis of rotation component in the bottom direction is configured for lift, and the axis of rotation component in the side direction is configured for rotation.

18. The method of claim **15**, further comprising:

providing a charging engagement element configured to charge the unmanned aerial vehicle.

19. The method of claim **15**, wherein:

the axis of rotation of a first of the rear air propulsion devices comprises a first direction forming an angle with the bottom direction; and

the axis of rotation of a second of the rear air propulsion devices comprises a second direction forming an angle with the bottom direction, wherein the first direction is different than the second direction.

20. The method of claim **19**, wherein the first and second directions are orthogonal to each other.

21. The method of claim **15**, further comprising:

providing a camera configured to face a front direction.

22. The method of claim **21**, wherein the camera is vibration isolated from the front air propulsion devices.

23. An unmanned aerial vehicle, comprising:

a frame portion oriented on a horizontal plane;

first and second rear arms extending away in fixed directions from the frame portion at acute angles relative to one another to form a V-shape between the first and second rear arms;

a first rear air propulsion device coupled to the first rear arm and having a fixed axis of rotation in a first direction non-orthogonal to the horizontal plane;

a second rear air propulsion device coupled to the second rear arm and having a fixed axis of rotation in a second direction non-orthogonal to the horizontal plane, wherein the first and second directions are orthogonal to each other; and

first and second front arms parallel to each other and extending away in fixed directions from the frame portion along the horizontal plane.

24. The unmanned aerial vehicle of claim **23**, wherein ends of the rear arms are elevated, relative to the front arms, in a top direction.

25. The unmanned aerial vehicle of claim **23**, further comprising:

a first front air propulsion device coupled to the first front arm and having an axis of rotation in a bottom direction perpendicular to the horizontal plane; and

a second front air propulsion device coupled to the second front arm and having an axis of rotation in the bottom direction.

26. The unmanned aerial vehicle of claim **25**, wherein the axis of rotation of each of the front air propulsion devices is fixed.

27. The unmanned aerial vehicle of claim **23**, further comprising a charging engagement element configured to charge the unmanned aerial vehicle.

28. The unmanned aerial vehicle of claim **27**, wherein the charging engagement element includes a number of hook members extending from the frame portion in a different direction.

