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(54) **Title:** UNMANNED AERIAL VEHICLE THROW MODE

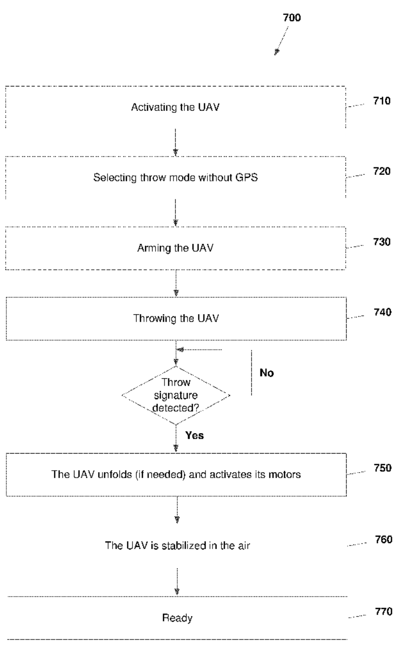

Fig. 7

(57) **Abstract:** An Unmanned Aerial Vehicle (UAV), comprising at least one power supply; at least one motor; at least one sensor configured to sense a throw action; and a controller connected with the at least one power supply, the at least one motor and the at least one sensor; wherein the UAV is configured to be thrown, detect a unique throw signature according to at least one measurement received from the at least one sensor and activate the at least one motor upon a the unique throw signature being detected

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UNMANNED AERIAL VEHICLE THROW MODE

FIELD OF THE INVENTION

The present invention generally relates to Unmanned Aerial Vehicles (UAV) and specifically to Unmanned Aerial Vehicles (UAV) in throw mode.

CROSS-REFERENCE TO RELATED PATENT APPLICATIONS

This patent application claims priority from and is related to U.S. Provisional Patent Application Serial Number 62790487, filed 01/10/2019 and U.S. Provisional Patent Application Serial Number 62790491, filed 01/10/2019, these U.S. Provisional Patent Applications incorporated by reference in its entirety herein.

BACKGROUND

Conventional Unmanned Aerial Vehicles (UAVs) are used for various purposes, as a hobby or for operational missions such as delivery, surveillance, observation, etc. These UAVs usually take off from the ground or other solid platforms under their own power. There are also thrown UAVs, which are initially carried or connected to an originating platform, and then released into the air in a manner that imparts them with an initial altitude and velocity and leaves them in free flight or freefall. The UAV then proceeds to stabilize itself and begin flying independently from the originating platform. These UAVs may also comprise a folding mechanism, providing for a folded state that may allow the UAV to fit into the originating platform and an unfolded state that allows the UAV to fly. Examples of originating platforms may include a human operator throwing the UAV, a canister allowing the UAV to be released from a canister launcher and an aerial carrier releasing the UAV while flying or gliding through the air.

In order to safely transition from being released into the air to flying independently, the UAV may implement a mechanism for disabling its engines while it is connected to the originating platform, and then quickly activate them and right itself after it is released, avoiding situations when the UAV starts its motors while still connected to the originating platform, interfering with its release and possibly harming itself and/or the originating platform.

The open-source autopilot ArduCopter implements it with an automated Throw Mode. This mode detects that the UAV has covered a significant safety distance in freefall or moved away from its initial location at a sufficiently high speed, indicating that it's now safely away from the originating platform and may start its motors. While this mode is effective at preventing the UAV from harming its operator even when it is thrown by hand, its operation relies on continuous GPS reception, and is not applicable for uses where the UAV does not spend a long time in freefall after being released.

Other implementations may rely on an external signal provided to the UAV once it is released, instructing it to activate its engines and begin flight. While this allows the UAV to be activated quickly, it requires reliable communication with the UAV as it is being released and relies on an operator or an external system to detect the release event. If communication with the UAV is unreliable, it may fail to activate, and if the external detection of a release event is unreliable, it may fail to activate or accidentally activate a UAV even when it was not released.

In known implementations of a launched or thrown UAV, the UAV faces a unique load when it first rights itself after being released, as it has to apply unusual accelerations and moments to counteract the speeds and angular rotation rates imparted to it by the originating platform before its release. This load may be significantly higher than the load experienced in normal flight, and in existing battery-powered implementations this forces the UAV's batteries to be specified for this high load, resulting in increased price and reduced efficiency.

Additionally, the accelerations encountered by a UAV before and during its release may exceed those encountered by a UAV in its routine flight. While the UAV body itself may be designed to accommodate these accelerations, new payloads integrated may not be able to handle such loads easily. For example, a camera gimbal's motors may be violently swung around their axes by the release process, damaging the gimbal. This constraint may require payloads to be heavier or disqualify certain payloads from being integrated.

For a launched UAV, the release process may additionally deteriorate the UAV's inertial sensing capabilities, for example, due to high accelerations leading to erroneous sensor readings "polluting" the UAV's sensor fusion algorithm, or the UAV rapidly moving from an environment with magnetic disruptions to a minimally disrupted free-sky environment which contradicts its pre-calibrated sensor offsets. These effects lead to the UAV flying less accurately and possibly less efficiently, reducing its effectiveness for missions requiring long endurance or accurate course planning or positioning. In existing implementations, these effects are either ignored, leaving them to be partially corrected over a long time by automatic self-calibration, or manually corrected by the operator initiating self-calibration routines after launch, consuming the operator's attention.

Additionally, the release process, possibly exhibiting abnormally rapid motion, may require the UAV's flight control loops and sensors to be configured to accommodate the rapid responses and high control effort required, for example, by configuring the control loops to be faster and the sensors to measure on larger scales. This may come at the expense of performance during slower and steadier portions making up the bulk of the flight, due to fast control loops being unnecessarily noisy for steady flight, or sensors configured for large scales losing accuracy and sensitivity in smaller scale work.

Therefore, there is a need for a thrown UAV more suited to the throw process, comprising a self-contained and reliable capability to arm, right and reconfigure itself after its release regardless of GPS and radio reception, and means to retain mass efficiency, energy efficiency and payload compatibility in spite of the constraints imposed by the release process.

SUMMARY

According to an aspect of the present invention there is provided an Unmanned Aerial Vehicle (UAV), comprising: at least one power supply; at least one motor; at least one sensor configured to sense a throw action; and a controller connected with the at least one power supply, the at least one motor and the at least one sensor; wherein the UAV is configured to be thrown, detect a unique throw signature according to at least one measurement received from the at least one sensor and activate the at least one motor upon a the unique throw signature being detected.

The at least one sensor may be selected from the group consisting of accelerometer, gyroscope and barometer.

The unique throw signature may be selected from the group consisting of a pulse of acceleration, a pulse or a change of air pressure and a predetermined change in the at least one sensor reading.

The at least one power supply may comprise: at least one high current power supply; and at least one low current power supply; and wherein the UAV may further comprise a switching mechanism connected with the at least one high current power supply and the at least one low current power supply; wherein the switching mechanism may be configured to switch between the at least one high current power supply and the at least one low current power supply upon at least one predetermined parameter being met.

The UAV may further comprise a power supply release mechanism configured to release at least one of the at least one high current power supply and the at least one low current power supply.

The UAV may be further configured to perform a self-configuration process.

The self-configuration process may comprise: awaiting at least one of GPS reception by the UAV, and the UAV reaching an upright orientation; and changing at least one of flight control loop, and parameters affecting at least one of reading, operation and fusion of at least one of the at least one sensor.

The self-configuration process may comprise enabling sensor calibration.

The self-configuration process may comprise conducting sensor calibration maneuvers.

According to another aspect of the present invention there is provided a method of throwing an Unmanned Aerial Vehicle (UAV), comprising: providing a UAV comprising:

at least one power supply; at least one motor; at least one sensor configured to sense a throw action; and a controller connected with the at least one power supply, the at least one motor and the at least one sensor; throwing the UAV into the air; detecting a unique throw signature according to at least one measurement received from the at least one sensor; and activating the at least one motor upon a the unique throw signature being detected.

The at least one sensor may be selected from the group consisting of accelerometer, gyroscope and barometer.

The unique throw signature may be selected from the group consisting of a pulse of acceleration, a pulse or a change of air pressure and a predetermined change in the at least one sensor reading.

The at least one power supply may comprise: at least one high current power supply; and at least one low current power supply; and wherein the UAV may further comprise a switching mechanism connected with the at least one high current power supply and the at least one low current power supply; wherein the method may further comprise switching between the at least one high current power supply and the at least one low current power supply upon at least one predetermined parameter being met.

