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Condon et al.

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(54) **REMOTE-CONTROL FLYING CRAFT**

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(51) **Int. Cl.**
A63H 27/127 (2006.01)
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(52) **U.S. Cl.**
CPC **A63F 13/235** (2014.09); **A63F 13/00** (2013.01); **A63F 13/245** (2014.09);
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(58) **Field of Classification Search**

USPC 446/34, 36, 37, 38, 48, 219, 454, 456, 446/457; 244/17.11, 17.23, 17.25
See application file for complete search history.

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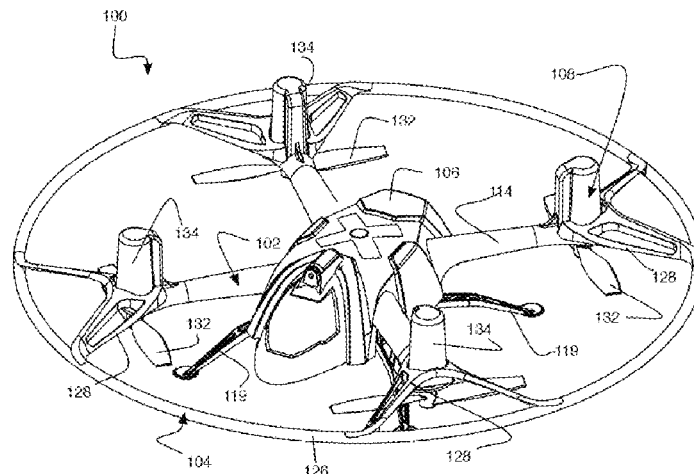
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(57) **ABSTRACT**

A hovering remote-control flying craft having a molded frame assembly includes a plurality of arms extending from a center body with an electric motor and corresponding propeller on each arm. In various embodiments, the motor and propeller are mounted downward-facing at a distal portion of each arm with a motor cover over the motor. The center body can be formed of a two-piece molded structure that sandwiches a circuit board to provide structural support for the frame. The circuit board can include a plurality of tabs that facilitate mounting of wire connectors, and can also provide antennas and emitters for both IR and RF communications. In some embodiments, a removable safety ring protects the propellers from lateral contact.

19 Claims, 21 Drawing Sheets



Related U.S. Application Data

- division of application No. 13/842,525, filed on Mar. 15, 2013, now Pat. No. 9,004,973.
- (60) Provisional application No. 61/710,671, filed on Oct. 5, 2012, provisional application No. 61/710,665, filed on Oct. 5, 2012.

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A63H 17/32 (2006.01)
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A63H 30/04 (2006.01)
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A63F 13/837 (2014.01)
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F21V 23/04 (2006.01)
F41G 1/36 (2006.01)
F21L 4/02 (2006.01)
A63H 33/26 (2006.01)