* * * * *

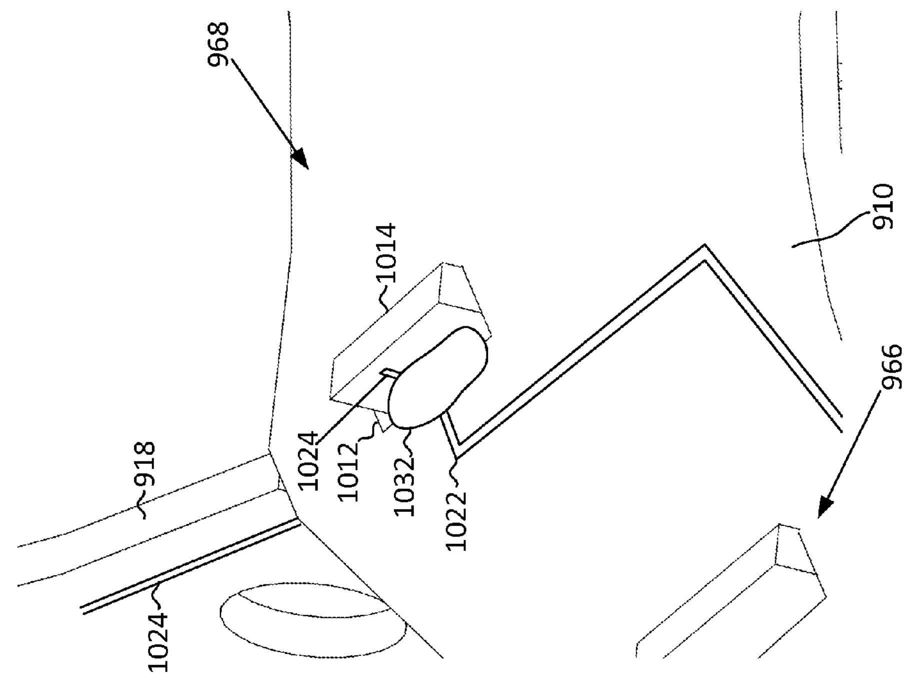


Figure 10B

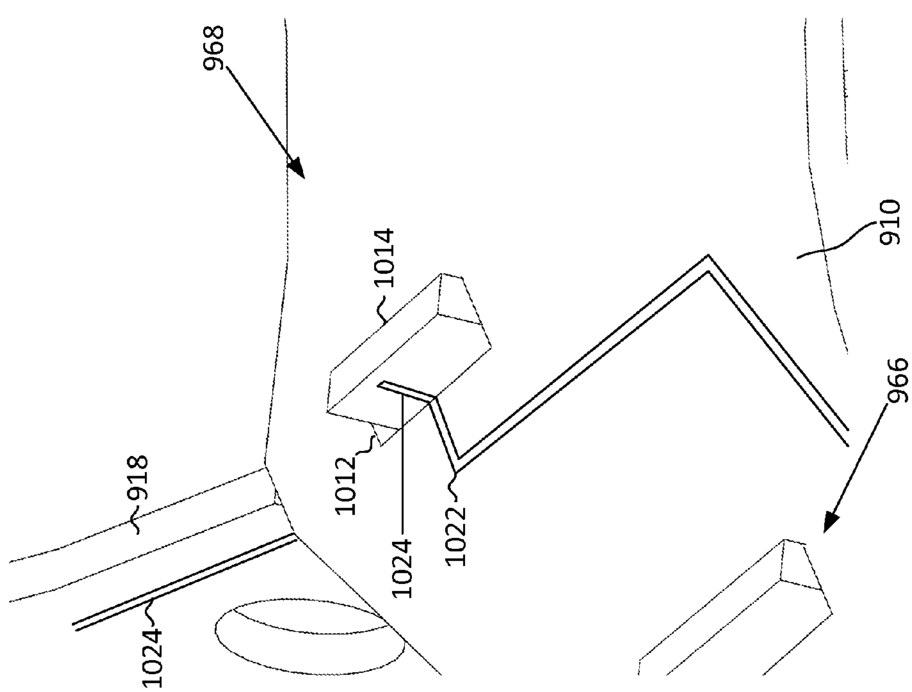