The UAV may further comprise a power supply release mechanism; and wherein the method may further comprise releasing at least one of the at least one high current power supply and the at least one low current power supply.

The method may further comprise performing a self-configuration process.

The self-configuration process may comprise: awaiting at least one of GPS reception by the UAV, and the UAV reaching an upright orientation; and changing at least one of flight control loop, and parameters affecting at least one of reading, operation and fusion of at least one of the at least one sensor.

The self-configuration process may comprise enabling sensor calibration.

The self-configuration process may comprise conducting sensor calibration maneuvers.

According to an aspect of the present invention there is provided an Unmanned Aerial Vehicle (UAV), comprising: at least one high current power supply; at least one low current power supply; and a switching mechanism connected with the at least one high current power supply and the at least one low current power supply; wherein the switching mechanism is configured to switch between the at least one high current power supply and the at least one low current power supply upon at least one predetermined parameter being met.

The UAV may further comprise a power supply release mechanism configured to release at least one of the at least one high current power supply and the at least one low current power supply.

BRIEF DESCRIPTION OF THE DRAWINGS

For better understanding of the invention and to show how the same may be carried into effect, reference will now be made, purely by way of example, to the accompanying drawings.

With specific reference now to the drawings in detail, it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion of the preferred embodiments of the present invention only, and are presented in the cause of providing what is believed to be the most useful and readily understood description of the principles and conceptual aspects of the invention. In this regard, no attempt is made to show structural details of the invention in more detail than is necessary for a fundamental understanding of the invention, the description taken with the drawings making apparent to those skilled in the art how the several forms of the invention may be embodied in practice. In the accompanying drawings:

Fig. 1 is a schematic view of an exemplary carrier encompassing a UAV's capsule, according to embodiments of the present invention;
Fig. 2 is an exploded view of **Fig. 1**;
Fig. 3 is an exploded view of the capsule encompassing the UAV;

Fig. 4 is a schematic view of an exemplary UAV deployment process, according to embodiments of the present invention;

Figs. 5A and **5B** are schematic top and bottom perspective views of an exemplary UAV **500,** according to embodiments of the present invention;

Fig. 5C is a side view of the exemplary UAV, according to embodiments of the present invention;

Fig. 6 is a block diagram of an exemplary UAV, according to embodiments of the present invention;

Fig. 7 is a flowchart showing the UAV's throw process, according to embodiments of the present invention;

Fig. 8 is a block diagram of the hybrid power supply, according to embodiments of the present invention;

Fig. 9 is a flowchart showing the process performed by a UAV comprising the hybrid power supply of **Fig. 8**, according to embodiments of the present invention;

Fig. 10 is a flowchart showing the process performed by a UAV, such as, UAV of **Fig. 6** comprising the hybrid power supply of **Fig. 8**, according to embodiments of the present invention;

Fig. 11 is a flowchart showing an exemplary process of throwing a UAV and performing self-configuration, according to embodiments of the present invention;

Fig. 12 is a flowchart showing an exemplary self-configuration process, according to embodiments of the present invention; and

Fig. 13 shows a schematic throw process from an originating platform and the UAV stages, from throw stage to the stage where the UAV is ready to begin its mission, according to embodiments of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not necessarily limited in its application to the details of construction and the arrangement of the components and/or methods set forth in the following description and/or illustrated in the drawings and/or the Examples. The invention is capable of other embodiments or of being practiced or carried out in various ways.

As will be appreciated by one skilled in the art, aspects of the present invention may be embodied as a system, method or computer program product. Accordingly, aspects of the present invention may take the form of an entirely hardware embodiment, an entirely software embodiment (including firmware, resident software, micro-code, etc.) or an embodiment combining software and hardware aspects that may all generally be referred to herein as a “circuit,” “module” or “system.” Furthermore, aspects of the present invention may take the form of a computer program product embodied in one or more computer readable medium(s) having computer readable program code embodied thereon.

Any combination of one or more computer readable medium(s) may be utilized. The computer readable medium may be a computer readable signal medium or a computer readable storage medium. A computer readable storage medium may be, for example, but not limited to, an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, apparatus, or device, or any suitable combination of the foregoing. More specific examples (a non-exhaustive list) of the computer readable storage medium would include the following: an electrical connection having one or more wires, a hard disk, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), an optical fiber, a portable compact disc read-only memory (CD-ROM), an optical storage device, a magnetic storage device, or any suitable combination of the foregoing. In the context of this document, a computer readable storage medium may be any tangible medium that can contain, or store a program for use by or in connection with an instruction execution system, apparatus, or device.

A computer readable signal medium may include a propagated data signal with computer readable program code embodied therein, for example, in baseband or as part of a carrier wave. Such a propagated signal may take any of a variety of forms, including, but not limited to, electro-magnetic, optical, or any suitable combination thereof. A computer readable signal medium may be any computer readable medium that is not a computer readable storage medium and that can communicate, propagate, or transport a program for use by or in connection with an instruction execution system, apparatus, or device.

Program code embodied on a computer readable medium may be transmitted using any appropriate medium, including but not limited to wireless, wire line, optical fiber cable, RF, etc., or any suitable combination of the foregoing.

Computer program code for carrying out operations for aspects of the present invention may be written in any combination of one or more programming languages, including an object oriented programming language such as Java, Smalltalk, C++ or the like and conventional procedural programming languages, such as the "C" programming language or similar programming languages. The program code may execute entirely on the user's computer, partly on the user's computer, as a stand-alone software package, partly on the user's computer and partly on a remote computer or entirely on the remote computer or server. In the latter scenario, the remote computer may be connected to the user's computer through any type of network, including a local area network (LAN) or a wide area network (WAN), or the connection may be made to an external computer (for example, through the Internet using an Internet Service Provider).

Aspects of the present invention are described below with reference to flowchart illustrations and/or block diagrams of methods, apparatus (systems) and computer program products according to embodiments of the invention. It will be understood that each block of the flowchart illustrations and/or block diagrams, and combinations of blocks in the flowchart illustrations and/or block diagrams, can be implemented by computer program instructions. These computer program instructions may be provided to a processor of a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

These computer program instructions may also be stored in a computer readable medium that can direct a computer, other programmable data processing apparatus, or

other devices to function in a particular manner, such that the instructions stored in the computer readable medium produce an article of manufacture including instructions which implement the function/act specified in the flowchart and/or block diagram block or blocks.
The computer program instructions may also be loaded onto a computer, other programmable data processing apparatus, or other devices to cause a series of operational steps to be performed on the computer, other programmable apparatus or other devices to produce a computer implemented process such that the instructions which execute on the computer or other programmable apparatus provide processes for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

The present invention provides a UAV (Unmanned Aerial Vehicles) that can be thrown from locations with no GPS (Global Positioning System) reception, such as, for example, under water, indoors, jammed areas, out of a capsule or a carrier, etc.
For the purpose of explanation and demonstration the UAV hereinafter may be presented as a quadcopter or a drone. It will be appreciated that the present invention is not limited to a quadcopter or a drone. According to embodiments of the present invention, the UAV may be any drone having at least two arms, a multi rotor copter, a counter rotor copter or any other aerial vehicle capable of being thrown, folded or unfolded, from a launcher, a capsule or a carrier or be hand thrown.

According to embodiments of the present invention, the UAV of the present invention includes innovative features intended to allow it to successfully and optimally transition between four states – storage and transportation while connected to an originating platform, a throw into the air, self-righting while tumbling through the air and stable flight as part of a mission. It will be appreciated that the present invention is not limited to those four states.

According to embodiments of the present invention, the UAV and all of its components are folded into a shape similar to a cylinder or a rectangle and may be mounted inside a hard enveloping “capsule” that may be launched or loaded into a carrier to be launched. The capsule may be shaped as a cylinder or a rectangle or may be shaped according to the UAV's contour. The capsule may be made from light and durable materials (e.g., PVC). The use of the capsule is intended to minimize environmental factors such as shocks, acceleration and vibration, and allow for smooth release of the UAV from the carrier.

It will be appreciated that the folded UAV's shape is not limited to a cylinder or a rectangle, the capsule's shape is not limited to a cylinder or a rectangle and the UAV is not limited to be encapsulated inside a capsule.

According to embodiments of the present invention, the UAV may be launched inside a carrier or a capsule and then released into the air. Alternatively, the launching and the releasing of the UAV may be the same stage when the UAV is thrown or released directly into the air.

