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(54) UNMANNED AIR-GROUND VEHICLE

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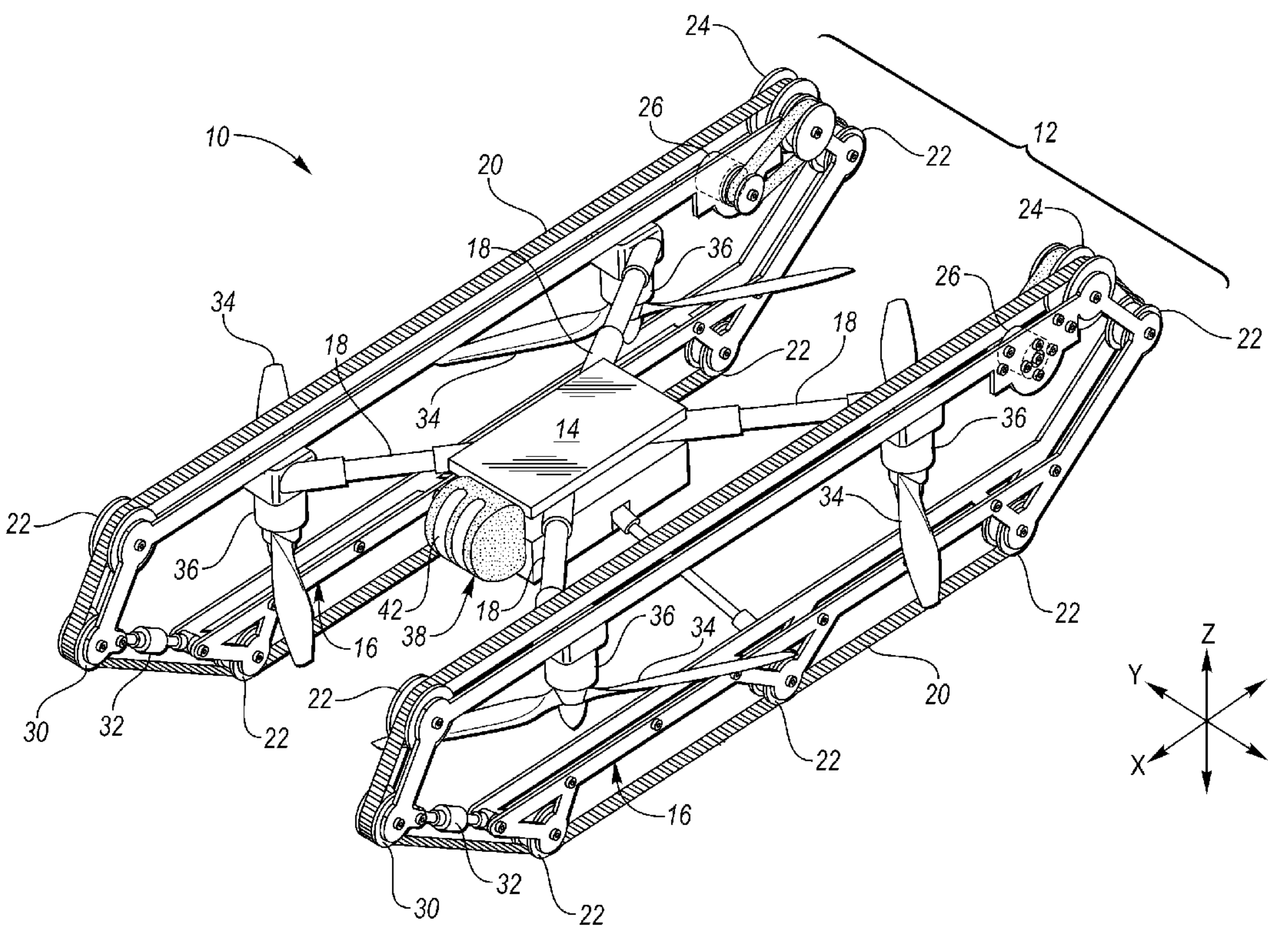
(57) **ABSTRACT**

An unmanned air-ground vehicle is provided. The unmanned air-ground vehicle includes a frame having a center portion connecting two substantially parallel transversely spaced apart track supports. Tracks that generally form loops are disposed about the track supports. Track drive motors are connected to the frame and configured to propel the tracks about the track supports. A plurality of propellers, each having propeller drive motors, are attached to the frame and disposed within the loops formed by the tracks. The tracks are configured to propel the vehicle in a ground mode while the propellers are configured to propel the vehicle in a flying mode.