Figure 10A

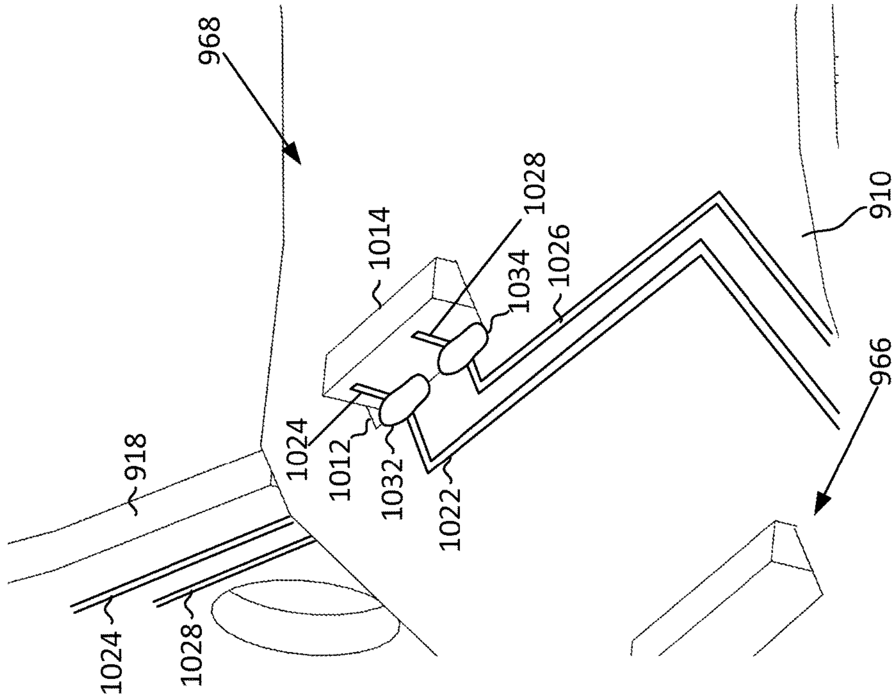


Figure 12B

