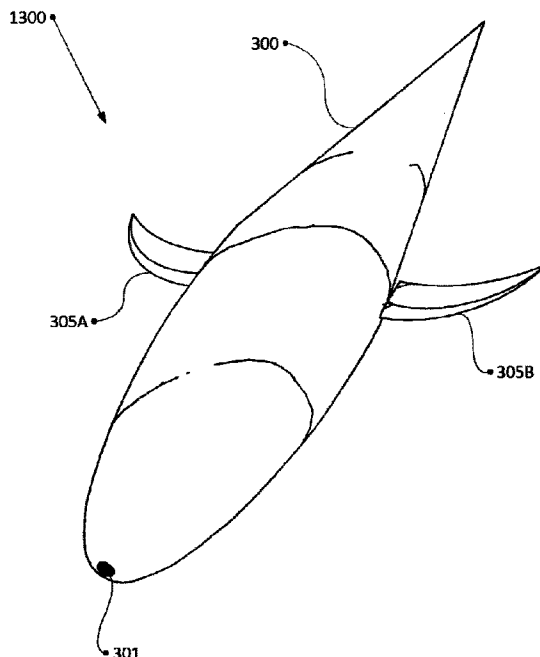




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(57) Abrégé/Abstract:

A watercraft comprises a motor, an inertial mass, and a fin. The motor oscillates the inertial mass about an axis, producing a torque reaction on and oscillation of the motor. Oscillation of the motor is communicated to the fin, producing thrust.

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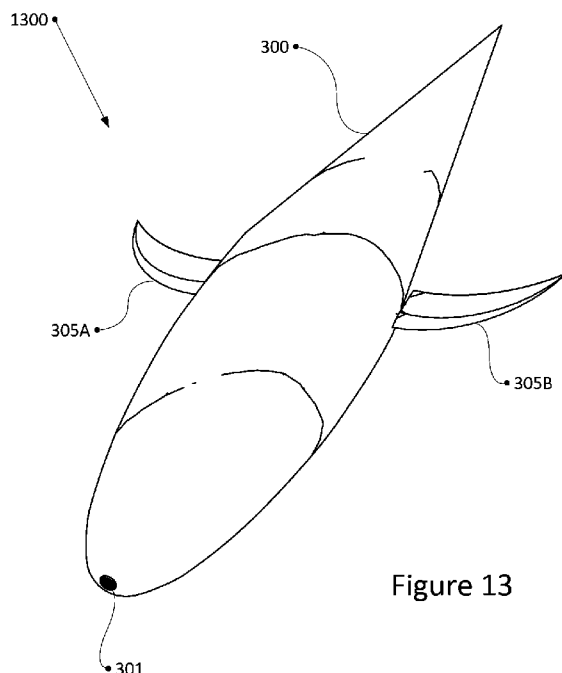


Figure 13

(57) Abstract: A watercraft comprises a motor, an inertial mass, and a fin. The motor oscillates the inertial mass about an axis, producing a torque reaction on and oscillation of the motor. Oscillation of the motor is communicated to the fin, producing thrust.

## FIN-BASED WATERCRAFT PROPULSION SYSTEM

## CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of United States Patent Application Serial Number 61/911,888, filed December 4, 2013, and United States Patent Application Serial Number 61/936,419, filed February 6, 2014.

## BACKGROUND

[0002] Design of propeller driven watercraft, including surface craft and submarines, involves a number of well known compromises involving propeller size, placement of the engine, and hull shape, to name but a few of the issues. In addition, the column of thrust fluid propelled by a single propeller rotates. Rotation of the thrust fluid does not produce thrust, though is required in order to move the thrust fluid backward (which does produce thrust). Thrust fluid rotation can be eliminated or at least balanced through the use of two counter-rotating propellers, though this results in twice the propeller surface area and (typically) twice as much drive train complexity, which reduces efficiency. In addition, efficient propeller-driven watercraft achieve roughly 0.7 on a graph of propulsive efficiency and thrust coefficient, and, even then, only in a narrow range of speeds. See, for example, "Hydrodynamic Flow Control in Marine Mammals", by Frank E. Fish, Laurens E. Howle, and Mark M. Murray, presented in the symposium, "Going with the Flow: Ecomorphological Variation across Aquatic Flow Regimes", presented at the annual meeting of the Society for Integrative and Comparative Biology, January 2-6, 2008, at San Antonio, Texas, United States, which shows an efficiency curve that is approximately an inverted parabola. Travel faster or slower than the speed where peak efficiency occurs, and the efficiency of the propeller-driven craft drops off rapidly.

[0003] In addition, propeller driven watercraft typically have a drive-shaft which, when the engine is inboard, penetrates the hull and creates the need for a drive-shaft seal (outboard motors have a severe bend in the drive-shaft, which reduces efficiency relative to inboard motors). Drive-shaft

seals create friction, require maintenance, and introduce added mechanical complexity (such as a bilge pump).

[0004] Electric motors can be utilized which are flooded with a liquid and which thereby reduce the internal-external pressure differential on the drive-shaft seal. Such motors are sometimes found in submarines; however, such motors experience greater friction because the rotor rotates in a liquid, rather than in air, and maintenance is more complex.

[0005] In contrast to propellers, fins—marine mammals and fish— have an efficiency/thrust coefficient of approximately 0.8 and the efficiency curve is very flat. Traveling faster or slower than the speed of peak efficiency results in only a modest change in efficiency. While vortexes are present in the thrust fluid propelled by a fin, unlike rotation of the column of thrust fluid coming off of a propeller, the vortexes behind a fin counter-rotate. The vortexes form a “reverse von Karman street” pattern, in which downstream vortices, as they spin and release energy over time, appear to pull upstream vortices further downstream, scavenging energy and contributing to overall thrust.

[0006] However, connecting a motor to a fin is a complex problem, particularly in a marine environment. Many fin-based propulsion systems have been designed and built, some of which produce a fish-like motion. Often, such systems have tens, hundreds, or even thousands of intricately machined parts with tight tolerances. Often, such systems have multiple moving bearings which are exposed to or which need to be sealed away from water by a “wet” seal (which attempts to seal the moving part or its bearings from water). Often, the bearings in such craft experience asymmetric loads, first on one side and then on the other. Some of such systems rely on exotic, expensive, and fragile materials, such as materials which contract or expand in an electric field.

[0007] The sheer number of parts, parts which move, seals, and asymmetrically loaded bearings reduce the efficiency of such systems, increase manufacturing costs, and decrease reliability, rendering most fin-based watercraft propulsion systems impractical for commercial use.

[0008] Needed is an inexpensive, efficient, robust, fin-based propulsion system.

[0009] Disclosed is an efficient fin-based propulsion system with only one directly powered component which, in some embodiments, is entirely sealed.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Figure 1 illustrates a perspective view of an embodiment of a remotely operated Fishboat Vertical Torque Reaction Engine ("TRE") attached to a Barge, which Barge carries a power source.

[0011] Figure 2 illustrates the Fishboat of Figure 1 in the same view, further illustrating a Horizontal Axis, Vertical Axis, Transverse Axis, and Waterline.

[0012] Figure 3A illustrates the perspective view of the Fishboat of Figure 1, with a section cut along the Horizontal Axis and a Symmetric Harness.

[0013] Figure 3B illustrates a Fishboat Vertical TRE embodiment with the same view and section cut of Figure 3A, but with an Asymmetric Bottom Harness.

[0014] Figure 3C illustrates a Fishboat Vertical TRE embodiment with the same view and section cut of Figure 3A, but with an Asymmetric Top Harness.

[0015] Figure 4A illustrates the Fishboat embodiment of Figure 3A, with section cut, in a side elevation parallel projection view.

[0016] Figure 4B illustrates the Fishboat embodiment of Figure 3B, with section cut, in a side elevation parallel projection view.

[0017] Figure 4C illustrates the Fishboat embodiment of Figure 3C, with section cut, in a side elevation parallel projection view.

[0018] Figure 5A illustrates a close perspective view of an embodiment of a Vertical TRE, generally as found in the embodiments illustrated in Figures 1-4C, with a section cut along the Horizontal Axis.

[0019] Figure 5B illustrates a perspective view of a Top Bearing, an Inertial Mass, a Stator Area, and a Bottom Bearing of a Vertical TRE, generally as found in the embodiments illustrated in Figures 1-4C, with a section cut along the Horizontal Axis and with the components partially disassembled.

[0020] Figure 5C illustrates a full TRE cycle.

[0021] Figure 6A illustrates a close parallel projection view of a portion of a Vertical TRE, generally as found in the embodiments illustrated in Figures 1-4C, with a section cut along the Horizontal Axis.

[0022] Figure 6B illustrates the view of the portion of the TRE of Figure 6A, with Inertial Mass not showing.

[0023] Figure 6C illustrates a detail of Figure 6A.

[0024] Figure 7 illustrates a front elevation parallel projection view of an embodiment of a Vertical TRE in a Fishboat embodiment, generally as found in the embodiments illustrated in Figures 1-4C, with a section cut along the Transverse Axis.

[0025] Figure 8A illustrates a front elevation parallel projection view of a schematic embodiment of a Vertical TRE in a Fishboat, further illustrating a Transverse TRE Position Adjustor.

[0026] Figure 8B illustrates a side elevation parallel projection view of a schematic embodiment of a Vertical TRE in a Fishboat, further illustrating a Horizontal TRE Position Adjustor.

[0027] Figure 9A illustrates a parallel projection view of certain electrical and magnetic components of an embodiment of a Vertical TRE with a section cut along the Horizontal Axis.

[0028] Figure 9B illustrates a perspective view of certain electrical and magnetic components of an embodiment of a Vertical TRE in wireframe.

[0029] Figure 9C illustrates the view and components of Figure 9B, in hidden-line.

[0030] Figure 10 illustrates a top plan parallel projection view of an embodiment of a Fishboat Vertical TRE.

[0031] Figure 11A illustrates a parallel projection view of an embodiment of Fluke-Flex adjustment components in a first position.

[0032] Figure 11B illustrates the view and components of Figure 11A, with Fluke-Flex adjustment components in a second position.

[0033] Figure 12 illustrates a perspective view of an embodiment of a remotely operated Fishboat Vertical TRE attached to a Streamlined Battery Pack containing a power source.

[0034] Figure 13 illustrates a perspective view of an embodiment of a Fishboat Horizontal TRE.

- [0035] Figure 14 illustrates the Fishboat of Figure 13 in the same view, further illustrating a Horizontal Axis, Vertical Axis, and Transverse Axis.
- [0036] Figure 15 illustrates the Fishboat of Figure 13, with a section cut along the Horizontal Axis.
- [0037] Figure 16 illustrates the Fishboat of Figure 13, further illustrating a TRE within the Fishboat with a section cut along the Transverse Axis.
- [0038] Figure 17 illustrates the Fishboat of Figure 13 in a side elevation parallel projection view.
- [0039] Figure 18 illustrates an embodiment of a Hull interior of the Fishboat of Figure 13 in the side elevation parallel projection view of Figure 17.
- [0040] Figure 19 illustrates an embodiment of a Stator Shell and Spindle of the Fishboat of Figure 13 in the side elevation parallel projection view of Figure 17.
- [0041] Figure 20 illustrates an embodiment of an Inertial Mass and Rotor of the Fishboat of Figure 13 in the side elevation parallel projection view of Figure 17, with a section cut along the Horizontal Axis.
- [0042] Figure 21 illustrates the Fishboat of Figure 13 in the side elevation parallel projection view of Figure 17, with a section cut along the Horizontal Axis.
- [0043] Figure 22 illustrates the Fishboat of Figure 13 in front elevation parallel projection view.
- [0044] Figure 23 illustrates the Fishboat of Figure 13 in front elevation parallel projection view, with a section cut along the Transverse Axis.
- [0045] Figure 24A illustrates a close perspective view of a Fin embodiment.
- [0046] Figure 24B illustrates the close perspective view of the Fin embodiment of Figure 24A, with the Fin not shown to illustrate an embodiment of Fin-Flex Adjustment components.
- [0047] Figure 25A illustrates a close perspective view of a Fin embodiment.
- [0048] Figure 25B illustrates the close perspective view of the Fin embodiment of Figure 25A, with the Fin not shown to illustrate an embodiment of Fin-Flex Adjustment components.
- [0049] Figure 26A illustrates the Fishboat of Figure 13 attached to a Barge via a Hawser.
- [0050] Figure 26B illustrates the Fishboat of Figure 13 attached to a Barge via a Whisker Pole.
- [0051] Figure 27A illustrates a detail perspective view of an embodiment of a connection point for

a Harness.

[0052] Figure 27B illustrates the detail view of Figure 26A, further comprising Harness components.

[0053] Figure 28A illustrates an embodiment of a Direct Drive Craft.

[0054] Figure 28B illustrates the Direct Drive Craft of Figure 27A with a section cut through the Horizontal Axis.

[0055] Figure 29 illustrates a detail of the Direct Drive Craft of Figure 26A with a section cut through the Horizontal Axis.

[0056] Figure 30 illustrates an embodiment of a set of circuits which may be used to control a TRE and a Fishboat or a Direct Drive Craft.