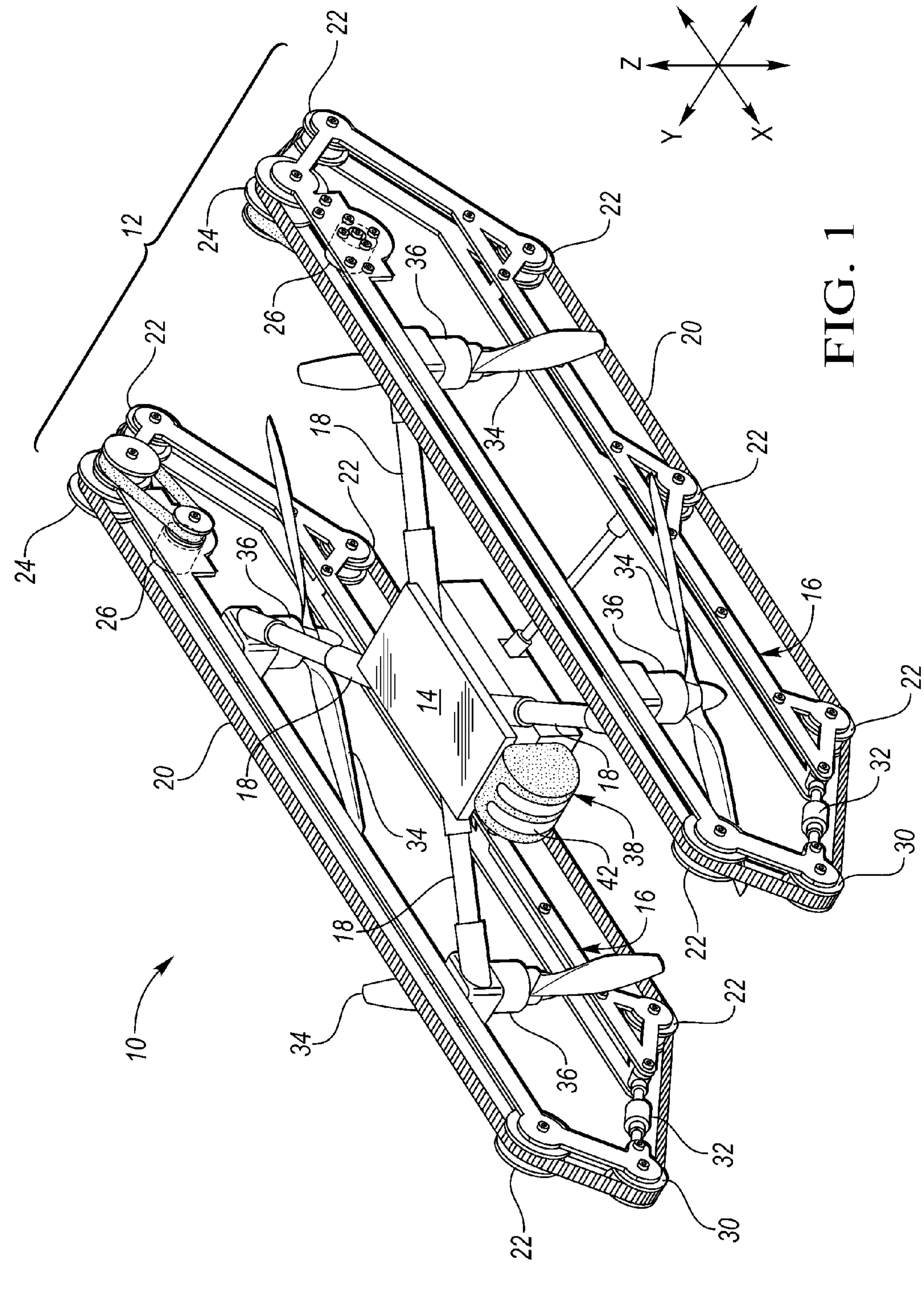


FIG. 1

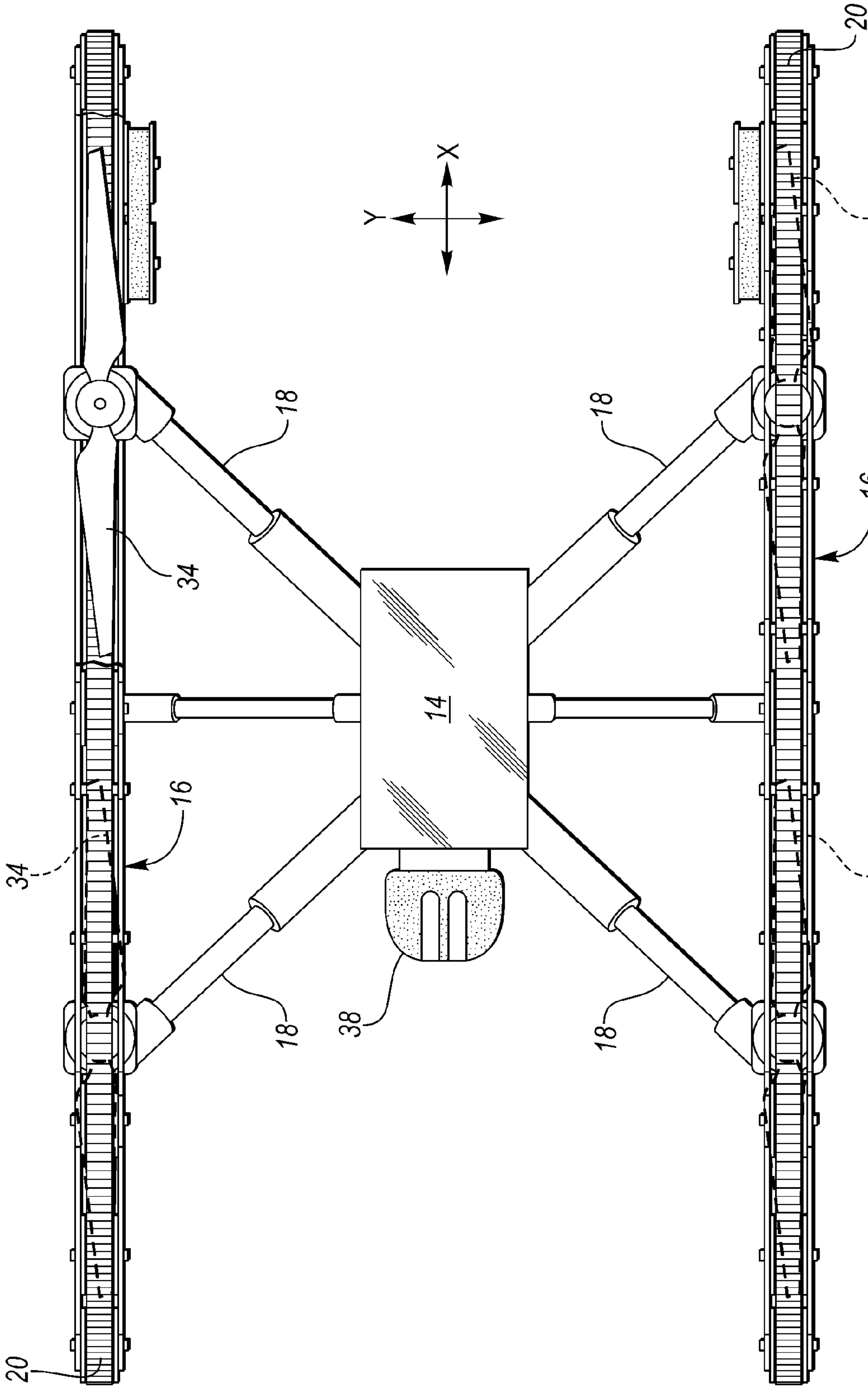


FIG. 2A

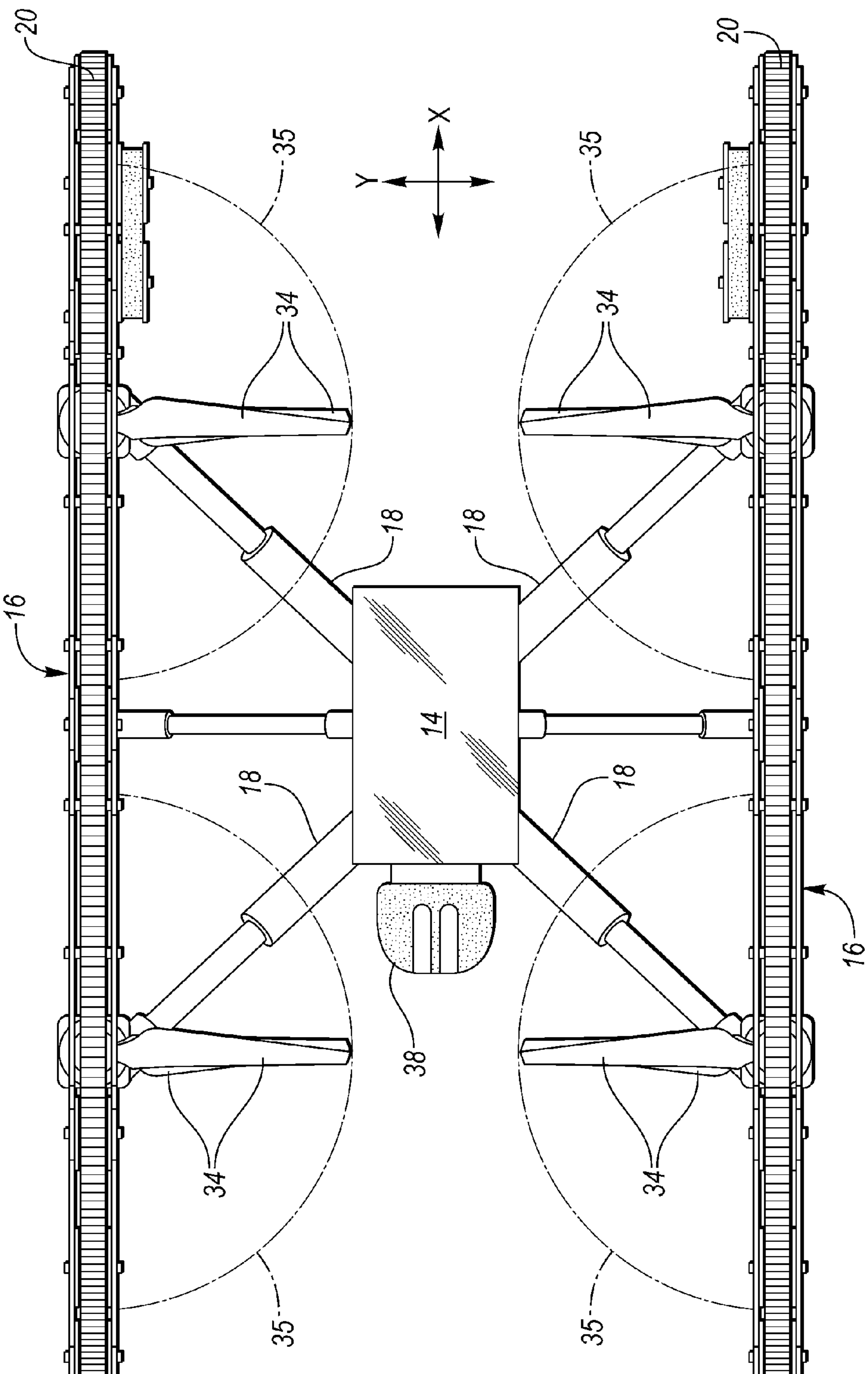


FIG. 2B

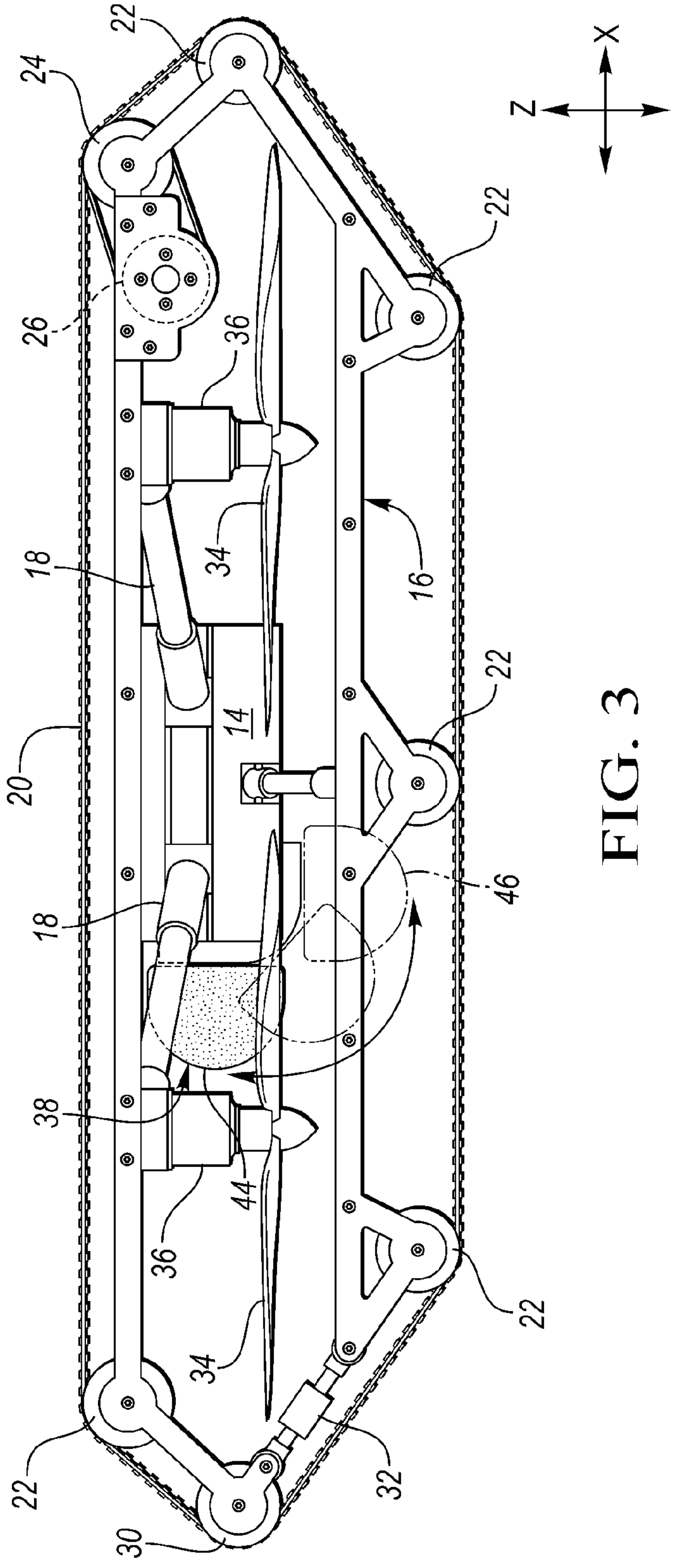