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FIG. 1

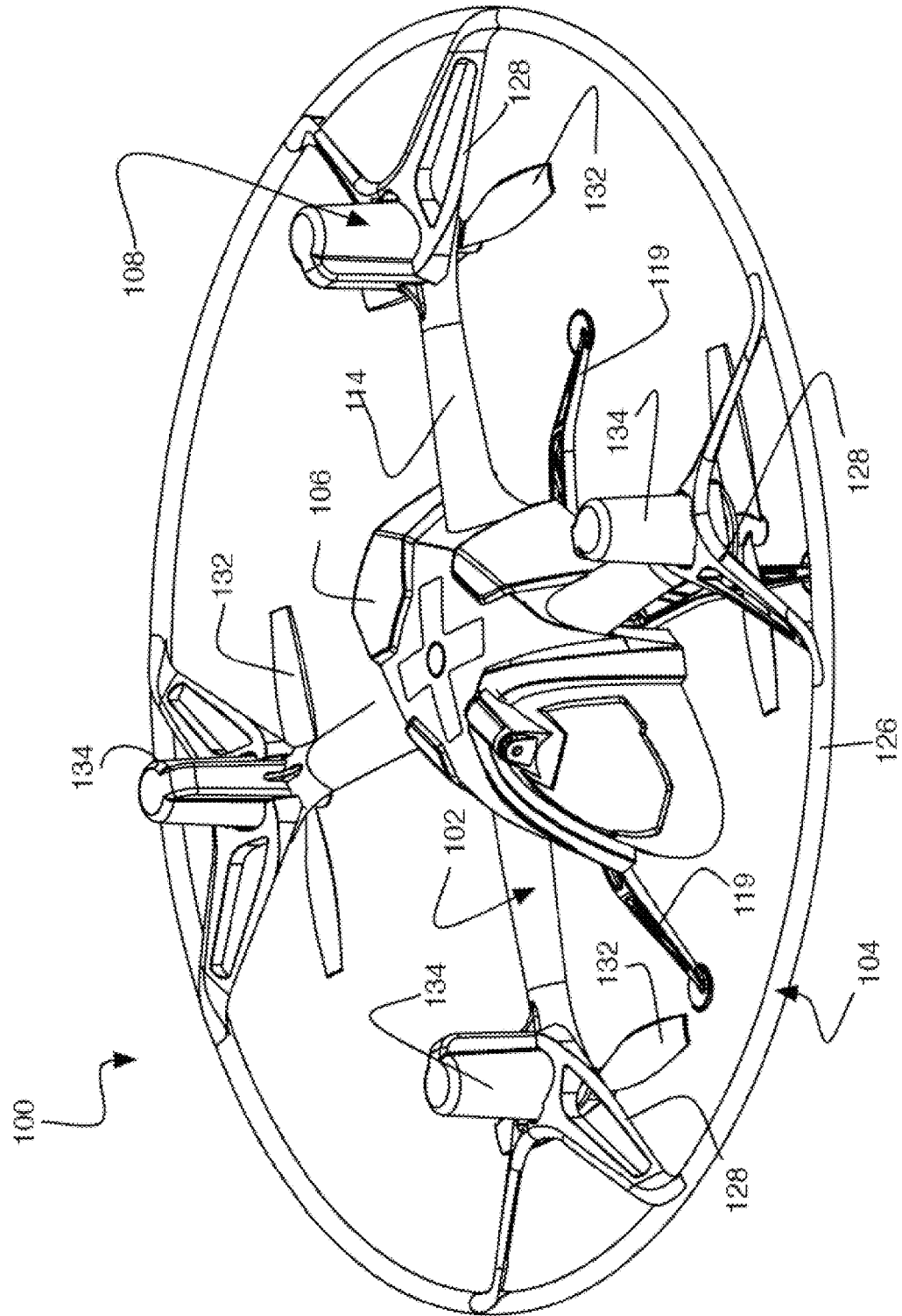


FIG. 2

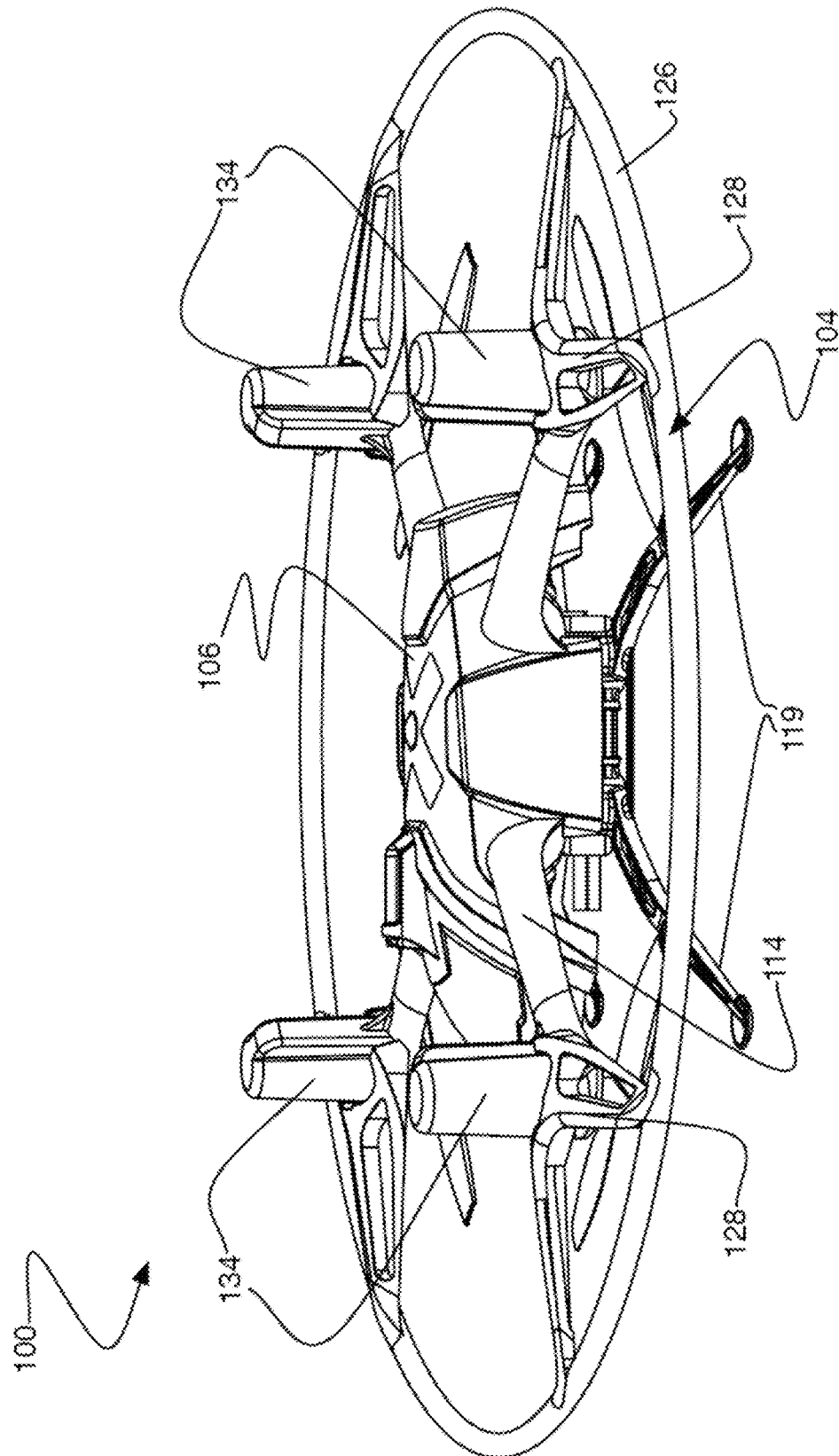


FIG. 3

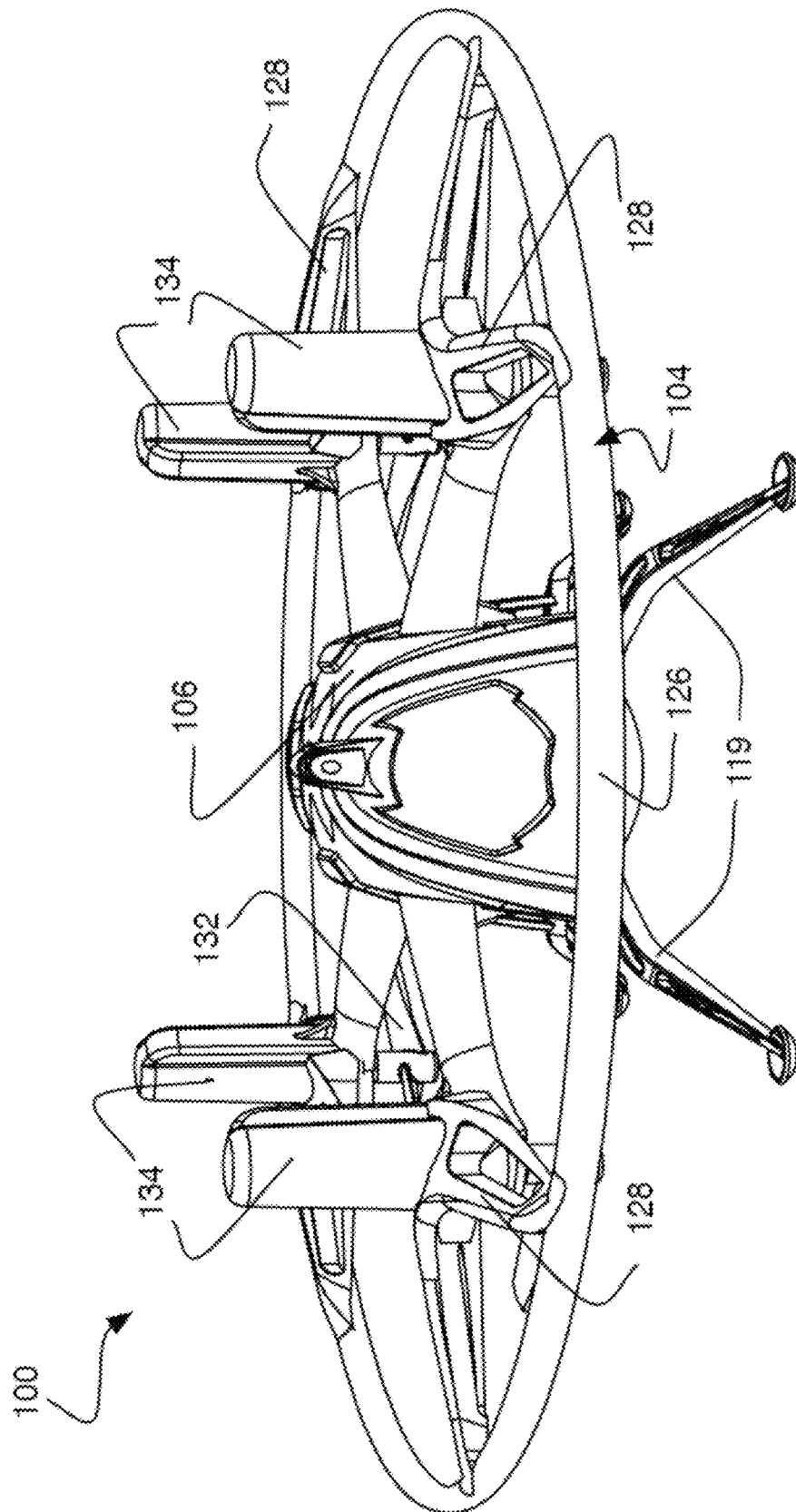


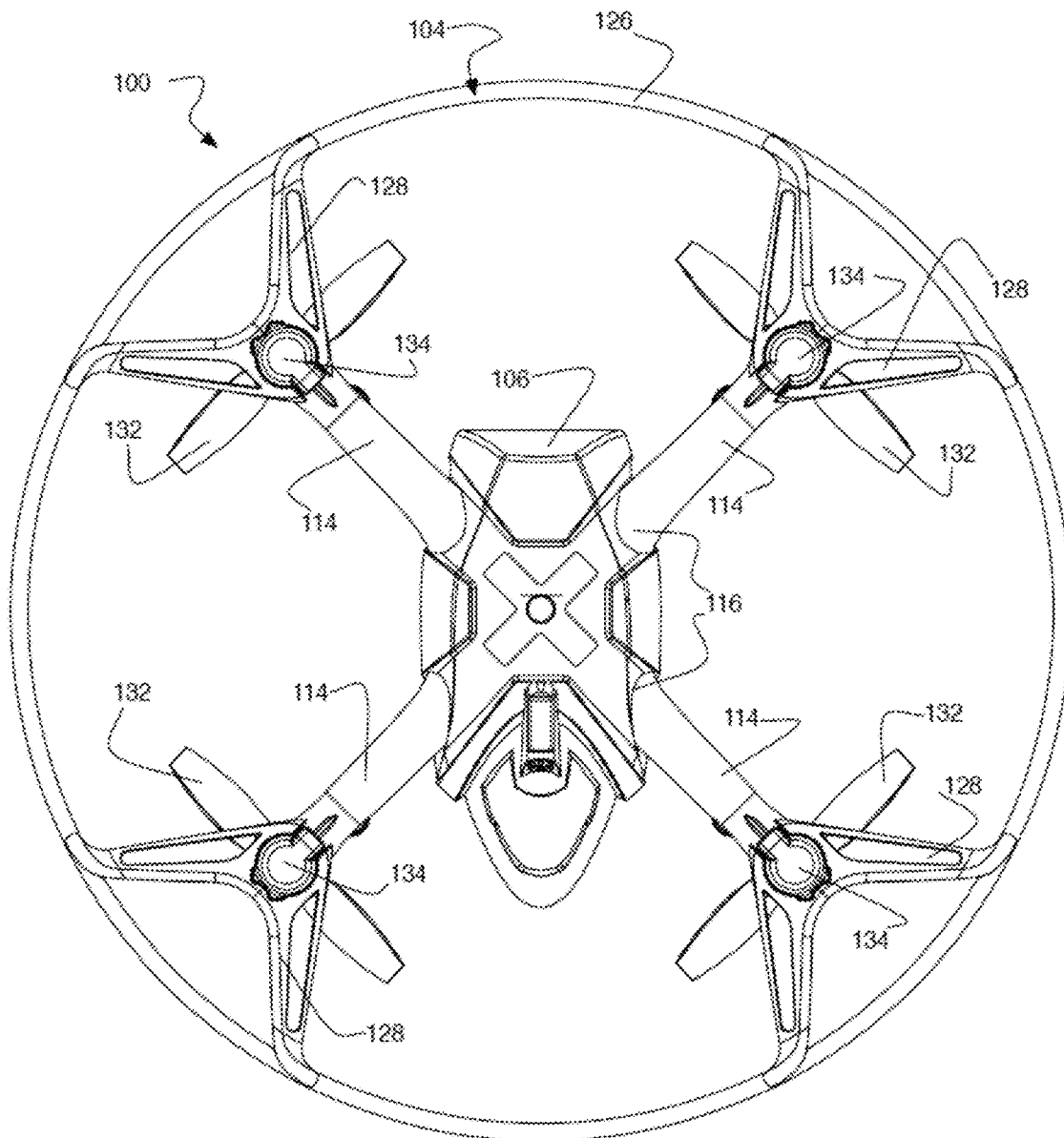
FIG. 4

FIG. 5

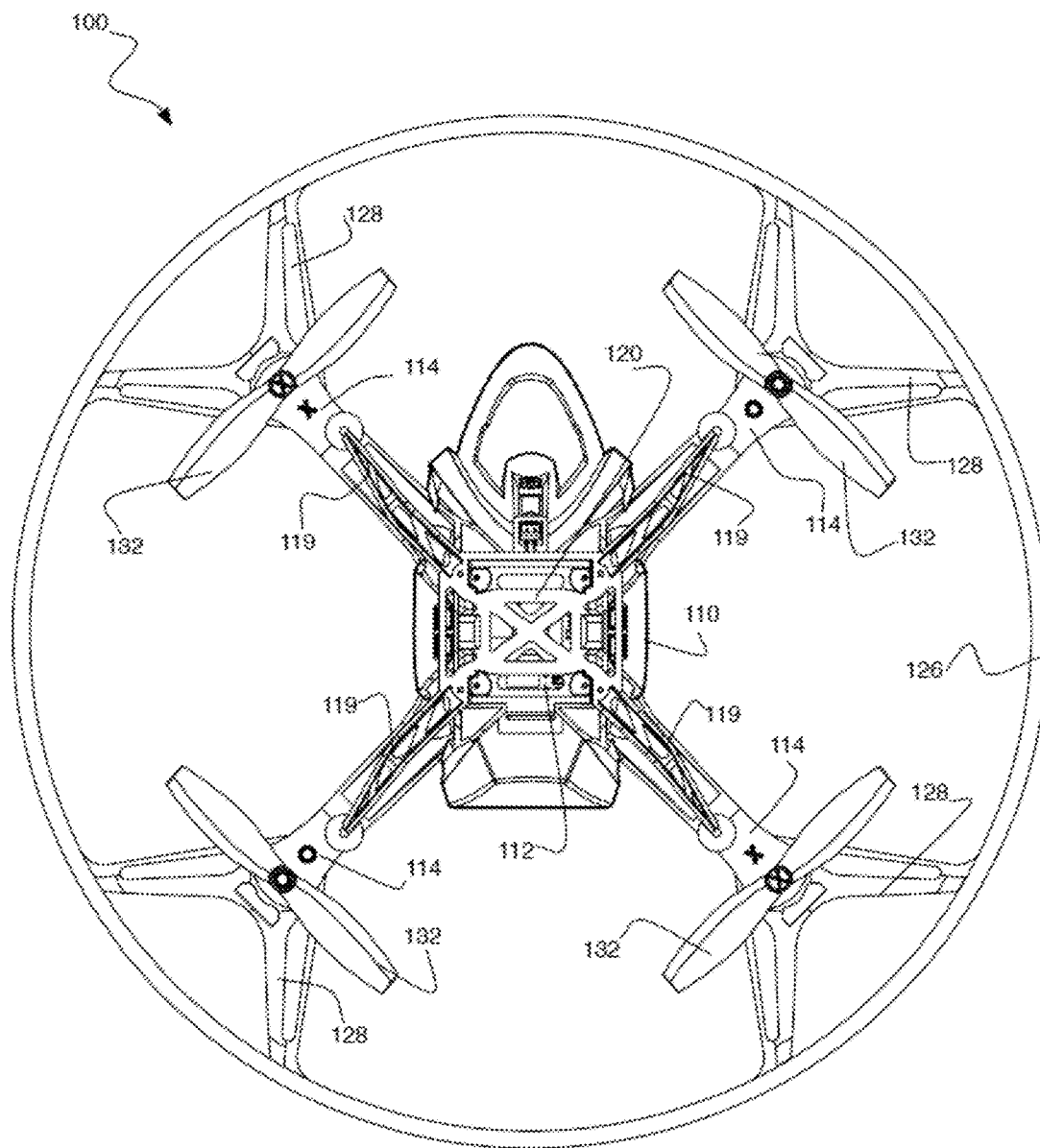


FIG. 6

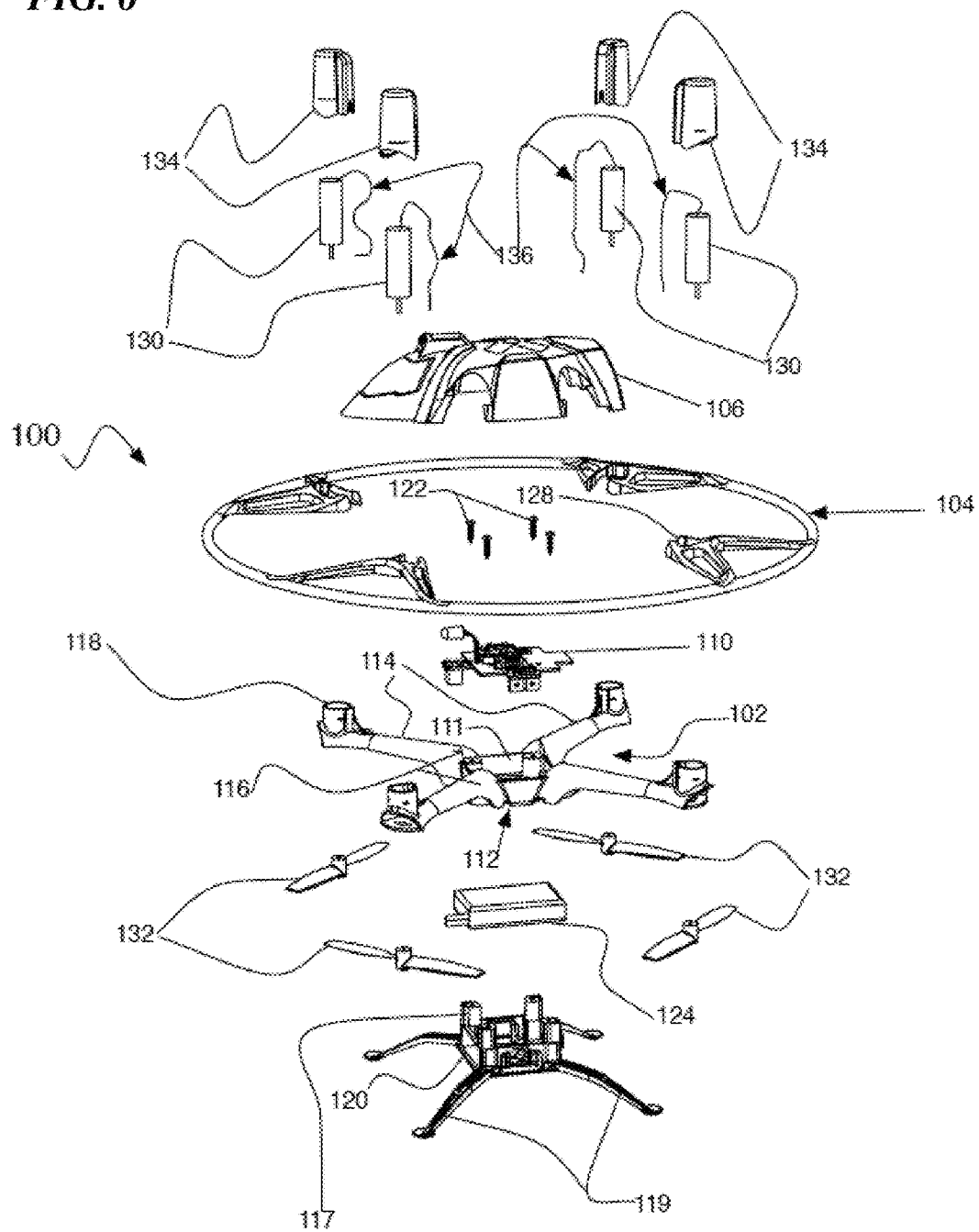


FIG. 7

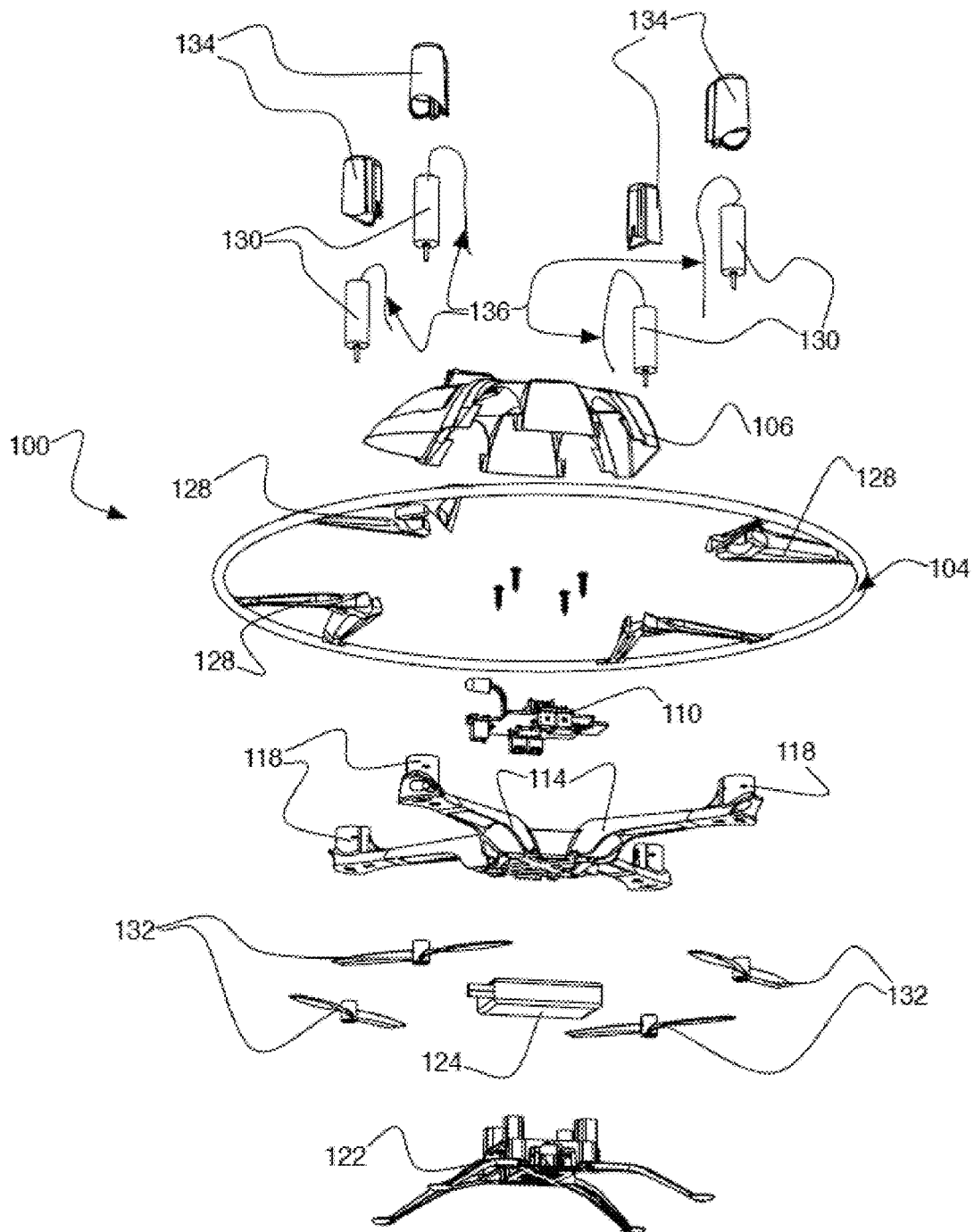


FIG. 8

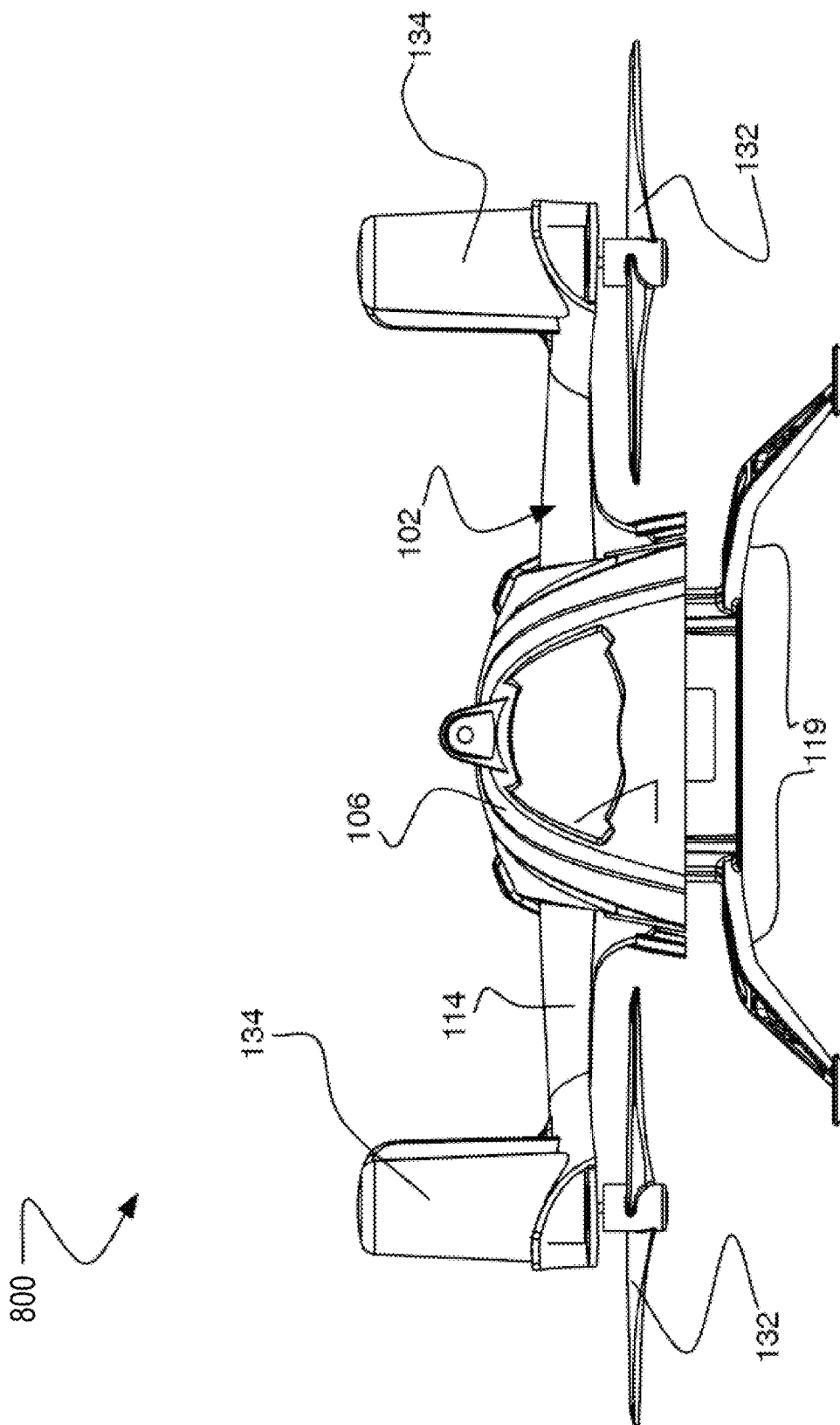


FIG. 9

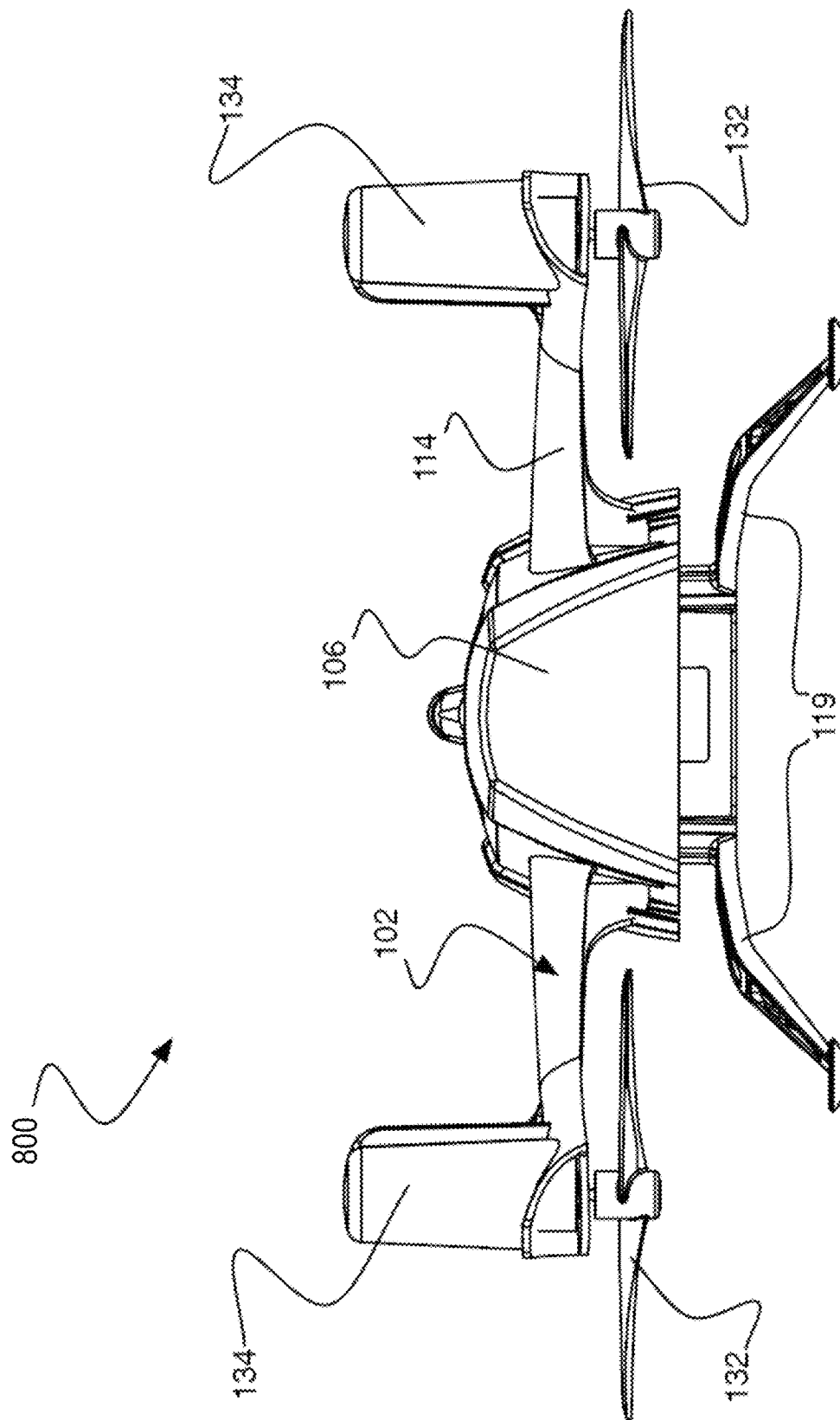


FIG. 10

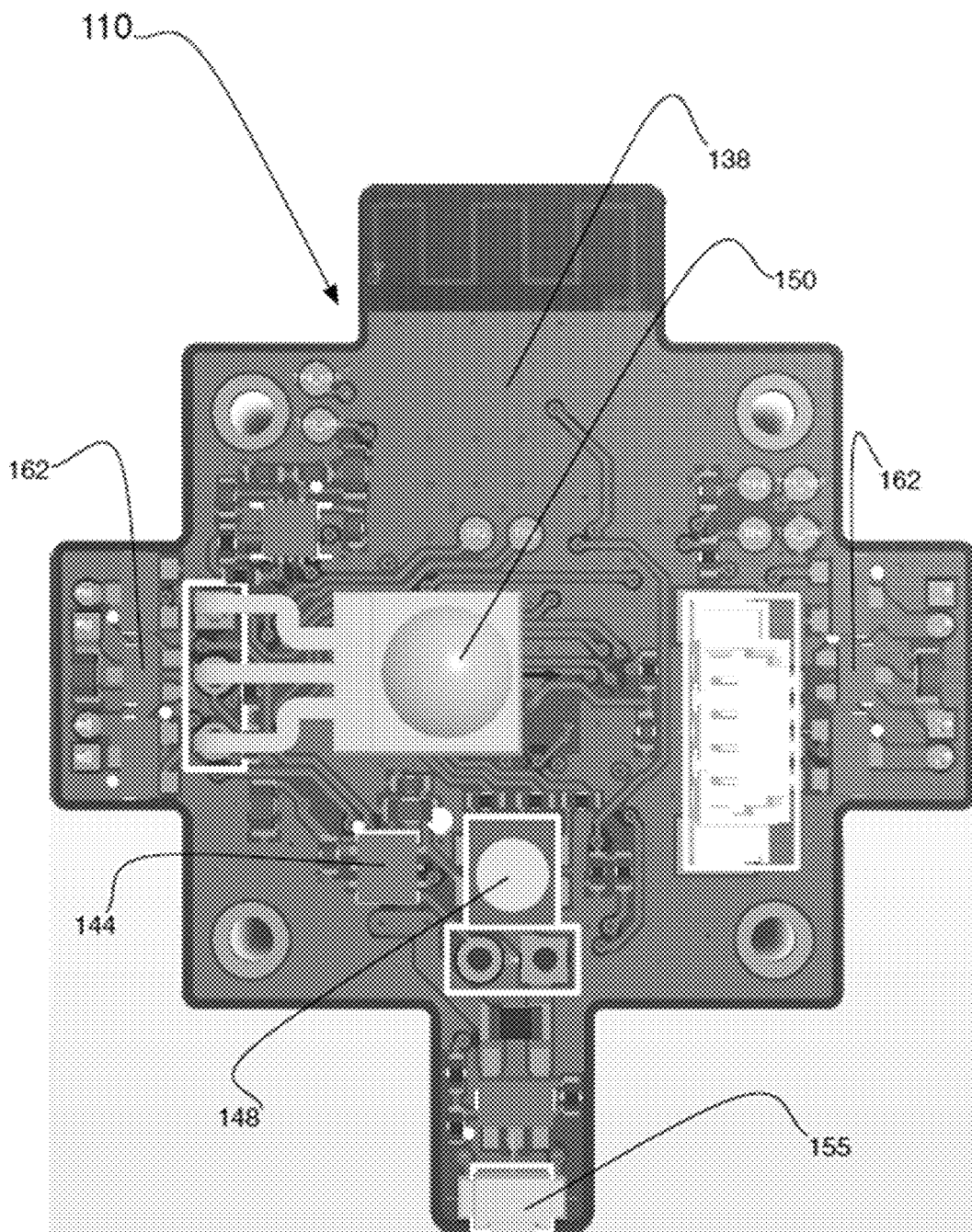


FIG. 11

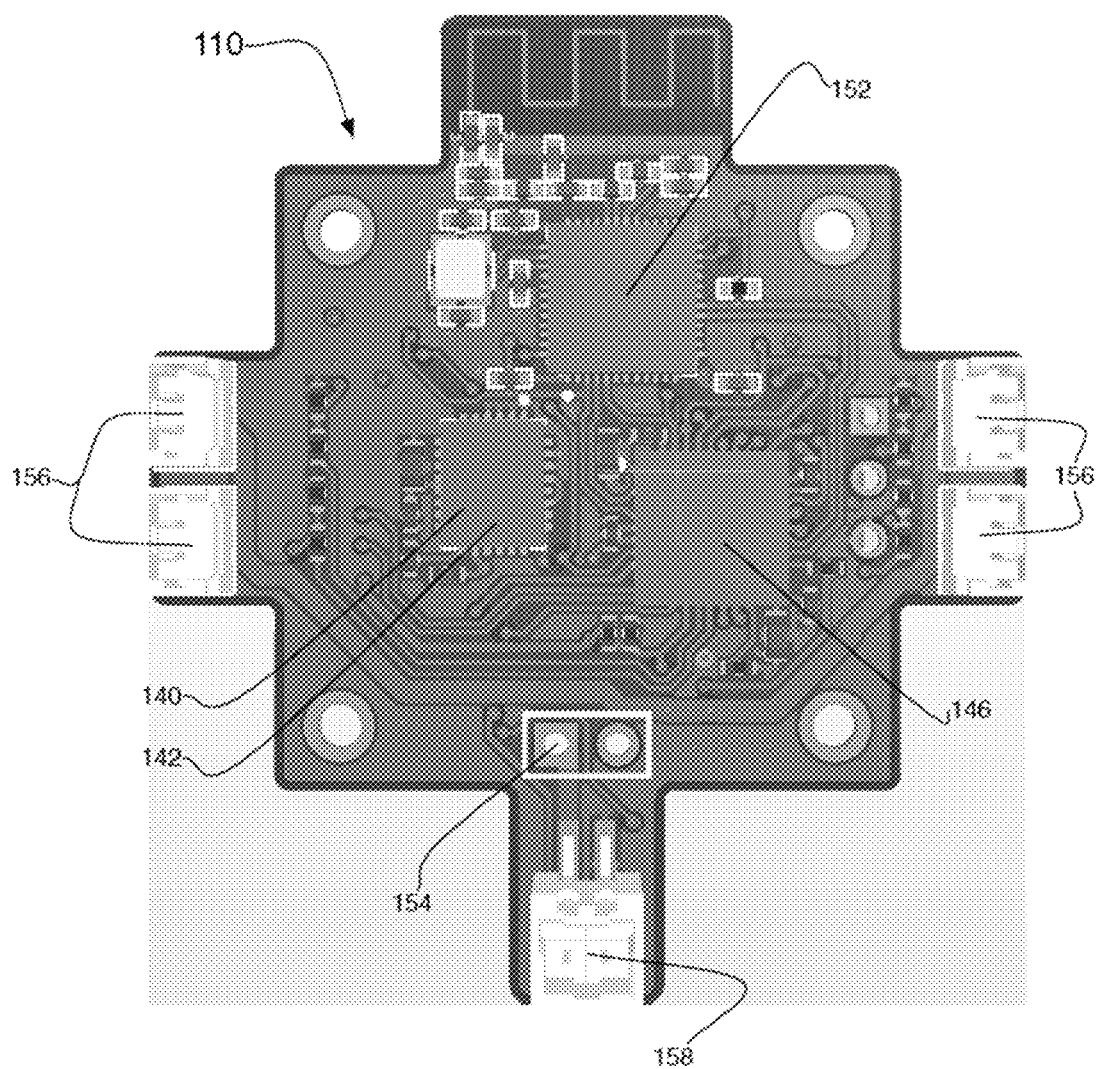


FIG. 12

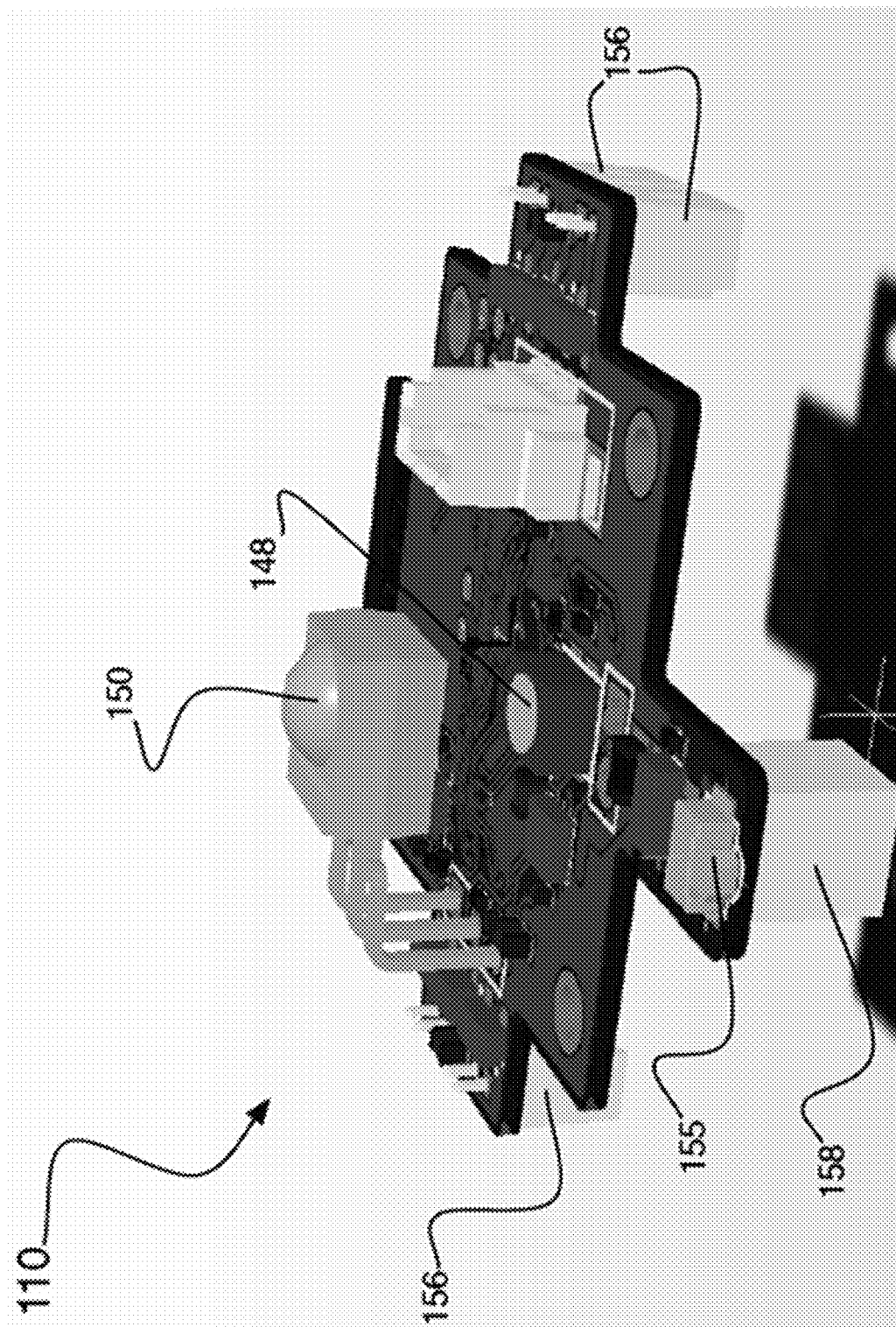


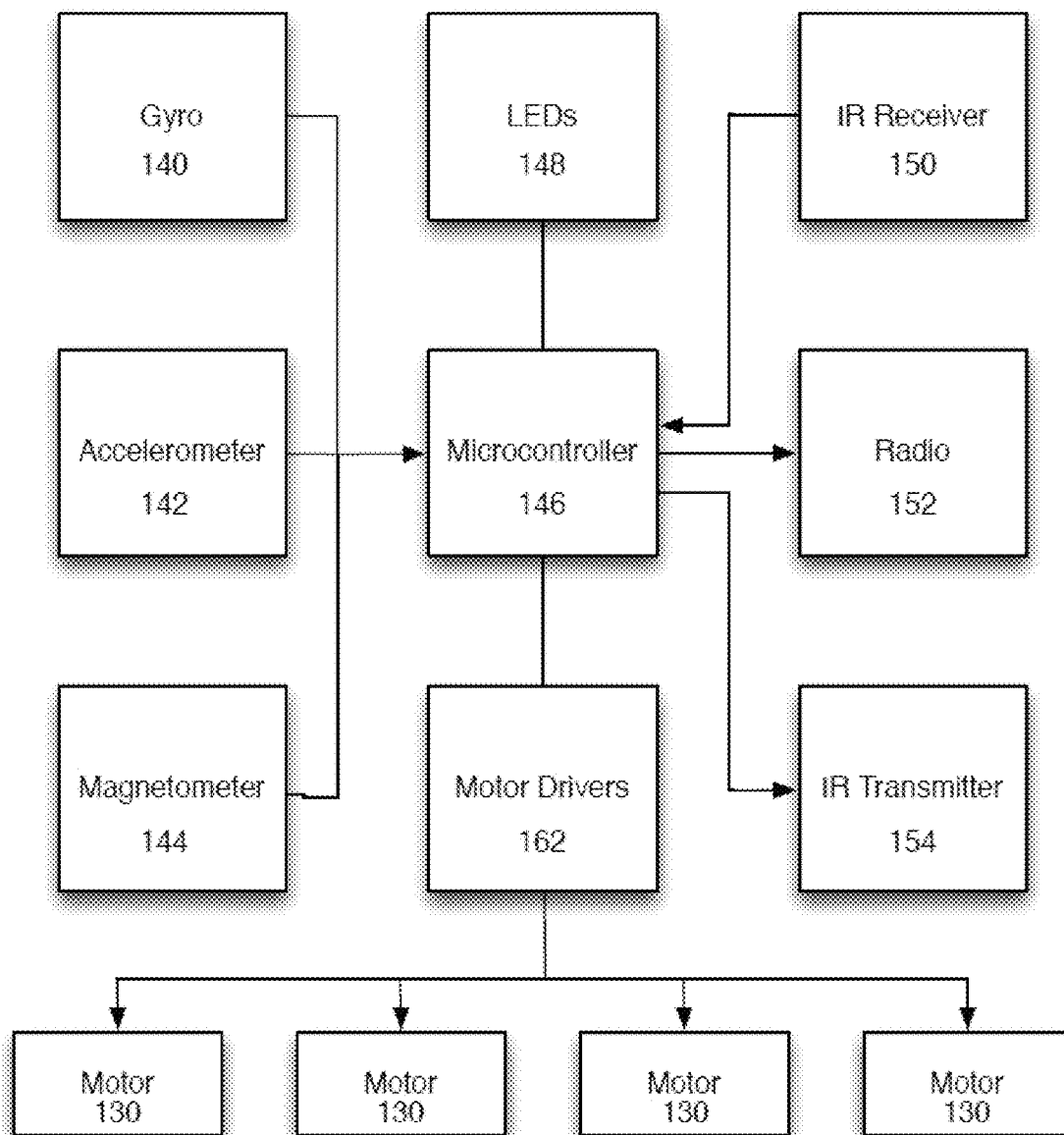
FIG. 13

FIG. 14

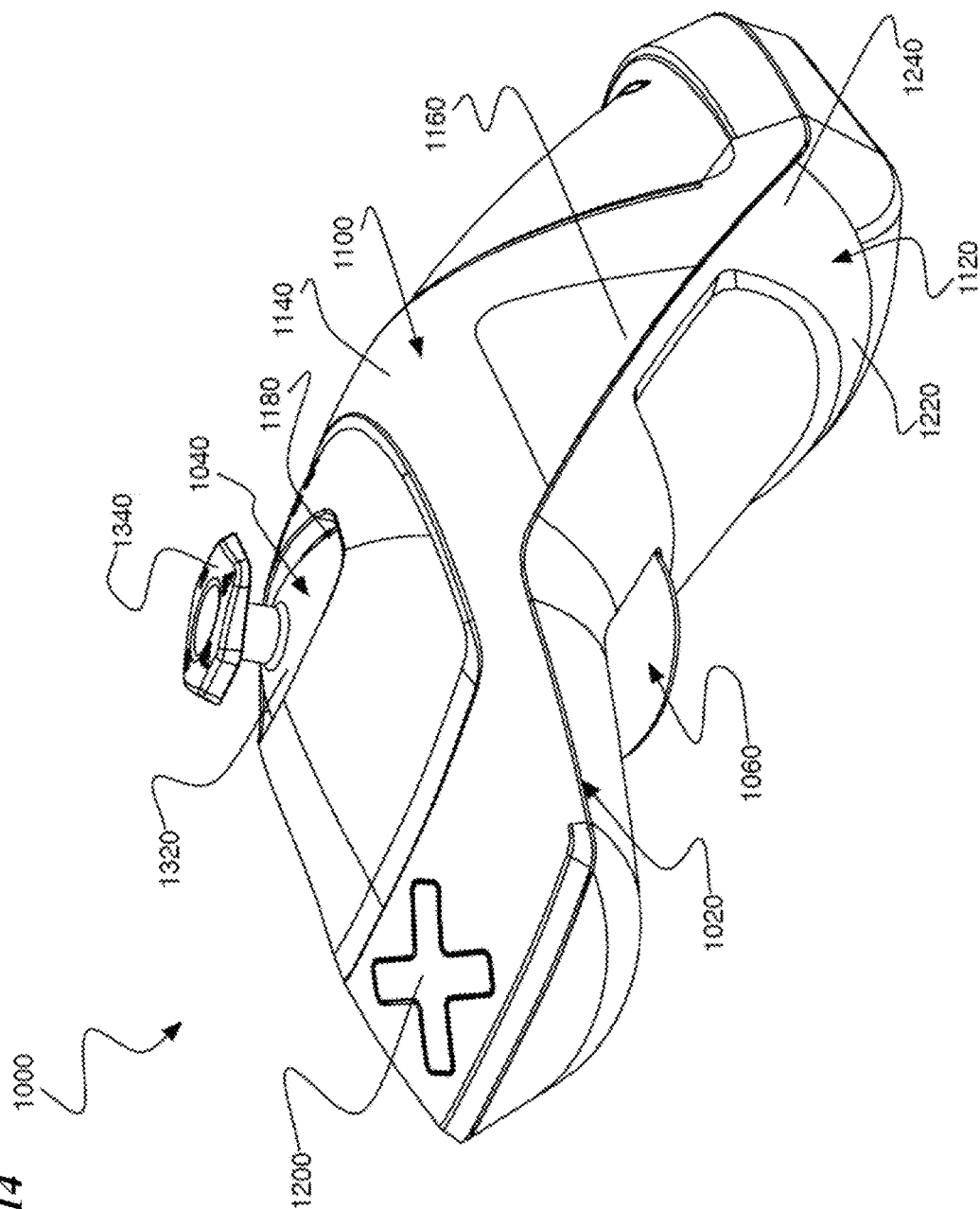


FIG. 15

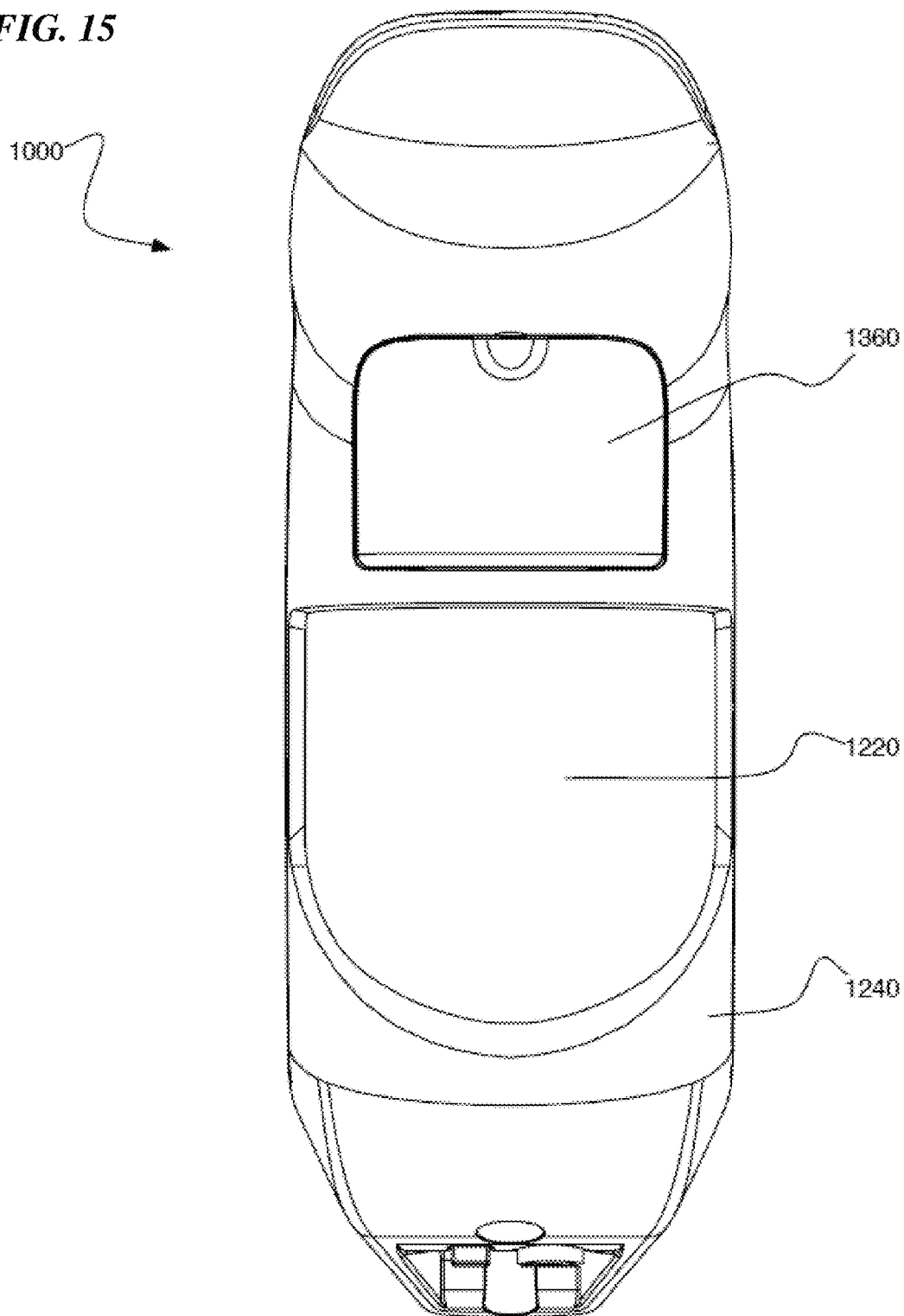


FIG. 16

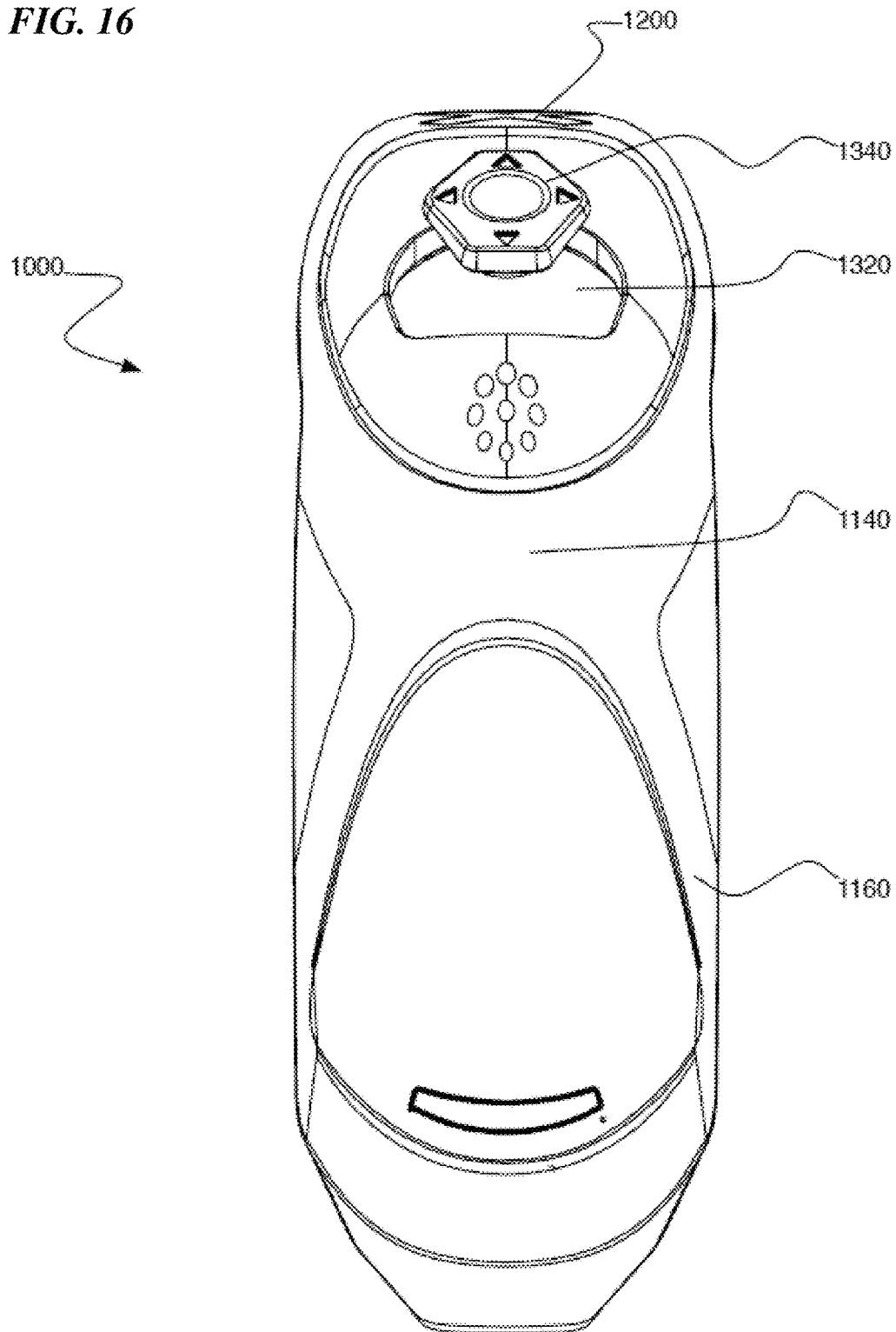


FIG. 17

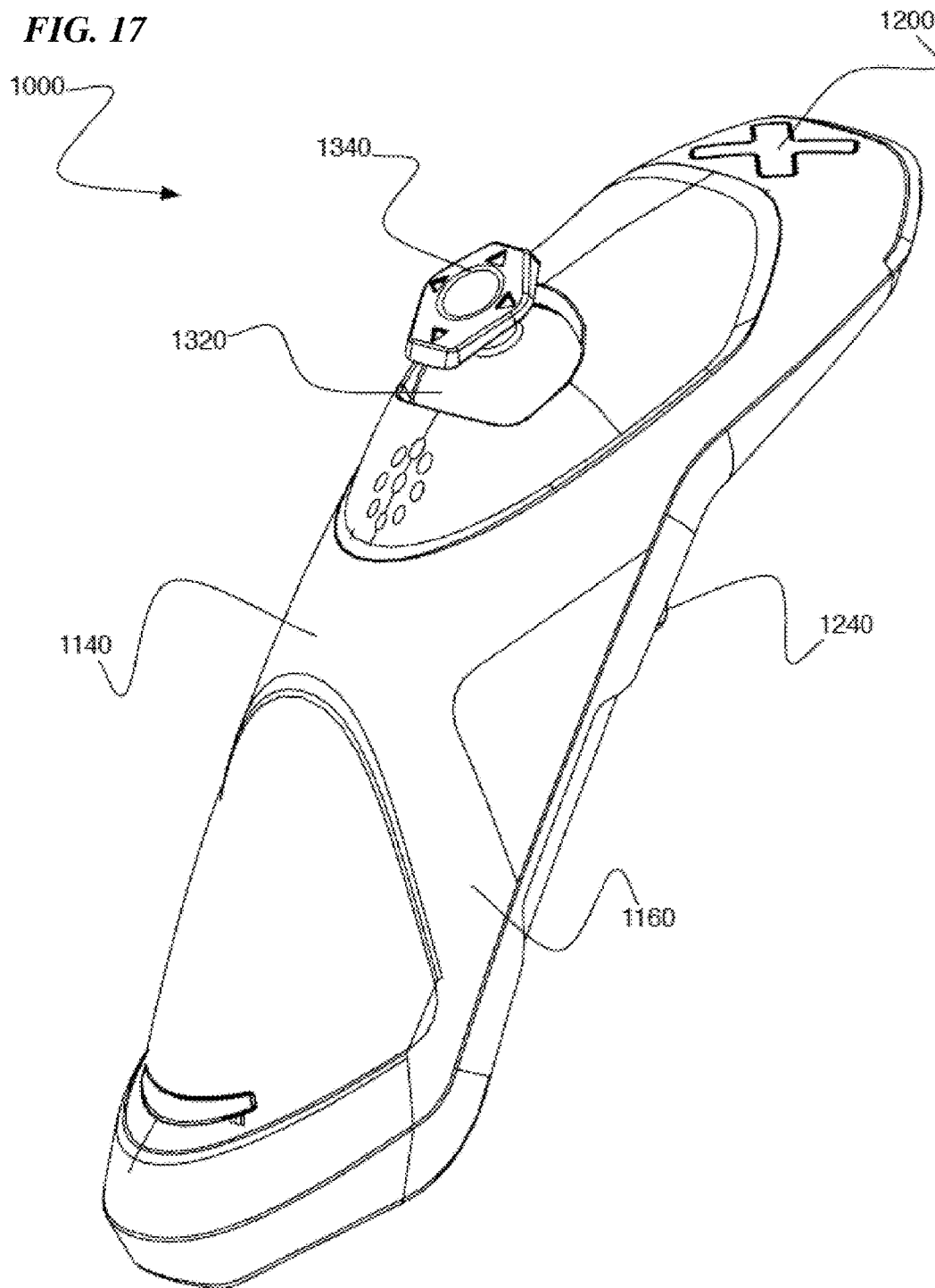


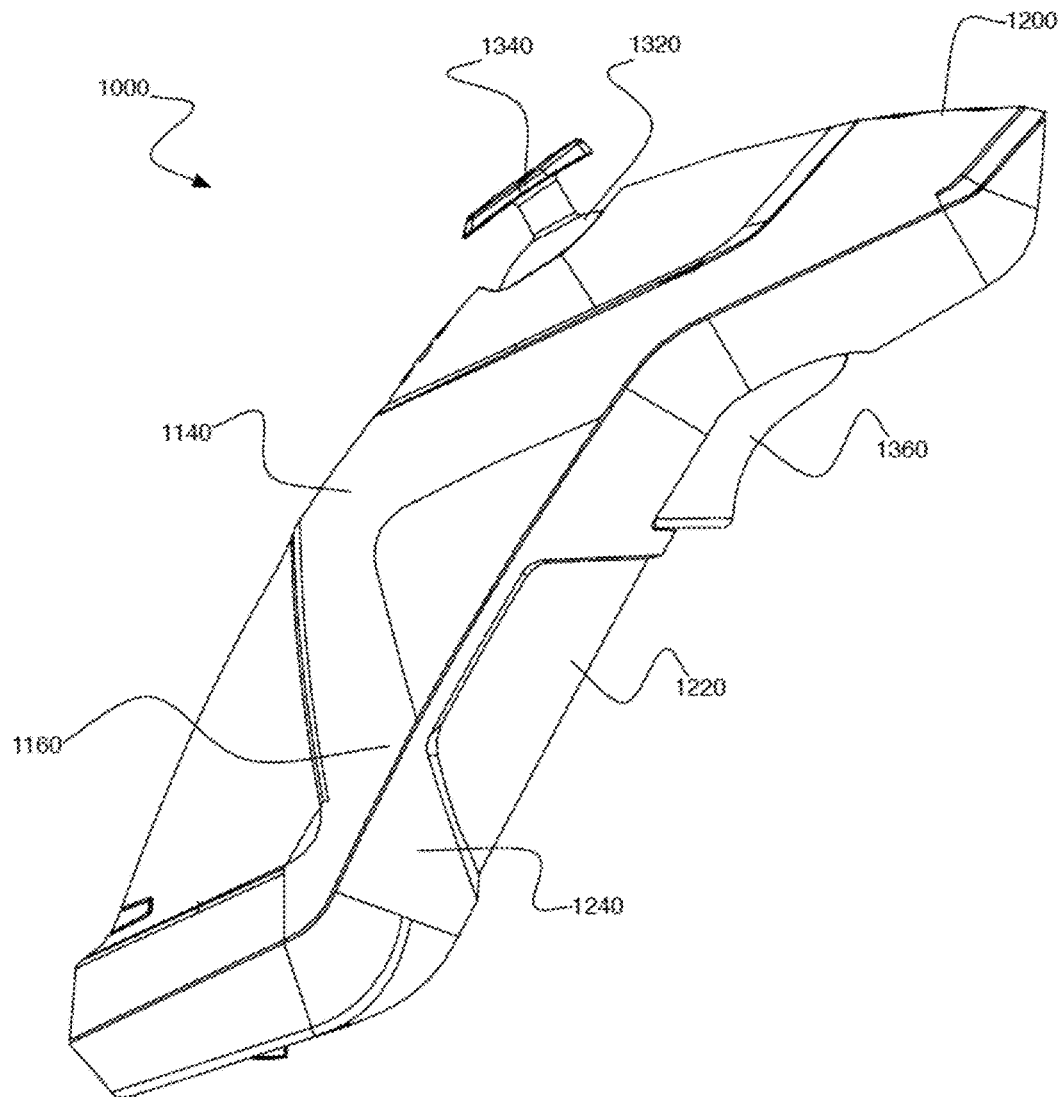
FIG. 18

FIG. 19

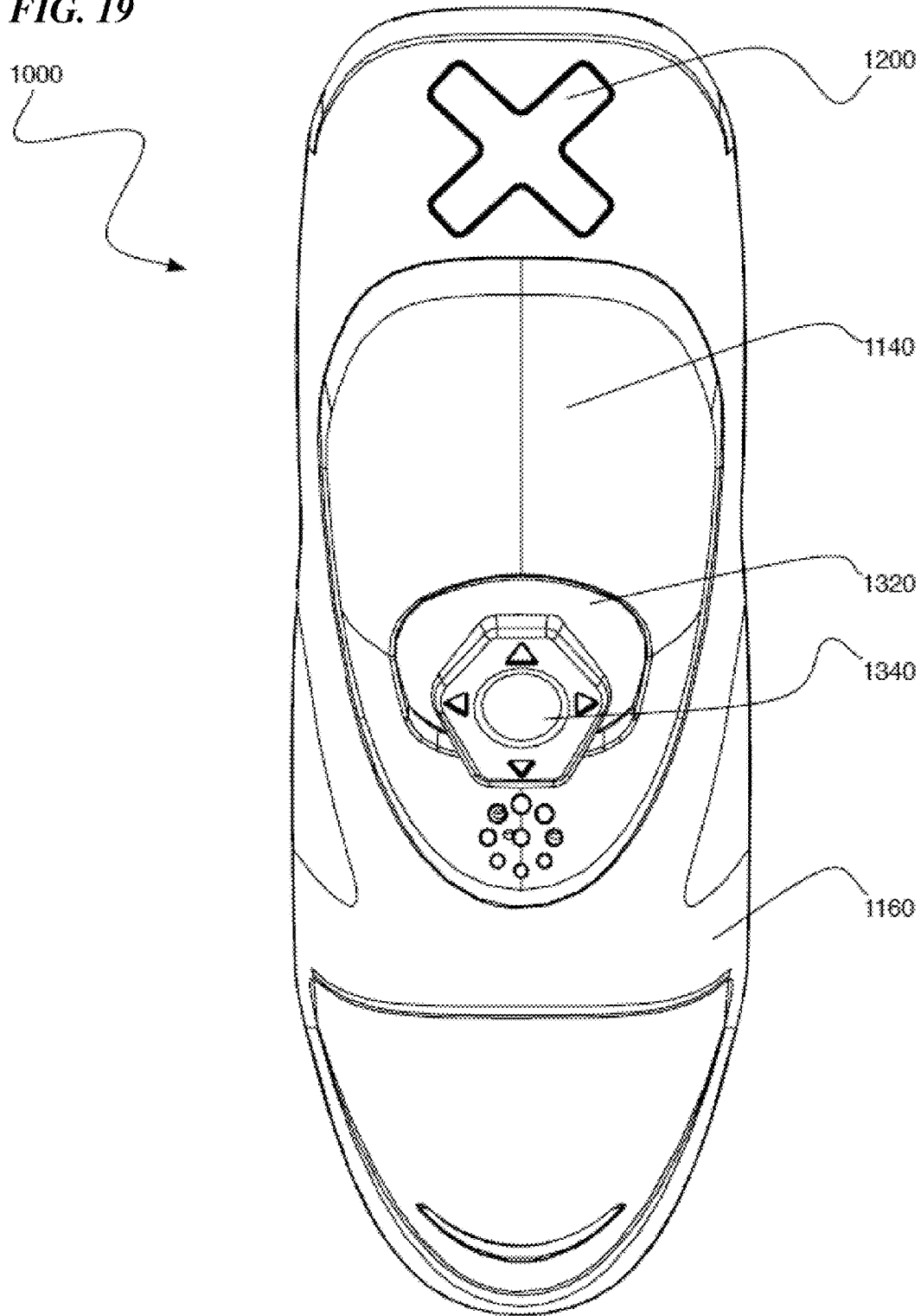
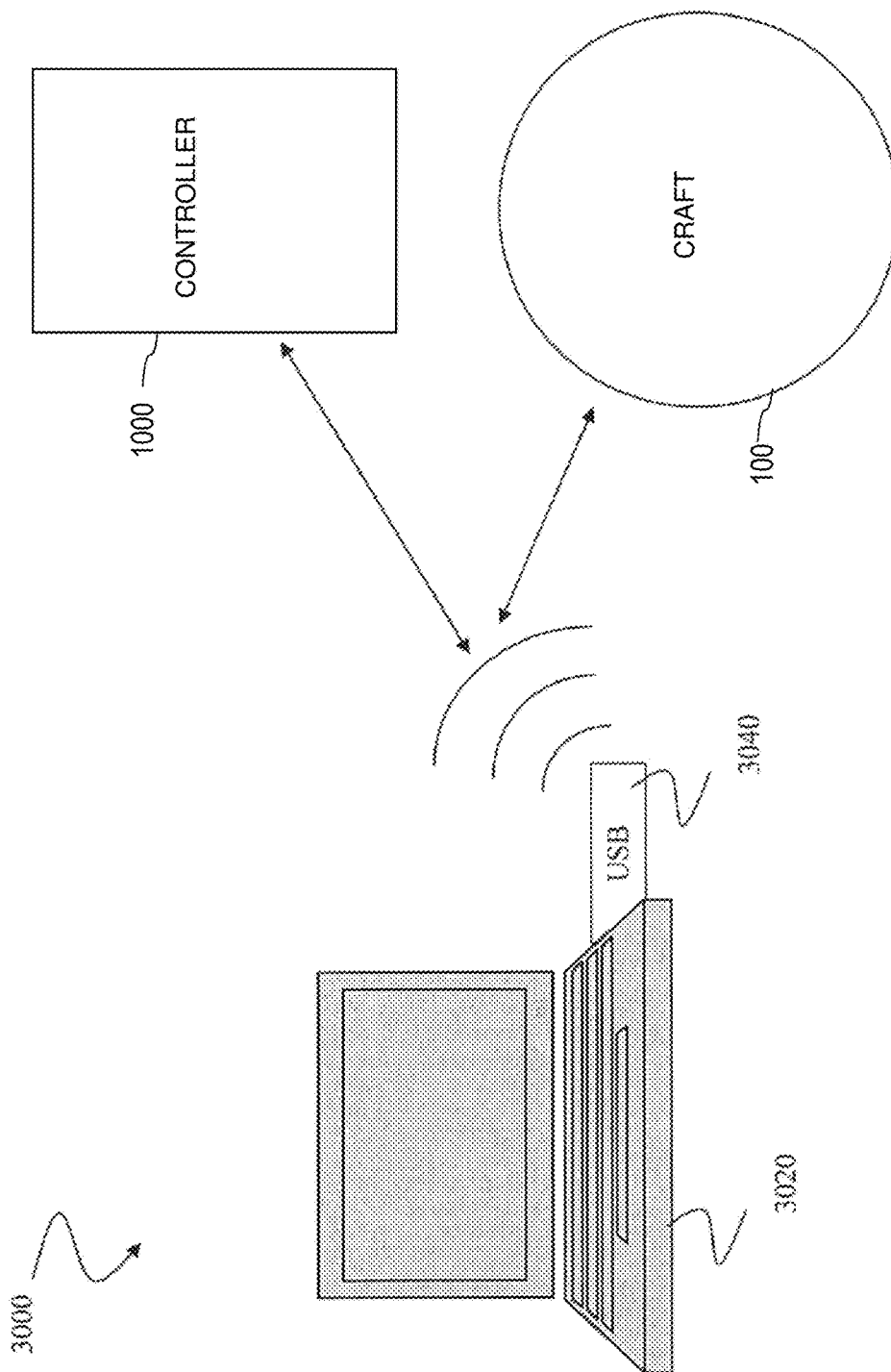


FIG. 21



REMOTE-CONTROL FLYING CRAFT**CROSS-REFERENCE TO RELATED APPLICATIONS**

This application is a continuation of U.S. patent application Ser. No. 14/686,335 filed Apr. 14, 2015, titled "REMOTE-CONTROL FLYING COPTER" (which issued as U.S. Pat. No. 9,682,316 on Jun. 20, 2017), which is a divisional of U.S. patent application Ser. No. 13/842,525 filed Mar. 15, 2013, titled "REMOTE-CONTROL FLYING COPTER AND METHOD" (which issued as U.S. Pat. No. 9,004,973 on Apr. 14, 2015), which claims benefit of U.S. Provisional Patent Application 61/710,665 filed Oct. 5, 2012, titled "REMOTE-CONTROL FLYING COPTER," and claims benefit of U.S. Provisional Patent Application 61/710,671 filed Oct. 5, 2012, titled "WIRELESS COMMUNICATION SYSTEM FOR GAME PLAY WITH MULTIPLE REMOTE CONTROL FLYING CRAFT," each of which is incorporated herein by reference in its entirety.

This invention is also related to prior U.S. Design Patent Application No. 29/433,939 filed Oct. 5, 2012, titled "Single-Handed Controller for a Remote Control Flying Craft" (which issued as U.S. Design Pat. No. D691,217 on Oct. 8, 2013); and to U.S. patent application Ser. No. 13/843,490, filed Mar. 15, 2013, titled "WIRELESS COMMUNICATION SYSTEM FOR GAME PLAY WITH MULTIPLE REMOTE-CONTROL FLYING CRAFT" (which issued as U.S. Pat. No. 9,011,250 on Apr. 21, 2015); each of which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

The invention relates generally to the field of heavier-than-air aeronautical vehicles that are sustained in air by the force of a fluid such as air. More particularly, the present invention relates to remote-control, hovering-type flying vehicles.

BACKGROUND

Remote-control flying vehicles are becoming increasingly more popular and sophisticated. While larger craft such as military and civilian drone aircraft have been in use for only the last two decades, smaller radio-controlled flying vehicles built and flown by hobbyists have been around for much longer. Generally, remote-control flying vehicles are either fixed wing, like a plane, or hovering, like a helicopter or quadcopter.

One example of a smaller, hovering type craft is described in U.S. Pat. No. 7,931,239, entitled "Homeostatic Flying Hovercraft," which teaches the use of a homeostatic hover control system in combination with a hand-held controller to cause the craft to mimic the orientation of the controller in terms of yaw, pitch, roll, and lateral flight maneuvers. Another example of a quadcopter is the Parrot AR Drone that utilizes a Wi-Fi connection between the quadcopter and a smart phone or tablet that serves as a tilt-based remote control. Still another example is the Walkera QR Lady Bird brand mini-quadcopter that is controlled via a conventional dual joystick remote control. These kinds of electronically stabilized hovercraft or quadcopter designs with three or more separate rotors are generally more stable and easier to learn to fly than the single shaft, dual counter-rotating rotor, model helicopters that may use some form of mechanical gyro stabilization. And, like the Lady Bird mini-quadcopter, these less-expensive single-shaft, dual counter-rotating