[0057] Figure 31 is a graph of the efficiency over coefficient of thrust for propellers and cetaceans showing a comparison of relationships of propulsive efficiency and thrust coefficient for four species of small cetaceans and a typical marine propeller, wherein data for whales were obtained from Fish (1998a, b) and data for the propeller (EMB 2294) were from Saunders (1957).

#### DETAILED DESCRIPTION

[0058] It is intended that the terminology used in the description presented below be interpreted in its broadest reasonable manner, even though it is being used in conjunction with a detailed description of certain examples of the technology. Although certain terms may be emphasized below, any terminology intended to be interpreted in any restricted manner will be overtly and specifically defined as such in this Detailed Description section.

[0059] Unless the context clearly requires otherwise, throughout the description and the claims, the words “comprise,” “comprising,” and the like are to be construed in an inclusive sense, as opposed to an exclusive or exhaustive sense; that is to say, in the sense of “including, but not limited to.” As used herein, the term “connected,” “coupled,” or any variant thereof means any connection or coupling, either direct or indirect between two or more elements; the coupling of connection between the elements can be physical, logical, or a combination thereof. Additionally, the words, “herein,” “above,” “below,” and words of similar import, when used in this application, shall refer to this application as a whole and not to particular portions of this application. When



the context permits, words using the singular may also include the plural while words using the plural may also include the singular. The word "or," in reference to a list of two or more items, covers all of the following interpretations of the word: any of the items in the list, all of the items in the list, and any combination of one or more of the items in the list. References are made herein to routines and subroutines; generally, it should be understood that a routine is a software program executed by computer hardware and that a subroutine is a software program executed within another routine. However, routines discussed herein may be executed within another routine and subroutines may be executed independently (routines may be subroutines and visa versa).

[0060] As used herein, "releasable," "connect," "connected," "connectable," "disconnect," "disconnected," and "disconnectable" refers to two or more structures which may be connected or disconnected, generally without the use of tools (examples of tools including screwdrivers, pliers, wrenches, drills, saws, welding machines, torches, irons, and other heat sources) and generally in a repeatable manner. As used herein, "attach," "attached," or "attachable" refers to two or more structures or components which are attached through the use of tools or chemical or physical bonding. As used herein, "secure," "secured," or "securable" refers to two or more structures or components which are either connected or attached.

[0061] Described herein are Fishboat and Direct Drive watercraft. Illustrated examples of Fishboat embodiments include Fishboat Vertical TRE 100 and Fishboat Horizontal TRE 1300. Examples of Direct Drive embodiment include Direct Drive Horizontal Engine 270.

[0062] As described further herein, Fishboats are watercraft in which a torque reaction engine ("TRE") is within a Capsule, which Capsule may be sealed. The TRE causes the Capsule to cyclically counter-rotate, in one direction and then the other, about a central axis. Cyclic counter-rotation of the Capsule (also referred to herein as "oscillation") is communicated to a Hull or other force transmitting member (referred to herein as a "Hull") which is secured to and generally surrounds the Capsule, producing oscillating yaw when the TRE is oriented on Vertical Axis 225, oscillating pitch when the TRE is oriented on Transverse Axis 230, and oscillating roll when the TRE is oriented

on Horizontal Axis 235.

[0063] Fin(s) are secured to the Hull. Cyclic counter-rotation (or oscillation) of the Capsule-Hull-Fin(s) through the surrounding thrust fluid generates thrust. In embodiments in which the Hull is a force transmitting member such as a beam, a fairing may be provided in addition to the Hull to streamline the flow of fluid around the Fishboat.

[0064] The TRE comprises a Rotor and a Stator. An Inertial Mass is secured to the Rotor; the Rotor and Inertial Mass are cyclically counter-rotated (or oscillated) by the Stator, in one direction and then the other, about an axis of rotation. Cyclic counter-rotation of the Inertial Mass causes an alternating torque reaction on the Stator. The Stator is secured to or forms the interior of the Capsule. The alternating torque reaction on the Stator causes the Capsule to cyclically counter-rotate. The Inertial Mass may be symmetric about a central axis shared with the Motor, though in alternative embodiments, the Inertial Mass may be asymmetric about the Motor's central axis.

[0065] The central axis of the Motor may be, for example, the Horizontal Axis 235, Vertical Axis 225, or Transverse Axis 230 (see Figure 2 or equivalent axis illustrated in Figure 14). If the TRE is oriented around a Vertical Axis 225—as in example embodiment of Fishboat Vertical TRE 100—the TRE causes oscillating yaw of the Fishboat about the Vertical Axis 225 and the Fishboat swims like a fish, with a vertically oriented rear Fin. If the TRE is oriented around a Transverse Axis 230, the TRE causes oscillating pitch of the Fishboat about the Transverse Axis 230 and the Fishboat swims like a marine mammal, with a horizontally oriented rear Fin—as in an example embodiment in Figure 7 of US Provisional Patent Application Serial Number 61/911,888. If the TRE is oriented along a Horizontal Axis 235, the TRE causes oscillating roll of the Fishboat about the Horizontal Axis 235 and the Fishboat swims with a cyclically counter-rotating (or oscillating) screw-type motion, as in embodiments of Fishboat Horizontal TRE 1300.

[0066] The Motor may be an “outrunner” style electric motor, in which a central Stator is surrounded by a Rotor and the Inertial Mass is secured to the Rotor. The Motor and Inertial Mass may be provided by an internal combustion engine or the like, though this paper uses an electric motor as an example of the TRE, because electric motors are mechanically simple, do not require

flow of an oxidizer or other chemicals into and exhaust of combustion or other reaction products out of the TRE and are flexible inasmuch as a wide range and rate of rotations of the Inertial Mass may be implemented. In embodiments in which the Motor is electric, a brushless DC motor may be used. A mechanically commutated brushed electric motor may be used, though a brushless motor offers reduced maintenance. A combustion-based TRE may utilize various rotary motor configurations, such as wherein a piston (including equivalent structures in a rotary engine) cyclically compresses and ignites gas and fuel in an enclosure, with release of the exhaust gases cyclically oscillating the Inertial Mass. As noted, the Inertial Mass may be asymmetric, though embodiments illustrated in this paper discuss a symmetric Inertial Mass.

[0067] The Inertial Mass may be provided by, for example, lead, iron, a battery pack, or the like.

[0068] In the case of an electric Motor, electrical power may be obtained from a Power Source. The Power Source may be on a Barge or other vessel towed by the Fishboat or the Power Source may internal to the Fishboat. If towed on a Barge, the Power Source may be a solar panel, a battery pack, a fuel cell, or a generator (wind, fossil fuel, or the like). If internal to the Fishboat, the Power Source may be a battery pack or fuel for an internal combustion engine. An embodiment is illustrated in Figure 12 in which the Power Source is towed in a vessel such as a Steamlined Battery Pack 205.

[0069] Fin(s) may be secured to the Fishboat. If secured to the Fishboat at the center of displacement of the Fin (which is also generally the wide point, 1/3rd back from the leading edge of the Fin, for a typical wing cross-section), but with nothing to resist rotation, Fin(s) will find the path of least resistance through the thrust fluid. Flexible Beam(s) may be included in the securement between Fin(s) and Fishboat, causing the Fin(s) to deflect in the thrust fluid less than the path of least resistance, causing the Fin(s) to achieve an angle of attack sufficient to generate thrust. The bending modulus of the Flexible Beam may be adjustable, to change the angle of attack achieved by the Fin(s). Though generally the Flexible Beam passively articulates due to forces experienced by the Fin as the Fin(s) translate through the thrust fluid (allowing the Fins to find the angle of attack based on the modulus of flexibility), the Flexible Beam may comprise

actuator(s) to bend the Flexible Beam or to change the normal angle between the Flexible Beam and the Hull, which may be done for purposes of achieving a desired angle of attack or which may be done to steer the Fishboat.

[0070] The Fishboat may also be steered by re-positioning the center of gravity of the TRE relative to the Fin and Hull. For example, in a Fishboat in which the TRE rotates about the Vertical Axis 225 to produce thrust and in which the TRE has a center of gravity located below the Horizontal Axis 235, the Capsule may be re-positioned along the Transverse Axis 230, which causes the Fishboat to roll to an angle off of horizontal and results in a steering force. See, for example, Figures 8A and 8B. The Fishboat may also be steered by producing more torque with the TRE on one side of it's cycle (such as by counter-oscillating the TRE further in one direction than the other) or by relaxing the Flexible Beam on one side, which may result in a difference in thrust between the sides, which produces a steering force.

[0071] The Fishboat comprises sensors to detect the relative and/or absolute position of various components and/or the strain experienced by components. For example, sensors may be present to sense a bend in the Flexible Beam, to detect the orientation of the craft (in terms of roll, pitch, and yaw), the position of the Inertial Shell and Rotor relative to the Stator, the orientation of the center of gravity of the TRE relative to the Hull, the orientation and angle of attack of the Fin(s), the status of the Stator and Rotor (such as magnetic fields, electrical current, etc.), the status of the Power Source, and the like.

[0072] The sensors may be part of electronic circuits, some of which may form feedback circuits, such as a circuit which controls power to the Stator and rotates the Inertial Shell until the craft yaws, rolls, or pitches (in the opposite direction of the rotation of the Inertial Shell) to a selected position relative to the normal direction of travel or until a bending angle is achieved in the Flexible Beam or until an angle of attack is obtained in the Fin(s), whereupon the feedback circuit may cause the rotation of the Inertial Shell to slow and reverse until the craft yaws or rolls in the other direction to an equivalent position, whereupon the rotation of the Inertial Shell may be slowed and reversed again, etc. When the Fishboat is at rest, the bending modulus of the Flexible Beam may

be started at a flexible setting, with the bending modulus made more stiff as speed increases.

[0073] The Direct Drive Craft is an embodiment with even fewer moving parts and no Inertial Mass, but which requires a flexible membrane, such as Membrane 285, a wet seal, or water tolerant bearings.

[0074] Both Fishboat and Direct Drive Craft are mechanically simple, physically robust, and provide greater efficiency than propeller driven craft.

[0075] Figure 1 illustrates a perspective view of an embodiment of a remotely operated Fishboat Vertical TRE 100 attached to a Barge 105, which Barge 105 carries a Power Source 110. Identified in this Figure are Nose 130, Tail 135, Fluke 215, Top Bearing 160, Central Tube 185, Symmetrical Harness 115, and Tether 120. Nose 130 and Tail 135 have approximately the same displacement. Displacement between Nose 130 and Tail 135 may be adjustable, to change the normal pitch of the craft. Overall displacement of the entire craft may be increased or decreased to change the normal depth of the craft in the water.

[0076] Figure 2 illustrates the Fishboat of Figure 1 in the same view, further illustrating Horizontal Axis 235, Vertical Axis 225, Transverse Axis 230, and Waterline 240. As discussed herein, roll is rotation about Horizontal Axis 235, yaw is rotation about Vertical Axis 225, and pitch is rotation about Transverse Axis 230.

[0077] Figure 3A illustrates the perspective view of the Fishboat of Figure 1, with a section cut along Horizontal Axis 235 and Symmetric Harness 115 and Catenary 120. Figures 1, 2, and 3A and Fishboat Vertical TRE 100 may be compared, one page and figure to the other. The securement point between Catenary 120 and Symmetric Harness 115 may be moved up or down along the trailing arc of Symmetric Harness 115, such as to change the pitch of the Fishboat.

[0078] Figure 3B illustrates a Fishboat Vertical TRE embodiment with the same view and section cut of Figure 3A, but with an Asymmetric Bottom Harness 140, generally forming a catenary drape.

[0079] Figure 3C illustrates a Fishboat Vertical TRE embodiment with the same view and section cut of Figure 3A, but with an Asymmetric Top Harness 150 and Catenary 151. To change the weight of Asymmetric Bottom Harness 140 or Catenary 120 or Catenary 151, more or less Harness may be

released from or drawn back onto Barge 105. Components may be incorporated into the attachment point between Symmetric Harness 115, Asymmetric Bottom Harness 140, or Asymmetric Top Harness 150, to change the normal angle between the Harness and the craft, for example, to cause the Fishboat to pitch or to allow more room between the Fluke and the Harness.

[0080] Figure 4A illustrates the Fishboat embodiment of Figure 3A, with section cut, in a side elevation parallel projection view.

[0081] Figure 4B illustrates the Fishboat embodiment of Figure 3B, with section cut, in a side elevation parallel projection view.

[0082] Figure 4C illustrates the Fishboat embodiment of Figure 3C, with section cut, in a side elevation parallel projection view.

[0083] Figure 5A illustrates a close perspective view of an embodiment of Vertical TRE 500, generally as found in the embodiments illustrated in Figures 1-4C, with a section cut along Horizontal Axis 235. Illustrated are Nose 130 and Tail 135, which contact Top Bearing 160 and Bottom Bearing 165. Top Bearing 160 and Bottom Bearing 165 support Inertial Mass 155 and allow Inertial Mass 155 to rotate about Vertical Axis 225. The Bearings may be located closer to Central Tube 185. In this embodiment, Inertial Mass 155 is faced with Permanent Magnets 156. Magnets 156 (which may be permanent) interact with Electromagnets 175 in Stator 170. Also illustrated are Rectifier 178, Space 179, Capacitor 180, Central Tube 185, and a Harness, in this example, Symmetrical Harness 115. Central Tube 185 and the Harness may be mediated by a bearing, such as a water tolerant set of ball bearings, though they may also be mediated by a bearing interface between the components, such as a brass-on-brass interface. In an example illustrated in Figures 26A and 26B, a Hitching Post 345 may project through the Central Tube 185 and secured with Collar 250.