FIG. 3

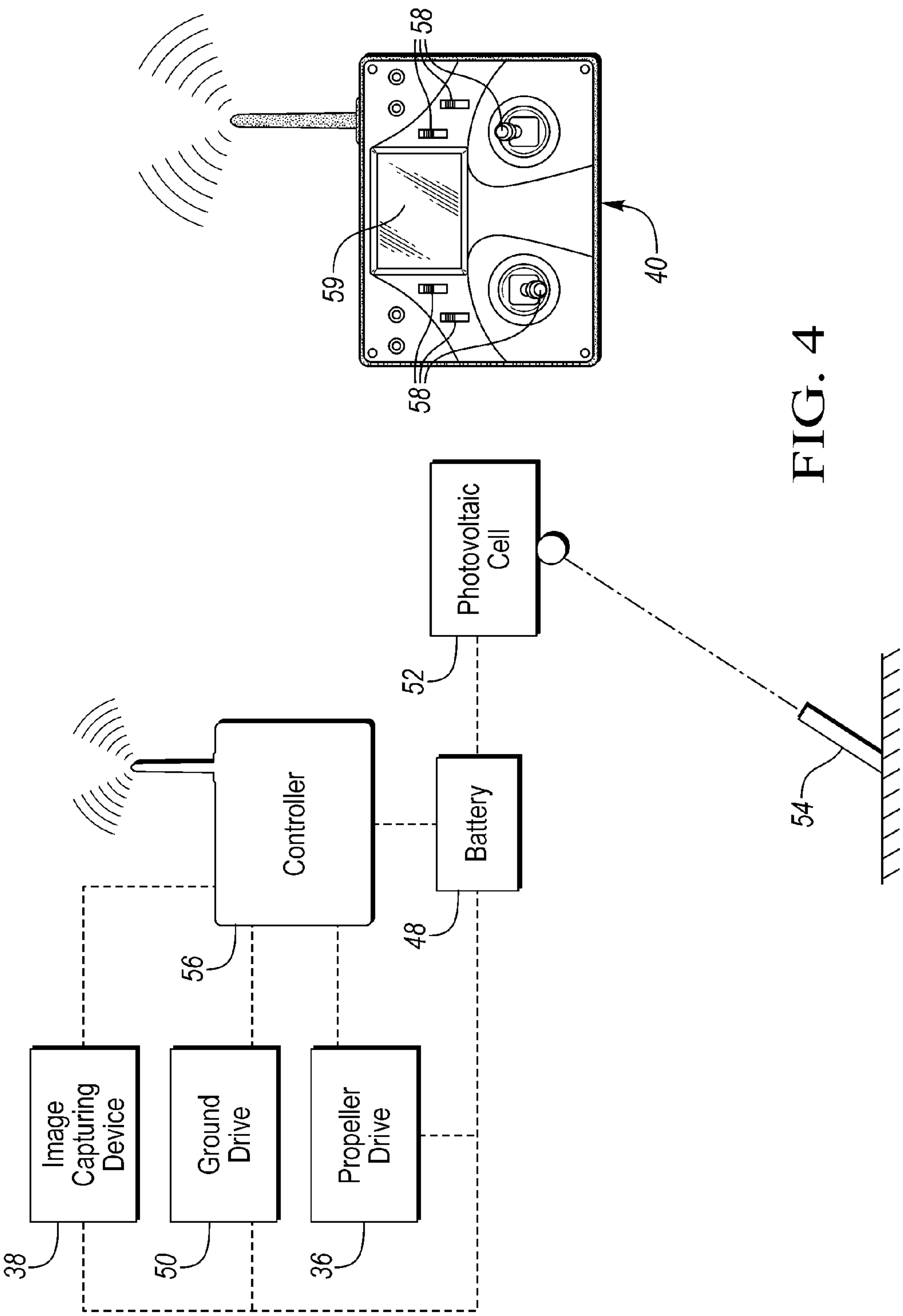


Image Capturing Device
Ground Drive
Propeller Drive
Controller
Battery
Photovoltaic Cell
38
50
36
56
48
52
54
59
58
58
40