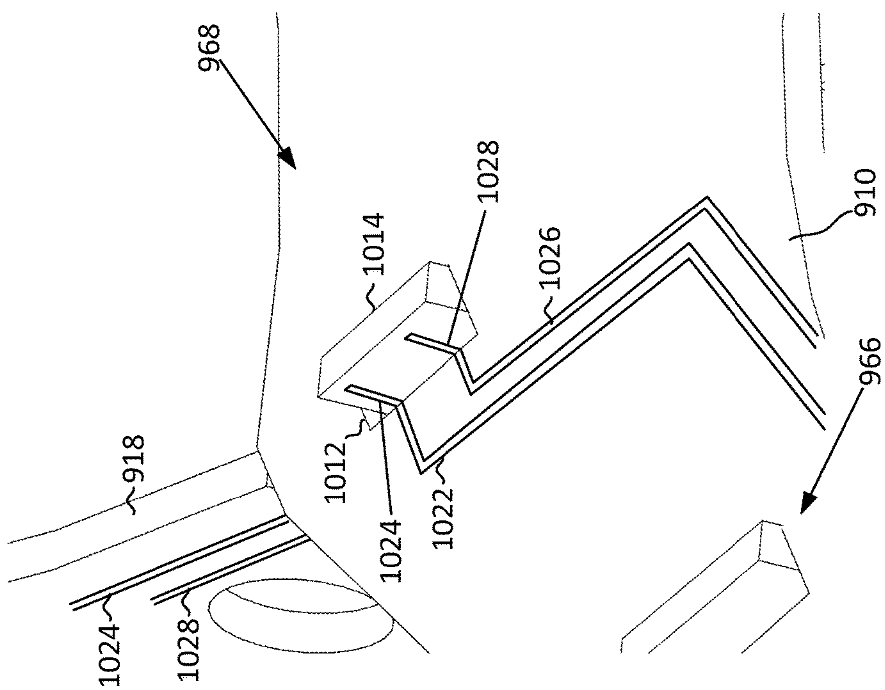
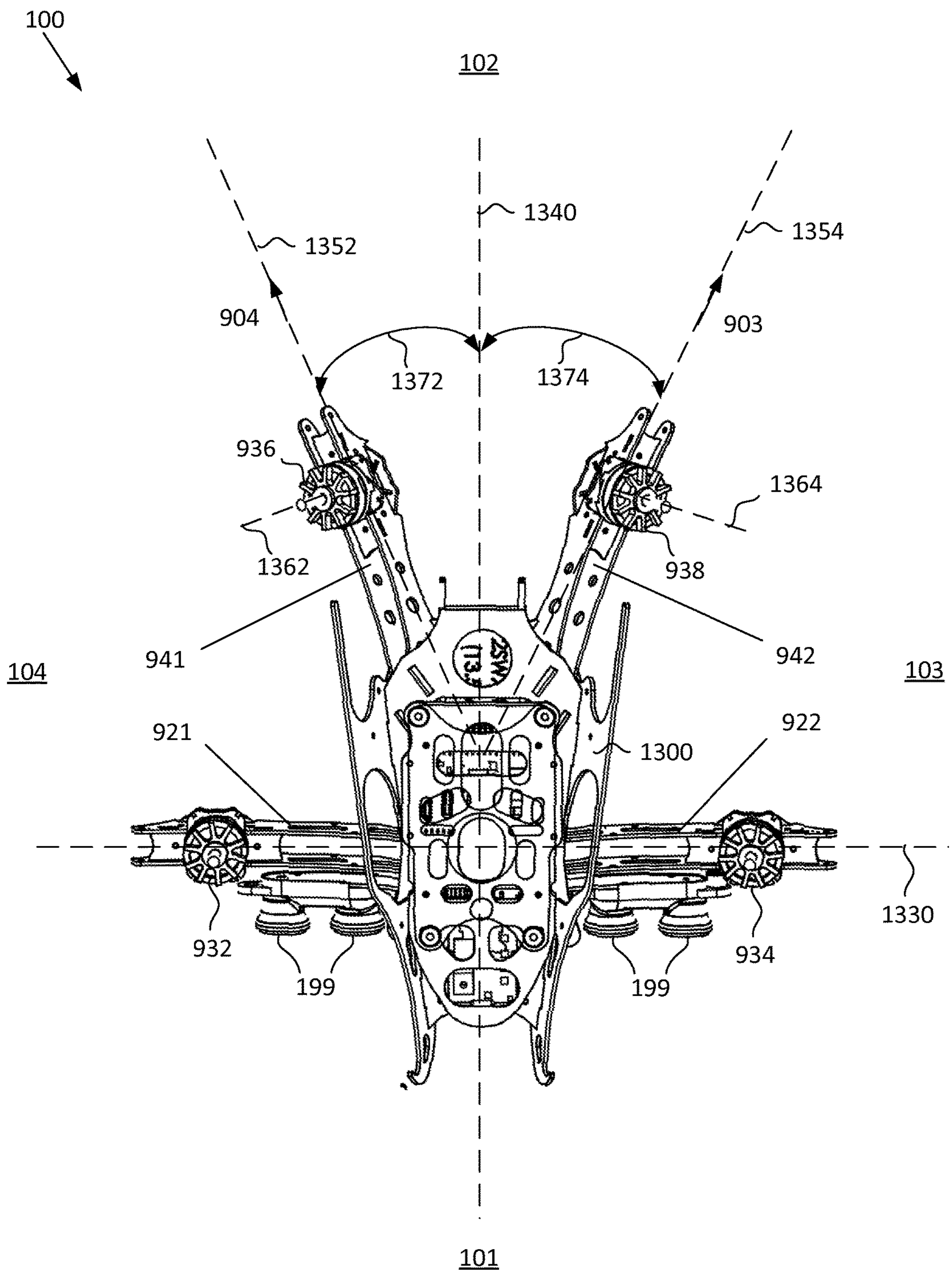