[0084] Electric power may be delivered through the Harness or through power lines which exit the Harness and, via Energy Transfer Circuit 415 (see Figure 30), enter Capacitor 180. Capacitor 180 is labeled as a "capacitor", but may be another power reservoir, such as a capacitor, a battery, or the like. Ultracapacitors can be cycled 500,000 to 1 million times, and require little to no maintenance.

Power exits Capacitor 180 and enters Power Transfer Circuit 420, which may incorporate or be connected to Rectifier 178, which may deliver power, such as three-phase power, to TRE or Motor 400. Rectifier 178 may utilize DC-DC boost to extract braking energy at lower speeds. A circuit diagram is provided in Figure 30. Part or all of Energy Transfer Circuit 415 may be located in Space 179 and/or in Cavity 168 or Cavity 169 between Bottom Bearing 165 or Top Bearing 160 the interior wall of Stator 170 frame and/or on the Barge. Power Transfer Circuit 420 may be present in Rectifier 178 and/or in Cavity 168 or Cavity 169. Control Circuit 425 may control Motor 400, Power Transfer Circuit 420, Energy Transfer Circuit 415, and may obtain information from and/or control Sensors-Actuators 430.

[0085] Figure 5B illustrates a perspective view of Top Bearing 160, Inertial Mass 155, Stator 170, and Bottom Bearing 165, generally as found in the embodiments illustrated in Figures 1-4C, with a section cut along the Horizontal Axis and with the components partially exploded (in Figure 5B, Bottom Bearing 165 is in position relative to Stator 170). A conventional "outrunner" electric torque motor may be used, with Inertial Mass mounted to the rotor.

[0086] Figure 5C illustrates a full TRE cycle, starting from the top, with acceleration of Inertial Mass in a counter-clockwise direction, illustrated in Arc 181, which produces a torque reaction in Stator which drives Stator in a clockwise direction, illustrated in Arc 182, followed by acceleration of Inertial Mass in a clockwise direction, illustrated in Arc 183, which produces a torque reaction in Stator which drives Stator in a counter-clockwise direction, illustrated in Arc 184.

[0087] Figure 6A illustrates a close parallel projection view of a portion of Vertical TRE 500, generally similar to the TRE embodiments illustrated in Figures 1-4C, with a section cut along Horizontal Axis 235. Figure 6B illustrates the view of the portion of the Vertical TRE 500 of Figure 6A, with Inertial Mass 155 not showing. Also labeled in this Figure are Bearing Top 162 and Bearing Bottom 163. Bearings 162 and 163 are illustrated as ball bearings, though bearings of another shape may be used, such as, for example, roller bearings. Figure 6C illustrates a detail of Figure 6A. Together, Figure 6A-6C illustrate components which do not move, relative to the one component which moves, Inertial Mass 155. Figure 6C also illustrates the air gap between Inertial Mass 155-

Magnet 156 and Stator 170. Per the discussion above, Electromagnets 175 in Stator 170 rotate Magnets 156 in Inertial Mass 155 first one way, then the other, around Vertical Axis 225, causing an opposing torque reaction in Electromagnets 175 and Stator 170. Because Electromagnets 175 and Stator 170 are anchored in or otherwise secured to Hull (in, for example, Nose 130 and Tail 135), the opposing torque reaction in Electromagnets 175 and Stator 170 is communicated to Fin(s), such as, for example, Fluke 215.

[0088] Figure 7 illustrates a front elevation parallel projection view of an embodiment of a Fishboat Vertical TRE, generally as found in the embodiments illustrated in Figures 1-4C, with a section cut along the Transverse Axis and many of the elements identified by number. Figure 7 also illustrates Outer Shell 136 and Capsule 133

[0089] Figure 8A illustrates a front elevation parallel projection view of a schematic embodiment of a Vertical TRE in a Fishboat, further illustrating Transverse TRE Position Adjustor 137. Figure 8B illustrates a side elevation parallel projection view of a schematic embodiment of a Vertical TRE in a Fishboat, further illustrating a Horizontal TRE Position Adjustor 139. Transverse TRE Position Adjustor 137 and Horizontal TRE Position Adjustor 139 may be used to adjust the position of Capsule 133, containing TRE. Adjustment of position may be performed to trim the orientation of the craft in the water and/or to provide a steering force. As illustrated, Capsule 133 is located approximately at the center of displacement and slightly below Horizontal Axis 235. Motor(s) (not illustrated) may provide power to drive Transverse TRE Position Adjustor 137 and Horizontal TRE Position Adjustor 139.

[0090] Figure 9A illustrates a parallel projection view of certain electrical and magnetic components of an embodiment of a Vertical TRE 900 with a section cut along the Horizontal Axis. Figure 9B illustrates a perspective view of certain electrical and magnetic components of the Vertical TRE of Figure 9A, in wireframe and without the section cut. Figure 9C illustrates the view, components, and reference numbers of Figure 9B, in hidden-line (which helps to identify where the number lines in Figure 9B point to). Labeled in Figures 9A-9C are Inertial Mass 155, Bottom Bearing 165, Hall Effect Sensor(s) and Hall Effect Sensor wires 201, Electromagnets 175, Rectifier 178,



Capacitor 180, and Winding-Rectifier Connection Wires 195. Because the Rectifier may be split into two components (the Rectifier may be in just the top or just the bottom), the Winding-Rectifier Connection Wires 195 are illustrated extending both upward and downward. Hall Effect Sensor(s) may be hall effect sensors, optical position sensors, or other sensors which detect the position of Inertial Mass 155 and/or Magnet(s) 156 (or DD Rotor 280) relative to Stator 170 and Electromagnets 175.

[0091] Various winding patterns may be followed for Electromagnets in Stator. For example, Wye configuration gives high torque at low speed, but not as high top speed, which may be desirable in this context.

[0092] Figure 10 illustrates a top plan parallel projection view of an embodiment of a Fishboat Vertical TRE 1000. An arrow arc indicates oscillation of the aft of Fishboat Vertical TRE 1000 due to torque reaction. A corresponding oscillation occurs at the bow of Fishboat Vertical TRE 1000.

[0093] Figure 11A illustrates a parallel projection view of an embodiment of Flexible Beam adjustment components in a first position. Figure 11B illustrates the view and components of Figure 11A, with Fluke-Flex adjustment components in a second position. In the embodiment illustrated in these Figures, Fluke 215 is secured to Flexible Beam 217, which may be, for example, a rod made of carbon fiber or another flexible material. Flexible Beam may extend into Tail 135, inside of a tube with an inside diameter just slightly larger than the outside diameter of Flexible Beam 217, allowing Flexible Beam 217 to slide back and forth within the tube within Tail 135. Fluke Extender 245 may comprise components, such as a motor, a rack and pinion system, a hydraulic system, or the like, to slide Flexible Beam 217 back and forth within the tube within Tail 135. When Flexible Beam 217 is extended, as in Figure 11B, Fluke 215 will deflect further when the Fishboat yaws about Vertical Axis 225 than when Flexible Beam 216 is withdrawn inside of the tube within Tail 135. This is an example embodiment of components to change or adjust the bending modulus of the Flexible Beam, which will change the angle of attack achieved by Fluke 215 when the craft yaws back and forth, driven by TRE.

[0094] Flexible Extender 245 may logically connect to Control Circuit 425 via Deflection Sensor-

Actuator Connector 247, providing information to Control Circuit 425 regarding the length of extension of Flexible Beam 217, regarding the deflection of Flexible Beam 217, regarding the orientation of Flexible Beam 217 relative to the Hull, and the like.

[0095] Flexible Beam 217 may rotate on the horizontal plane about its connection with Tail 135, such as by operation of a motor which may pull Flexible Extender 245 back and forth withing Tail 135, allowing Flexible Beam 217 and Fluke 215 to be used to provide a steering force (for an alternative embodiment, see, for example, Figures 10A and 10B in United States Provisional Patent Application Serial Number 61/911,888, in which a steering disk is located at the connection point between the Fluke and the Tail).

[0096] Figure 12 illustrates a perspective view of an embodiment of a remotely operated Fishboat Vertical TRE 1200 attached to a Streamlined Battery Pack 205 containing a Power Source, such as a battery. The position of the Streamlined Battery Pack 205 may be adjusted, such as up and down along the trailing arc of Symmetrical Harness 115, to change the pitch of the Fishboat. Streamlined Battery Pack 205 may also be used to steer the Fishboat 1200. Streamlined Battery Pack 205 may be used with a Harness which is not symmetrical.

[0097] Figure 13 illustrates a perspective view of an embodiment of a Fishboat Horizontal TRE 1300. Identified are Spinner Hull 300, Starboard Fin 305A, Port Fin 305B, and Sensor Hole 301. Spiral lines are drawn on Spinner Hull 300 in these figures to provide a visual reference.

[0098] Figure 14 illustrates the Fishboat of Figure 13 in the same view, further illustrating Horizontal Axis 320, Vertical Axis 310, and Transverse Axis 315. The waterline is generally above the level of the Fishboat 1300, which may generally operate fully submerged and at great depth, because no drive-shaft penetrates Spinner Hull 300.

[0099] Figure 15 illustrates Fishboat 1300, with a section cut along Horizontal Axis 320, providing a view of, for example, Spinner Inertial Mass 330, Spinner Motor 325, Forward Bearing 331, and Aft Bearing 332. Similar to the TRE oriented along the Vertical Axis, with the TRE oriented along Horizontal Axis 320, Spinner Motor 325 remains stationary and attached to Spinner Hull 300. Spinner Motor 325 interacts with Spinner Inertial Mass 330, rotating Spinner Inertial Mass 330 first

in one direction, then the other, about Horizontal Axis 320, causing an alternating torque reaction against the Spinner Motor 325, which is attached to Spinner Hull 300, which is secured to Fin 305A and 305B. Spinner Inertial Mass 330 may not touch Spinner Motor 325 directly, but instead may be supported on Spinner Motor 325 by Forward Bearing 331 and Aft Bearing 332.

[0100] In addition to allowing Spinner Inertial Mass 330 to rotate about Horizontal Axis 320, Forward Bearing 331 and Aft Bearing 332 may also carry electrical power between Spinner Inertial Mass 330, which may comprise a battery, and Spinner Motor 325, as well as components which may control Spinner Motor 325 (equivalent to components illustrated in Figure 30). Electrical contacts may be provided on, for example, the aft or forward end of Spinner Motor 325, which electrical contacts may be used to charge a battery in Spinner Inertial Mass 330 and/or to provide or obtain electrical power to Fishboat 1300.

[0101] Any of the Fishboat embodiments illustrated herein may be positioned in a moving current of water, secured to a line or the like, and may generate power from movement of the thrust fluid over Fin(s), in which case the Flexible Beam securing Fin(s) may be biased to present the Fin(s) with an alternating angle of attack to the thrust fluid, such that the Fishboat oscillates much as it would when net power is supplied to (rather than generated by) the TRE.

[0102] Induction principals may be used in any TRE to induce a current and/or magnetic field in components which otherwise may not have a direct electrical connection. For example, permanent or electromagnets may be present in one or both of the Spinner Inertial Mass and the Spinner Motor 325. The TRE may be or incorporate a polyphase double cage AC induction motor with variable-frequency drive.

[0103] Figure 16 illustrates Fishboat 1300, further illustrating the TRE within Fishboat 1300 with a section cut along the Transverse Axis 315 of the TRE. Labeled are Spinner Inertial Mass 330, Spinner Motor 325, and Sensor Hole 301, which may extend into and even through Fishboat 1300. Sensors, cameras and the like may be located in Sensor Hole 301.

[0104] Figure 17 illustrates Fishboat 1300 in a side elevation parallel projection view, with Spinner Hull 300 and Port Fin 305B labeled.

[0105] Figure 18 illustrates an embodiment of Hull 300 in the side elevation parallel projection view of Figure 17, with a section cut along Horizontal Axis 320, illustrating the interior of Hull 300. Note that the graphical spiral lines on the exterior continue on the interior.

[0106] Figure 19 illustrates an embodiment of a Spinner Motor 325, Forward Bearing 331, and Aft Bearing 332, within the Fishboat of Figure 13 in the side elevation parallel projection view of Figure 17.

[0107] Figure 20 illustrates an embodiment of an Inertial Mass 330 of Fishboat 1300 in the side elevation parallel projection view of Figure 17, with a section cut along the Horizontal Axis. Forward Bearing 331 and Aft Bearing 332 are illustrated and labeled for continuity's sake.

[0108] Figure 21 illustrates Fishboat 1300 in the side elevation parallel projection view of Figure 17, with a section cut along the Horizontal Axis, illustrating and labeling components discussed elsewhere. The air gap between Spinner Motor 325 and Spinner Inertial Mass 330 is visible.