rotor, model helicopters are typically controlled via a conventional dual joystick remote control.

A problem with current designs for these kinds of smaller, hovering remote-control flying craft is that the competing design considerations of weight, cost and performance have resulted in a very limited set of designs for how these craft are constructed. The design of the single-shaft model helicopters has the dual counter-rotating rotors on the top of the craft where they are exposed to obstacles both above and to the sides of the rotors. Running the rotors into an obstacle, like a ceiling when flying indoors, almost always causes the craft to crash and potentially suffer damage as a result. The design of most quadcopters utilizes a cross configuration formed of very stiff, carbon-fiber rods that hold the motors away from the center of the craft. Stiff carbon-fiber rods are used to minimize the torsion and vibration that occurs in a quadcopter design when the motors are not mounted in the center of gravity of the craft as is done in a single-shaft, counter-rotating helicopter design.

These existing designs for smaller, hovering remote-control flying craft suffer from various problems, including cost of manufacture, ease of operation, accuracy of navigation, durability, and safety during operation, among others problems. There is a need for an inexpensive, yet robust design for a smaller, hovering remote-control flying craft.

SUMMARY

Embodiments of this invention relate to a smaller, hovering flying craft adapted to be controlled by a handheld remote control having a molded frame assembly including a center body formed of a top member having at least three arms integrally molded with and extending outwardly from the center body and a bottom member having at least three legs integrally molded with and extending downwardly from the center body, at least three motor assemblies that each include an electromechanical motor and at least one corresponding propeller operably mounted downwardly-facing, with at least one motor assembly operably mounted at a distal portion of each of the at least three arms, a circuit-board assembly operably mounted to the center body and configured to control the craft in response to radio frequency signals from the handheld remote control, and a replaceable rechargeable battery insertable into a battery compartment defined by the top member and the bottom member and operably connectable to electrically power the circuit-board assembly and the at least three motor assemblies.

Embodiments relate to a hovering flying craft system including a hovering flying craft having a frame assembly including a center body having at least three arms extending outwardly from the center body, at least three motor assemblies that each include an electromechanical motor and at least one corresponding propeller mounted at a distal portion of each arm, a circuit-board assembly operably mounted to the center body and configured to control the craft in response to radio-frequency signals and to control an infrared emitter and an infrared receiver; and a replaceable rechargeable battery insertable into the frame assembly and operably connectable to electrically power the circuit-board assembly and the at least three motor assemblies. In embodiments, the system includes a handheld controller configured to allow a user to control the hovering flying craft by providing inputs for an intended pitch and attitude of the hovering flying craft, and a thrust and yaw of the hovering flying craft, the controller having a trigger assembly adapted to be manipulated by a finger of the user to provide the user with a control for sending commands to control at least the