Figure 12A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1364
1362
938
941
942
104
103
921
922
1300
932
934
1330
199
199
101

Figure 14

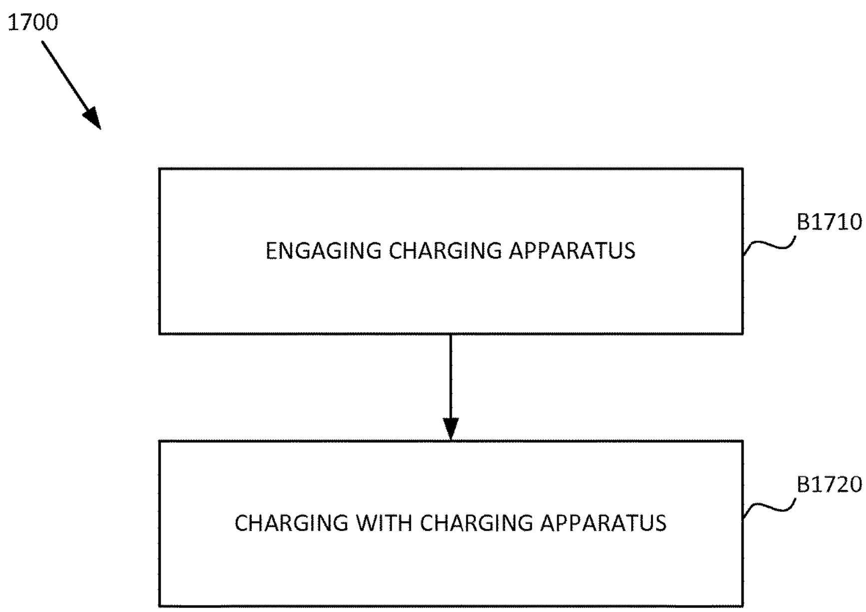
1700
ENGAGING CHARGING APPARATUS
B1710
CHARGING WITH CHARGING APPARATUS
B1720

Figure 17