Moreover, the launching of a capsule may be a separate stage from the releasing (throw) of the UAV from the capsule when the capsule is launched and then the UAV is thrown from the capsule.

Moreover, the launching of a carrier may be a separate stage from the releasing of the capsule from the carrier which is a separate stage from the releasing (throw) of the UAV from the capsule when the carrier is launched and then the capsule is released from the carrier and then the UAV is released from the capsule.

For the purpose explanation and demonstration, all of these processes and similar processes may be generalized into a process where the UAV is initially carried by an originating platform, and subsequently thrown (e.g., the drone's release from a capsule or carrier is considered a throw), where the throwing action encompasses the UAV's release from the platform and any prior motion that leads up to the UAV's actual release essentially inevitably (e.g., in a UAV that is hand-thrown, the release may encompass only the wrist motion ending with the UAV leaving the hand, while the throw may also encompass the preceding arm swing as the operator accelerates the UAV prior to releasing it).

For that purpose, the UAV of the present invention is designed to detect its throw and/or its successful release, according to a unique throw signature.

It will be appreciated that the term 'throw' refers to the process of releasing a UAV into the air whether it is carried by an originating platform, a capsule, a carrier, thrown by hand or any other method of releasing a UAV into the air.

In order to accommodate circumstances of a UAV thrown without up-to-date GPS ephemeris data or into an environment with poor or no GPS reception, the UAV may complete the process of being thrown, self-righting and preparation for mission, without GPS reception, relying solely on independent on-board sensors such as accelerometers, gyroscopes, barometers, etc.

According to embodiments of the present invention, in a case where the UAV is encapsulated inside a capsule, the order to release the capsule from the carrier may be given by the carrier’s computer. Alternatively, the order to release the capsule may be given from the UAV to the carrier via communication means between the UAV and the carrier. The order may be given, for example, in a predetermined location, altitude, time etc. or by an operator from a distance.

It will be appreciated that, according to embodiments of the present invention, the unique throw signature is detected without GPS reception and without using the GPS sensor.

The unique throw signature may be, but is not limited to:

A pulse of acceleration, of acceleration particular to the operation of the device used to release the UAV from the capsule, the carrier, the hand of an operator, etc. measured by on-board accelerometers.

A pulse or a change of air pressure, such as a sudden rise in air pressure caused by pressurized gas breaching the capsule or carrier, or a sudden drop in air pressure caused by the air escaping the breached capsule and equalizing with the lower ambient pressure at the release altitude, measured by on-board barometers.

A combination of one or more features, extracted from one or more sources, including but not limited to, the above-mentioned sensors using a computer algorithm or signal processing methods. The features may include, for example, the amplitude, width and decay characteristic of a pulse in a sensor reading; the amplitude and rise time characteristic of a step change in a sensor reading; or the degree of confidence in a match between a sensor's measured outputs and a predefined waveform considered representative of a throw event such as a release from a capsule or a carrier, a manual throw out of an operator's hand or a launch using a catapult.

Fig. 1 is a schematic view of an exemplary carrier **100** encompassing a UAV's capsule **110**, according to embodiments of the present invention.
It will be appreciated that the carrier is not limited to the carrier shown in **Figs. 1**, **2** and **4**.

Fig. 2 is an exploded view of **Fig. 1**.

Fig. 3 is an exploded view of the capsule **110** encompassing the UAV **300**.

According to embodiments of the present invention, the capsule **110** may include an inner shape or supports (such as supports **310**) for tightly holding the UAV **300** in order to minimize environmental factors such as shocks, acceleration, vibration, etc.

According to embodiments of the present invention, springs may be mounted between the capsule parts for assisting the capsule to split.

Fig. 4 is a schematic view of an exemplary UAV deployment process, according to embodiments of the present invention.

Figs. 5A and **5B** are schematic top and bottom perspective views of an exemplary UAV **500**, according to embodiments of the present invention. The UAV **500** comprises four arms **505A-505D**, each intended to be opened in the direction of the respective arrow **510A-510D**; each arm has an engine controller **515A-515D** for controlling the respective engine **517A-517D** and its propeller **516A-516D**. The UAV **500** further comprises a GPS antenna **520**; a capturing device **530** mounted on a support allowing stable movement of the capturing device (e.g., a camera mounted on a gimbal); at least one battery **540A**; a transceiver **560** and a flight controller (shown in **Fig. 5C**).

According to embodiments of the present invention, the UAV **500** is surrounded by a frame **580**.

Fig. 5C is a side view of the exemplary UAV **500** (without the frame **580**) showing the transceiver **560**, the flight controller **570**, batteries **540A-540C** (in this exemplary embodiment three are used) where, according to embodiments of the present invention, batteries **540B** and **540C** are fixed and battery **540A** is detachable as will be detailed below. It will be appreciated that battery **540A** may be fixed and batteries **540B** and **540C** may be detachable.

It will be appreciated that the drown shown in **Fig. 5A-5B** is an exemplary drone shown for the purpose of explanation and demonstration and the present invention is not limited to such a drone.
As said above, it will be appreciated that the UAV of the present invention is not limited to be launched or thrown from a carrier and/or a capsule and may be thrown from a throwing device or from an operator's hand.

Fig. 6 is a block diagram of an exemplary UAV **600**, according to embodiments of the present invention. The UAV **600** comprises a flight controller **610** comprising sensors, such as, a gyro and an accelerometer (not shown). The flight controller **610** is connected, optionally, with a barometer **620**, optionally, with a GPS and compass module **625**, with a Power Distribution Board (PDB) **630** and with RC receiver **635**. The

PDB **630** is further connected with the UAV's motors **640** and with at least one battery **645**.

It will be appreciated that for clarity, **Fig. 6** shows an exemplary configuration and certain components or interfaces may be omitted, added, integrated in one another or act as separate modules. For example, the motors may be connected to the PDB indirectly through one or more Electronic Speed Controllers (ESC, not shown), and the one or more ESCs may be controlled by the flight controller in order to adjust the rotational speed of the motors. Additionally or alternatively, the functions of the flight controller and/or the PDB may be split among two or more discrete components within the UAV (e.g., a PDB and a separate voltage converter module, or a flight controller and a separate companion computer). Moreover, The ESC may be integrated in the PDB as presented or may be a separate component. It will be appreciated that the sensors described – gyro, accelerometer, barometer, GPS and compass – are given as a concrete example of just one possible UAV configuration. It will be appreciated that the UAV may include more or less sensors than described, including different sensor types (e.g., altimeters, optical flow sensors, collision avoidance sensors, hall effect sensors and microswitches) and that the sensors may be integrated into the flight controller or other components or alternately be discrete components of the UAV and that the actions carried out by the invention with respect to the sensors described, may be carried out with respect to any sensor installed on the UAV.

As said above, the UAV **600** is no limited to be the drown shown in **Fig. 5A-5C** and may be any drone having at least two arms, a multi rotor copter, a counter rotor copter or any other aerial vehicle capable of being thrown, folded or unfolded, from a launcher, a capsule or a carrier, be released or hand thrown.

As said above, the UAV **600** is intended to be thrown from locations with no GPS reception, such as, for example, under water, indoors, jammed areas, a canister or a capsule. It is desirable (e.g., for safety and for keeping the UAV intact) for the UAV to refrain from activating its motors until it is thrown, and to activate its motors promptly (e.g., immediately or after a short time) following its throw. For this purpose, the UAV makes use of sensors such as a barometer and/or an accelerometer, capable of detecting changes in the UAV's motion or environment, and makes operation of its motors conditional on readings from these sensors indicative of a throw action.

When the UAV is thrown, it is subjected to massive forces due to the UAV's acceleration. Upon a throw, the barometer senses the pressure changes, the accelerometer senses the acceleration changes, and according to these measurements, the UAV can reliably detect a successful throw and act on it as a trigger for engine activation.

According to embodiments of the present invention, upon activation of the motors, the UAV may be programmed to gradually gain height by controlling the rotors speed in order to enable the UAV to stabilize in the air without losing height. The max height and the climbing speed may also be programmed.

Fig. 7 is a flowchart **700** showing the UAV's **600** throw process, according to embodiments of the present invention.

In step **710**, activating the UAV, e.g., drone.

In step **720**, selecting throw mode without GPS.

In step **730**, arming the UAV, namely, enabling the motors.

In step **740**, throwing the UAV.

When the UAV is thrown and senses the unique throw signature, in step **750**, the UAV unfolds (if needed) and activates its motors.