FIG. 4

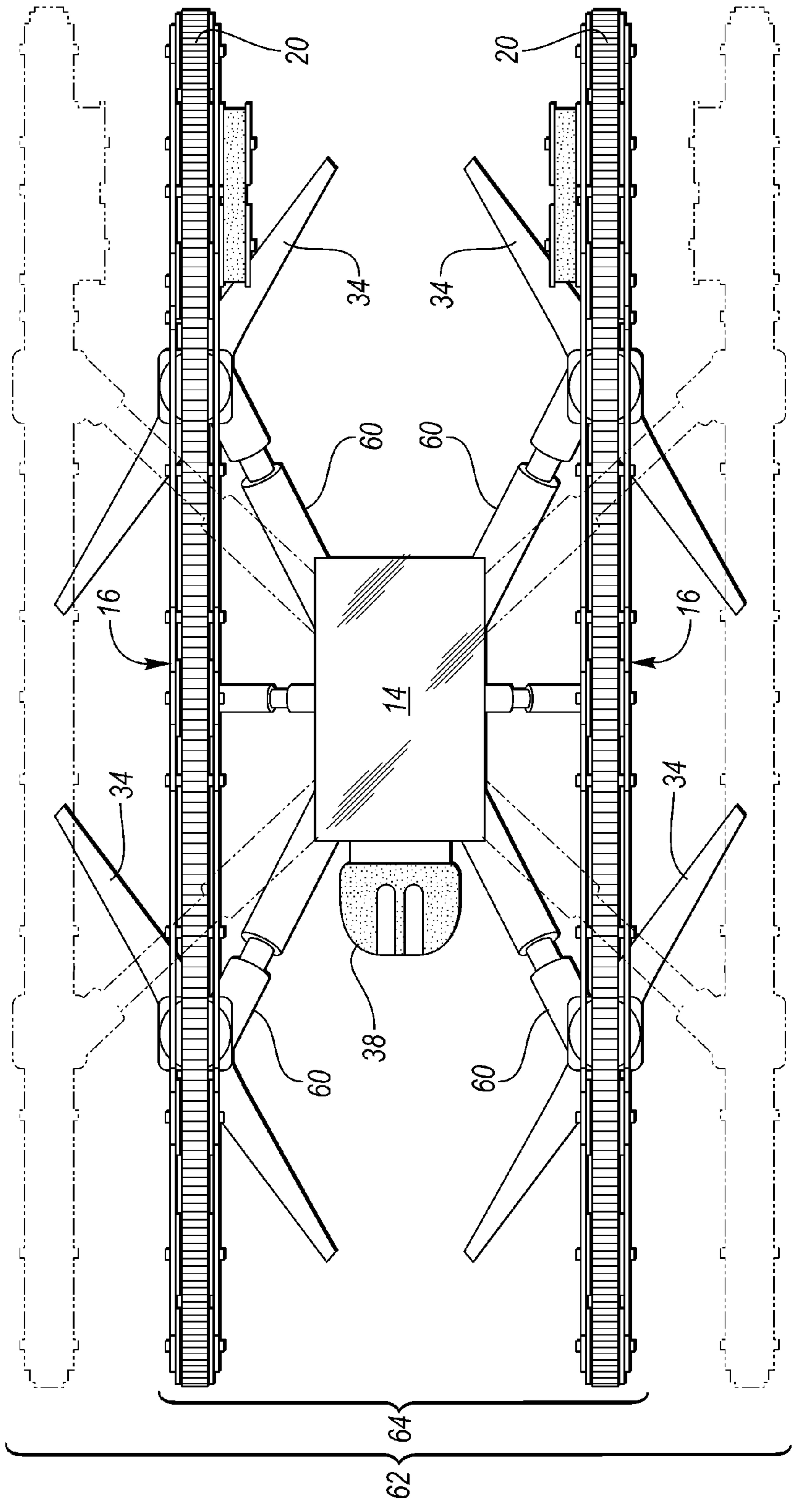


FIG. 5

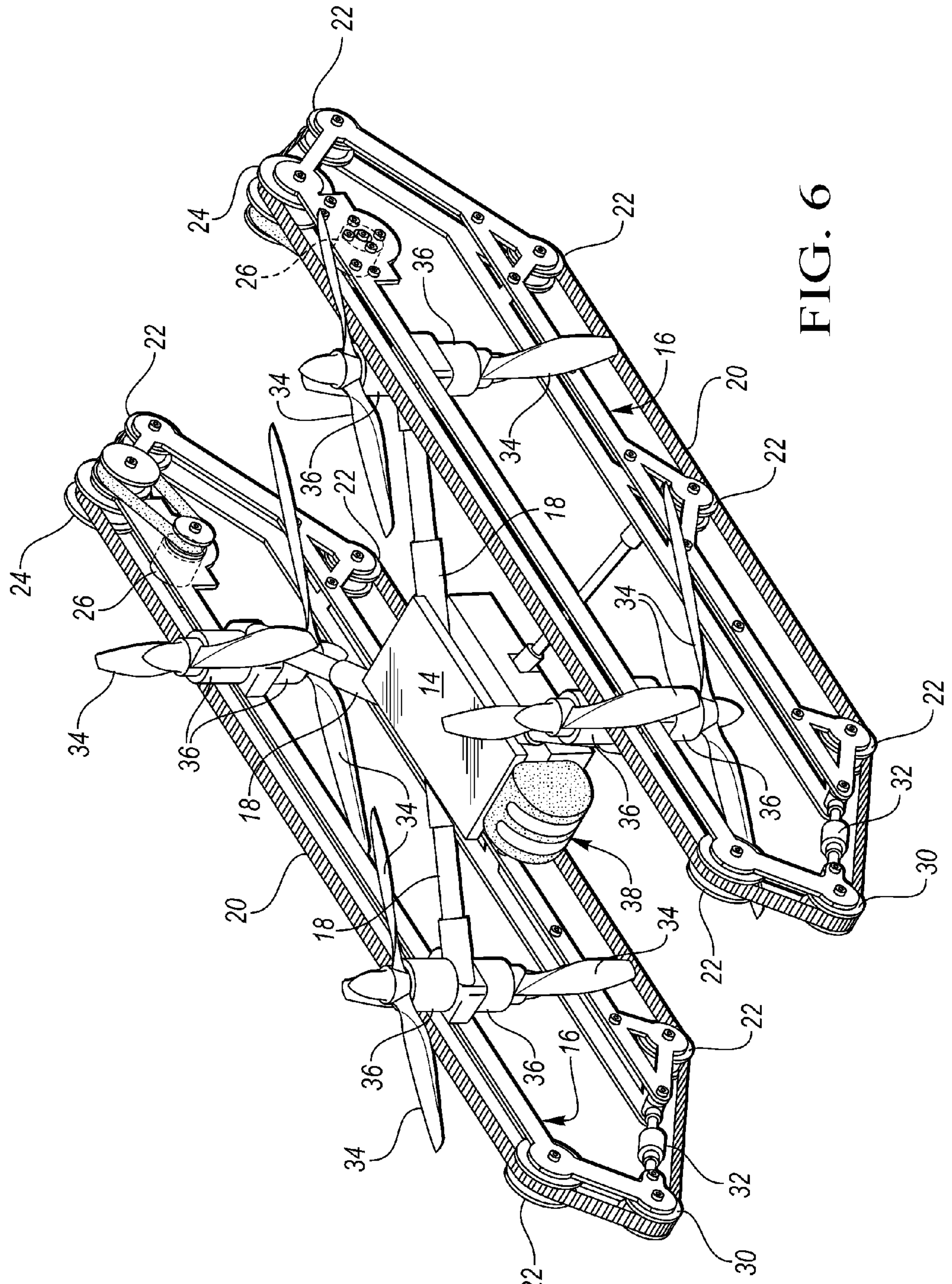


FIG. 6

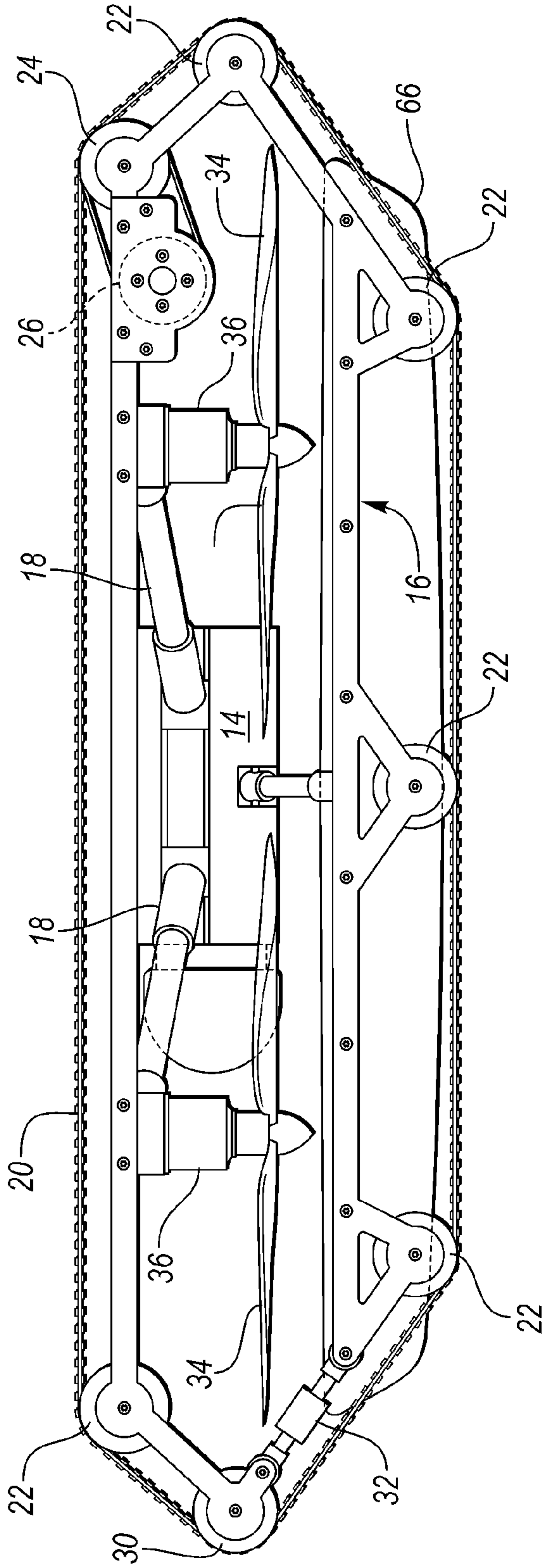


FIG. 7

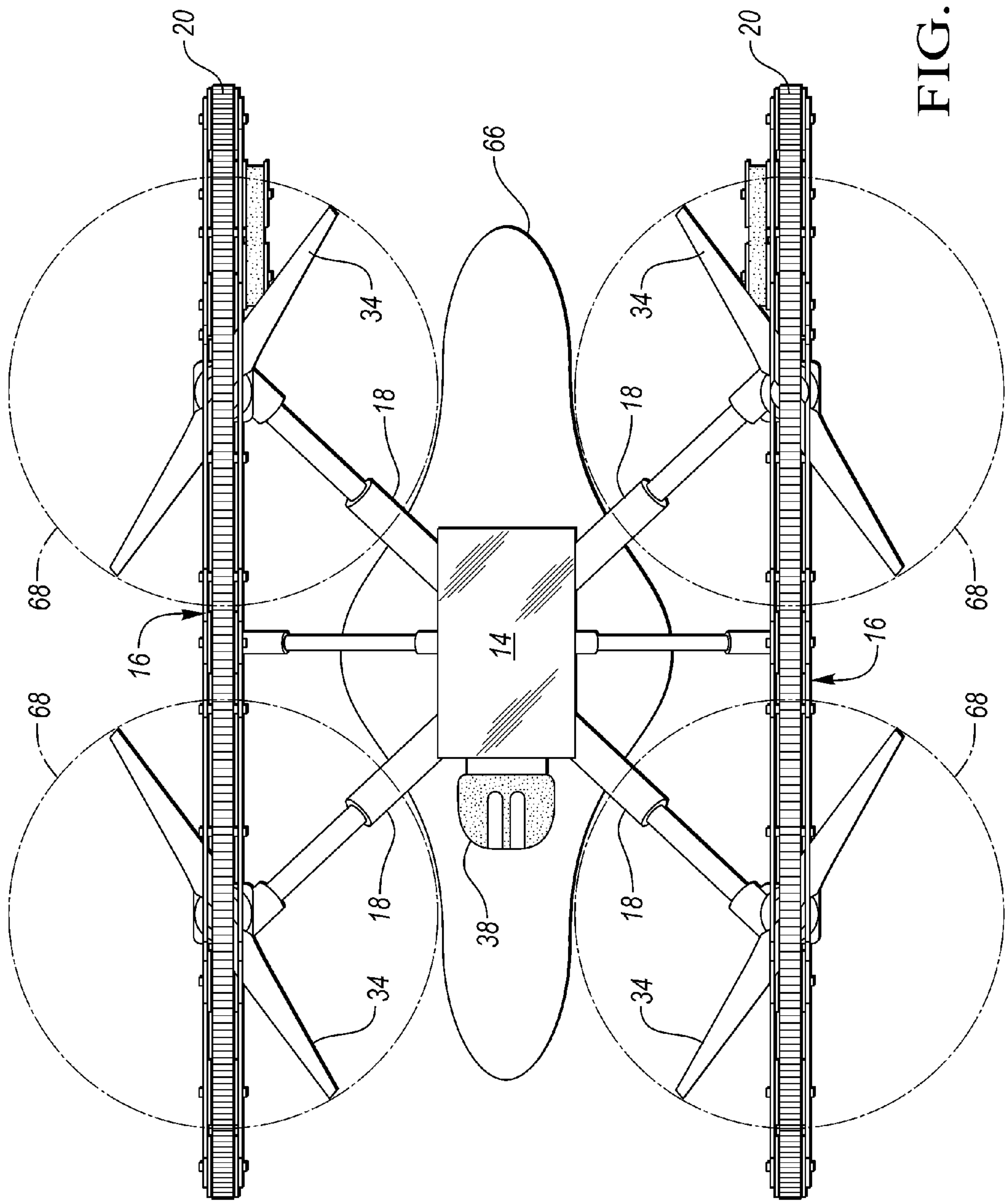


FIG. 8

UNMANNED AIR-GROUND VEHICLE

TECHNICAL FIELD

[0001] The present disclosure relates to unmanned air-ground vehicles.

BACKGROUND

[0002] Unmanned vehicles, also known as robots or drones, may be utilized for various purposes including various delivery services, law enforcement, surveillance, and military operations. Most robots are dedicated ground vehicles while most drones are dedicated aerial vehicles. A limited number of unmanned air-ground vehicles combine the functions of ground and aerial vehicles.