infrared emitter on the hovering flying craft, a control processor configured to provide control signals to a radio that generates the radio-frequency signals for communication to and control of the hovering flying craft and the infrared emitter, and a battery to electrically power the handheld controller.

Embodiments also relate to a system for wirelessly reprogramming a hovering flying craft and a handheld controller, the hovering flying craft adapted to be controlled by the handheld controller including a hovering flying craft including a craft processor and a craft radio, the craft radio comprising a craft radio processor, a handheld controller including a controller processor and a controller radio, the controller radio comprising a controller radio processor, a computing device including a computing device processor and computing device memory, wherein the computing device processor is configured to store craft operating code in the computing device memory, store controller operating code in the computing device memory, package the craft operating code according to the protocol of the craft radio, and package the controller operating code according to the protocol of the controller radio; and a wireless interface adapted to transmit the packaged craft operating code from the computing device to the craft radio and the packaged controller operating code from the computing device to the controller radio, wherein the craft operating code is programmed within the craft processor by the craft radio processor, and the controller operating code is programmed within the controller processor by the controller radio processor after transmission of the craft operating code and the controller operating code along the wireless interface.

In various embodiments, a smaller, hovering remote-control flying craft includes features to support aerial game play based on both infrared (IR) and radio frequency (RF) communications, including a pairing button, an infrared emitter and sensor configured for aerial game play, a high-intensity light-emitting diode (LED) output for indicating team selection, and a vacuum-formed shell with windows and internal reflective surfaces for enhancing the visibility of light-emitting diode (LED) output.

In other various embodiments, the aforementioned features can be combined in any fashion such that certain embodiments can include all, some, or even one of these features, and not others.

Embodiments of the smaller, hovering remote-control flying craft of the present invention are small enough to safely fly in small indoor areas, but powerful enough to fly outdoors. Due to the rugged, lightweight design and only the four motors as moving parts, the hovering remote-control flying craft of the present invention is more durable than existing designs.

The hovering remote-control flying craft can be controlled by a single-handed controller to be used by a user for controlling the craft, the controller comprising a controller body having an angled shape and including a flat top surface for orientation reference of the controller, a trigger projecting from the controller body adapted to interface with a forefinger of the user, a top hat projecting from the flat top surface adapted to interface with a thumb of the user; and electronics including at least one accelerometer, a processor for sampling data from the at least one gyroscope and at least one accelerometer, and a radio adapted to transmit the sampled data to the vehicle antenna(s).