In step **760**, the UAV is stabilized in the air using its sensors including one or more of its barometer, accelerometer and gyro.

As said above, upon activation of the motors, the UAV may be programmed to gradually gain height by controlling the rotors speed in order to enable the UAV to stabilize in the air without losing height.

In step **770**, the UAV is ready to perform its mission.

It will be appreciated that steps **710** to **730** are optional and may be truncated, e.g., by automatically performing steps **710** to **730** upon launch, or by automatically performing steps **720** and **730** upon UAV activation. Additionally, the arming step of **730** may be same or distinct from the act of arming the UAV as known in the art, and step **730** may also be omitted, with the arming of the UAV taking place for example in step **750**.

It will be appreciated that between step **730** and step **740**, additional actions may be performed, such as, for example, transporting, carrying, storing, launching, deploying the UAV, etc.

When the UAV is thrown into the air, the stabilization process requires high current supply. On the contrary, during flight, the UAV needs low current supply for as much time as possible. In order to provide high current supply, a high current power supply is needed, such as, for example, a Li-Poly battery which can provide high current supply to a relatively short time. In order to provide low current supply, a low current power supply is needed, such as, for example, a Li-Ion battery which cannot provide high current supply but can provide low current supply to a relatively long time.

Therefore, if only a high current power supply is used, the UAV may be stabilized but is limited in fight time. On the contrary, if only a low current power supply is used, the UAV cannot be stabilized properly.

For that purpose, according to embodiments of the present invention, the UAV may comprise a hybrid power supply (e.g., a battery) comprising at least one high current power supply and at least one low current power supply (e.g., battery or battery pack) capable of powering the drone, along with a switching mechanism that allows at least one of the power supplies to power the drone at any given time, and safely switches between them as required. An algorithm within the drone selects the appropriate power supply to be used according to the drone's needs, at least one predetermined parameter, etc. and performs the switch.

The hybrid power supply comprises at least one high current power supply and at least one low current power supply which are used for different purposes as explained above.

When the drone is thrown, the high current power supply is connected for the high-power maneuvers required to stable the drone.

Upon stabilization, the connection is switched and the low current power supply is connected.

According to embodiments of the present invention, the connection may be switched back to the high current power supply when high-power maneuvers are required (according to at least one predetermined parameter).

Alternatively or additionally, according to embodiments of the present invention, when the connection is switched from the high current power supply to the low current power supply, at least one high current power supply may be discarded.

It will be appreciated that at least one low current power supply may also be discarded.

It will be appreciated that the term 'power supply' may refer to a battery, a battery pack and the like.

Fig. 8 is a block diagram of the hybrid power supply, according to embodiments of the present invention. The hybrid power supply **800** comprises a Power Distribution Board (PDB) **810** connected with a smart switch **820** which is connected with at least one high current power supply **830** and at least one low current power supply **840**.

According to embodiments of the present invention, the hybrid power supply **800** comprises a physical connector, electric connectors and may further comprise springs sockets. At least one spring is intended to be held by the at least one socket and pressed against the UAV body for quick release of at least one of the power supplies batteries of the hybrid battery. It will be appreciated that the battery **800** is not limited to include the sockets and springs.

According to embodiments of the present invention, a battery release mechanism e.g., a servo motor connected to the UAV's body is intended to rotate and release a physical connector (e.g., a screw) upon a signal indicating that the at least one of the batteries of the hybrid battery should be discarded. When the screw is released the selected battery is detached and discarded. It will be appreciated that this mechanism may be used for discarding other items such as a package for example. It will be appreciated that more than one or none of the batteries may be detachable. It will be appreciated that other release mechanisms may be used, such as, pyrotechnic mechanisms, mechanical mechanisms, etc.

It is important to maintain the center of gravity of the UAV thus, according to embodiments of the present invention, the power supply intended to be discarded is located such that the center of gravity will be maintained when the selected power supply is discarded.

According to embodiments of the present invention, in a case where the selected power supply is not located in the center of gravity of the UAV, the UAV may further include at least one weight located such that the center of gravity is maintained thus, when the selected power supply is discarded, the respective weight(s) is discarded as well thus maintaining the center of gravity.

Fig. 9 is a flowchart **900** showing the process performed by a UAV comprising the hybrid power supply **800** of **Fig. 8**, according to embodiments of the present invention.

In step **910**, throwing the UAV while it is connected to the high current power supply **830**.

In step **920**, the UAV is stabilized in the air.

In step **930**, upon stabilization and/or according to a predetermined current and/or voltage threshold, the smart switch **820** switches the electrical connection to the low current power supply **840**.

In step **940**, The UAV continues its flight using the low current power supply **840**.

As said above, according to embodiments of the present invention, the high current power supply **830** may be discarded after step **930** or after step **940**.

It will be appreciated that the hybrid power supply of the present invention is not limited to include a high discharge battery and a low discharge battery or a Li-Poly and a Li-Ion battery.

Alternatively, any combination of power supplies which enables the UAV to stabilize, execute high power maneuvers and fly for as much time as possible may be used.

Fig. 10 is a flowchart **1000** showing the process performed by a UAV, such as, UAV **600** of **Fig. 6** comprising the hybrid power supply **800** of **Fig. 8**, according to embodiments of the present invention.

In step **1010**, activating the UAV, e.g., drone.

In step **1020**, selecting throw mode without GPS.

In step **1030**, arming the UAV, namely, supplying voltage to the motors.

In step **1040**, throwing the UAV while it is connected to the high current power supply **330**.

When the UAV is thrown and senses the unique throw signature, in step **1050**, the UAV unfolds (if needed) and activates its motors.

In step **1060**, the UAV is stabilized in the air using its sensors including one or more of its barometer, accelerometer and gyro.

As said above, upon activation of the motors, the UAV may be programmed to gradually gain height by controlling the rotors speed in order to enable the UAV to stabilize in the air without losing height.

In step **1070** upon stabilization and/or according to a predetermined current and/or voltage threshold, the smart switch switches the electrical connection to the lowcurrent power supply **840**.

In step **1080**, The UAV continues its flight using the low current power supply **840**.

According to embodiments of the present invention, at least one high current power supply may be discarded after step **1070** or after step **1080**.

It will be appreciated that steps **1010** to **1030** are optional and may be truncated, e.g., by automatically performing steps **1010** to **1030** upon launch, or by automatically performing steps **1020** and **1030** upon UAV activation. Additionally, the arming step of **1030** may be same or distinct from the act of arming the UAV as known in the art, and step **1030** may also be omitted, with the arming of the UAV taking place for example in It will be appreciated that between step **1030** and step **1040**, additional actions may be performed, such as, for example, transporting, carrying, storing, launching, deploying the UAV, etc.

It will be appreciated that the hybrid power supply of the present invention is not limited to include a high discharge battery and a low discharge battery or a Li-Poly and a Li-Ion battery.

Alternatively, any combination of power supplies which enables the UAV to stabilize, execute high power maneuvers and fly for as much time as possible may be used.

It will be appreciated that the UAV **600** of the present invention is not limited to include the hybrid power supply.

Alternatively, any UAV may include the hybrid power supply of the present invention.

It will be appreciated that the carrier is presented as ejecting the capsule from its front end but the present invention is not limited to carriers that eject the capsule from their front end. According to embodiments of the invention, the capsule may be ejected from the bottom of the carrier, the rear end of the carrier, etc. depending on the carrier's type.

It will be appreciated that the UAV of the present invention is not limited to be encapsulated inside the capsule described above. Alternatively, the UAV may be carried (or encompassed) inside the aerial carrier and thrown therefrom from the bottom of the carrier, the rear end of the carrier, etc. depending on the carrier's type.

It will be appreciated that the carrier of the present invention may carry a plurality of UAVs and throw them separately or all together. According to embodiments of the present invention, the carrier may comprise a plurality of release mechanisms, less or as the number of the UAVs.

It will be appreciated that the UAV of the present invention is not limited to be carried by a carrier or a capsule and may be thrown directly from a launcher or an operator's hand or from a window or other opening in a structure or vehicle.

According to embodiments of the present invention, the UAV may conduct a self-configuration sequence after righting itself following the throw. The self-configuration sequence may comprise changes in flight controller and power distribution parameters, standby periods conditional on sensor inputs and conduction of autonomous maneuvers and sensor operations, all intended to bring the UAV from a state of readiness for self-righting to a state of optimal performance during the rest of its flight, and/or undo adverse effects on its sensor performance caused by the violent effects of the throw process.