[0109] Figure 22 illustrates Fishboat 1300 in front elevation parallel projection view.

[0110] Figure 23 illustrates Fishboat 1300 in front elevation parallel projection view, with a section cut along the Transverse Axis 315.

[0111] Figure 24A illustrates a close perspective view of a Fin 305B embodiment. Figure 24B illustrates the close perspective view of Figure 24A, with Fin 305B not shown to illustrate an embodiment of Fin-Flex Adjustment components. Similar to Flexible Beam, Fin-Flex Adjustment components allow the Fin to achieve an angle of attack which produces thrust. In the embodiment illustrated in Figures 24A and 24B, a Spinner Fin Rod 335 is attached to Spinner Hull 300, generally at the center of displacement of Spinner Hull 300. Spinner Fin Rod 335 penetrates Fin 305B, generally at the center of displacement of Fin 305B. In this illustration, Fin 305B rotates about Spinner Fin Rod 335, generally with low resistance, generally along Arrow 342. This may be facilitated by bearings, which may include a simple brass-on-brass bearing surface between Fin 305B and Spinner Fin Rod 335. As the Spinner Hull 300 rolls about Horizontal Axis 320, first one way and then the other (in reaction to torque produced by Spinner Motor 325 as Spinner Motor 325 rotates Spinner Inertial Mass 330), Fin 305B will rotate about Spinner Fin Rod 335 and will find

a path of least resistance through the thrust fluid (water) and will not produce thrust. However, if Fin 305B is also secured to Spinner Fin Spring 340, Spinner Fin Spring 340 retards deflection, prevents Fin 305B from following the path of least resistance, and causes Fin 305B to generate thrust. The bending modulus of Spinner Fin Spring 340 may be adjustable. The attachment location of Fin 305B to Spinner Fin Rod 335 may be adjustable, so as to move Fin 305B forward and back relative to Spinner Fin Rod 335, which may be done to change the angle of attack achieved by Fin 305B.

[0112] Figure 25A illustrates a perspective view of a Fin 2500 embodiment. Figure 25B illustrates the perspective view of Figure 25A, with Fin 2500 not shown to illustrate another example of Fin-Flex Adjustment components, which does not involve a bearing surface (between Fin and Spinner Fin Rod). In the embodiment illustrated in Figures 25A and 25B, Fin 2500 may be attached to the Spinner Hull forward of the center of displacement of the Fin, such as at Spinner Fin-Spring-Rod 341. Spinner Fin-Spring-Rod 341 comprises a bending modulus. Fin follows a path similar to that described above (it would be prevented from following the path of least resistance by Spinner Fin-Spring-Rod 341) and generates thrust, generally along Arrow 342. The bending modulus of Spinner Fin-Spring-Rod 341 may be adjustable, so that the amount of thrust can be varied.

[0113] Figure 26A illustrates the Fishboat of Figure 13 attached to a Barge via a Hawser. The securement between the Fishboat and the Hawser may comprise a bearing to allow the Fishboat to oscillate with less resistance. Figure 26B illustrates the Fishboat of Figure 13 attached to a Barge via a Whisker Pole. The Hawser or Whisker Pole may supply power to the Fishboat.

[0114] Figure 27A illustrates an embodiment of a Hitching Post 345 projecting through the approximate center of displacement of a Fishboat embodiment. Figure 27B illustrates an embodiment of Collar 350 on a Harness 355 secured to Hitching Post 345. The bending modulus of the Harness 355 may be sufficient to accommodate cyclic counter-rotation ("oscillation") of the Fishboat while securing the Fishboat to a Harness. Facilitating this, the Harness may comprise a portion such as a flexible cord, strap, chain or the like, which portion is secured to Hitching Post 345 or an equivalent structure.

[0115] Figure 28A illustrates an embodiment of a Direct Drive Craft 270. Figure 28B illustrates the Direct Drive Craft 270 of Figure 28A with a section cut through the Horizontal Axis. Figure 29 illustrates a detail of the Direct Drive Craft of Figure 28A with a section cut through the Horizontal Axis. The following components in Direct Drive Craft 270 are labeled: Direct Drive ("DD") Stator 275, DD Rotor 280, Membrane 285, and Harness 288. DD Stator 275 and DD Rotor 280 are separated by a gap. A bearing, not illustrated, supports components which are part of DD Rotor 280 relative to DD Stator 275. Membrane 285 may protect the gap between DD Stator 275 and DD Rotor 280. Membrane 285 must be flexible to tolerate oscillation of DD Rotor 280 relative to Harness 288.

[0116] Figure 30 illustrates an embodiment of a circuit or set of circuits which may be used to control a TRE and a Fishboat or a Direct Drive Craft. Motor 400 comprises a TRE or, for example, DD Stator 275 and DD Rotor 280. Power Source 110 is equivalent to the Power Source discussed elsewhere and may be, for example, a generator, battery, and the like.

[0117] Electric power from Power Source 110 may be connected to Energy Transfer Circuit 415 through the Harness or through power lines which exit the Harness or, when Inertial Mass comprises a Power Source or Capacitor, through, for example, Forward Bearing 331 and Aft Bearing 332 or through a contact provided for this purpose. Between Energy Transfer Circuit 415 and Power Transfer Circuit 420 may be found Capacitor 180 which, as noted elsewhere, may be a capacitor, a battery, or another power reservoir. Power exits Capacitor 180 and enters Power Transfer Circuit 420, which may incorporate or be connected to Rectifier 178, which may communicate power, such as three-phase power, to TRE or Motor 400. Three lines are illustrated in Figure 30 to illustrate three-phase power. Three-phase power may be delivered in the form of a pulse-code modulated signal regulated by Control Circuit 425 and output by Power Transfer Circuit 420. Sensors-Actuators 430 may comprise, for example, Hall Sensors 201, Deflection Sensor-Actuator 247, strain, bend, or deflection sensors in Spinner Fin-Spring Rod 341 (and the like), position-orientation sensors, and sensors and actuators in the Power Source, in steering mechanisms, and the like.

[0118] Motor 400, Power Transfer Circuit 420, Energy Transfer Circuit 415, Power Source 110,

Capacitor 180, and Sensors-Actuators 430 may communicate with or form among them Control Circuit 425. Control Circuit 425 may provide power to Motor 400, rotating Inertial Mass first in one direction, then the other.

[0119] Control Circuit 425 may control Motor 400 across a drive phase and a brake phase, which phases are repeated to produce thrust. Control Circuit 425 may, for example, detect the angle of attack or an indicator of the angle of attack of a Fin (such as a bend in a Flexible Beam) and, based on the angle of attack, may instruct Power Transfer Circuit 420 to drive Motor 400 to accelerate the Inertial Mass in a drive phase, causing a torque reaction against a stator, which is torque is communicated to the Fin (such as via the Hull), which may cause the angle of attack of Fin to increase (or a bend in the Flexible Beam to increase), until a desired angle of attack of Fin is reached, at which point Control Circuit 425 may instruct Power Transfer Circuit 420 to apply an electronic brake to the Inertial Mass in a brake phase, causing a torque reaction against the stator opposite the torque experienced during the drive phase, which torque is communicated to the Fin, which may cause the angle of attack of the Fin to decrease. When the angle of attack returns to, for example, normal relative to the desired direction of travel of the craft, the drive phase may be engaged, with the process returning to the process outlined at the start of this paragraph. The Power Transfer Circuit 420 and Motor 400 may generate power during application of the electronic brake, which power may be transferred to Capacitor 180 for storage. Power from Capacitor 180 and Power Source 110 may be used during the drive phase. Other and/or additional feedback loops may be employed, such as a feedback loop based on available power in Capacitor 180, which may control, via Control Circuit 425, Energy Transfer Circuit 415 and power produced or supplied by Power Source 110.

[0120] The drive phase may bring the Inertial Mass up to a rotational speed of X, while the brake phase may reduce the rotational speed to Y, wherein Y remains a positive number (the brake phase may not fully stop the Inertial Mass).

[0121] There are four possible modes or quadrants of operation using a DC motor, brushless or otherwise. In an X-Y plot of speed versus torque, Quadrant I is forward speed and forward torque.

The Torque is propelling the motor in the forward direction. Conversely, Quadrant III is reverse speed and reverse torque. Now the motor is "motoring" in the reverse direction, spinning backwards with the reverse torque. Quadrant II is where the motor is spinning in the forward direction, but torque is being applied in reverse. Torque is being used to "brake" the motor, and the motor is now generating power as a result. Finally, Quadrant IV is exactly the opposite. The motor is spinning in the reverse direction, but the torque is being applied in the forward direction. Again, torque is being applied to attempt to slow the motor and change its direction to forward again. Once again, the motor is generating power.



## CLAIMS

Claim 1. A watercraft comprising a fin, a motor mounted to a hull, and an inertial mass, wherein the motor is attached to the hull and the inertial mass is supported about an axis by a bearing, wherein the motor is operable to accelerate the inertial mass such that the motor becomes subject to a torque reaction caused by the acceleration of the inertial mass, wherein the watercraft is operable to communicate to the fin, via the hull, the torque reaction on the motor from acceleration of the inertial mass so as to cause a translation of the fin through a surrounding thrust fluid, and wherein the fin, via translation through the surrounding thrust fluid, is operable to produce thrust.

Claim 2. The watercraft according to Claim 1, wherein the motor rotates the inertial mass about one of a horizontal axis, a vertical axis, and a transverse axis.

Claim 3. The watercraft according to Claim 1, wherein the motor and inertial mass are inside the hull.

Claim 4. The watercraft according to Claim 1, wherein the motor is an electric motor.

Claim 5. The watercraft according to Claim 4, wherein the electric motor is controlled by a circuit to cyclically counter-accelerate the inertial mass, wherein to cyclically counter-accelerate the inertial mass the circuit alternately applies power to accelerate the inertial mass and applies an electronic brake to decelerate the inertial mass.

Claim 6. The watercraft according to Claim 5, wherein the electronic brake generates power.

Claim 7. The watercraft according to Claim 6, wherein the circuit further comprises a power reservoir and power generated by the electronic brake is stored in the power reservoir.

Claim 8. The watercraft according to Claim 5, wherein the circuit further receives a sensor information and wherein the circuit cyclically counter-accelerates the inertial mass at least partially in response to the sensor information.

Claim 9. The watercraft according to Claim 1, wherein the motor comprises a stator and a rotor, the inertial mass is attached to the rotor, and the stator is attached to the hull.

Claim 10. The watercraft according to Claim 1, wherein the fin is secured to the motor by a flexible beam.

Claim 11. The watercraft according to Claim 10, wherein a bending modulus of the flexible beam is adjustable.

Claim 12. The watercraft according to Claim 1, wherein the inertial mass comprises a battery.

Claim 13. The watercraft according to Claim 1, further comprising a power source for the motor, wherein the power source is towed by the watercraft.

Claim 14. The watercraft according to Claim 13, wherein the power source is a generator.

Claim 15. The watercraft according to Claim 13, wherein the power source is towed on a surface barge or in a submerged vessel.

Claim 16. The watercraft according to Claim 13, further comprising a hawser, wherein the hawser secures the watercraft and power source.

Claim 17. The watercraft according to Claim 1, further comprising a steering mechanism and a displacement adjustment mechanism attached to the hull.

Claim 18. The watercraft according to Claim 17, wherein the steering mechanism biases the angle of attack of the fin relative to the watercraft.

Claim 19. The watercraft according to Claim 1, wherein the motor is inside of a capsule.