SUMMARY

[0003] In one aspect of the disclosure, an unmanned air-ground vehicle is provided. The unmanned air-ground vehicle includes a frame having a center portion connecting two substantially parallel transversely spaced apart track supports. Tracks that generally form loops are disposed about the track supports. Track drive motors are connected to the frame and configured to propel the tracks about the track supports. A plurality of spaced apart propellers each having propeller drive motors are attached to the frame and disposed within the loops formed by the tracks. The tracks are configured to propel the vehicle in a ground mode while the propellers are configured to propel the vehicle in a flying mode.

[0004] In another aspect of the disclosure, a vertical take-off and landing unmanned air-ground vehicle is provided. The vertical take-off and landing unmanned air-ground vehicle includes a frame having a center portion and two substantially parallel transversely spaced apart side portions connected to the center portion. A ground drive is attached to the side portions and is configured to propel the vehicle in a ground mode. The ground drive may include wheels or tracks and associated drive motors. A plurality of propellers each having propeller drives are attached to the frame and disposed within the side portions. The plurality of propellers are configured to propel the vehicle in a flying mode. The propeller blades are configured to shift into parked positions, the parked positions ranging from substantially parallel to the side portions of the frame to substantially perpendicular to the side portions of the frame, so that the blades do not extend laterally outward substantially beyond the frame, when the vehicle is operating in the ground mode.

[0005] In yet another aspect of the disclosure, a vertical take-off and landing unmanned air-ground vehicle is provided. The vertical take-off and landing unmanned air-ground vehicle includes a frame having a center portion, two side portions, and a collapsible mechanism that connects the side portions to the center portion. The collapsible mechanism enables the side portions to shift from a ready position where the two side portions are substantially parallel to a storage position. A ground drive attached to the side portions is configured to propel the vehicle in a ground mode. A plurality of propellers each having propeller drives are attached to the frame and disposed within the side portions. The plurality of propellers are configured to propel the vehicle in a flying mode. A battery is attached to the frame and configured to provide power to the ground drive and propeller drives. Various payloads such as a camera are attachable to the frame.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] FIG. **1** is an isometric view of an unmanned air-ground vehicle;

[0007] FIG. **2***a* is a top view of the unmanned air-ground vehicle illustrating the propellers parked in storage positions;

[0008] FIG. **2***b* is a top view of the unmanned air-ground vehicle illustrating an alternative configuration of the propellers, where the propellers of the alternative configuration are parked in storage positions;

[0009] FIG. **3** is a side view of the unmanned air-ground vehicle illustrating an image capturing device that is capable of shifting between multiple positions;

[0010] FIG. **4** is a flow chart illustrating the electrical and control systems of the unmanned air-ground vehicle;

[0011] FIG. **5** is a top view of the unmanned air-ground vehicle illustrating a collapsible mechanism that allows the unmanned air-ground vehicle to shift from a ready position to a storage position;

[0012] FIG. **6** is isometric view of the unmanned air-ground vehicle illustrating an alternative embodiment that includes additional propellers;

[0013] FIG. **7** is a side view of the unmanned air-ground vehicle illustrating an alternative embodiment that includes a pontoon; and

[0014] FIG. **8** is a top view of the unmanned air-ground vehicle illustrating the embodiment of FIG. **7**.

DETAILED DESCRIPTION

[0015] As required, detailed embodiments of the present invention are disclosed herein; however, it is to be understood that the disclosed embodiments are merely exemplary of the invention that may be embodied in various and alternative forms. The figures are not necessarily to scale; some features may be exaggerated or minimized to show details of particular components. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a representative basis for teaching one skilled in the art to variously employ the present invention.

[0016] Referring to FIG. **1**, an unmanned air-ground vehicle **10** (hereinafter "vehicle") is illustrated. The vehicle **10** may be capable of vertical take offs and landings. The vehicle **10** includes a frame **12**. The frame **12** includes a center portion **14** and two side portions **16**. A series of cross members **18** may be used to connect the center portion **14** of the frame **12** to the side portions **16**. The two side portions **16** may be substantially parallel and transversely spaced apart from each other. The side portions **16** may also be track supports **16**, each supporting a track **20**. The elements of the frame **12**, including the center portion **14**, side portions **16**, and cross members **18**, may be made from any structural material such as metals (including steel, titanium, aluminum), metal alloys, plastics (including thermoplastics and thermosetting resins and polymers), fiber reinforced polymers (including carbon fibers, glass fibers, basalt fibers, aramid fibers or other structural fibers reinforced in epoxy, vinylester, polyester thermosetting plastic, phenol formaldehyde resins, or other thermosetting plastic), or any other structural material or composite material that may be appropriate when taking into account costs and weigh restrictions.

[0017] The tracks **20** are configured to propel the vehicle **10** over the ground when the vehicle **10** is operating in a ground mode. The tracks **20** may be continuous tracks that generally form loops and are disposed about the track supports **16**. The tracks **20** may be made from a rubber or plastic material that may be reinforced with a metal wire, such as steel wire. This may include using a cog belt as the tracks **20**, with the cogs facing outward for traction. In the alternative, the tracks **20** may be made from a series of linked metal pieces or plates, such as steel plates. This may include using tank tread or caterpillar track for the tracks **20**.

[0018] The track supports **16** may also support a series of wheels, sprockets, or pulleys that are used to propel and guide the tracks **20** about the track supports **16**. For simplicity purposes, the wheels, sprockets, or pulleys that are used to propel and guide the tracks **20** about the track supports **16** will be referred to solely as wheels **22**. At least one of the wheels **22** on each track support **16** may be drive wheel **24** that is drivably connected to a track drive motor **26**. The drive wheels **24** and the track drive motors **26** may be connected via a pulley and belt (or sprocket and chain) system that may have a gear or speed reduction ratio. In the alternative a gearing connection, such as a gearbox, may be used to connect the drive wheels **24** and the track drive motors **26**. The gearing connection may have a gear or speed reduction. In yet another alternative, the drive wheels **24** may be directly connected to the drive motors **26**.

[0019] At least one of the wheels **22** on each track support **16** may be an idler wheel **30** that is used to tension the track **20** to prevent the track **20** from slipping or being thrown off of the wheels **22**. The idler wheel **30** may be connected to tensioner **32** that provides the tension force. The tensioner **32** may include a gas spring, a linear spring, torsional spring, or any other device capable of providing tension force to the tracks **20** via the idler wheel **30**.

[0020] Other forms of ground drives, other than tracks, may be utilized to propel the vehicle **10** when the vehicle **10** is operating in the ground mode. For example, a series of wheels that propel the vehicle **10** over the ground may be connected to the side portions **16** of the frame **12**. In this configuration, at least one wheel on each side portion **16** may be a drive wheel that is drivably connected to a drive motor. The drive wheels may be connected to the drive motors via a pulley and belt (or sprocket and chain) system that may have a gear or speed reduction ratio. In the alternative a gearing connection, such as a gearbox, may be used to connect the drive wheels and the drive motors. The gearing connection also may have a gear or speed reduction. In yet another alternative, the drive wheels may be directly connected to the drive motors.

[0021] Another example of a ground drive may include a series of walking legs that may be connected the frame **12** that are utilized to walk the vehicle **10** over the ground when the vehicle **10** is operating in the ground mode. Examples of walking legs are disclosed in U.S. Pat. No. 6,481,513, U.S. Pat. No. 6,238,264, and U.S. Pat. No. 5,127,484. The disclosures of U.S. Pat. No. 6,481,513, U.S. Pat. No. 6,238,264, and U.S. Pat. No. 5,127,484 are incorporated herein by reference in their entirety.