According to embodiments of the present invention, the UAV may comprise several sets of tunings for its control loops, intended to accommodate the different phases of its flight, including, for example, one set to properly execute the righting procedure, and another set, to adequately execute the main mission.

Based on the current flight state, the UAV changes its tunings and thus provides adequate performance at all flight phases. For example, it uses an aggressive tuning for righting itself, and then switches to an economical tuning to achieve a long endurance time in its mission. In this case, the self-configuration sequence may comprise a change in tuning parameters, from a set supporting self-righting to a set supporting long mission endurance.

According to embodiments of the present invention, the thrown UAV may conduct post-throw calibration after righting itself, automatically or on command. This calibration may include the following steps required to recover from the throw and/or adjust to the outside environment:

- Resetting the Kalman filter to remove any distortions caused by anomalous readings during and following the throw.
- Resetting the magnetic compass calibration coefficients.
- Waiting for the GPS receiver to update its data and begin providing fixes.
- Conducting special maneuvers in order to provide the necessary data for correct calibration, for example, figure-eight turns.
- Evaluating sensor inputs to verify a complete and successful calibration procedure.
- Handing-off control of the drone to the operator or to a preloaded mission.

According to embodiments of the present invention, a self-calibration process as mentioned above may form part or all of the self-configuration sequence mentioned above.

Fig. 11 is a flowchart **1100** showing an exemplary process of throwing a UAV and performing self-configuration, according to embodiments of the present invention.

In step **1110**, activating the UAV, e.g., drone.

In step **1120**, preparing the UAV for throw, e.g., selecting throw mode, arming motors, etc.

Upon a throw of the UAV and a unique throw signature being detected, in step **1130**, the UAV unfolds (if needed), activates its motors and is stabilized in the air using its sensors including one or more of its barometer, accelerometer and gyro.

As said above, upon activation of the motors, the UAV may be programmed to gradually gain height by controlling the rotors speed in order to enable the UAV to stabilize in the air without losing height.

Upon stabilization, in step **1140**, the UAV conducts self-configuration.

In step **1150**, the UAV starts its mission.

Fig. 12 is a flowchart **1200** showing an exemplary self-configuration process **1200**, according to embodiments of the present invention.

The self-configuration process begins with the UAV awaiting a GPS reception.

Upon GPS reception being detected, in step **1210**, the flight controller changes flight control loop to mission tuning.

In step **1220**, the flight controller changes sensor and sensor fusion parameters to mission configuration.

In step **1230**, the flight controller enables in-flight sensor calibration.

In step **1240**, the flight controller conducts in-flight sensor calibration maneuvers.

In step **1250**, the PDB switches between high-current power supply and low-current power supply upon a command from the flight controller.

In step **1260**, the self-configuration is ended.

It will be appreciated that the self-configuration process may include more or less steps and the steps order may be different. For example, self-configuration steps may be omitted where they are deemed unnecessary (e.g., a given set of control loop tunings is good enough for the entire flight), and each step may be accompanied by a default or failsafe in case it fails (e.g., detecting a lack of GPS reception and proceeding without it).

It will be appreciated that step **1250** is optional and may be performed in the embodiment comprising the hybrid power supply.

As said above, the UAV of the present invention is not limited to be thrown using a carrier or a capsule and may alternatively thrown directly from an originating platform.

Fig. 13 shows a schematic throw process **1300** from an originating platform and the UAV stages, from throw stage to the stage where the UAV is ready to begin its mission, according to embodiments of the present invention. As can be seen, **1310** represents the originating platform. **1320** to **1350** represent the UAV from throw, through stabilization to the stage where it is ready to start its mission.

It will be appreciated by persons skilled in the art that the present invention is not limited to what has been particularly shown and described hereinabove. Rather the scope of the present invention is defined by the appended claims and includes combinations and sub-combinations of the various features described hereinabove as well as variations and modifications thereof which would occur to persons skilled in the art upon reading the foregoing description.

CLAIMS

1. An Unmanned Aerial Vehicle (UAV), comprising:

   at least one power supply;

   at least one motor;

   at least one sensor configured to sense a throw action; and

   a controller connected with said at least one power supply, said at least one motor and said at least one sensor;

   wherein said UAV is configured to be thrown, detect a unique throw signature according to at least one measurement received from said at least one sensor and activate said at least one motor upon a said unique throw signature being detected.

2. The UAV of claim 1, wherein said at least one sensor is selected from the group consisting of accelerometer, gyroscope and barometer.
3. The UAV of claim 1, wherein said unique throw signature is selected from the group consisting of a pulse of acceleration, a pulse or a change of air pressure and a predetermined change in said at least one sensor reading.
4. The UAV of claim 1, wherein said at least one power supply comprises:

   at least one high current power supply; and

   at least one low current power supply; and

   wherein said UAV further comprises a switching mechanism connected with said at least one high current power supply and said at least one low current power supply;

   wherein said switching mechanism is configured to switch between said at least one high current power supply and said at least one low current power supply upon at least one predetermined parameter being met.

5. The UAV of claim 4, further comprising a power supply release mechanism configured to release at least one of said at least one high current power supply and said at least one low current power supply.
6. The UAV of claim 1, further configured to perform a self-configuration process.
7. The UAV of claim 6, wherein said self-configuration process comprises:

awaiting at least one of GPS reception by said UAV, and said UAV reaching an upright orientation; and

changing at least one of flight control loop, and parameters affecting at least one of reading, operation and fusion of at least one of said at least one sensor.

8. The UAV of claim 6, wherein said self-configuration process comprises enabling sensor calibration.
9. The UAV of claim 6, wherein said self-configuration process comprises conducting sensor calibration maneuvers.
10. A method of throwing an Unmanned Aerial Vehicle (UAV), comprising:
    providing a UAV comprising:
        at least one power supply;
        at least one motor;
        at least one sensor configured to sense a throw action; and
        a controller connected with said at least one power supply, said at least one motor and said at least one sensor;
    throwing said UAV into the air;
    detecting a unique throw signature according to at least one measurement received from said at least one sensor; and
    activating said at least one motor upon a said unique throw signature being detected.
11. The method of claim 10, wherein said at least one sensor is selected from the group consisting of accelerometer, gyroscope and barometer.
12. The method of claim 10, wherein said unique throw signature is selected from the group consisting of a pulse of acceleration, a pulse or a change of air pressure and a predetermined change in said at least one sensor reading.
13. The method of claim 10, wherein said at least one power supply comprises:
    at least one high current power supply; and
    at least one low current power supply; and

wherein said UAV further comprises a switching mechanism connected with said at least one high current power supply and said at least one low current power supply;

wherein said method further comprises switching between said at least one high current power supply and said at least one low current power supply upon at least one predetermined parameter being met.

14. The method of claim 13, wherein said UAV further comprises a power supply release mechanism; and
wherein said method further comprises releasing at least one of said at least one high current power supply and said at least one low current power supply.
15. The method of claim 10, further comprising performing a self-configuration process.
16. The method of claim 15, wherein said self-configuration process comprises:
awaiting at least one of GPS reception by said UAV, and said UAV reaching an upright orientation; and
changing at least one of flight control loop, and parameters affecting at least one of reading, operation and fusion of at least one of said at least one sensor.
17. The method of claim 15, wherein said self-configuration process comprises enabling sensor calibration.
18. The method of claim 15, wherein said self-configuration process comprises conducting sensor calibration maneuvers.
19. An Unmanned Aerial Vehicle (UAV), comprising:
at least one high current power supply;
at least one low current power supply; and
a switching mechanism connected with said at least one high current power supply and said at least one low current power supply;

wherein said switching mechanism is configured to switch between said at least one high current power supply and said at least one low current power supply upon at least one predetermined parameter being met.

20. The UAV of claim 19, further comprising a power supply release mechanism configured to release at least one of said at least one high current power supply and said at least one low current power supply.