In various embodiments, a single-handed remote controller has a reference surface on top of the controller, in combination with a top hat arrangement and a trigger button, internal components having structure for supporting and

mounting one or more circuit boards and a rechargeable battery, control sequences (which, in some embodiments, are transmitted (e.g., wirelessly or otherwise) to the associated craft) for changing the associated craft from novice mode to expert mode and vice versa, a USB (universal serial bus) connection for charging the remote controller, components for the selection of a team, including synchronization of the associate craft team, light-emitting diode (LED) output identifying a team color, a selectively vibrating motor to indicate status of the associated craft (by providing a vibrating sensation that can be felt by the person holding the remote controller), and wireless pairing components, including an easy-to-use wireless pairing button. In other various embodiments, the aforementioned features can be combined in any fashion such that certain embodiments can include all, some, or even one of these features, and not others.

The single-handed remote controller can be tilted forward, back, left, or right, and the corresponding controlled flying vehicle responds accordingly, thereby providing total one-handed control over the vehicle. In embodiments, the controller has an ergonomic design made for the human hand. In embodiments, the same controller is comfortable and easy to use both for right-handed or left-handed pilots. Moreover, the controller exemplifies U.S. Air Force Human Factors data considerations for aircraft controls, creating a realistic and high-tech interface.

The above summary of the invention is not intended to describe each illustrated embodiment nor every implementation of the present invention. The figures and the detailed description that follow more particularly exemplify some of these embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention may be more completely understood in consideration of the following detailed description of various embodiments of the invention in connection with the accompanying drawings, in which:

FIG. 1 is a perspective view of a hovering remote-control flying craft 100, according to an embodiment.

FIG. 2 is a side back perspective view of the smaller, hovering remote-control flying craft 100 of FIG. 1, according to an embodiment.

FIG. 3 is a side front perspective view of the hovering remote-control flying craft 100 of FIG. 1, according to an embodiment.

FIG. 4 is a top plan view of the hovering remote-control flying craft 100 of FIG. 1, according to an embodiment.

FIG. 5 is a bottom plan view of the hovering remote-control flying craft 100 of FIG. 1, according to an embodiment.

FIG. 6 is an exploded side perspective view of a kit of parts for hovering remote-control flying craft 100, according to an embodiment.

FIG. 7 is an exploded perspective view of a kit of parts for hovering remote-control flying craft 100, according to an embodiment.

FIG. 8 is a side front view of a hovering remote-control flying craft 800, which is equivalent to craft 100 without a safety ring, according to an embodiment.

FIG. 9 is a side back view of hovering remote-control flying craft 800, according to an embodiment.

FIG. 10 is a top plan view of a circuit board for a hovering remote-control flying craft, according to an embodiment.

FIG. 11 is a bottom plan view of a circuit board for a hovering remote-control flying craft, according to an embodiment.