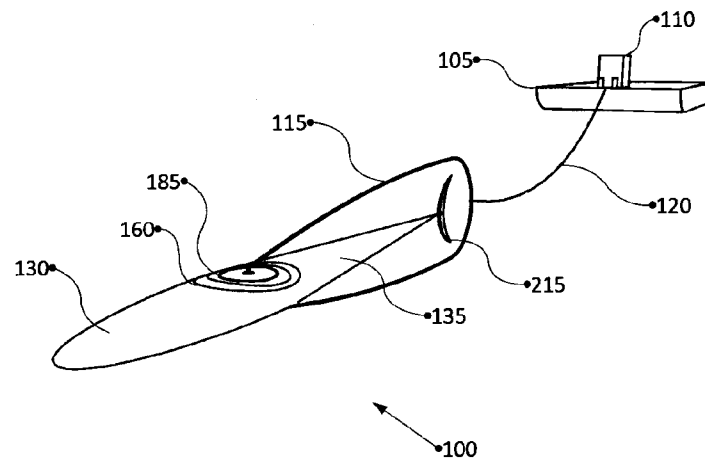


Figure 1

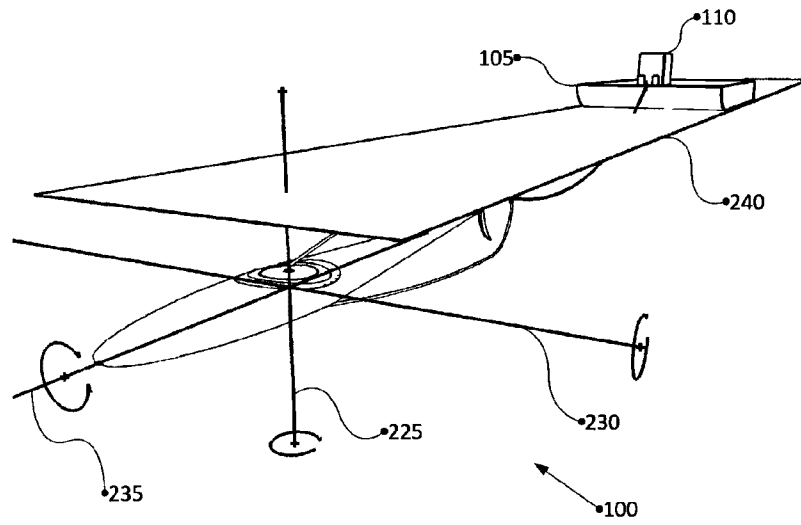
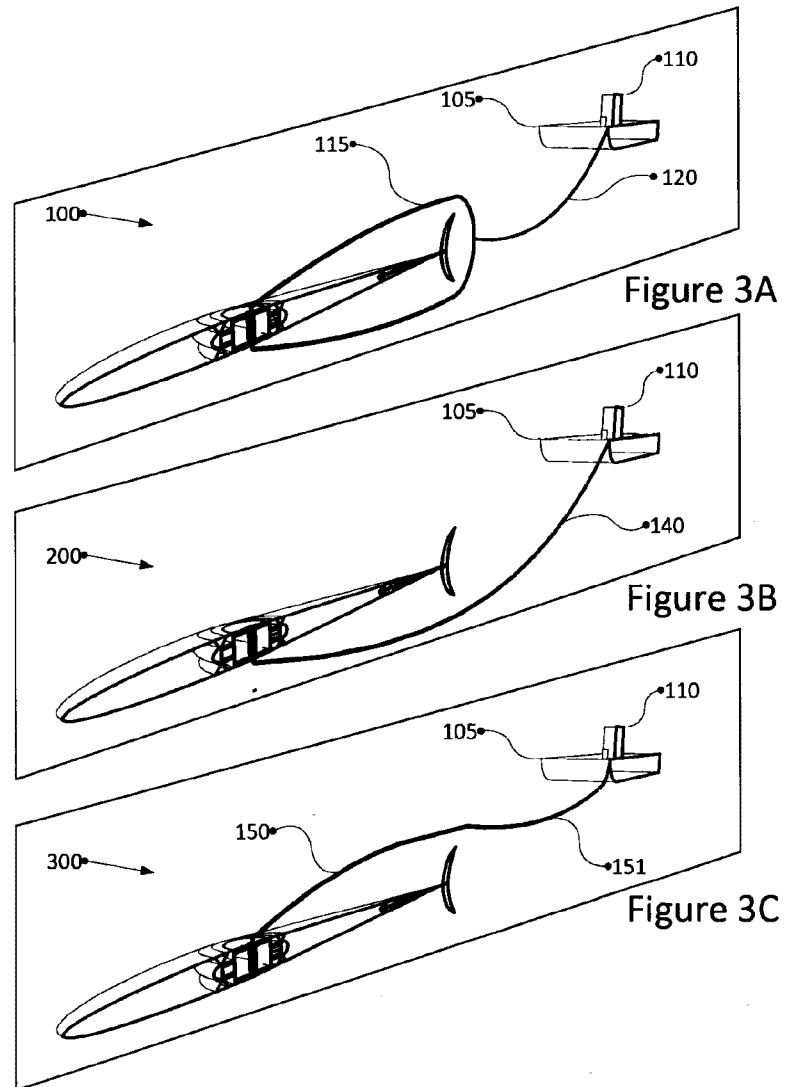