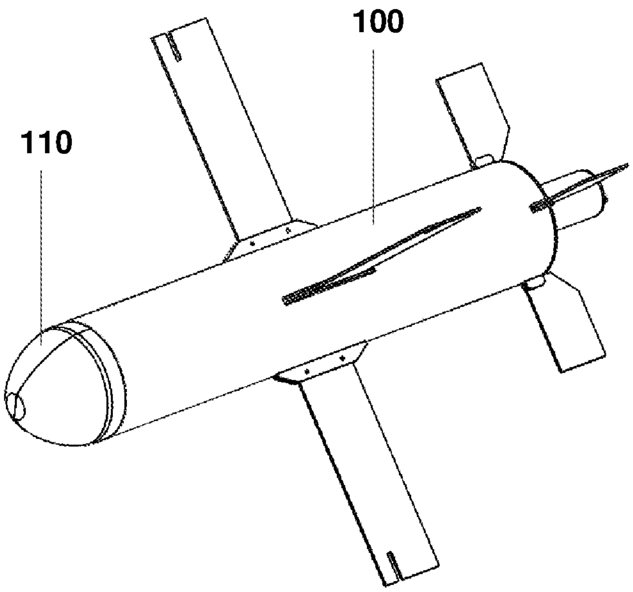

Fig. 1

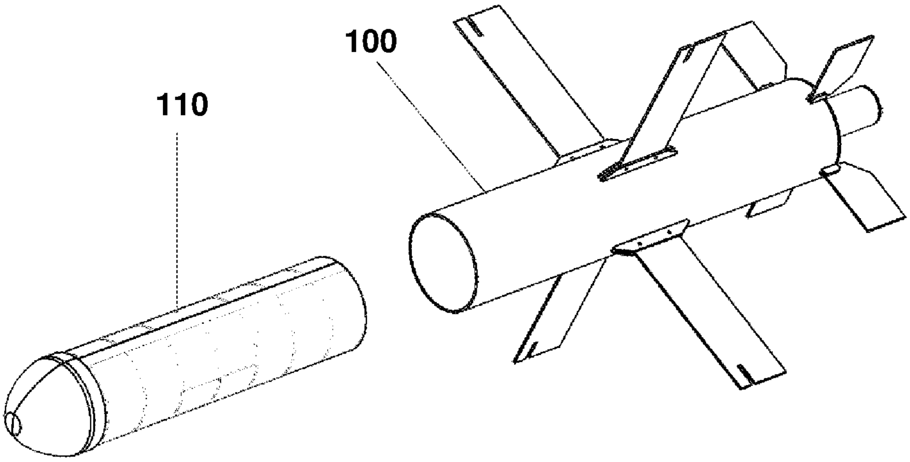

Fig. 2

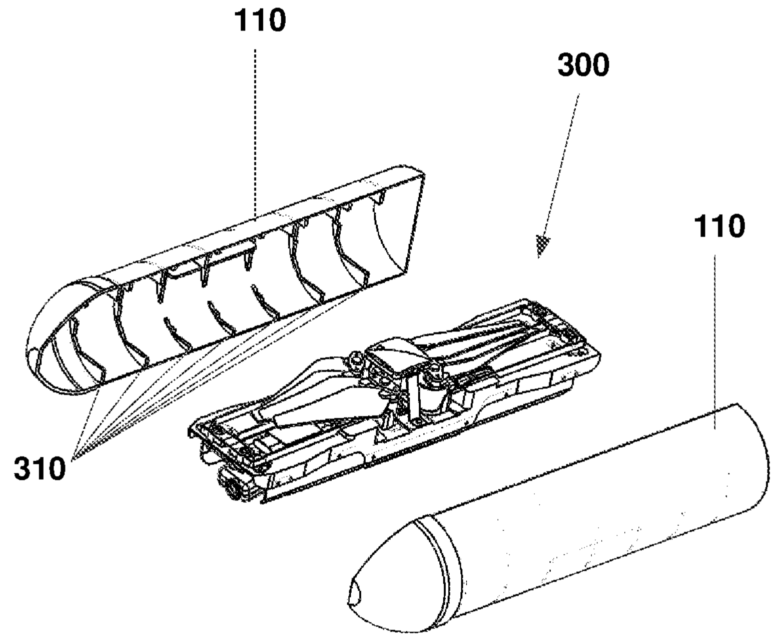

Fig. 3

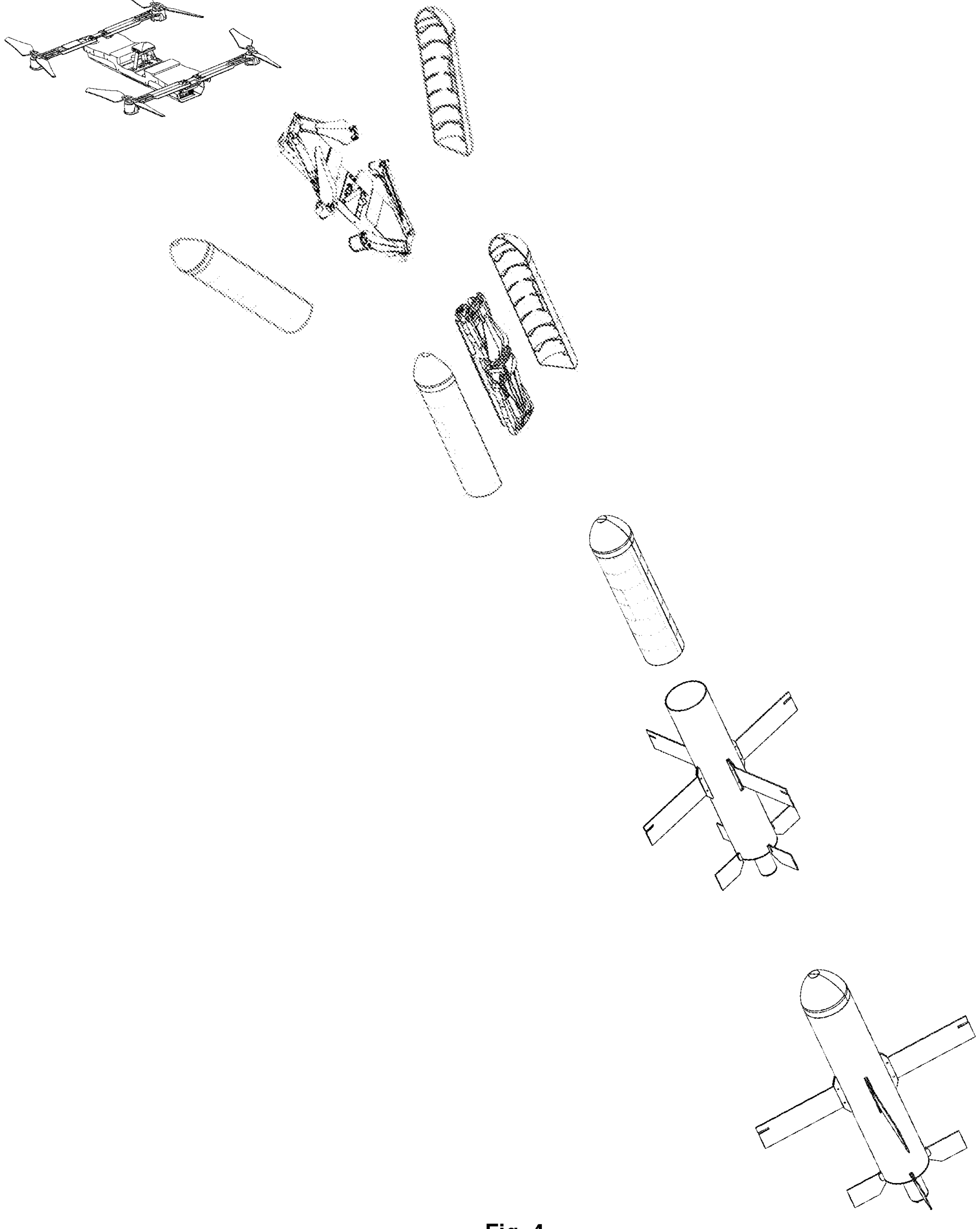

Fig. 4