[0022] The disclosure should not be construed as limited to ground drives that include tracks, wheels, or walking legs, but should include any ground drive or combination of ground drives that are capable of moving the vehicle **10** over the ground when the vehicle **10** is operating in the ground mode.

[0023] With continued reference to FIG. **1**, the vehicle **10** may also include a plurality of propellers **34** that are attached to the frame **12** and disposed within the side portions **16** of the frame. In the embodiment that includes tracks **20**, the propellers **34** may be attached to the frame **12** and disposed within the track supports **16** and the loops that are generally formed by the tracks **20**. The plurality of propellers **34** each have a propeller drive **36**, which may be a propeller drive motor **36**, that is configured to rotate the propellers **34** in order to propel the vehicle **10** in a flying mode. Although four propellers **34** are depicted in FIG. **1**, the disclosure should be not be construed as limited to unmanned air-ground vehicles having four propellers, but should be construed to include unmanned air-ground vehicles having one or more vertical axis propellers, and preferably three or more spaced apart vertical axis propellers.

[0024] The propellers **34** may be made from any material such as metals (including steel, titanium, and aluminum), metal alloys, plastics (including thermoplastics and thermosetting resins and polymers), fiber reinforced polymers (including carbon fibers, glass fibers, basalt fibers, aramid fibers or other structural fibers reinforced in epoxy, vinylester, polyester thermosetting plastic, phenol formaldehyde resins, or other thermosetting plastic), or any other material or composite material that may be appropriate when taking into account the costs, weigh restrictions, and functionality of the propellers.

[0025] Referring to FIG. **2***a*, the propellers **34** are shown in storage or parked positions where the propellers **34** are substantially parallel to the side portions **16** (or track supports **16**) of the frame **12**. A portion of the upper part of the track **20** and track support **16** has been cut out in FIG. **2***a* to illustrate the parked position of one of the propellers **34**. The view in FIG. **2***a* includes The storage or parked positions ensure a smaller footprint of the vehicle **10** when it is operating in the ground mode and also prevents the propellers **24** from becoming entangled with obstacles when the vehicle **10** is operating in the ground mode. The propellers **34** in FIG. **2***a* are shown as a dual blade propeller design comprised as single solid pieces. However, the propellers **34** may include multiple blades of two or more that are configured to either fold into positions where the multiple blades overlap each other or where the multiple blades shift to positions that point in the same direction when the propellers **34** are not propelling the vehicle **10** in the flying mode. Such an alternative configuration where multiple propeller blades are in a folded position or rotated to point in the same direction is illustrated in FIG. **2***b*. The propeller blades may be positioned in storage or parked positions that range from substantially parallel to the side portions **16** of the frame **12** to substantially perpendicular to the side portions **16** of the frame **12**, so that the blades do not extend laterally outward substantially beyond the frame **12**. The range of storage or parked positions of the propeller blades is illustrated by the line **35**.

[0026] Referring to FIGS. **1-3**, the vehicle **10** may also include an image capturing device, such as a camera, **38** that provides feedback to a human machine interface (HMI) **40** (See FIG. **4**). The image capturing device **38** may provide video, infrared, or other forms of imaging back to the HMI **40**.

[0027] The image capturing device **38** may be capable of rotating about several axes to increase the field of view. The image capturing device **38** illustrated in FIG. **1** is attached to the front side of the center portion **14** of the frame **12**. The image capturing device **38** has panes **42** that allow an internally mounted lens to view the surrounding environment. The lens may rotate along the Y axis increasing the field of view through the panes **42**. The image capturing device **38** may also be mounted to a rotating device that allows the image capturing device **38** to rotate along the X axis also increasing the field of view. In addition, a second image capturing device (not show) may be mounted to the back side of the center portion **14** of the frame **12** to further increase the field of view. Referring now to FIG. **3**, the image capturing device **38** may also be mounted to a shifting device that allows the image capturing device to transition from a front position **44** along the front side of the center portion **14** of the frame **12** to a lower position **46** along the lower side of the center portion **14** of the frame **12**, again further increasing the field of view of the image capturing device **38**.

[0028] The disclosure however, should not be limited to the type of image capturing devices and devices that increase the field of view of the image capturing device described herein, but should include any type of image capturing device and any type of rotating, sliding, or other mechanism that increases the field of view of an image capturing device **38**. For example the image capturing device **38** depicted in FIG. **3** may also include an upper position where the camera may be shifted to an upper position along the top side of the center portion **14** of the frame **12**.

[0029] Referring to FIG. **4**, a flow chart of the electrical and control system of the unmanned air-ground vehicle **10** is illustrated. A battery **48** may be used to supply to power the propeller drives **36**, which may include propeller motors, when the vehicle **10** is operating in a flying mode. The battery **48** may also be used to supply power to the ground drives **50**. The ground drives **50** may include motors, such as the track drive motors **26**, to propel wheels or tracks when the vehicle **10** is operating in the ground mode. The battery **48** may be attached to the frame **12**, or more specifically may be housed in the center portion **14** of the frame **12**. The battery **48** may be recharged by plugging the battery **48** into a power outlet or via a photovoltaic cell **52**. The photovoltaic cell **52** may be capable of recharging the battery **48** when a laser beam is directed onto the photovoltaic cell **52** (also known as power beaming). Power beaming may be used while the vehicle **10** is not operating or while the vehicle **10** is operating in either the flying mode or ground mode. Alternative power sources, such as an internal combustion engine (ICE), may be used in place of a battery to power the propeller drives **36** and the ground drives **50**. Alternatively, various combinations of power sources may be used such as an electrical/ICE hybrid having a quiet electric mode and a long range ICE mode.

[0030] A controller **56** is configured to control the ground drives **50** and propeller drives **36** of the vehicle **10**, when the vehicle **10** is either in the ground mode or the flying mode. The controller **56** may include a receiver and transmitter (or alternatively a transceiver) for communicating with the HMI **40**. The HMI **40** may also include a receiver and transmitter (or alternatively a transceiver) for communicating with the controller **56**. The controller **56** and HMI **40** may communicate with each other via wireless network technology, Bluetooth® technology, infra-red transmission technology, radio frequency, or any other form of wireless communication.

[0031] The HMI **40** may include a series of control buttons, levers, or other devices (control devices **58**) that are configured to communicate a user input to the HMI **40**. The HMI **40** may then communicate the user input to the controller **56**, which is located on the vehicle **10**, allowing a user to remotely control the vehicle **10** when the vehicle **10** is operating in the ground mode or flying mode.

[0032] The controller **56** may further transmit video, infrared, or other forms of imaging from the image capturing device **38** back to an imaging display device **59**, which may be located on the HMI **40**.

[0033] While illustrated as one controller, the controller **56** may be part of a larger control system and may be controlled by various other controllers throughout the vehicle **10**. It should therefore be understood that the controller **56** and one or more other controllers can collectively be referred to as a "controller" that controls various actuators, drives, motors, etc. in response to various sensors, inputs, signals, etc. The controller **56** may include one or more microprocessors or central processing units (CPUs) in communication with various types of computer readable storage devices or media. Computer readable storage devices or media may include volatile and nonvolatile storage in read-only memory (ROM), random-access memory (RAM), and keep-alive memory (KAM), for example. KAM is a persistent or non-volatile memory that may be used to store various operating variables while the CPU is powered down. Computer-readable storage devices or media may be implemented using any of a number of known memory devices such as PROMs (programmable read-only memory), EPROMs (electrically PROM), EEPROMs (electrically erasable PROM), flash memory, or any other electric, magnetic, optical, or combination memory devices capable of storing data, some of which represent executable instructions, used by the controller **56** in controlling the vehicle **10**.