Figure 2



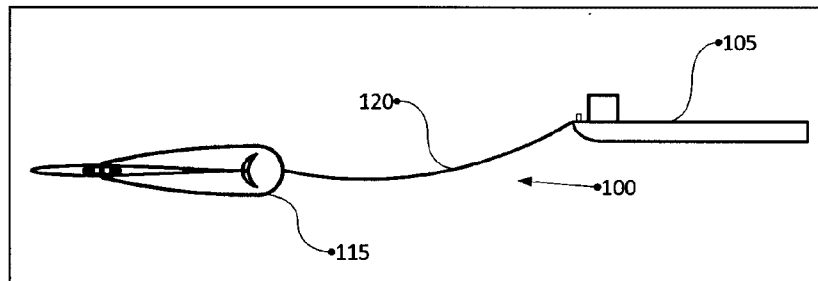


Figure 4A

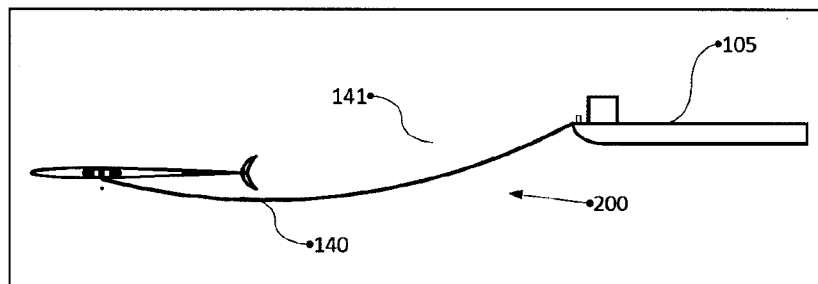


Figure 4B

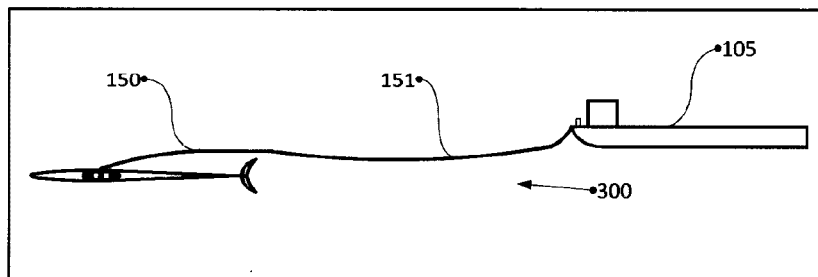


Figure 4C

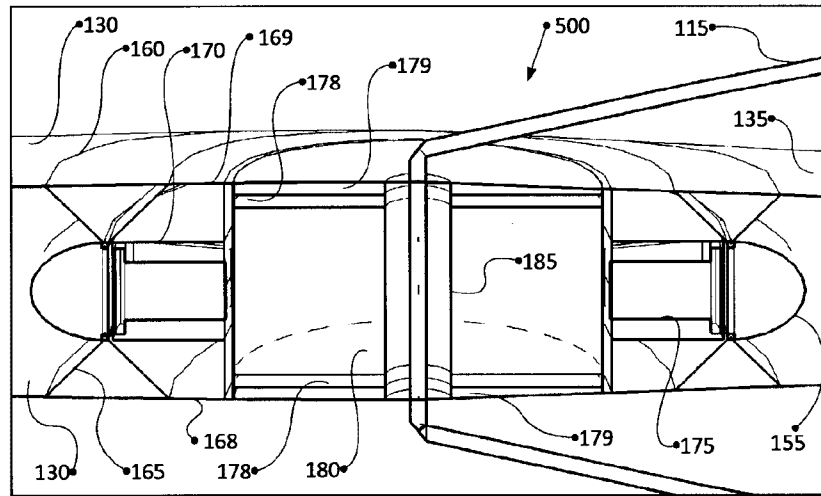


Figure 5A

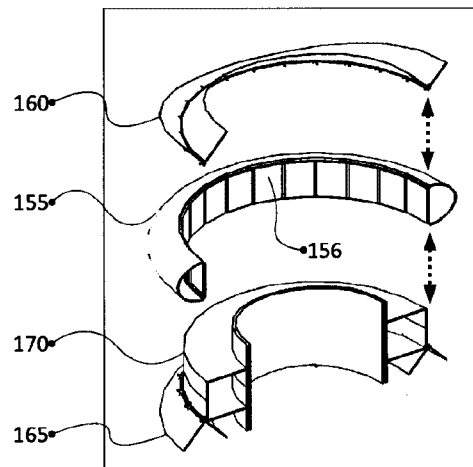


Figure 5B

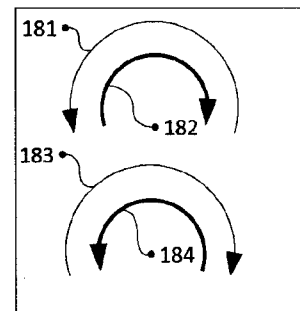


Figure 5C

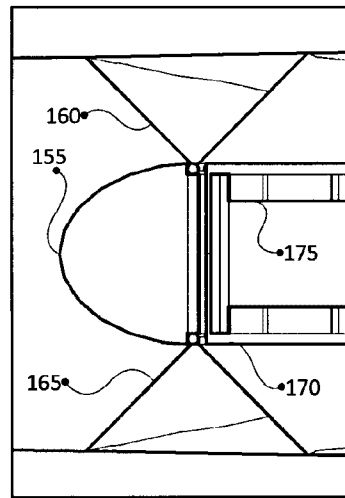


Figure 6A

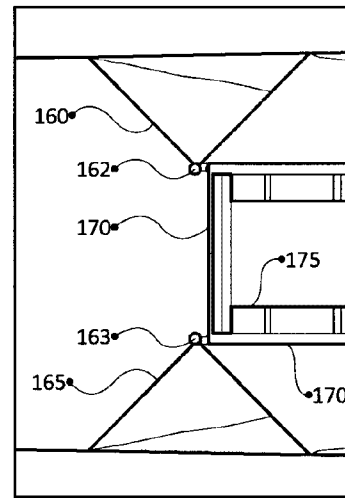


Figure 6B

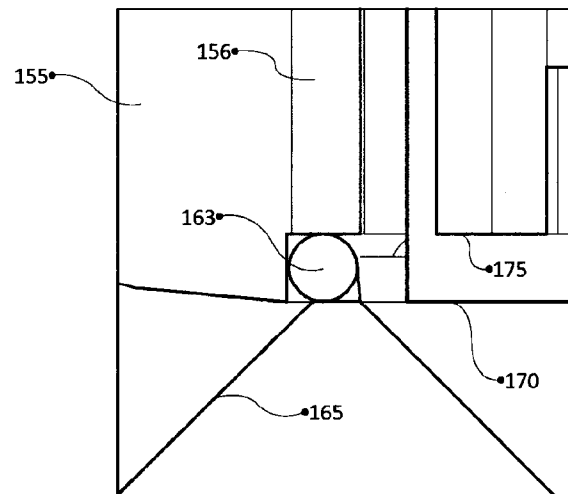


Figure 6C



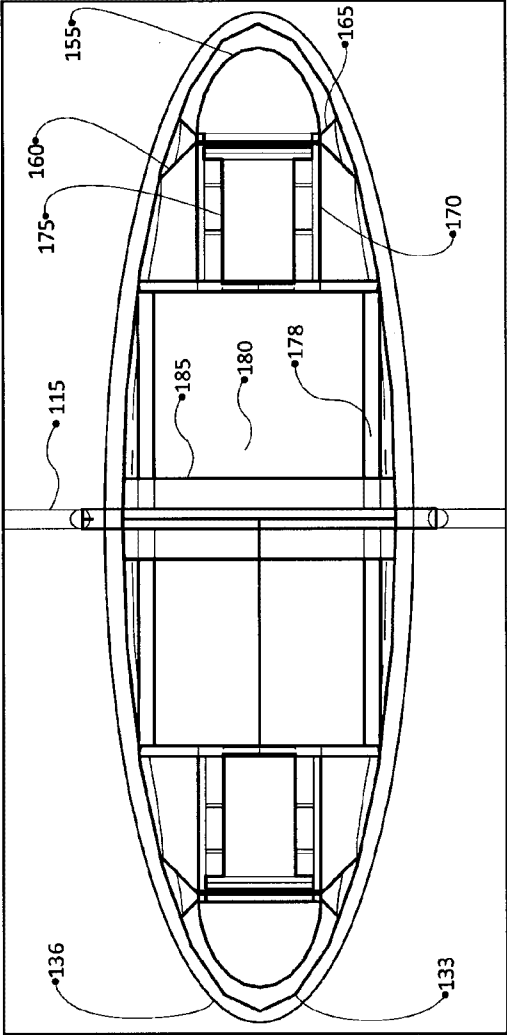


Figure 7

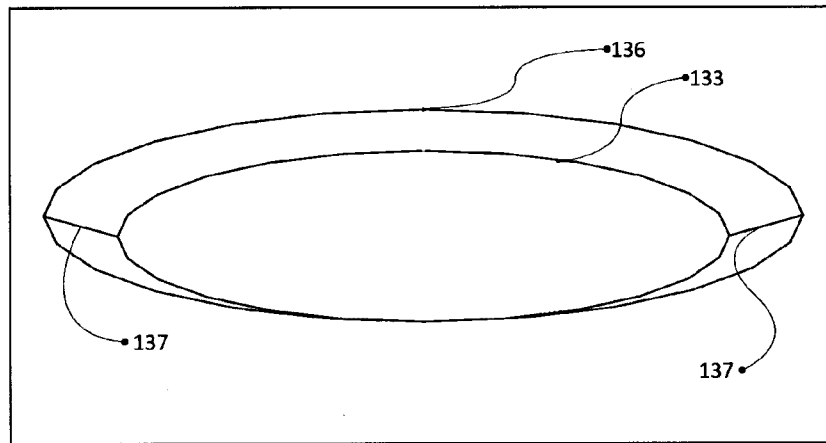


Figure 8A

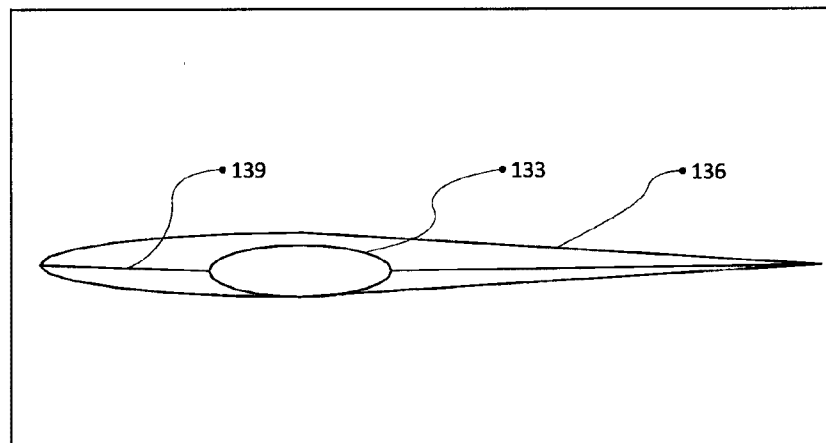


Figure 8B

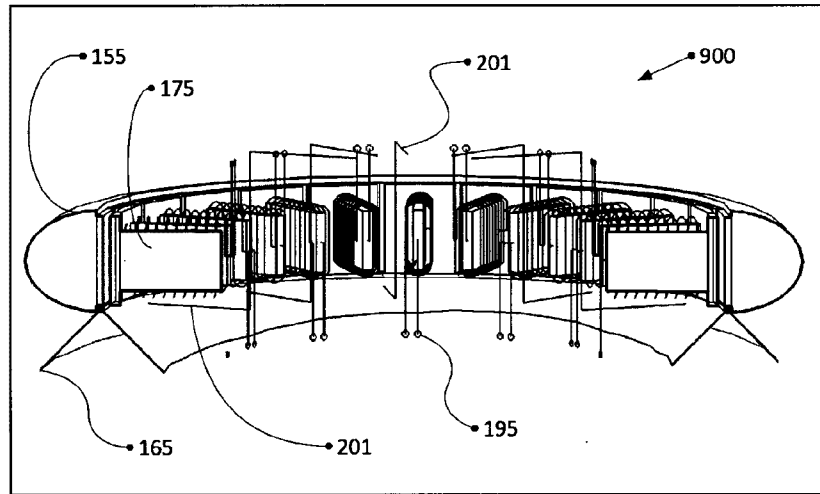


Figure 9A

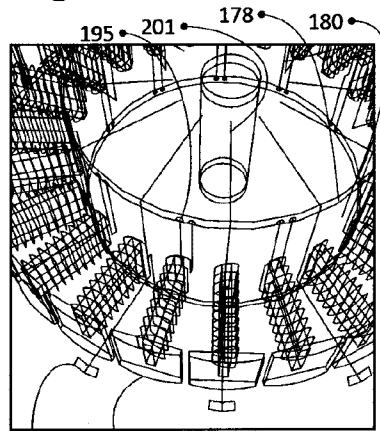


Figure 9B

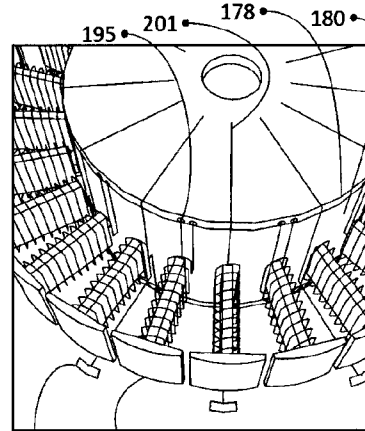