FIG. 12 is a perspective view of the circuit board for a hovering remote-control flying craft of FIG. 10, according to an embodiment.

FIG. 13 is a block diagram of the components of the circuit board of FIG. 10, according to an embodiment.

FIG. 14 is a side perspective view of a controller 1000 for a hovering remote-control flying craft, according to an embodiment.

FIG. 15 is a bottom plan view of controller 1000 of FIG. 14, according to an embodiment.

FIG. 16 is a top back plan view of controller 1000 of FIG. 14, according to an embodiment.

FIG. 17 is a side perspective view of controller 1000 of FIG. 14, according to an embodiment.

FIG. 18 is a right side view of controller 1000 of FIG. 14, according to an embodiment.

FIG. 19 is a top front plan view of controller 1000 of FIG. 14, according to an embodiment.

FIG. 20 is an exploded side view of controller 1000 of FIG. 14, according to an embodiment.

FIG. 21 is a block diagram of a system for reprogramming a controller and an associated hovering remote-control flying craft, according to an embodiment.

While the invention is amenable to various modifications and alternative forms, specifics thereof have been shown by way of example in the drawings and will be described in detail. It should be understood, however, that the intention is not to limit the invention to the particular embodiments described. On the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION

Although the following detailed description contains many specifics for the purpose of illustration, a person of ordinary skill in the art will appreciate that many variations and alterations to the following details are within the scope of the invention. Very narrow and specific examples are used to illustrate particular embodiments; however, the invention described in the claims is not intended to be limited to only these examples, but rather includes the full scope of the attached claims. Accordingly, the following preferred embodiments of the invention are set forth without any loss of generality to, and without imposing limitations upon the claimed invention. Further, in the following detailed description of the preferred embodiments, reference is made to the accompanying drawings that form a part hereof, and in which are shown by way of illustration specific embodiments in which the invention may be practiced. It is understood that other embodiments may be utilized and structural changes may be made without departing from the scope of the present invention. The embodiments shown in the Figures and described here may include features that are not included in all specific embodiments. A particular embodiment may include only a subset of all of the features described, or a particular embodiment may include all of the features described.

The leading digit(s) of reference numbers appearing in the Figures generally corresponds to the Figure number in which that component is first introduced, such that the same reference number is used throughout to refer to an identical component which appears in multiple Figures. Signals and

connections may be referred to by the same reference number or label, and the actual meaning will be clear from its use in the context of the description.

Referring generally to FIGS. 1-7, according to an embodiment of the invention, a hovering remote-control flying craft 100 is depicted. Hovering remote-control flying craft 100 generally comprises a molded frame assembly 102, an optional removable safety ring 104, a shell 106, a plurality of motor assemblies 108, and a circuit-board assembly 110. In various embodiments, the plurality of motor assemblies 108 may number greater or less than four, thereby creating a craft other than a quadcopter. The components of frame assembly 102, removable safety ring 104, and other components are thereby adaptable to support the defined number of motor assemblies 108 of any particular craft, but are described herein for ease of illustration as a hovering remote-control flying craft 100 having four discrete motor assemblies 108. The intention is not to limit the invention to only the particular embodiments described.

Molded frame assembly 102 generally comprises a center body 112 and a plurality of arms 114 each extending from a plurality of shoulders 116 of center body 112, thereby creating a stiff molded frame. In embodiments, molded frame assembly 102 can be made of molded polymer (commonly called plastic), including thermoplastics, thermosets, and elastomers, and optionally including fillers and/or entrapped gas bubbles or passages (to reduce weight) and/or optionally including reinforcing agents such as polymer fibers and/or glass fibers and the like. As used herein, the term "plastic" means any suitable polymer material and composites thereof.

Center body 112, in an embodiment, includes structure defining an aperture or frame adapted to operably couple to circuit-board assembly 110 to secure circuit-board assembly 110 in place. As depicted in the embodiment of FIGS. 6-7, center body 112 can be shaped roughly like a square or other parallelogram, with cutouts or projections for circuit board assembly 110, as will be described. It will be seen that the combination of the circuit-board assembly 110 in the structure of the center body 112 serves to add structural integrity and rigidity to the molded frame assembly 102.

In some embodiments, each of shoulders 116 has a rounded portion of frame extending from a relative "corner" of center body 112 and curving distally away from center body 112. Each of arms 114 extends therefrom further distally away from center body 112. Each of arms 114 can include an intra-arm channel such that time and cost is saved in production by limiting production materials to those outside the channel while providing a conduit for routing of wires from the motor assemblies 108. Arms 114 extend from shoulder 116, and more specifically, center body 112, to allow room for motor assemblies 108 to operate. The combination of shoulder 116 and arm 114 thereby forms a generally L-shaped structure, each extending generally orthogonal to the next adjacent combination of shoulder 116 and arm 114 from center body 112, so that the first set of two arms 114 lie along the same axis, and the second set of two other arms 114 lie along another axis that is perpendicular to the axis of the first set of arms 114.

In embodiments, molded frame assembly 102 is a two-piece assembly that can include a top member 111 forming center body 112 with at least three arms 114 integrally molded with and extending outwardly from center body 112 and a bottom member 117 having at least three legs 119 integrally molded with and extending downwardly. In an embodiment, top member 111 is formed of an injectable molded plastic having a durometer greater than 70 Shore D

7

and bottom member **117** is formed of an injectable molded plastic having a durometer less than 60 Shore D. In some embodiments, top member **111** is formed of ABS plastic with a durometer of about 75 Shore D and bottom member **117** is formed of a low density polypropylene plastic with a durometer of about 55 Shore D.

In these embodiments for a molded frame assembly **102** that is a two-piece assembly, the top member **111** is stiffer than the bottom member **117** so as to provide rigidity of the arms **114** to decrease torsion and resonance vibrations that can otherwise interfere with the accelerometers and gyroscope sensors on circuit board assembly **110**, while the bottom member **117** is more flexible to enhance durability of the assembly during landings and crashes. In other embodiments, molded frame assembly **102** may be a single piece mold that may optionally have top and bottom portions with differing durometers.

A motor housing **118** is located at the distal end of each arm **114**. Motor housing **118** is adapted to secure the operational components of motor assemblies **108**. In an embodiment, as depicted, motor housing **118** comprises an open-ended cylinder, but can be otherwise shaped, depending on the shape of the specific motor assemblies **108**. Distally further beyond motor housing **118** along each of arms **114**, the ends of arms **114** are shaped to snap-fit with portions of removable safety ring **104** and portions of each motor assembly **108**. In an embodiment, each of these ends are angled relative to the rest of arm **114** to adapt to a corresponding projecting portion of removable safety ring **104** such that arm **114** can fit over the projecting portion of removable safety ring **104**.

In the prior art, the conventional carbon-fiber “X” configuration used to address vibration issues, suffers from cost and assembly issues, among others. Frame assembly **102** of some embodiments of the invention remedies these problems. The molded body of center body **112** having arms **114** extending from shoulders **116**, in combination with the solid arms **114** with an intra-arm channel instead of struts or a beam configuration as in the prior art, provides a solid base to absorb vibration, while reducing weight. In an embodiment, the use of circuit-board assembly **110** as a major structural support as operably coupled to center body **112**, as will be described, provides stiffness and strength to frame assembly **102**.

In an embodiment, referring to FIGS. 6 and 7, center body **112** further comprises a battery compartment member **120**. Corner screws **122** sandwich the circuit-board assembly **110** between battery-compartment member **120** and shoulders **116** to create the center shape. Replaceable and rechargeable battery **124** is shown in FIG. 6 offset from the other components of frame assembly **102** for ease of viewing, and in line with the other components of frame assembly **102** in FIG. 7.

In embodiments, battery compartment member **120** is defined by the top member and bottom member of center body **112** as described above.

In another embodiment, frame assembly **102** is formed as a single-piece (not shown), and includes a battery-compartment member **120** and plurality of arms **114**, with the circuit-board assembly **110** operably coupled to the single-piece frame in the corners of center body **112** by screws or snap-fit.

In embodiments, the height of center body **112** in the vertical axis of hovering remote-control flying craft **100**, and optionally in combination with battery-compartment mem-

8

ber **120** and corner screws **122**, provides enough clearance for the rotational components of the downward-facing motor assemblies **108**.

Removable safety ring **104** generally comprises an outer band **126** and a plurality of Y-arms **128**. Outer band **126**, in an embodiment, comprises a circular band of material that surrounds the components of hovering remote-control flying craft **100** with a diameter large enough so that each of the rotational components of motor assemblies **108** has room to operate. Effectively, outer band **126** provides the bounds of the footprint of the hovering remote-control flying craft **100**. Therefore, outer band **126** is configured to protect propellers of each motor assembly **108** from lateral contact. In other embodiments, outer band **126** is not perfectly circular, but is instead formed in an oblong or oval shape, or in other embodiments, has a polygon shape. In embodiments, outer band **126** can be made of plastic polymer(s), metal, or other lightweight, yet durable material.

Individual Y-arms **128** extend from the inner surface of outer band **126** proximate the location of arms **114**, and spaced similarly to the extension location of arms **114** away from center frame **112**, at arms **114** respective distal locations. Each of the upper extending prongs of each Y-arm **128** is operably coupled to the inner surface of outer band **126**. The stem of the Y thereby projects toward the relative center of the circle formed by outer band **126** towards center frame **112**. Each of Y-arms **128** includes a projecting portion on the stem that is adapted to interface with each of ends of arms **114** and each of motor assemblies **108**. As depicted, four Y-arms **128** extend from the inner surface of outer band **126**, but a greater or lesser number of Y-arms **128** can also be utilized to support the defined number of motor assemblies **108** of any particular vehicle.

A common problem exists for all aeronautical vehicles that utilize propellers, rotors, or other rotating means for propulsion. The propellers can be damaged by objects in the vehicle's flight path, and further, there is a danger to the user or others from the rotating propellers. In the prior art, myriad solutions have been tried, including the use of a conventional wire “globe” encompassing the entire craft, or a foam enclosure around each propeller. However, these solutions are aesthetically unpleasing and often hinder the craft's functionality. In embodiments of the present invention, the removable safety ring **104** provides a minimally-intrusive outer band **126** for protection. Further, the Y-arms **128** extending from the outer band **126** distribute impact forces and/or stiffen the craft. Additionally, the snap-on functionality of removable safety ring **104** allows for easy transition between operation with and without removable safety ring **104**. FIGS. 8-9 depict a hovering remote-control flying craft **800**, which is equivalent to craft **100** without safety ring **104**, according to an embodiment.

Shell **106** provides an enclosure or partial enclosure that protects the components of circuit-board assembly **110**. In an embodiment, as depicted in FIGS. 1-7, shell **106** includes apertures formed to receive each of arms **114**. The body of shell **106** is likewise formed to receive center frame **112**. Snap-fit components or tabs interface with frame assembly **102**, and specifically, arms **114**, as illustrated in FIG. 5, to secure shell **106** to frame assembly **102**. Shell **106** can be made of plastic, metal, or other lightweight, yet durable material, such as a thermoplastic, and vacuum-formed into myriad shapes, as will be understood by one skilled in the art. In embodiments, shell **106** includes translucent or transparent windows for enhancing the visibility of LED output from circuit-board assembly **110**. In other embodiments,

shell **106** includes reflective surfaces on the inner portions for similarly enhancing the visibility of LED output.

Each of the plurality of motor assemblies **108** may generally comprise a motor **130**, a propeller **132**, an optional motor cover **134**, and wiring **136**. Motor **130** can be any electromechanical device that converts electrical energy into mechanical energy. In an embodiment, as illustrated, motor **130** comprises a cylindrical structure having outer edges that are slightly smaller than the inner edges of motor housing **118**. In other embodiments, motor **130** can be any other desired structure shape. Of course, the corresponding support structures, such as motor housing **118**, Y-arm **128**, and arm **114** can also be adapted to support other motor **130** shapes.

Propeller **132** converts rotary motion to provide propulsive force. In an embodiment, as illustrated, propeller **132** is in a twisted airfoil shape. Other shapes are also considered, depending on the performance properties desired for the propeller **132** in terms of efficiency, thrust, attack angle and RPM. Propeller **132** can be made from plastic, metal, or other lightweight, yet durable material. In embodiments, propeller **132** can be smaller or bigger, and of different pitches. In some embodiments with four propellers **132**, two propellers are designed for clockwise rotation and two propellers are designed for counter clockwise rotation. In other embodiments (not shown) the number of thrust elements comprised of an arm, motor and one or more propellers can be any number greater than two. In other embodiments, a pair of propellers, one facing downward and one facing upward, may be used for each motor and arm combination of a thrust element.

In some embodiments, motor cover **134** comprises a capped cylinder such that the cylinder is open on one end and adapted to receive motor **130** and a portion of Y-arm **128** and motor housing **118**. Motor cover **134** is shaped slightly larger than motor **130**, and more particularly, motor housing **118** such that the inner edges of motor cover **134** are slightly larger than the outer edges of motor housing **118**. The motor cover **134** is adapted to be oversized or provide a structural channel to enclose and protect wiring **136** that extends from a top end of the motor **130** and are routed via the arms **114** to the center body **112**. In certain embodiments, the open end of motor cover **134** can be shaped or cut out to conform to the opposite receiving end of the respective portions of Y-arm **128** and motor housing **118**. Motor cover **134** is thus adapted to provide the snap-on fit of safety ring **104** to secure Y-arm **128** to motor housing **118** and arm **114**. In some embodiments, motor cover **134** may be a solid cylindrical cover and in other embodiments, motor cover **134** may include slots or cutout sections in either or both the side and top walls of the motor cover **134**. In other embodiments, motor housing **118** may be molded into arms **114**, or motor **130** may be secured in position to arms **113** by other mechanical arrangements.

Wiring **136** comprises insulated conductors adapted to carry electricity for power and/or control. Wiring **136** operably couples the power source, such as battery **124**, to motor **130** to provide the proper electrical signal to operate motor **130**, and may optionally include control signal as part of the power signals, or may include separate control wires.

Similar to the safety problem discussed above with respect to safety ring **104**, a common problem exists with respect to the motors **130** and propellers **132** in that they can be damaged by items in the flight path of the hovering remote-control flying craft **100**. Further, problems exist in mounting the motor, effectively wiring the motor, and having structure proximate the propeller that creates inefficient

airflow. In the prior art, motors are typically mounted by a holder on an end of a carbon-fiber rod that such that the propellers are upward-facing. In embodiments of the present invention, the motor assemblies **108** are mounted downward for improved efficiency. Motor housing **118** provides an easy manufacturing guide during assembly, as well as improves the ability of frame assembly **102** to absorb shock and vibration. Motor cover **134** not only protects wiring **136** from motor **130**, but also aids in securing motor **130**, and also improves the aesthetics of hovering remote-control flying craft **100**.

Referring to FIGS. **10-13**, circuit-board assembly **110** is depicted. Circuit-board assembly **110** generally comprises printed board **138** and electrical components gyroscope **140**, accelerometer **142**, magnetometer **144**, microcontroller **146**, LED **148**, infrared receiver **150**, radio **152**, infrared transmitter **154** (e.g., an infrared laser), a plurality of motor connectors **156**, and power connector **158**.

Printed board **138** comprises a circuit board to mechanically support and electronically connect the aforementioned electronic components. Embodiments of printed board **138** therefore comprise layers of conducting material and insulating material. In some embodiments, printed board **138** comprises a unique tabbed design. The tabs of printed board **138** mechanically support the plurality of motor connectors **156**, power connector **158**, and radio **152**, while the body of printed board **138** is left free to support the electronic components, which require relative proximity to each other due to the required electrical connections. In some embodiments, printed board **138** is operably coupleable to frame assembly **102**, and specifically, center body **112** via fasteners **122**, as shown in FIG. **6**. In other embodiments, printed circuit board **138** is snap-fit into center body **112**. The tabbed design of printed board **138** further aids in securing printed board **138** into center body **112**. Embodiments of printed board **138** positioned and secured into center body **112** further provide structural support for the top member and bottom member of center body **112**, as previously described, as well as each of arms **114**.

Problems exist for printed boards of the prior art. Cost, extensive assembly time, board space limitations, and wireless-transmission design issues are all prevalent in conventional designs. Traditionally, power wiring is soldered directly to the circuit board. Further, wire-to-wire connectors are often utilized for battery connection to the circuit board, which all take up valuable space on the circuit board. In embodiments of the present invention, the printed board **138** comprises a plurality of tabs extending from the sides of the body of the printed board **138** that have plug in connectors **156** for power wires to motors **130**. Additionally, in embodiments, a printed board **138** comprises a tab extending for the surface mount power connector **158** on the bottom side of printed board **138** and a tab on the opposite end of printed board **138** for radio **152**. Such a tabbed printed board **138** design saves valuable retail space on the body of the printed board **138**, enables efficient assembly, and allows for the effective transmission of wireless data.

Gyro **140** comprises a sensor or set of sensors for measuring the orientation or angular position of hovering remote-control flying craft **100**. Gyro **140** comprises, in an embodiment, a 3-axis microelectromechanical (MEMS) gyro capable of measuring roll, pitch, and yaw. As illustrated, circuit-board assembly **110** comprises a single gyro **140** chip package for all three axes. In embodiments, additional gyros **140** or gyro chip packages can be utilized.

Accelerometer **142** comprises a sensor or set of sensors for measuring the acceleration relative to hovering remote-

11

control flying craft **100**. In an embodiment, accelerometer **142** is used to measure Earth's gravity as a reference for the "down" vector upon which errors in gyro **140** are estimated and removed. Accelerometer **142** comprises, in an embodiment, a MEMS accelerometer. As illustrated, circuit-board assembly **110** comprises a single 3-axis accelerometer **142**. In embodiments, additional accelerometers **142** or accelerometers packages can be utilized.