[0034] The vehicle **10** may also include a collapsible mechanism **60** that allows the side portions (or track supports) **16** of the frame **12** to shift from ready position **62** to a storage position **64**. The collapsible mechanism **60** may (instead of the cross members **18**) connect the side portions **16** of the frame **12** to the center portion **14** of the frame **12**. The collapsible mechanism **60** may be comprised of a telescoping mechanism that is configured to allow the side portions **16** of the frame **12** to extend away from the center portion **14** when moving into the ready position **62**, and collapse inward toward the center portion **14** of the frame **12** when moving into the storage position **64**. The collapsible mechanism **60**, however, should not be limited to telescoping mechanisms, but should include any mechanism that is configured to decrease the footprint of the vehicle **10** or an area or space required to store the vehicle **10** when the vehicle **10** transitions from the ready position **62** to the storage position **64**. Alternative embodiments may include various configurations of links and pivots that allow the side portions **16** of the vehicle **10** to transition into a storage position from a ready position.

[0035] Referring to FIG. **6**, an alternative embodiment that includes additional propellers **34** and propeller drives **36** located on the top of the side portions **16** of the frame **12** is illustrated. The additional set of propellers **34** and propeller drives **36** increases the power output capability of the vehicle **10** when operating in the flying mode.

[0036] The additional propellers **34** may be configured to park in positions where the propellers **34** are substantially parallel to the side portions **16** of the frame **12**. In the alternative, a configuration that includes multiple blades of two or more that are configured to either fold into positions where the multiple blades overlap each other or where the multiple blades shift to positions that point in the same direction, the propeller blades **34** may be positioned in storage or parked positions that range from substantially parallel to the side portions **16** of the frame **12** to substantially perpendicular to the side portions **16** of the frame **12**, so that the blades do not extend laterally outward substantially beyond the frame **12**.

[0037] Referring to FIGS. **7** and **8**, another alternative embodiment may include at least one pontoon **66** that is attached to the frame **12** and allows the vehicle **10** to float and operate in a water mode. As depicted in FIG. **8**, the pontoon **66** may a single pontoon that is designed not to overlap with the footprint **68** of the propellers **34**, so that the pontoon does not restrict the airflow of the propellers **34** when the vehicle **10** is operating in the flying mode. In the alternative, multiple pontoons may be used. For example, two smaller pontoons may be connected to the side portions **16** of the frame **12**. The pontoon **66** may also be placed at a level lower than the center portion **14** of the frame **12** (where the controller **56** and the battery **48** may be housed), the track drive motors **26**, propeller drives **36**, and other various electrical components, so that the electrical components stay above a water line when the vehicle **10** is operating in the water mode. The center portion **14** of the frame **12** (where the controller **56** and the battery **48** may be housed), the track drive motors **26**, propeller drives **36**, and other various electrical components may also be encased in waterproof housings to prevent damage to the electrical components when the vehicle **10** is operating in the water mode.

[0038] The tracks **20** may be used to propel the vehicle **10** through the water when the vehicle **10** is operating in the water mode. Alternative embodiments that include ground drives such as wheels may also be used to propel the vehicle **10** through the water when the vehicle **10** is operating in the water mode. The vehicle may also include a water drive that may be comprised of water jets or a propeller that is operatively linked to a power source, such as an electric motor or internal combustion engine.

[0039] While exemplary embodiments are described above, it is not intended that these embodiments describe all possible forms of the invention. Rather, the words used in the specification are words of description rather than limitation, and it is understood that various changes may be made without departing from the spirit and scope of the invention. Additionally, the features of various implementing embodiments may be combined to form further embodiments of the invention.

What is claimed is:

1. An unmanned air-ground vehicle comprising:

a frame having a center portion connecting two substantially parallel transversely spaced apart track supports;

two tracks generally forming loops, each track disposed about one of the track supports;

two track drive motors, each connected to the frame and configured to propel one of the two tracks about the track supports; and

a plurality of propellers, each having a propeller drive motor, attached to the frame and disposed within the loops formed by the tracks, wherein the tracks are configured to propel the vehicle in a ground mode, and the propellers are configured to propel the vehicle in a flying mode.

2. The vehicle of claim **1**, wherein the frame further comprises a collapsible mechanism enabling the track supports to shift from a ready position to a storage position.

3. The vehicle of claim **1**, wherein the plurality of propellers are configured to park in storage positions, the storage positions ranging from substantially parallel to the track supports to substantially perpendicular to the track supports so that the blades of the propellers do not extend laterally outward substantially beyond the frame, when the vehicle is operating in the ground mode.

4. The vehicle of claim **1**, further comprising a controller configured to control the track drive motors in the ground mode and the propeller drive motors in the flying mode.

5. The vehicle of claim **4**, further comprising a human machine interface that wirelessly communicates with the controller allowing a user to control the vehicle in the ground mode or the flying mode.

6. The vehicle of claim **5**, further comprising an image capturing device connected to the frame that provides feedback to the human machine interface.

7. The vehicle of claim **6**, wherein the image capturing device is shiftably mounted to the frame in order to vary the field of view of the image capturing device.

8. The vehicle of claim **1**, wherein a least one pontoon is attached to the frame.

9. A vertical take-off and landing unmanned air-ground vehicle comprising:

a frame having a center portion and two substantially parallel transversely spaced apart side portions connected to the center portion;

a ground drive, attached to the side portions, configured to propel the vehicle in a ground mode; and

a plurality of propellers, each having a propeller drive, attached to the frame and disposed within the side portions, wherein the plurality of propellers are configured to propel the vehicle in a flying mode, and wherein the propeller blades are configured to shift into parked positions, the parked positions ranging from substantially parallel to the side portions of the frame to substantially perpendicular to the side portions of the frame so that the blades do not extend laterally outward substantially beyond the frame, when the vehicle is operating in the ground mode.

10. The vehicle of claim **9**, further comprising a controller configured to control the ground drive in the ground mode and the propeller drives in the flying mode.

11. The vehicle of claim **10**, further comprising a human machine interface that wirelessly communicates with the controller allowing a user to control the vehicle in the ground mode or the flying mode.

12. The vehicle of claim **11**, further comprising an image capturing device connected to the frame that provides feedback to the human machine interface.

13. The vehicle of claim **12**, wherein the image capturing device provides video feedback to the human machine interface.

14. The vehicle of claim **12**, wherein the image capturing device provides infrared feedback to the human machine interface.

15. The vehicle of claim **12**, wherein the image capturing device is shiftably mounted to the frame in order to vary the field of view of the image capturing device.

16. The vehicle of claim **9**, wherein the frame further comprises a collapsible mechanism enabling the side portions to shift from a ready position to a storage position.

17. A vertical take-off and landing unmanned air-ground vehicle comprising:

a frame having a center portion, two side portions, and a collapsible mechanism that connects the side portions to the center portion and enables the side portions to shift from a ready position, where the two side portions are substantially parallel, to a storage position;

a ground drive, attached to the side portions, configured to propel the vehicle in a ground mode;

a plurality of propellers, each having a propeller drive, attached to the frame and disposed within the side portions, the plurality of propellers configured to propel the vehicle in a flying mode; and

a battery attached to the frame configured to provide power to the ground drive and propeller drives.

18. The vehicle of claim **17**, wherein the plurality of propellers are shifted into parked positions, the parked positions ranging from substantially parallel to the side portions of the frame to substantially perpendicular to the side portions of the frame so that the blades do not extend laterally outward substantially beyond the frame, when the vehicle is operating in the ground mode.

19. The vehicle of claim **17**, where a photovoltaic cell attached to the frame is configured to recharge the battery.

20. The vehicle of claim **19**, wherein the photovoltaic cell is configured to recharge the battery through power beaming.

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