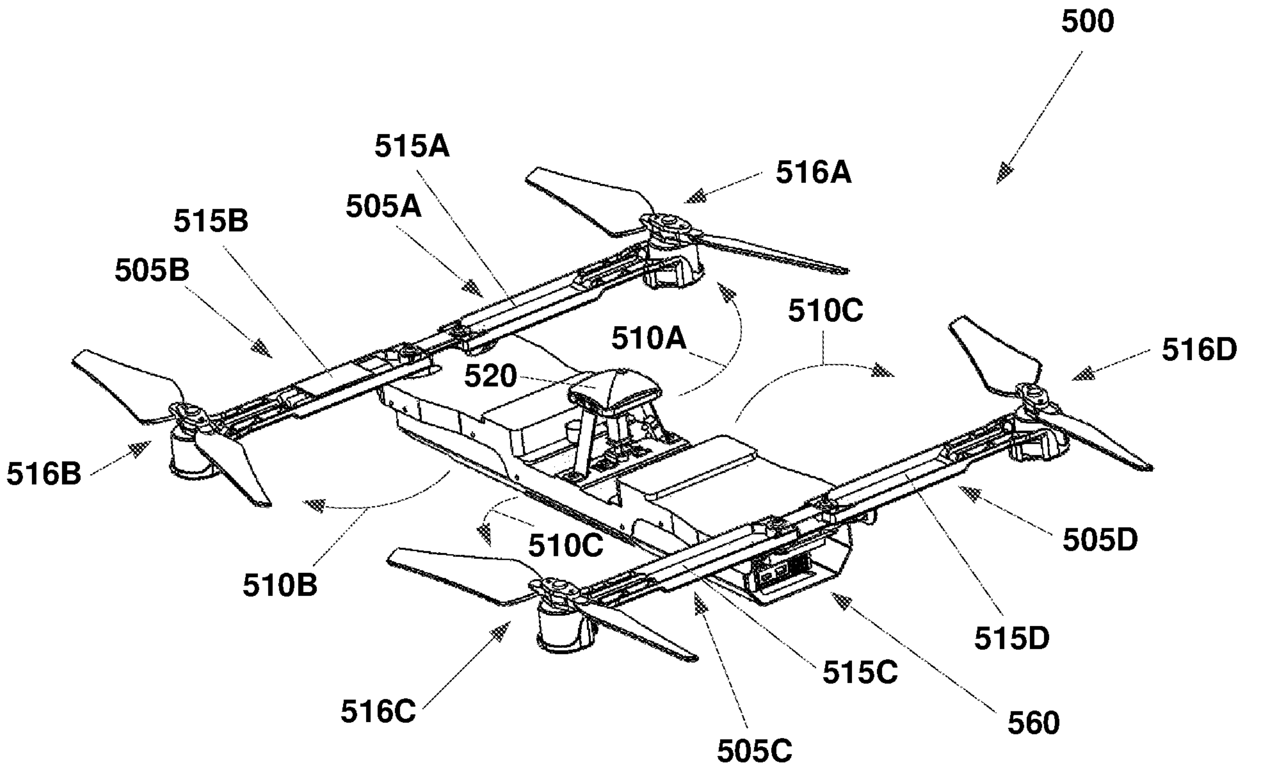
500
515A
516A
515B
505A
505B
510A
510C
520
516D
516B
510C
505D
510B
515D
516C
515C
560
505C

Fig. 5A

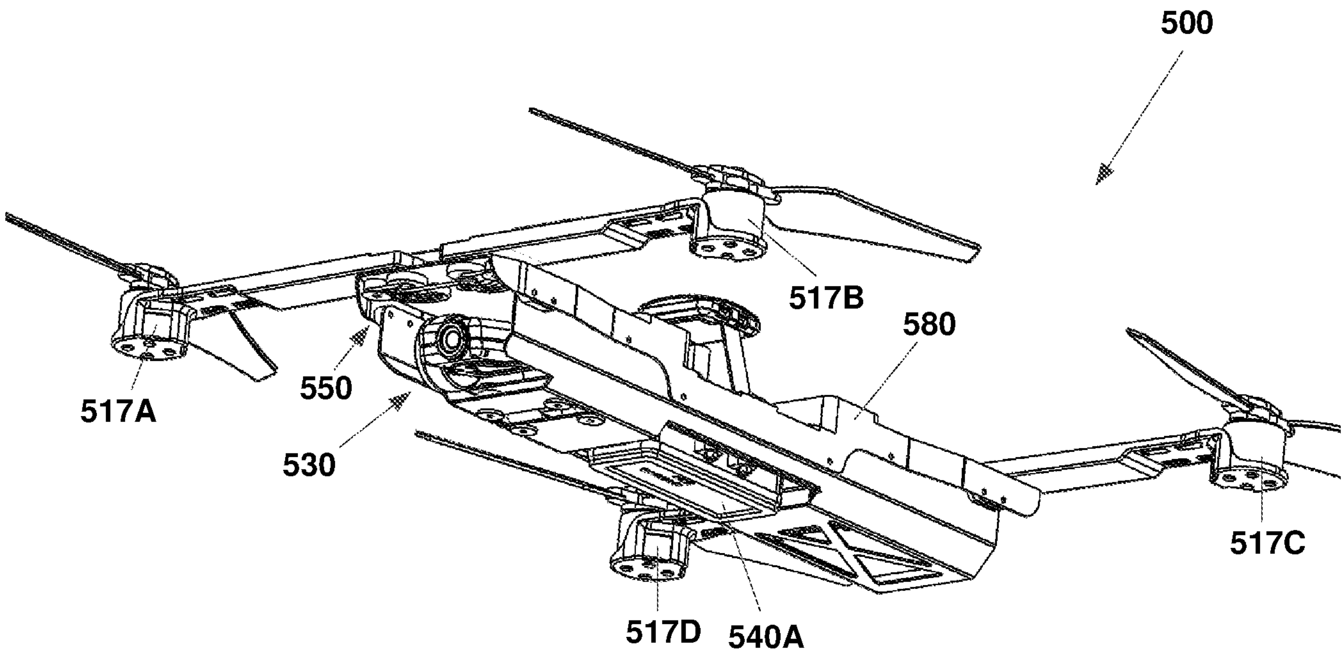
500
517B
580
517A
550
530
517C
517D
540A