Magnetometer **144** comprises a sensor or set of sensors for measuring the strength or direction of magnetic fields for compassing and dead reckoning of hovering remote-control flying craft **100**. Magnetometer **144**, in an embodiment, can also be used to measure the Earth's magnetic field to use as a static reference vector upon which the errors of the gyroscope **140** are estimated and removed. As illustrated, circuit-board assembly **110** comprises a single magnetometer **144**. In embodiments, additional magnetometers **144** or magnetometer packages can be utilized.

Microcontroller **146** comprises an integrated circuit containing a processing core and memory, and is configured to receive input and promulgate output. Specifically, microcontroller **146** is configured to control motors **130**. In an embodiment, the integrated circuit of microcontroller **146** comprises motor drivers **162** configured to interface with motors **130**. In embodiments microcontroller **146** comprises machine-executable code for navigation, filtering, and compensation algorithms, among other guidance-based algorithms incorporating gyro **140**, accelerometer **142**, and/or magnetometers **144** inputs.

LED **148** comprises a semiconductor light source for lighting hovering remote-control flying craft **100**. In embodiments, LED **148** is configured to illuminate in several different colors. Circuit-board assembly **110** can comprise a single LED **148**. In other embodiments, multiple LEDs **148** can be utilized. In embodiments, LED **148** is selectable in response to RF signals from a controller.

Infrared receiver **150** comprises a receiver of infrared signals. As illustrated, circuit-board assembly **110** comprises a single infrared receiver **150**. In embodiments, additional infrared receivers can be utilized.

Radio **152** comprises a radio transmitter for interfacing with other radios or devices configured to receive radio signals. In embodiments, radio **152** further comprises a radio receiver for interfacing with transmitted radio signals. As illustrated, circuit-board assembly **110** comprises a single radio **152**. In embodiments, additional radios **152** can be utilized.

Infrared transmitter **154** comprises a transmitter of infrared signals. As illustrated, circuit board assembly **110** comprises a single infrared transmitter **154**. In embodiments, additional infrared transmitters can be utilized. In embodiments, the functionalities of infrared receiver **150** and infrared transmitter **154** are combined into a single infrared transceiver (not shown).

Optionally, circuit-board assembly **110** can further comprise pairing button **155**. As illustrated, a portion of pairing button **155** extends over the bounds of printed board **138** to provide an interface for activating pairing functionality, as will be described.

Referring generally to FIGS. **14-20**, an embodiment of a one-handed controller **1000** for controlling hovering remote-control flying craft **100** is illustrated. Controller **1000** generally comprises a controller body **1020**, a top hat assembly **1040**, a trigger assembly **1060**, and a circuit-board assembly **1080**.

Controller body **1020** generally comprises a top housing **1100** and a bottom housing **1120**. Top housing **1100** com-

12

prises a partial enclosure for the components of controller **1000** and generally includes a center wall **1140**, side walls **1160**, a top-hat aperture **1180**, and an infrared cutaway **1200**. Body **1020** or portions thereof can be made of molded plastic, including thermoplastics, thermosets, and elastomers, in embodiments.

In an embodiment, the lengthwise span of center wall **1140** is overall slightly curved or angled to form a pleasing tactile interface with the hand of a user as well as provide a reference indication. In embodiments, center wall **1140** comprises a plurality of sections angled relative to each other to create a slightly curved overall structure. A top surface of center wall **1140** is generally flat to provide a reference surface for the user. The flat top surface informs the user how to hold controller **1000** via the structure itself. Orientation of remote-control flying craft **100** controlled by controller **1000** relative to the flat surface is thereby expressed to the user. The opposing underneath surface can optionally comprise fastener receiving apertures adapted to assist in securing top housing **1100** and bottom housing **1120**.

Side walls **1160** extend from center wall **1140** in a slightly curved manner to form a relative U-shape with center wall **1140** and thereby, partial walls of the enclosing structure of body **1020**. In embodiments, the edges of side walls **1160** are slightly projected and adapted to couple to a corresponding lip aperture of bottom housing **1120**. In operation, when gripped by a user, top housing **1100**, and particularly, center wall **1140** and side walls **1160** generally interfaces with the palm of the user's hand. In embodiments, portions of center wall **1140** and/or portions of side walls **1160** can include cutaways to better conform to the hand of the user.

Top-hat aperture **1180** is provided within center wall **1140** and extends into portions of side walls **1160**, in embodiments, to allow top-hat assembly **1040** to project above top housing **1100** when controller **1000** is assembled, as illustrated, for example, in FIG. **14**. Top-hat aperture **1180** is positioned in the relative "front" of top housing **1100** distal the "back" end of top housing **1100** that interfaces with the palm of the user. Top-hat aperture **1180** is large enough to allow full motion of top-hat assembly **1040**, as will be described.

Infrared cutaway **1200** is provided proximate top-hat aperture **1180** within center wall **1140** and extending into portions of side walls **1160**, in embodiments, to allow targeted infrared communication with other devices, for example, remote-control flying craft **100**. As illustrated, infrared cutaway **1200** is substantially X-shaped, but can be other shapes or sizes, depending on the embodiment. Further, infrared cutaway **1200** can be covered with transparent or translucent material to enable the display of light-emitting diode (LED) coloring via components of circuit-board assembly **1080**.

In embodiments, a pair of one hovering flying craft **100** and one handheld controller **1000** are selectively associated with each other and both craft **100** and controller **1000** of the pair each include at least one multi-color LED configured to display a common selectable color that is the same for both craft **100** and the controller **1000** and indicates a team to which the pair of the craft **100** and controller **1000** are assigned for purposes of playing multiplayer team games.

Bottom housing **1120** comprises the opposing structure to top housing **1100** for the enclosure of the components of controller **1000**. Bottom housing **1120** generally includes a center wall **1220**, side walls **1240**, trigger aperture **1260**, and internal supporting structure **1280**. Optionally, bottom housing **1120** can further comprise fastener apertures.

13

In an embodiment, the lengthwise span of center wall **1220** is overall slightly curved or angled to form a pleasing tactile interface with the hand of a user. In embodiments, center wall **1220** comprises a plurality of sections angled relative to each other to create a slightly curved overall structure, as illustrated in FIG. **20**, mirroring that of top housing **1100**.

Side walls **1240** extend from center wall **1220** in a slightly curved manner to form a relative U-shape with center wall **1220** and thereby, partial walls of the enclosing structure of body **1020**. A receiving lip is formed along the edges of side walls **1240** of bottom housing **1120** in order to create a tight interface to top housing **1100**, and particularly, the projecting lip of side walls **1160**. When gripped by a user, bottom housing **1120** generally interfaces with the fingers of the user's hand. In embodiments, portions of center wall **1220** and/or portions of side walls **1240** can include cutaways to better conform to the hand of the user.

Trigger aperture **1260** is provided within center wall **1220** and extends into portions of side walls **1240** in embodiments, to allow trigger assembly **1060** to project through bottom housing **1120** when controller **1000** is assembled, as illustrated, for example, in FIG. **14**. Trigger aperture **1260** is shaped similarly to trigger assembly **1060** but slightly larger than trigger assembly **1060**; for example in a rectangle having rounded corners. Trigger aperture **1260** is positioned in bottom housing **1120** proximate the relative positioning of top-hat aperture **1180** in top housing **1100**, that is, near where the forefinger or trigger finger can comfortably grip trigger assembly **1060** when the user grips body **1020**.

Supporting structure **1280** is provided within bottom housing **1120** for supporting and mounting a circuit-board assembly **1080** and related components. Supporting structure **1280** can comprise a series of rails or an enclosed frame. As illustrated in FIG. **20**, portions of circuit-board assembly **1080** can be slid into place, as will be described, to securely lock and position the operational electronic components.

Top-hat assembly **1040** generally includes a base **1320** and a top hat **1340**. Base **1320**, as illustrated, can comprise a half-dome shape. Base **1320** can be rounded or flat, but is angled such that top hat **1340** can be maneuvered around the shape of base **1320** with a full range of motion. Base **1320** is secured to portions of bottom housing **1120** proximate the relative location of top hat aperture **1180** when top housing **1100** is coupled to bottom housing **1120**. A portion of base **1320** can thereby project above the plane of top housing **1100** to allow full range of motion of top hat **1340**.

Top hat **1340** extends from base **1320** to provide a tactile interface for the thumb of the user to further control remote-control flying craft **100**. Top hat **1340** can comprise any number of shapes, but preferably includes a flat top surface and one or more angled side surfaces. For example, referring to FIGS. **16-18**, top hat **1340** comprises a rounded hexagon. The flat top surface can be textured to further provide additional grip for the thumb of the user.

Trigger assembly **1060** generally includes finger interface **1360** and actuating structure **1380**. Finger interface **1360** comprises a generally rectangular body having a rounded crescent side for directly and comfortably contacting the finger of the user. When trigger assembly **1060** is assembled to body **1020**, finger interface **1360** projects outside of body **1020**. Actuating structure **1380** is operably coupled to finger interface **1360** and is coupled inside of body **1020**. Actuating structure **1380** provides a resilient spring-like feel to finger interface **1360**, and can be constructed via components known in the art such as mechanical components such as springs, pneumatic actuators, or electric actuators, for

14

example. Due to the angle of trigger assembly **1060** relative to body **1020**, components of actuating structure **1380** can be coupled to top housing **1100** and/or bottom housing **1120**, in various embodiments. In various embodiments, circuit-board assembly **1080** provides a stiff backing wall for trigger assembly **1060**.

Circuit-board assembly **1080** generally comprises a printed board **1400** and electrical components an accelerometer (not shown), a magnetometer (not shown), a microcontroller **1420**, an LED **1440**, an infrared receiver (not shown), a radio (not shown), and an infrared transmitter (not shown).

Printed board **1400** comprises a board to mechanically support and electronically connect the aforementioned electronic components. Embodiments of printed board **1400** therefore comprise layers of conducting material and insulating material. Printed board **1400** comprises a unique tabbed design. The body of printed board **1400** supports the electronic components, which require relative proximity to each other due to the required electrical connections. Printed board **1400** can be operably coupled to supporting structure **1280** via fasteners. In other embodiments, printed board **1400** is snap-fit into supporting structure **1280**.

The accelerometer comprises a sensor or set of sensors for measuring the acceleration of controller **1000**. Accelerometer comprises, in an embodiment, a MEMS accelerometer. In an embodiment, circuit-board assembly **1080** comprises a single accelerometer. In embodiments, additional accelerometers or accelerometers packages can be utilized.

The magnetometer comprises a sensor or set of sensors for measuring the strength or direction of magnetic fields for compassing and dead reckoning of controller **1000**. In an embodiment, circuit board assembly **1080** comprises a single magnetometer. In embodiments, additional magnetometers or magnetometer packages can be utilized.

Microcontroller **1420** comprises an integrated circuit containing a processing core and memory, and is configured to receive input and promulgate output. Specifically, microcontroller **1420** is configured to sample data from the gyros and accelerometers. In an embodiment, the integrated circuit of microcontroller **1420** comprises machine-executable code for interfacing with remote-control flying craft **100** under control by controller **1000**.

LED **1440** comprises a semiconductor light source for lighting controller **1000**. In embodiments, LED **1440** is configured to illuminate in several different colors. Circuit-board assembly **1080** can comprise a discrete LED board, in embodiments. Further, LED **1440** can comprise a single LED **1440**. In other embodiments, multiple LEDs **1440** can be utilized. Team play can thereby be facilitated, by providing a uniform color to each controller **1000** for a particular team.

The infrared receiver comprises a receiver of infrared signals. In an embodiment, circuit-board assembly **1080** comprises a single infrared receiver. In embodiments, additional infrared receivers can be utilized.

The radio comprises a radio transmitter for interfacing with other radios or devices configured to receive radio signals. In embodiments, radio further comprises a radio receiver for interfacing with transmitted radio signals. In an embodiment, circuit-board assembly **1080** comprises a single radio. In embodiments, additional radios can be utilized.

The infrared transmitter comprises a transmitter of infrared signals. In an embodiment, circuit-board assembly **1080** comprises a single infrared transmitter. In embodiments, additional infrared transmitters can be utilized. In embodi-

15

ments, the functionalities of the infrared receiver and the infrared transmitter are combined into a single infrared transceiver (not shown).

In embodiments, controller **1000** can further comprise a gyro package. The gyro package can comprise a sensor or set of sensors for measuring the orientation or angular position of controller **1000**. The gyro comprises, in an embodiment, a 3-axis microelectromechanical (MEMS) gyro capable of measuring roll, pitch, and yaw. In an embodiment, circuit-board assembly **1080** comprises a single gyro package for all three axes. In embodiments, additional gyros or gyro packages can be utilized, or no gyros can be used, in other embodiments.

In embodiments, controller **1000** further comprises rechargeable battery **1460** configured to power the aforementioned electrical components. In embodiments, controller **1000** further comprises a USB connection (not shown) adapted to receive a standard USB cable. The opposite end of the USB cable can be connected to a computer, wall outlet, or other power source, in order to recharge rechargeable battery **1460**. In embodiments, the USB connection further interfaces with components of circuit board assembly **1080**.

In embodiments, controller **1000** further comprises a vibrator motor (not shown). The vibrator motor can provide real-time feedback to the user during operation of the controlled remote-control flying craft **100**. For example, obstructions encountered by remote-control flying craft **100** can be relayed to the user via vibrations. In embodiments, warnings or status can likewise be vibrated to the user.

In embodiments, controller **1000** further comprises a speaker **1450**. The speaker **1450** can provide real-time feedback to the user during operation of the controlled remote-control flying craft **100**. For example, obstructions encountered by remote-control flying craft **100** can be relayed to the user via sounds and/or spoken words. In various embodiments, warnings or status can likewise be communicated to the user by sound.

Optionally, controller **1000** can include a pairing button **1470**. A problem exists when many RF devices are within RF range of each other. In the prior art, the devices are similarly forced to use different “channels” implemented by different radio frequencies. In additional embodiments of controller **100**, the frequency-agile radio can support “pairing” via a push button or pairing key. Myriad RF communication possibilities thus exist, and are not limited to a finite number of pre-programmed “channels.”

Fasteners **1480**, as depicted in FIG. **20**, can be positioned through bottom housing **1120**, and specifically, fastener apertures, and into top housing **1100**, and specifically, fastener receiving apertures in order to operably couple top housing **1100** and bottom housing **1120** to assemble controller **1000**.

In embodiments, controller **1000** microcontroller comprises operation code for control sequences for changing craft from novice to expert mode. A series of signals sent from controller **1000**, for example, via top hat **1340**, can activate code inside the microcontroller to toggle modes. Novice mode provides a throttling or limiting filter on data collected from controller **1000** for implementation by remote-control flying craft **100**. In other words, any large magnitude motion or movement is scaled back as interpreted movement to remote-control flying craft **100**. In contrast, expert mode provides no filter or throttling; the user is free to operate remote-control flying craft **100** to its limits.

During game play, trigger assembly **1060** can be used. Specifically, the forefinger of the user can interface with

16

finger interface **1360** and become depressed via actuating structure **1380**. In this way, shooting games such as those using air-to-air or air-to-ground targets, as well other directional transmission games such as capture the flag, elimination, domination, and tag can be implemented.

In embodiments of controller **1000** used for game play, the infrared transmitter and infrared receiver can be configured for aerial game play with team selection capabilities. A problem exists in selecting and maintaining teams with aerial game play where there are a plurality of players and teams. This problem is further exacerbated by the close proximity of several transmitters and receivers, which can result in jamming. In the prior art, devices on separate sides are forced to use different “channels” implemented by different IR frequencies. Such a solution provides very limited game play options. Embodiments of the present invention feature code transmission with a simple code unique to the craft’s team. The craft can thereby ignore codes for other teams. Additional or multiple teams can then be easily created, resulting in much greater range of game-playing options.

Referring to FIG. **21**, a system **3000** for reprogramming a controller **1000** and a remote-control flying craft **100** controlled by controller **1000** is illustrated. System **3000** comprises a computing device **3020**, a wireless interface **3040**, and of course, the aforementioned controller **1000** and remote-control flying craft **100**.

Computing device **3020** can include a desktop or laptop computer configured to download controller **1000** and/or remote-control flying craft **100** operating code. Computing device **3020** is further adapted to package the operating code in the protocols and messages prescribed by the controller **1000** and remote-control flying craft **100** interfaces.

Wireless interface **3040** comprises an interface over which operating code programming signals can be transmitted. In an embodiment, wireless interface **3040** comprises a USB dongle, as illustrated in FIG. **21**. In other embodiments, wireless interface **3040** comprises Bluetooth, WIFI, or any other wireless transmission protocol.

To reprogram a controller **1000** and remote-control flying craft **100**, computing device activates wireless interface **3040**. Wireless signals are transmitted to controller **1000** and remote-control flying craft **100**, either in combination or serially, with new operational code, which is received by the corresponding antenna of each controller **1000** and remote control flying craft **100**. Wireless reprogramming can be done in this way due to the functionality of the controller **1000** radio and microcontroller. The controller **1000** radio, in embodiments, includes its own microcontroller for reset. Therefore, the radio firmware exists during reprogramming, despite the resetting of the other operational code.

In flight operation, the user grips, via one-handed operation, body **1020** of controller **1000**. Preferably, the user grips body **1020** approximately in the center of body **1020**, near the angle of top housing **1100** and bottom housing **1120**, with the palm of the user interfacing to top housing **1100** and the fingers of the user interfacing to bottom housing **1120**. The user’s fingers can comfortably wrap around the curved sides of bottom housing **1120** to touch or slightly interface with the sides of top housing **1100**, depending on the size of the user’s hand. The grip ideally is placed such that the thumb of the user comfortably reaches the center of top hat **1340**.

Controller **1000** is synched or paired with remote control flying craft **100** to activate remote control flying craft **100** relative to controller **1000**. The user can then motion, with one hand via controller **1000**, forward, backward, left, or

17

right to subsequently direct remote control flying craft **100**. Thrust and yaw are controlled through top hat assembly **1040**. Specifically, top hat **1340** is directed around base **1320** by the user's thumb. Top hat **1340** is magnitude sensitive such that additional force on top hat **1340** creates additional thrust of remote control flying craft **100**.