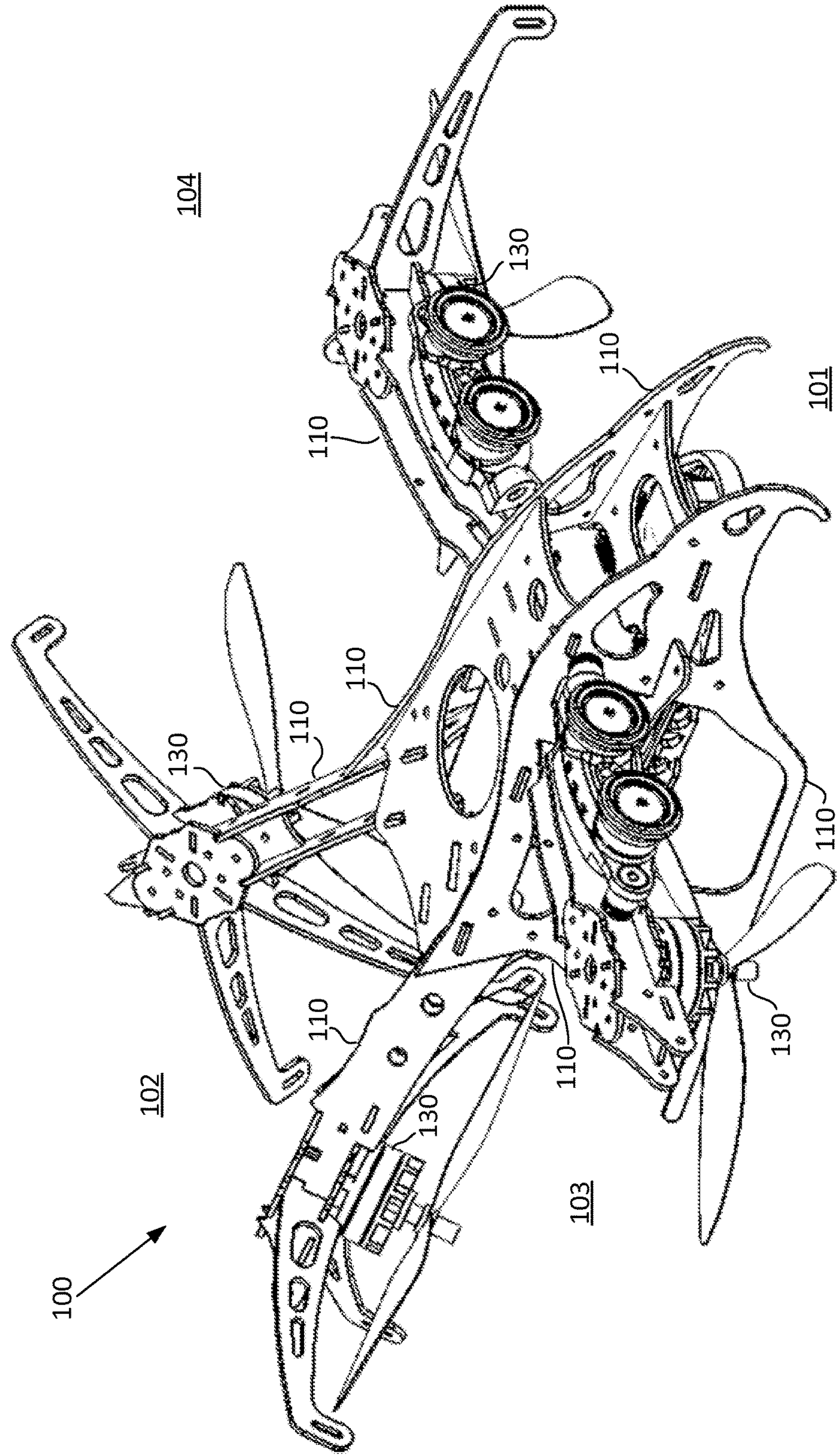

Figure 1

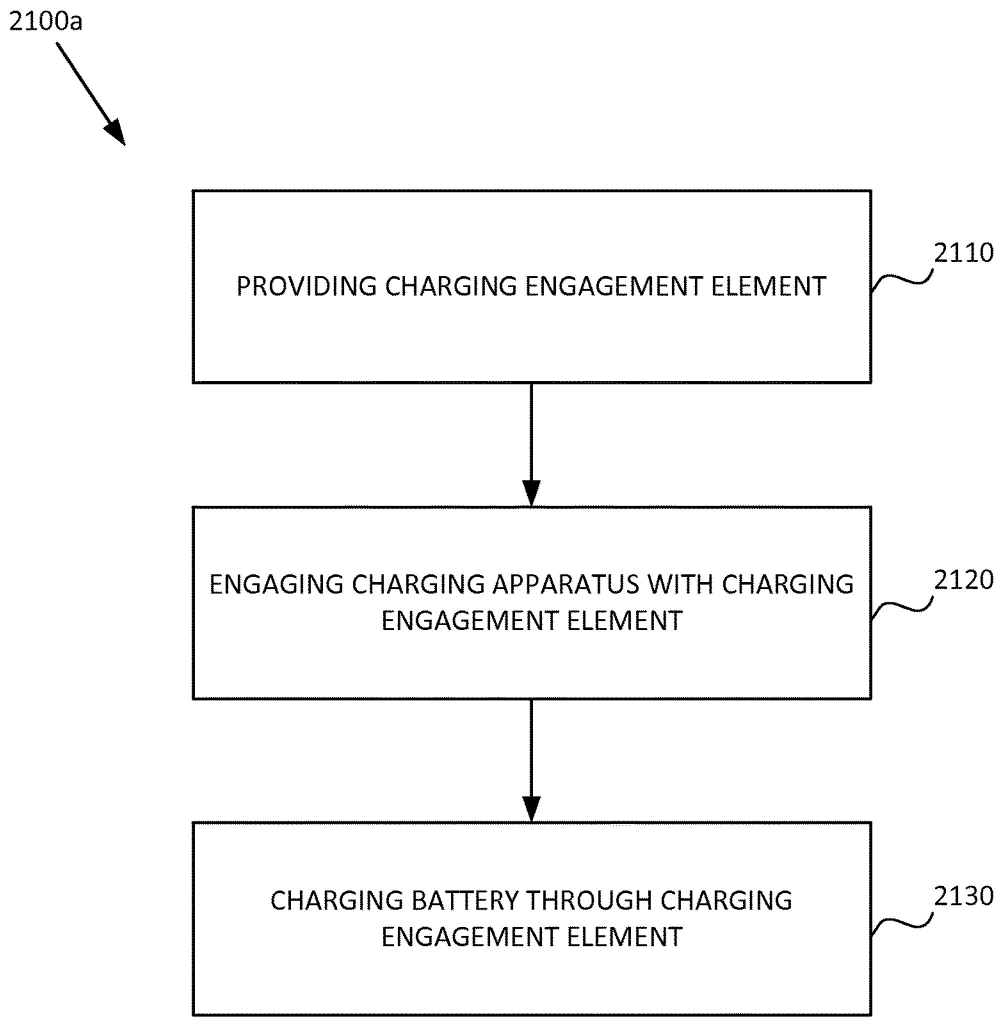
2100a
PROVIDING CHARGING ENGAGEMENT ELEMENT
2110
ENGAGING CHARGING APPARATUS WITH CHARGING ENGAGEMENT ELEMENT
2120
CHARGING BATTERY THROUGH CHARGING ENGAGEMENT ELEMENT
2130