Figure 9C

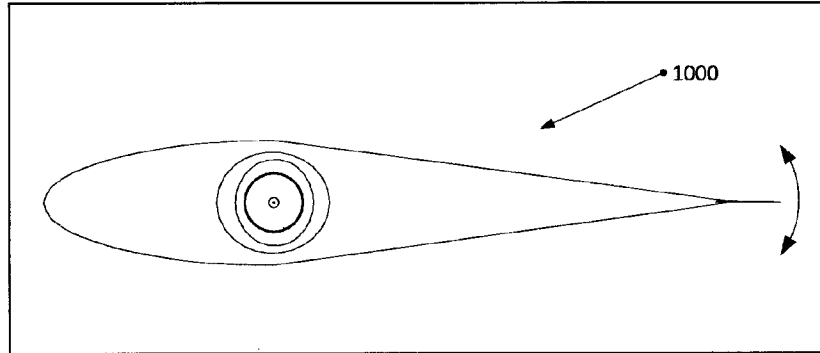


Figure 10

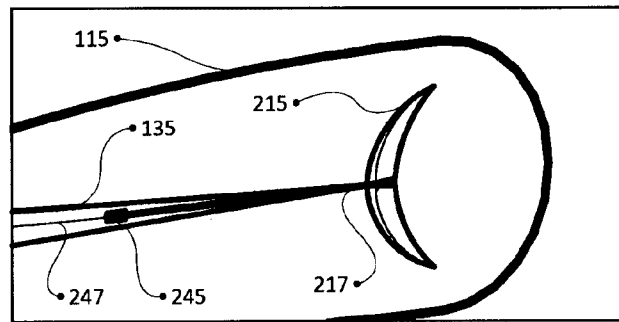


Figure 11A

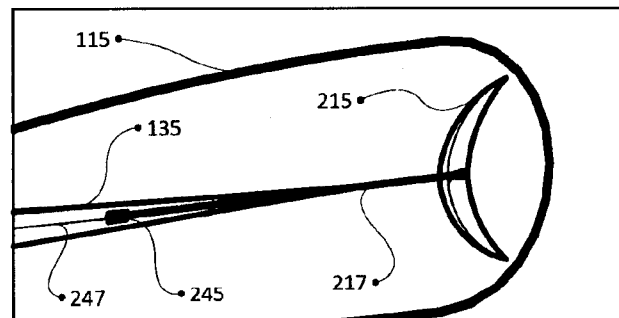


Figure 11B

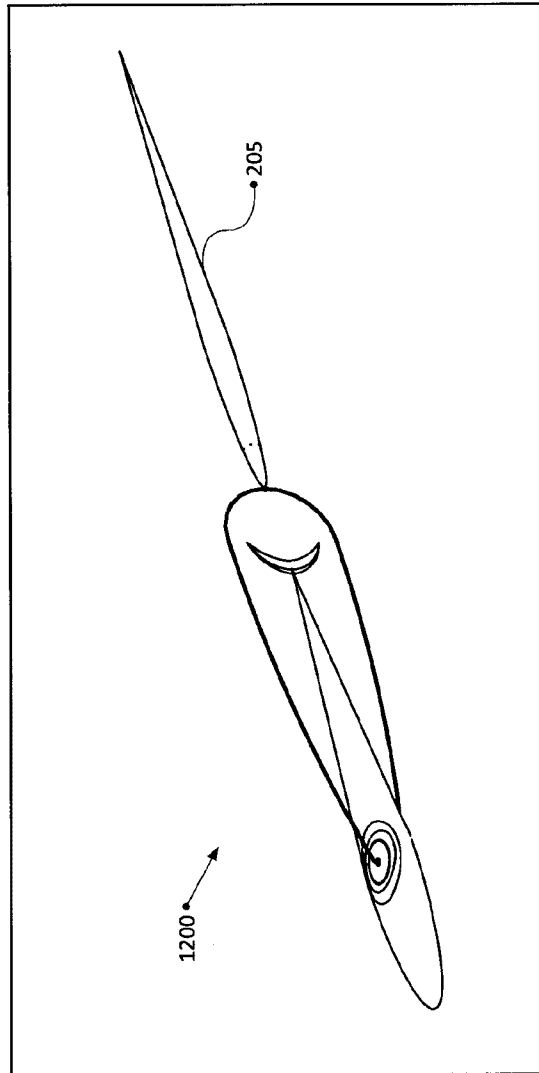


Figure 12

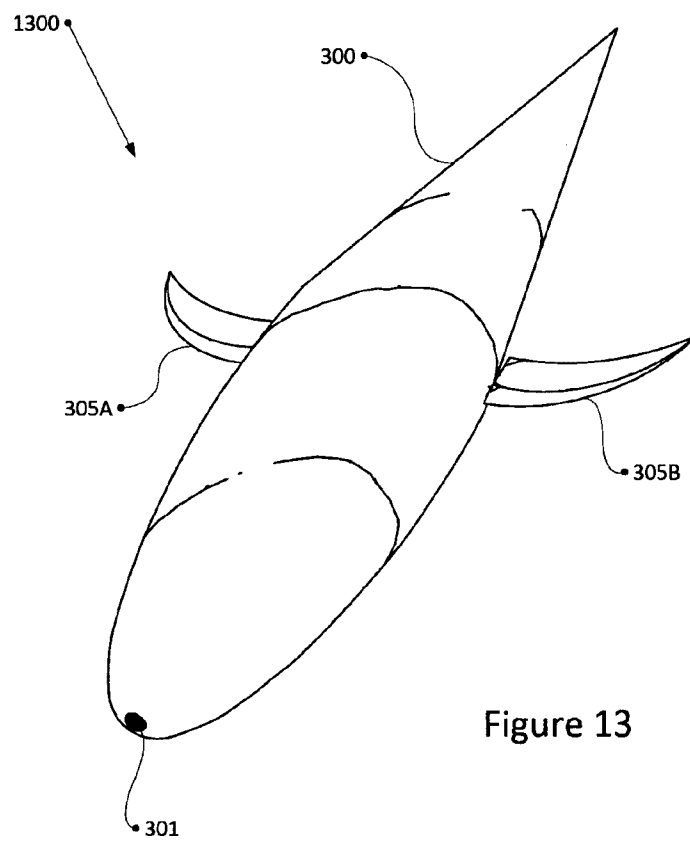


Figure 13

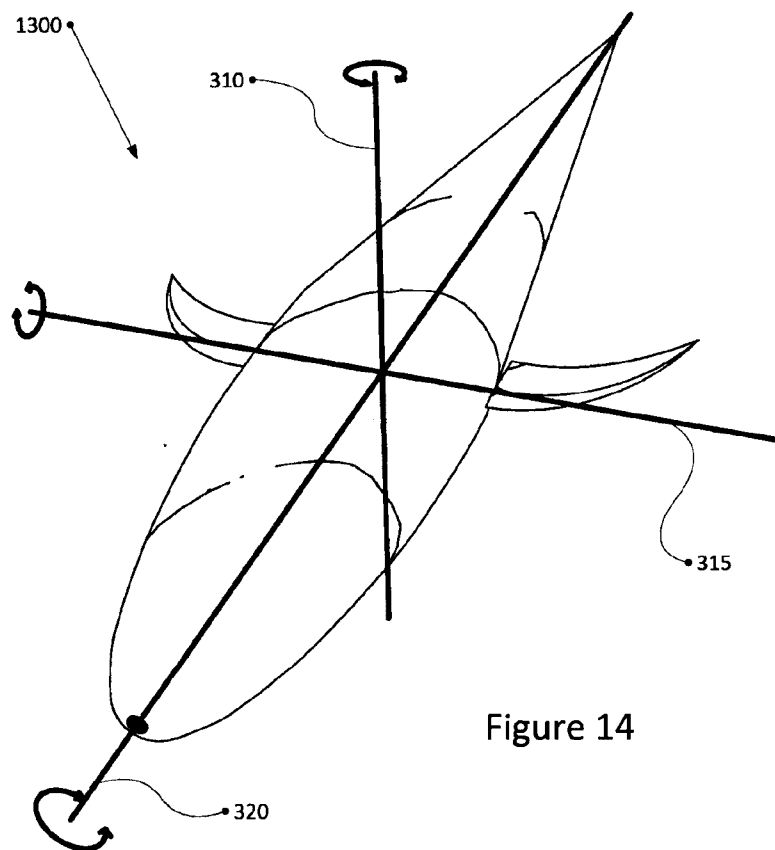


Figure 14



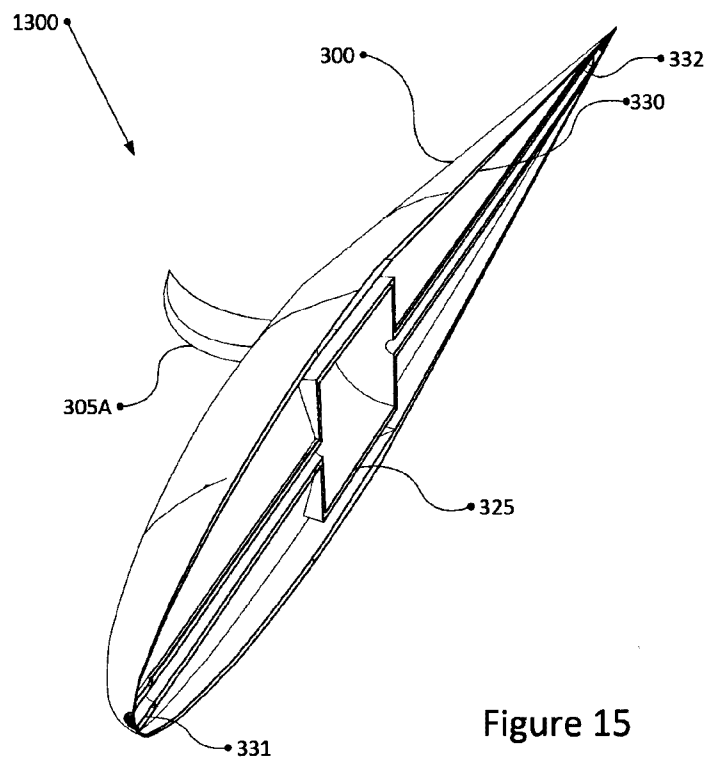


Figure 15

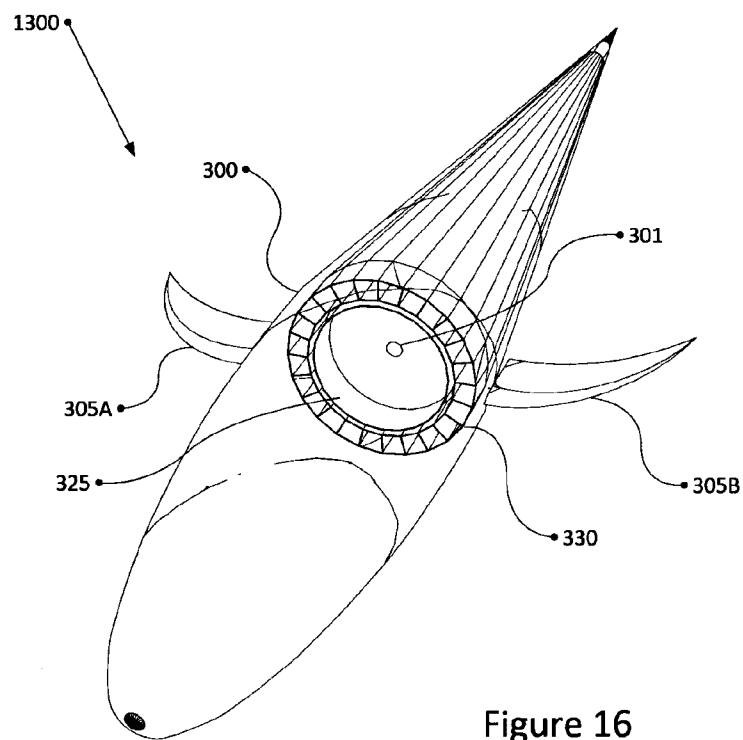


Figure 16

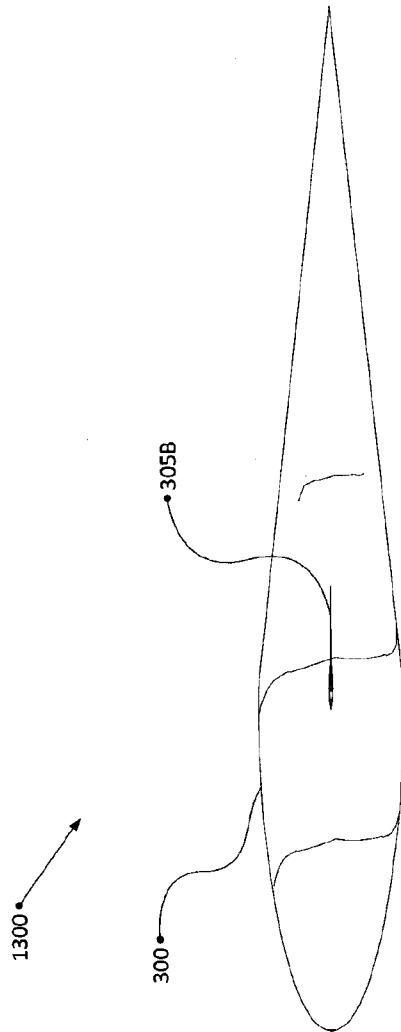


Figure 17

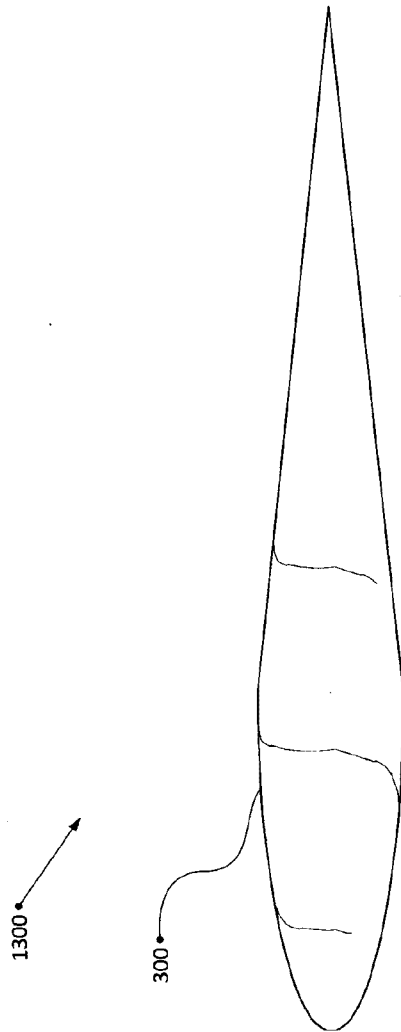


Figure 18

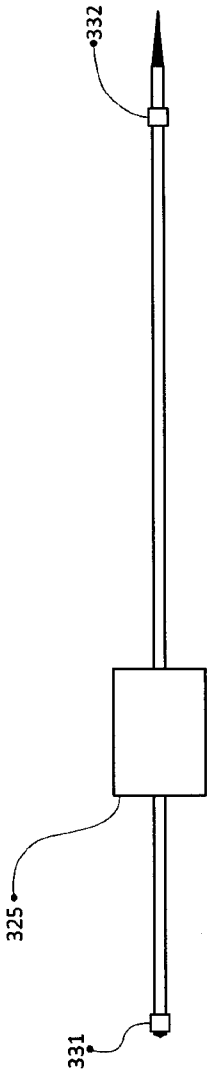


Figure 19

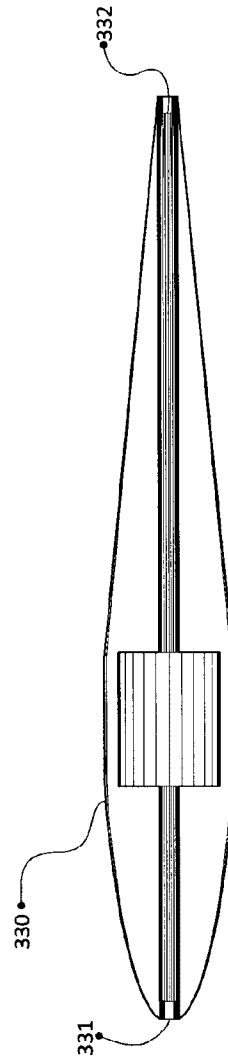


Figure 20

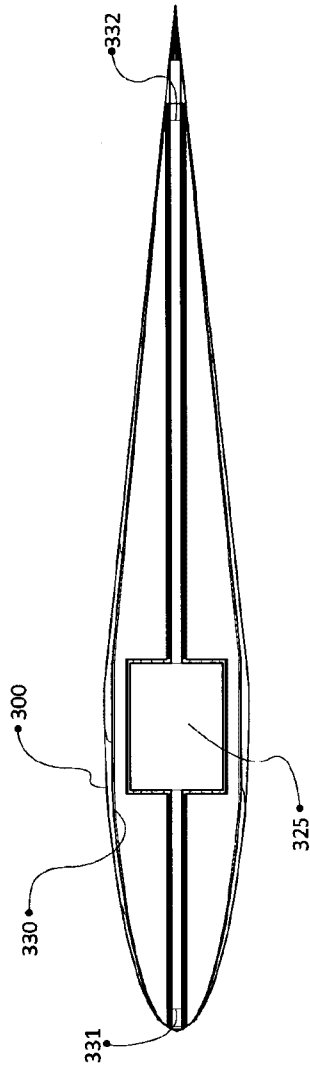


Figure 21

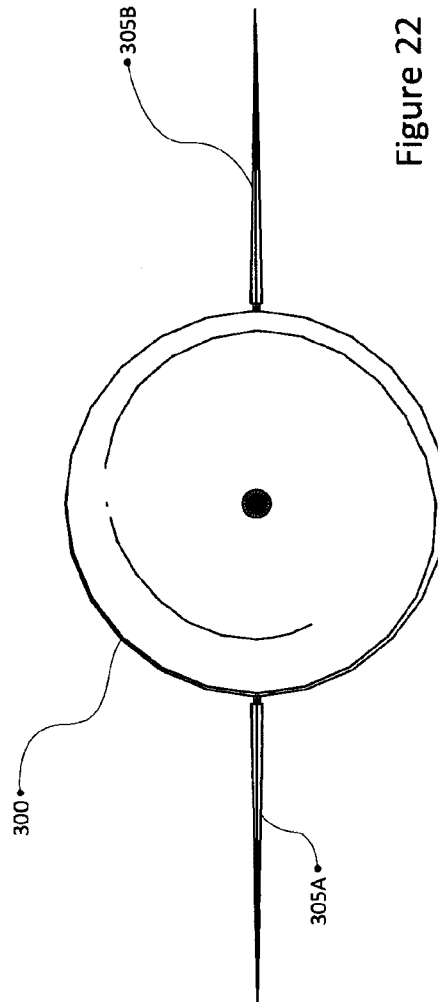
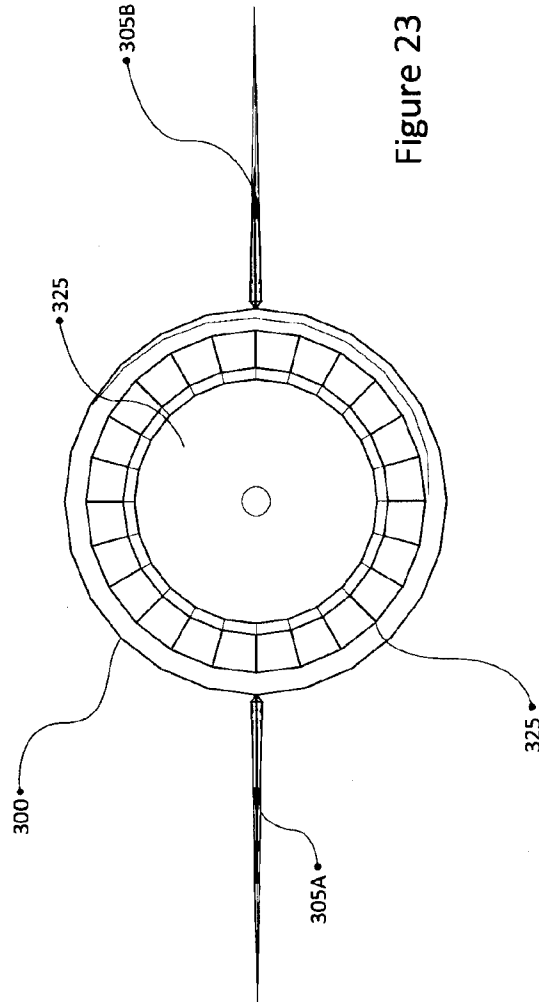