Sensors within controller **1000** are sampled and this data output from controller **1000** and transmitted to hovering remote control flying craft **100** via the radio of controller **1000** and received by radio **152**. The user's operational signals are transmitted to microcontroller **146** in the form of the interface control protocol. Referring again to FIG. **13**, gyro **140**, accelerometer **142**, and magnetometer **144** sensor readings are input into microcontroller **146**. Based on the sensed data and control instructions, microcontroller **146** can, via motor driver **162**, control the individual motors **130** in order to navigate hovering remote control flying craft **100** by mimicking the motion of controller **162**.

In embodiments, various predefined maneuvers for craft **100** can be implemented by special or a particular sequence of commands from controller **1000**. For example, a "flip" mode can be commanded to craft **100** by holding trigger assembly **1060** for longer than a defined period of time, while simultaneously tilting controller **1000** in the direction of the desired flip. In an embodiment, the period of time can be 1-5 seconds, for example. Code is subsequently sent by controller **1000** to craft **100** to implement the flip in the direction of the controller **1000**.

Other maneuvers can also be implemented; for example, a pursuit curve, oblique turn, vertical turn, displacement roll, flat scissors, rolling scissors, barrel roll, yo-yo, or lag roll. Additionally, combinations of particular maneuvers can also be implemented based on a sequence of controller **1000** commands. In an embodiment, controller **1000** can command a leftward flip followed by an oblique turn by a trigger assembly **1060** hold for 1-5 seconds with movement of controller **1000** leftward followed by a trigger assembly **1060** hold for 1-5 seconds with movement of controller **1000** downward. Myriad combinations of maneuvers are considered.

Further, microcontroller **146** can illuminate LEDs **148**, depending on the particular application and desire of the user; for example, during game play. Additionally, microcontroller **146** can transmit data via radio **152**. Infrared receiver **150** can input data to microcontroller **146**. Likewise, microcontroller **146** can command infrared transmitter **154** to output IR data, depending on the application.

In embodiments of hovering remote control flying craft **100** used for game play, infrared transmitter **154** and infrared receiver **150** can be configured for aerial game play with team selection capabilities. A problem exists in selecting and maintaining teams with aerial game play where there are a plurality of players and teams. This problem is further exacerbated by the close proximity of several transmitters and receivers, which can result in jamming. In the prior art, devices on separate sides are forced to use different "channels" implemented by different IR frequencies. Such a solution provides very limited game play options. Embodiments of the present invention feature code transmission with a simple code unique to the device's team. The device can thereby ignore codes for other teams. Additional or multiple teams can then be easily created, resulting in much greater range of game-playing options.

A similar problem exists when many devices are within RF range of each other. In the prior art, the devices are similarly forced to use different "channels" implemented by different radio frequencies. In additional embodiments of

18

hovering remote control flying craft **100**, the frequency-agile radio **152** can support "pairing" via a push button or pairing key. Myriad RF communication possibilities thus exist, and are not limited to a finite number of pre-programmed "channels." For example, referring again to FIGS. **10** and **12**, pairing button **155** can enable this functionality.

In some embodiments, the present invention provides a hovering flying craft adapted to be controlled by a handheld remote control, the craft including a molded frame assembly including a center body formed of a top member having at least three arms integrally molded with and extending outwardly from the center body and a bottom member having at least three legs integrally molded with and extending downwardly from the center body; at least three motor assemblies that each include an electromechanical motor and at least one corresponding propeller operably mounted downwardly-facing, with at least one motor assembly operably mounted at a distal portion of each of the at least three arms; a circuit board assembly operably mounted to the center body and configured to control the craft in response to radio frequency signals from the handheld remote control, and a replaceable rechargeable battery insertable into a battery compartment defined by the top member and the bottom member and operably connectable to electrically power the circuit board assembly and the at least three motor assemblies.

In some embodiments of the craft, the circuit board assembly is positioned and secured in the center body to provide structural support for the top member and the arms of the molded frame assembly. In some embodiments, the circuit board assembly includes a printed board having a plurality of tabs that extend outwardly from a central surface structure adapted to support circuit board assembly components, including a gyroscope, an accelerometer, a magnetometer, a microcontroller, and a radio. In some embodiments, the plurality of tabs include a tab having a power connector for the rechargeable battery, a tab having a radio frequency antenna for the radio, and a tab having both an infrared emitter and an infrared receiver.

In some embodiments, the craft further includes at least one multi-color LED operably connected to the circuit board assembly and configured to display a selectable color in response to frequency signals from the handheld remote control. In some embodiments, the craft further includes a removable safety ring mountable to and extending from the distal portion of the arms and configured to protect the propellers from lateral contact. In some embodiments, each of the motor assemblies includes a motor cover that is configured to secure the motor to the arm by a snap fit. In some embodiments, the arms are formed of an injectable molded plastic having a durometer greater than 70 Shore D and the legs are formed of an injectable molded plastic having a durometer less than 60 Shore D.

In some embodiments of the craft, the center body is formed of a two-piece structure that sandwiches the circuit board assembly to provide structural support for the molded frame assembly. In some embodiments, the craft further includes a removable safety ring that protects the propellers from lateral contact and includes an outer ring supported by a plurality of Y-arms that are each adapted to correspond to and interface with a corresponding one of the at least three arms. In some embodiments, at least one of the at least three motor assemblies includes a second propeller operably mounted upwardly-facing, in addition to the at least one propeller operably mounted downwardly-facing.

In some embodiments, the present invention provides a hovering flying craft system or kit that includes a hovering

flying craft including: a frame assembly including a center body having at least three arms extending outwardly from the center body; at least three motor assemblies that each include an electromechanical motor and at least one corresponding propeller mounted at a distal portion of each arm; a circuit board assembly operably mounted to the center body and configured to control the craft in response to radio frequency signals and to control an infrared emitter and an infrared receiver; and a replaceable rechargeable battery insertable into the frame assembly and operably connectable to electrically power the circuit board assembly and the at least three motor assemblies; and a handheld controller configured to allow a user to control the hovering flying craft by providing inputs for an intended pitch and attitude of the hovering flying craft, and a thrust and yaw of the hovering flying craft, the controller including: a trigger assembly adapted to be manipulated by a finger of the user to provide the user with a control for sending commands to control at least the infrared emitter on the hovering flying craft; a control processor configured to provide control signals to a radio that generates the radio frequency signals for communication to and control of the hovering flying craft and the infrared emitter; and a battery to electrically power the handheld controller.

In some embodiments of the system or kit, the handheld controller is a one-handed controller including: a controller body adapted to be gripped by a single hand of a user and manipulated in space by the user to control the hovering flying craft, the controller body including a flat top reference surface to provide the user with a visual reference for an intended pitch and attitude of the hovering flying craft; a top hat controller adapted to be manipulated by a thumb of the single hand of the user to provide the user with a control for a thrust and yaw of the hovering flying craft; and at least one sensor configured to sense motion of the controller body as manipulated in space by the user. In some embodiments, the battery is a rechargeable battery mounted within the controller body to electrically power the handheld controller. In some embodiments, a pair of one hovering flying craft and one handheld controller are selectively associated with each other and both the craft and controller of the pair each include at least one multi-color LED configured to display a common selectable color that is the same for both the craft and the controller and indicates a team to which the pair of the craft and controller are assigned for purposes of playing multiplayer team games. In some embodiments, the circuit board assembly is operably mounted to the center body by a snap fit. In some embodiments, the center body is formed of a two-piece structure that sandwiches the circuit board assembly to provide structural support for the frame assembly.

In some embodiments, the present invention provides a system for wirelessly reprogramming a hovering flying craft and a handheld controller, the hovering flying craft adapted to be controlled by the handheld controller, the system including a hovering flying craft including a craft processor and a craft radio, the craft radio comprising a craft radio processor; a handheld controller including a controller processor and a controller radio, the controller radio comprising a controller radio processor; a computing device including a computing device processor and computing device memory, wherein the computing device processor is configured to: store craft operating code in the computing device memory, store controller operating code in the computing device memory, package the craft operating code according to the protocol of the craft radio, and package the controller operating code according to the protocol of the controller

radio; and a wireless interface adapted to transmit the packaged craft operating code from the computing device to the craft radio and the packaged controller operating code from the computing device to the controller radio, wherein the craft operating code is programmed within the craft processor by the craft radio processor, and the controller operating code is programmed within the controller processor by the controller radio processor after transmission of the craft operating code and the controller operating code along the wireless interface.

In some embodiments of the system, the wireless interface is provided by one of a USB dongle, Bluetooth, or WIFI. In some embodiments, the craft operating code is transmitted from the computing device to the craft radio and the controller operating code is transmitted from the computing device to the controller radio serially or at an overlapping time.

In some embodiments, the present invention provides a hovering flying craft adapted to be controlled by a handheld remote control, the craft including a molded frame assembly including a plurality of arms extending from a center body; a plurality of downward-facing motor assemblies, each including a motor, a propeller, and a motor cover, and located at the interface of each of the arms and the Y-arms extending therefrom, the motor cover configured to snap-fit secure an individual Y-arm and an individual arm; and a tabbed circuit board assembly operably coupleable to the center body and configured to control the plurality motor assemblies based on radio frequency signals from the handheld remote control.

In some embodiments of the craft, the center body is formed of a two-piece structure that sandwiches the circuit board assembly to provide structural support for the molded frame assembly. In some embodiments, the circuit board assembly includes a plurality of tabs that are adapted to support mounting of wire connectors, and provide surface structure on which a radio frequency antenna is constructed and emitters for both an infrared emitter and an infrared receiver. In some embodiments, the craft further includes a removable safety ring that protects the propellers from lateral contact and includes an outer ring supported by a plurality of Y-arms that are each adapted to correspond to and interface with a corresponding one of the plurality of arms.

In some embodiments, the present invention provides a method that includes providing a molded frame assembly including a plurality of arms extending from a center body; locating a plurality of downward-facing motor assemblies, each including a motor and a propeller and a motor cover, at an interface of each of the arms and Y-arms extending therefrom, the motor cover configured to snap-fit secure an individual Y-arm and an individual arm; and a tabbed circuit board assembly operably coupleable to the center body and configured to control the plurality motor assemblies based on radio frequency signals from the handheld remote control.

Various embodiments of systems, devices and methods have been described herein. These embodiments are given only by way of example and are not intended to limit the scope of the invention. It should be appreciated, moreover, that the various features of the embodiments that have been described may be combined in various ways to produce numerous additional embodiments. Moreover, while various materials, dimensions, shapes, configurations and locations, etc. have been described for use with disclosed embodiments, others besides those disclosed may be utilized without exceeding the scope of the invention.

21

Persons of ordinary skill in the relevant arts will recognize that the invention may comprise fewer features than illustrated in any individual embodiment described above. The embodiments described herein are not meant to be an exhaustive presentation of the ways in which the various features of the invention may be formed or combined. Accordingly, the embodiments are not mutually exclusive combinations of features; rather, the invention may comprise a combination of different individual features selected from different individual embodiments, as understood by persons of ordinary skill in the art.

The entire content of each and all patents, patent applications, articles and additional references, mentioned herein, are respectively incorporated herein by reference.

The art described is not intended to constitute an admission that any patent, publication or other information referred to herein is “prior art” with respect to this invention, unless specifically designated as such. In addition, any description of the art should not be construed to mean that a search has been made or that no other pertinent information as defined in 37 C.F.R. § 1.56(a) exists.

Any incorporation by reference of documents above is limited such that no subject matter is incorporated that is contrary to the explicit disclosure herein. Any incorporation by reference of documents above is further limited such that no claims included in the documents are incorporated by reference herein. Any incorporation by reference of documents above is yet further limited such that any definitions provided in the documents are not incorporated by reference herein unless expressly included herein.

It is to be understood that the above description is intended to be illustrative, and not restrictive. Although numerous characteristics and advantages of various embodiments as described herein have been set forth in the foregoing description, together with details of the structure and function of various embodiments, many other embodiments and changes to details will be apparent to those of skill in the art upon reviewing the above description. The scope of the invention should be, therefore, determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled. In the appended claims, the terms “including” and “in which” are used as the plain-English equivalents of the respective terms “comprising” and “wherein,” respectively. Moreover, the terms “first,” “second,” and “third,” etc., are used merely as labels, and are not intended to impose numerical requirements on their objects.

What is claimed is:

1. A hovering flying craft adapted to be controlled by remote control, the craft comprising:

a frame assembly including a center body having at least three arms extending outwardly from the center body and at least three legs extending downwardly from the center body;

at least three motor assemblies that each include an electromechanical motor and at least one corresponding propeller operably mounted downwardly-facing, with at least one motor assembly operably mounted at a distal portion of each of the at least three arms;

a circuit board assembly operably mounted to the center body and configured to control the craft in response to radio frequency signals; and

a replaceable rechargeable battery insertable into a battery compartment defined in the center body and operably connectable to electrically power the circuit board assembly and the at least three motor assemblies.

22

2. The craft of claim 1, wherein the circuit board assembly is positioned and secured in the center body to provide structural support for the arms of the frame assembly.

3. The craft of claim 1, wherein the circuit board assembly includes a printed board having a plurality of tabs that extend outwardly from a central surface structure adapted to support circuit board assembly components, including a gyroscope, an accelerometer, a magnetometer, a microcontroller, and a radio.

4. The craft of claim 3, wherein the plurality of tabs includes a tab having a power connector for the rechargeable battery, and a tab having a radio frequency antenna for the radio.

5. The craft of claim 1, further comprising at least one multi-color LED operably connected to the circuit board assembly and configured to display a selectable color.

6. The craft of claim 1, further comprising a removable safety assembly mountable to and extending from the distal portion of the arms and configured to protect the propellers from lateral contact.

7. The craft of claim 1, wherein each of the motor assemblies include a motor cover that is configured to secure the motor to the arm by a snap fit.

8. The craft of claim 1, wherein the arms are formed of an injectable molded plastic having a durometer value greater than 70 Shore D and the legs are formed of an injectable molded plastic having a durometer value less than 60 Shore D.

9. The craft of claim 1, wherein the center body is formed of a two-piece structure that sandwiches the circuit board assembly to provide structural support for the frame assembly.

10. The craft of claim 1, wherein at least one of the at least three motor assemblies includes a second propeller operably mounted upwardly-facing, in addition to the at least one propeller operably mounted downwardly-facing.

11. The craft of claim 1, wherein the center body is formed of a top member having the at least three arms extending outwardly from the center body and a bottom member having the at least three legs extending downwardly from the center body, and wherein the battery compartment is located between the top member and the bottom member.

12. The craft of claim 11, wherein the circuit board assembly is positioned and secured in the center body to provide structural support for the top member and the arms of the frame assembly.

13. The craft of claim 1, wherein the at least three motor assemblies further include a fourth motor assembly that includes at least one propeller operably mounted downwardly-facing.

14. A hovering flying craft adapted to be controlled by remote control, the craft comprising:

at least three means for rotating that each include at least one corresponding propeller operably mounted downwardly-facing;

means for holding the at least three means for rotating, wherein the means for holding further includes at least three legs extending downwardly from the means for holding;

means for controlling the craft in response to radio frequency signals, wherein the means for controlling is operably mounted to the means for holding the at least three means for rotating; and

means for powering the at least three means for rotating, wherein the means for powering is insertable into a compartment defined in the means for holding and is

23

operably connectable to supply electrical power to means for controlling and the at least three means for rotating.

15. The craft of claim 14, wherein the means for holding is formed of an injectable molded plastic having a durometer value greater than 70 Shore D and the legs are formed of an injectable molded plastic having a durometer value less than 60 Shore D.

16. A hovering flying craft adapted to be controlled by remote control, the craft comprising:

a frame assembly including a center body having at least three arms extending outwardly from the center body and at least three legs extending downwardly from the center body;

at least three motor assemblies that each include an electromechanical motor and at least one corresponding propeller operably mounted downwardly-facing, with at least one motor assembly operably mounted at a distal portion of each of the at least three arms;

a circuit board assembly operably mounted to the center body and configured to control the craft in response to radio frequency signals;

a replaceable rechargeable battery insertable into a battery compartment defined in the center body and operably connectable to electrically power the circuit board assembly and the at least three motor assemblies;

at least one multi-color LED operably connected to the circuit board assembly and configured to display a selectable color; and

a removable safety assembly mountable to and extending from a distal portion of each one of the at least three arms and configured to protect the propellers from lateral contact,

wherein the circuit board assembly is positioned and secured in the center body to provide structural support for the arms of the frame assembly,

wherein the circuit board assembly includes a printed board having a plurality of tabs that extend outwardly from a central surface structure adapted to support

24

circuit board assembly components, including a gyroscope, an accelerometer, a magnetometer, a microcontroller, and a radio,

wherein the plurality of tabs include a tab having a power connector for the rechargeable battery, a tab having a radio frequency antenna for the radio,

wherein each of the motor assemblies include a motor cover that is configured to secure the motor to the arm by a snap fit,

wherein the arms are formed of an injectable molded plastic having a durometer value greater than 70 Shore D and the legs are formed of an injectable molded plastic having a durometer value less than 60 Shore D,

wherein the center body is formed of a two-piece structure that sandwiches the circuit board assembly to provide structural support for the frame assembly, and

wherein at least one of the at least three motor assemblies includes a second propeller operably mounted upwardly-facing, in addition to the at least one propeller operably mounted downwardly-facing.

17. The craft of claim 16, wherein the center body is formed of a top member having the at least three arms extending outwardly from the center body and a bottom member having the at least three legs extending downwardly from the center body.

18. The craft of claim 16, wherein the center body is formed of a top member having the at least three arms extending outwardly from the center body and a bottom member having the at least three legs extending downwardly from the center body, and wherein the battery compartment is defined between the top member and the bottom member.

19. The craft of claim 1, wherein the at least three motor assemblies further include a fourth motor assembly that includes at least one propeller operably mounted downwardly-facing.

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