Figure 21A

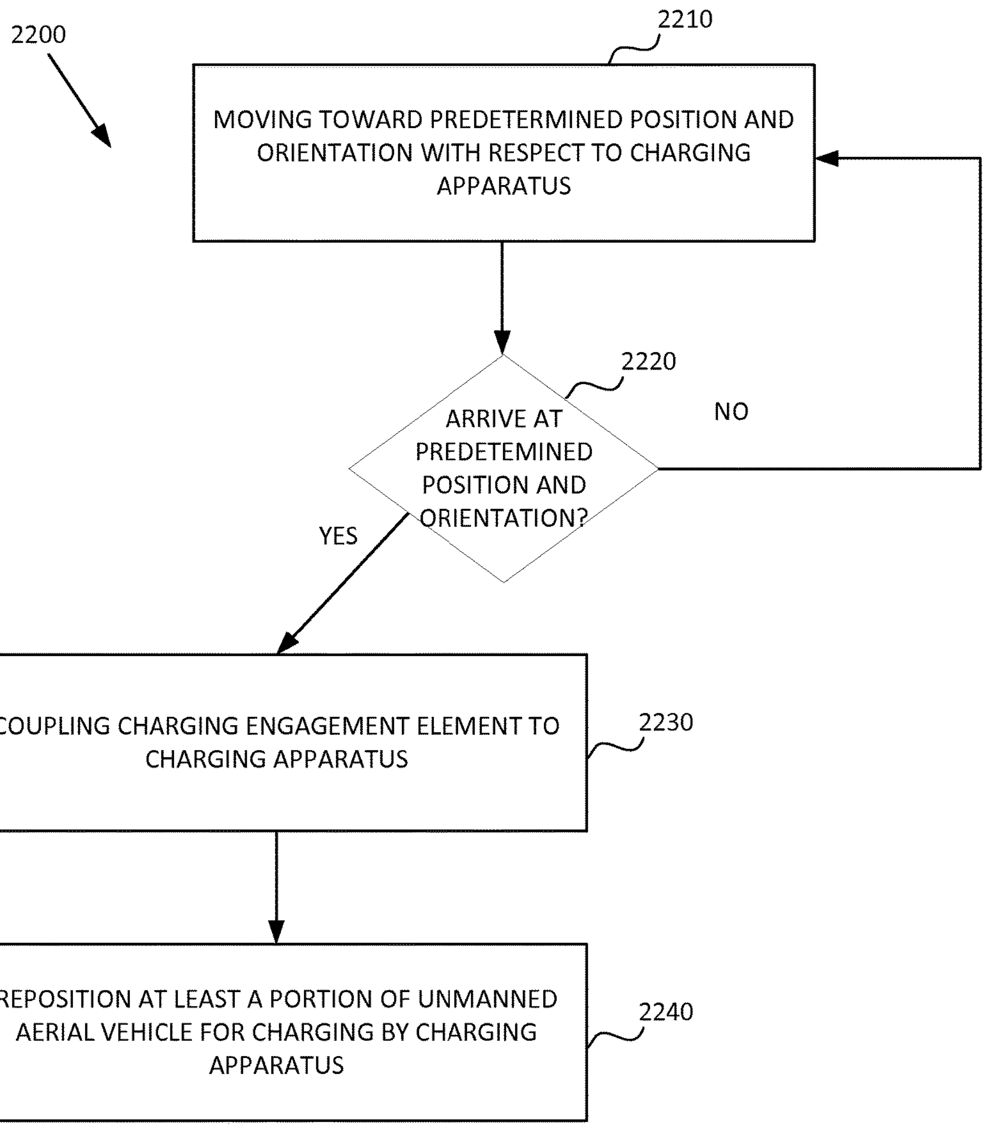
2200
2210
MOVING TOWARD PREDETERMINED POSITION AND ORIENTATION WITH RESPECT TO CHARGING APPARATUS
2220
ARRIVE AT PREDETEMINED POSITION AND ORIENTATION?
NO
YES
COUPLING CHARGING ENGAGEMENT ELEMENT TO CHARGING APPARATUS
2230
REPOSITION AT LEAST A PORTION OF UNMANNED AERIAL VEHICLE FOR CHARGING BY CHARGING APPARATUS
2240