Figure 22





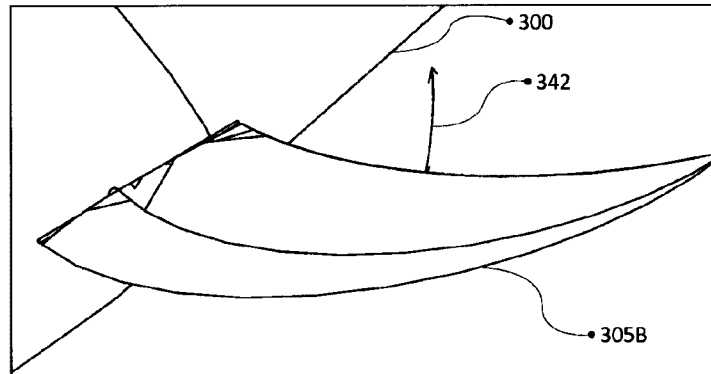


Figure 24A

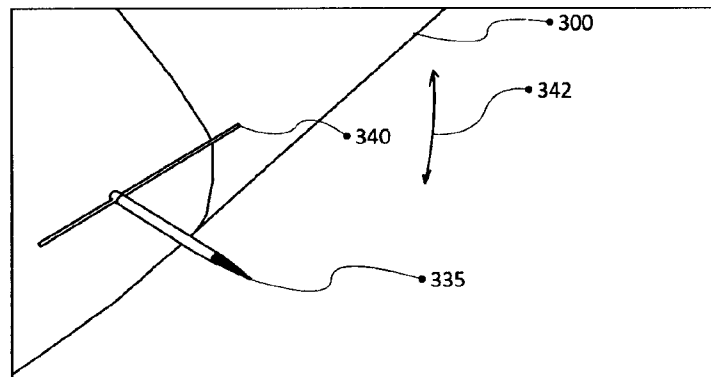


Figure 24B

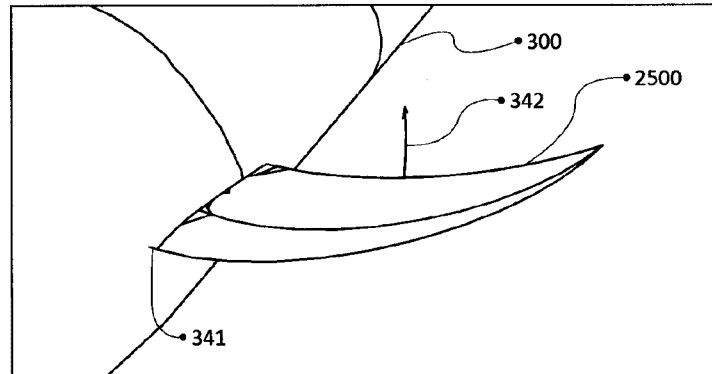


Figure 25A

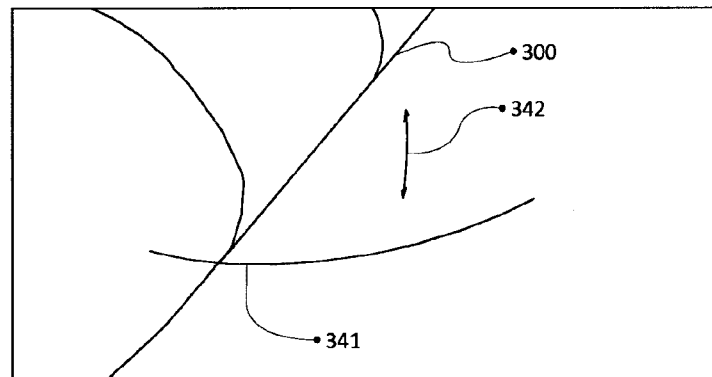


Figure 25B

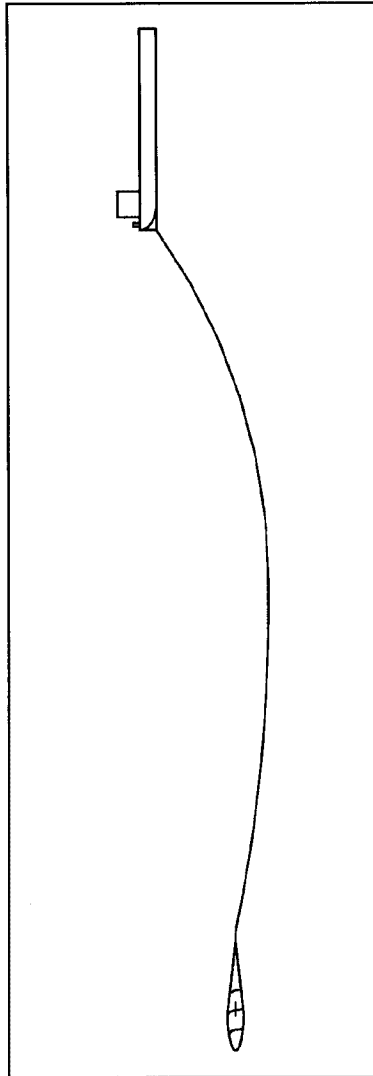


Figure 26A

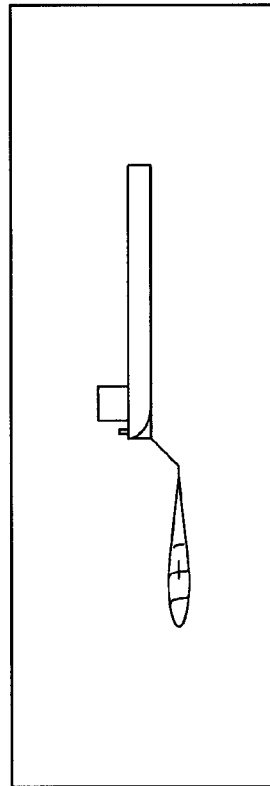


Figure 26B

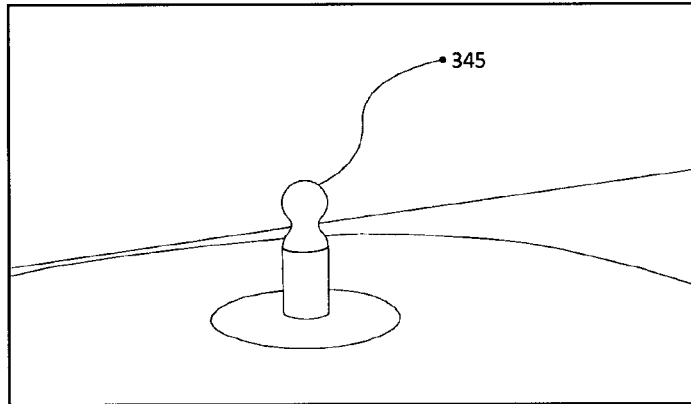


Figure 27A

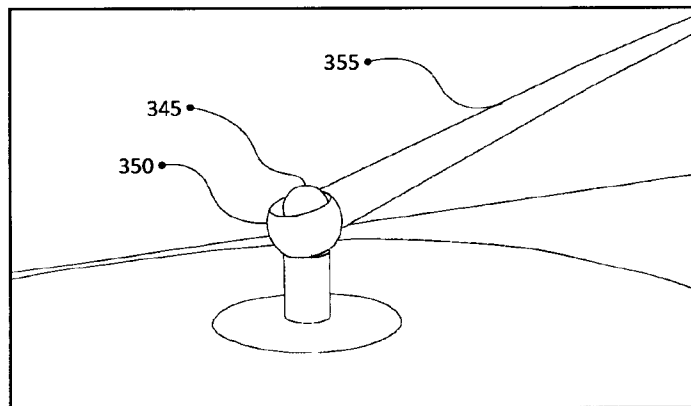


Figure 27B

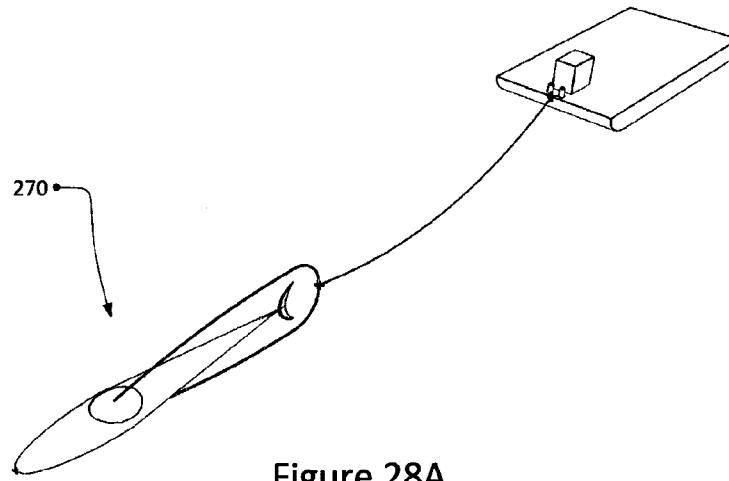


Figure 28A

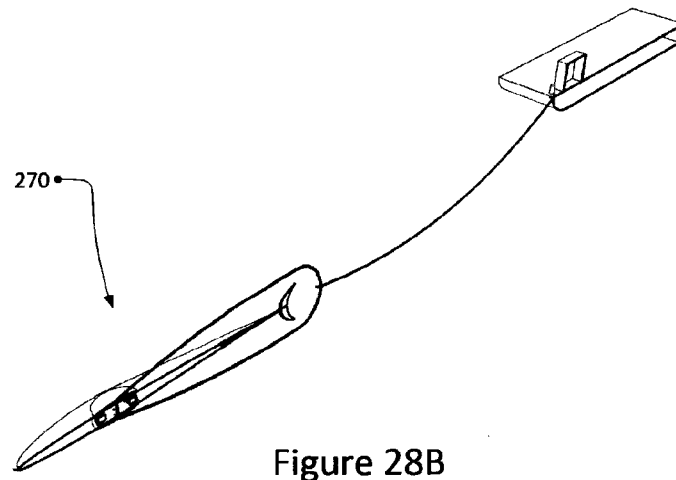


Figure 28B

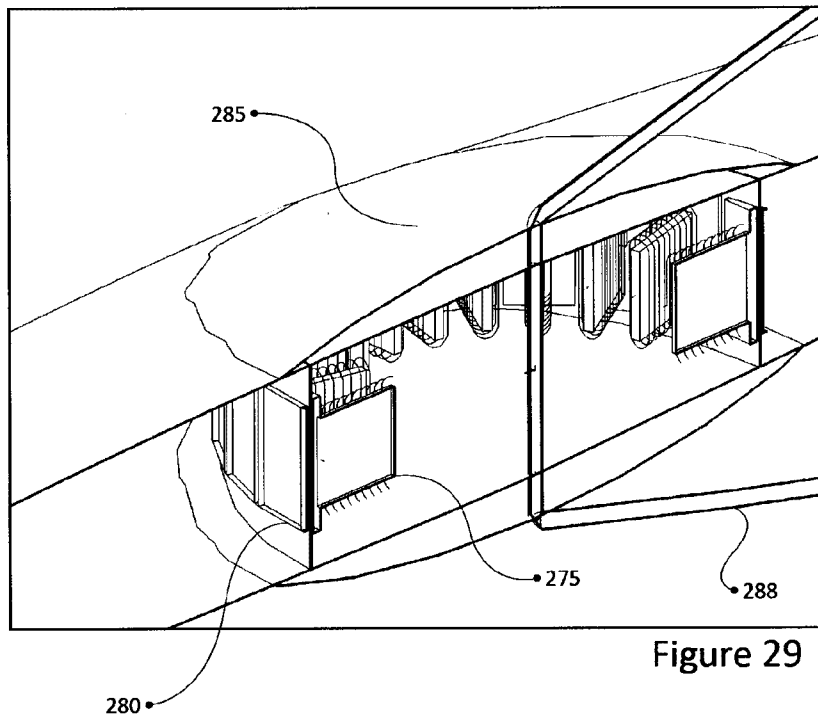


Figure 29

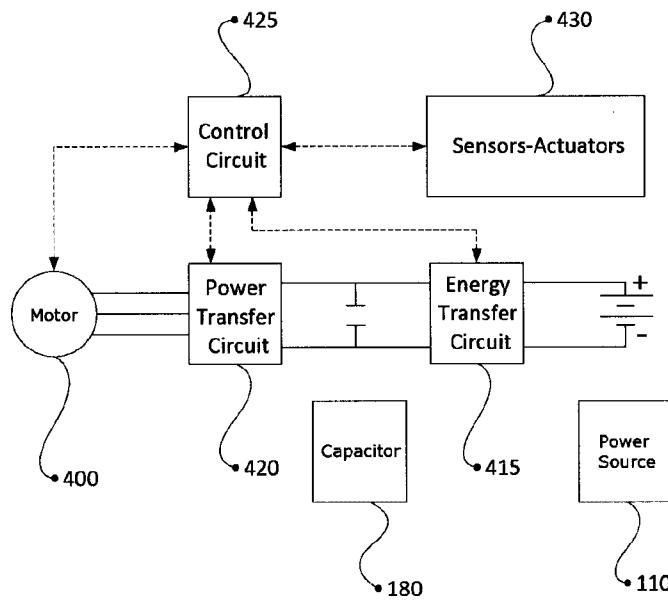


Figure 30



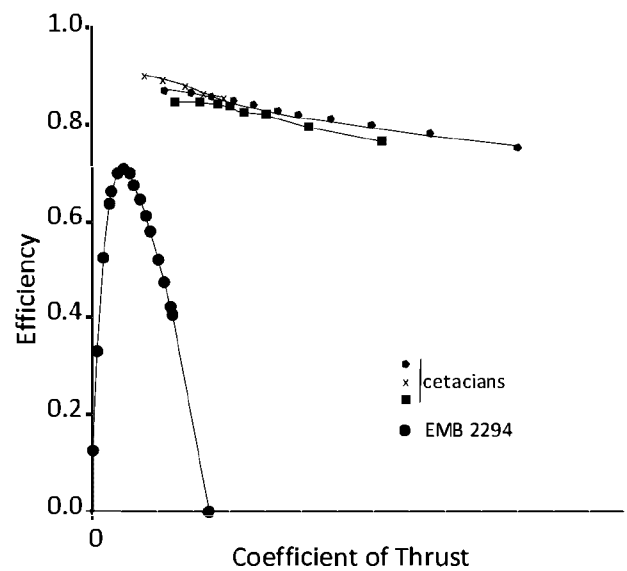


Figure 31