Figure 22

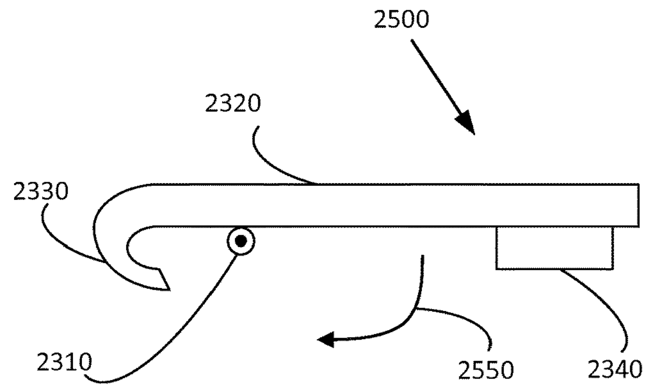

Figure 25

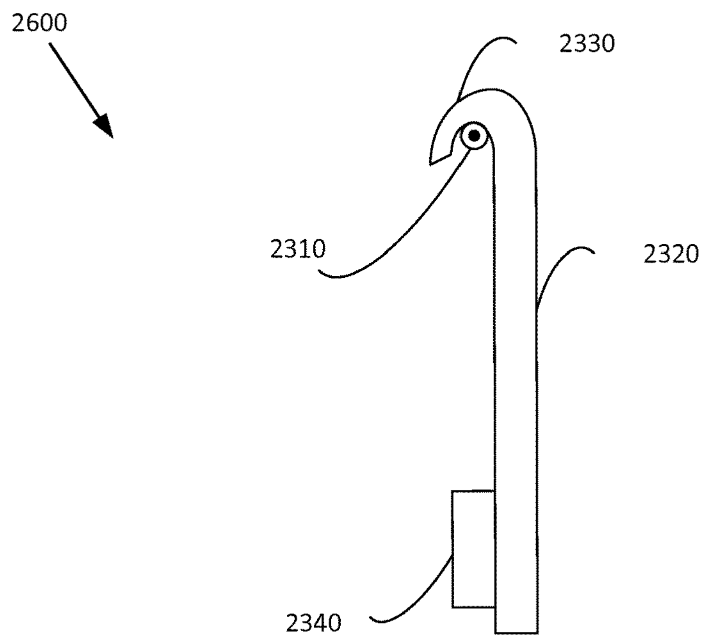

Figure 26

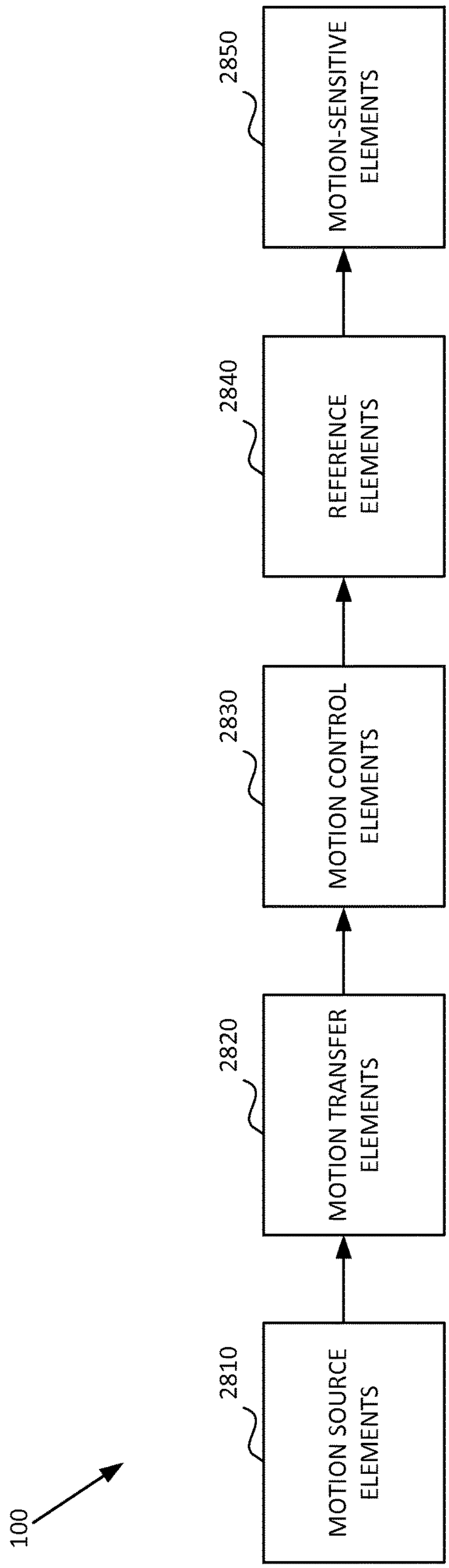
100
2810
MOTION SOURCE ELEMENTS
2820
MOTION TRANSFER ELEMENTS
2830
MOTION CONTROL ELEMENTS
2840
REFERENCE ELEMENTS
2850
MOTION-SENSITIVE ELEMENTS

Figure 28