Fig. 5B

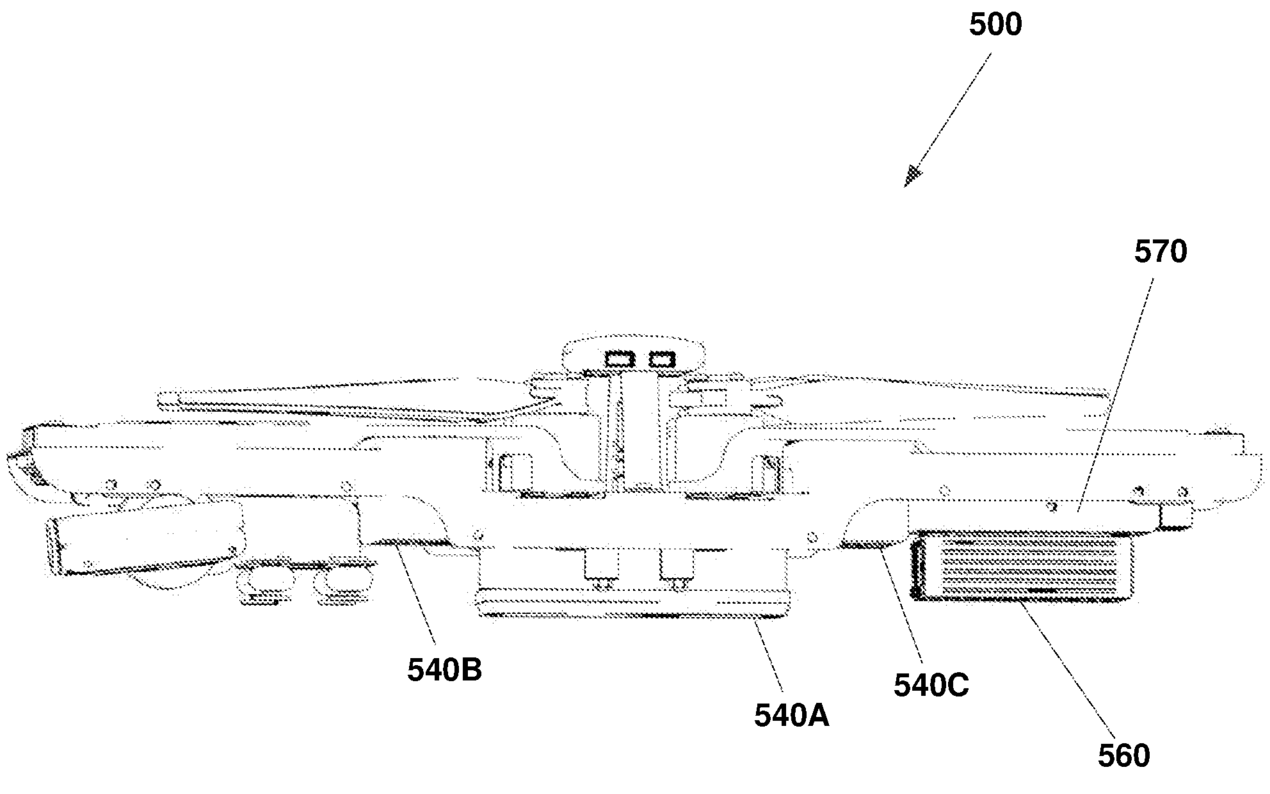

Fig. 5C

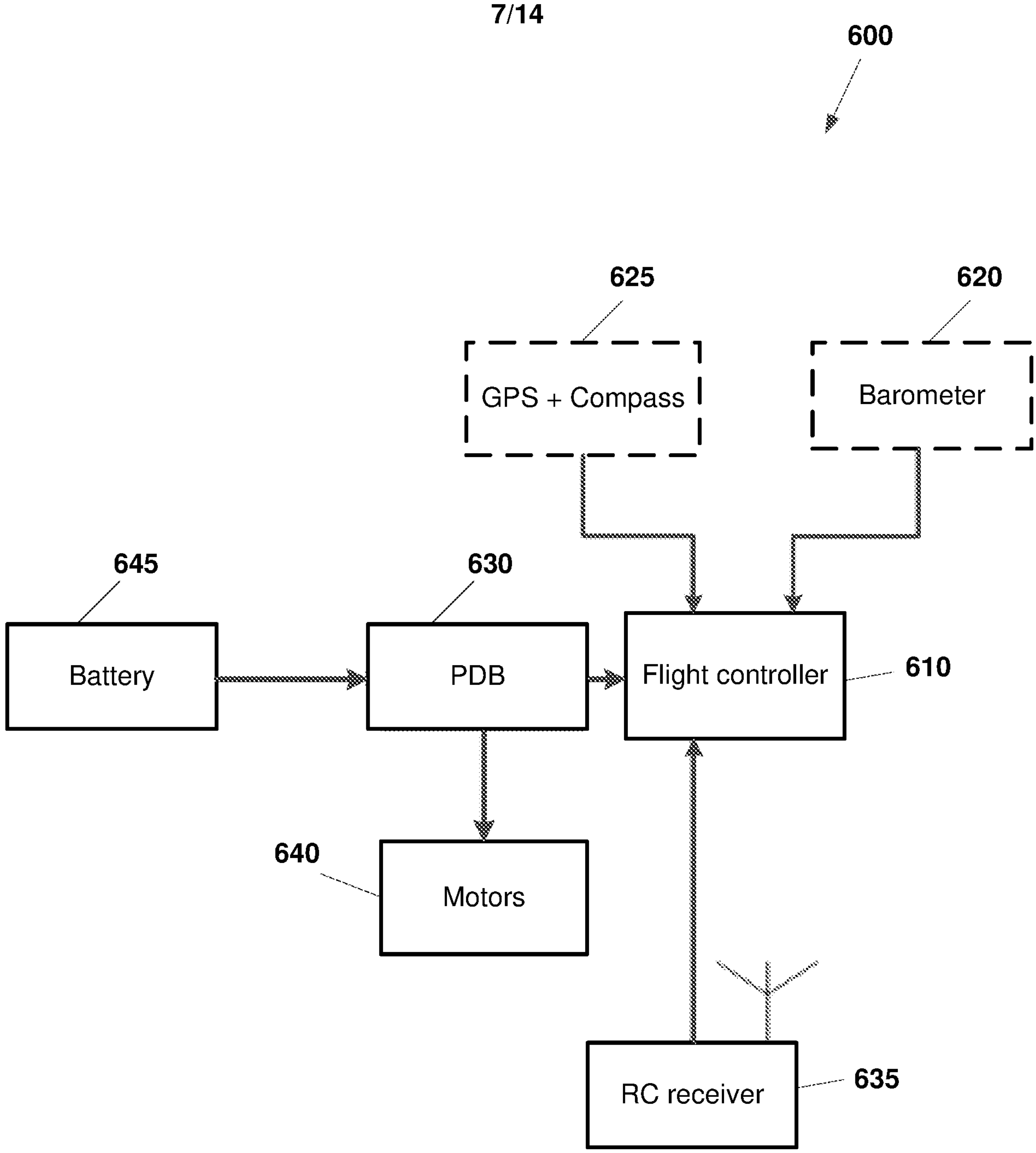
600
625
620
GPS + Compass
Barometer
645
630
Battery
PDB
Flight controller
610
640
Motors
RC receiver
635

Fig. 6

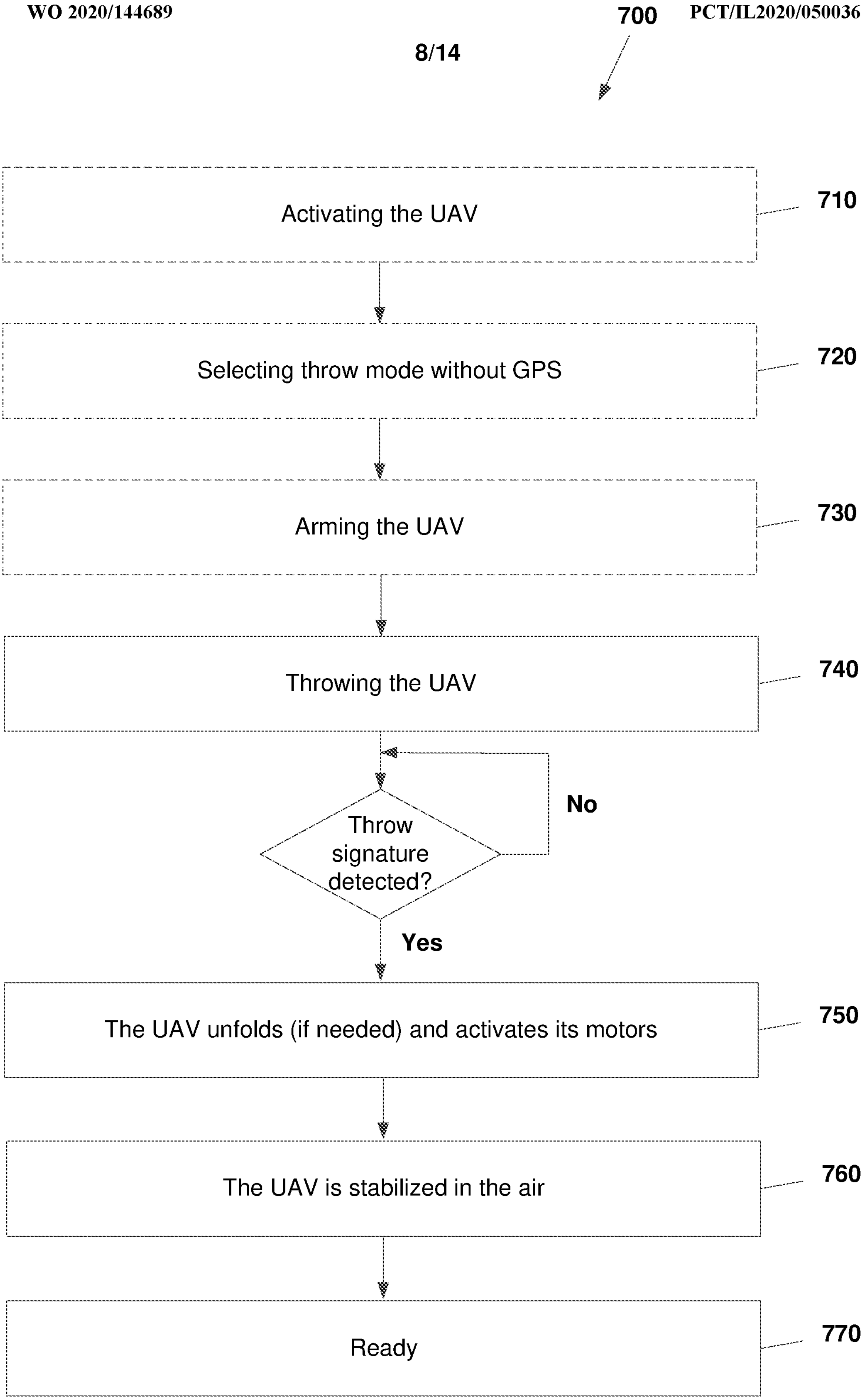
700
Activating the UAV
710
Selecting throw mode without GPS
720
Arming the UAV
730
Throwing the UAV
740
Throw signature detected?
No
Yes
The UAV unfolds (if needed) and activates its motors
750
The UAV is stabilized in the air
760
Ready
770

Fig. 7

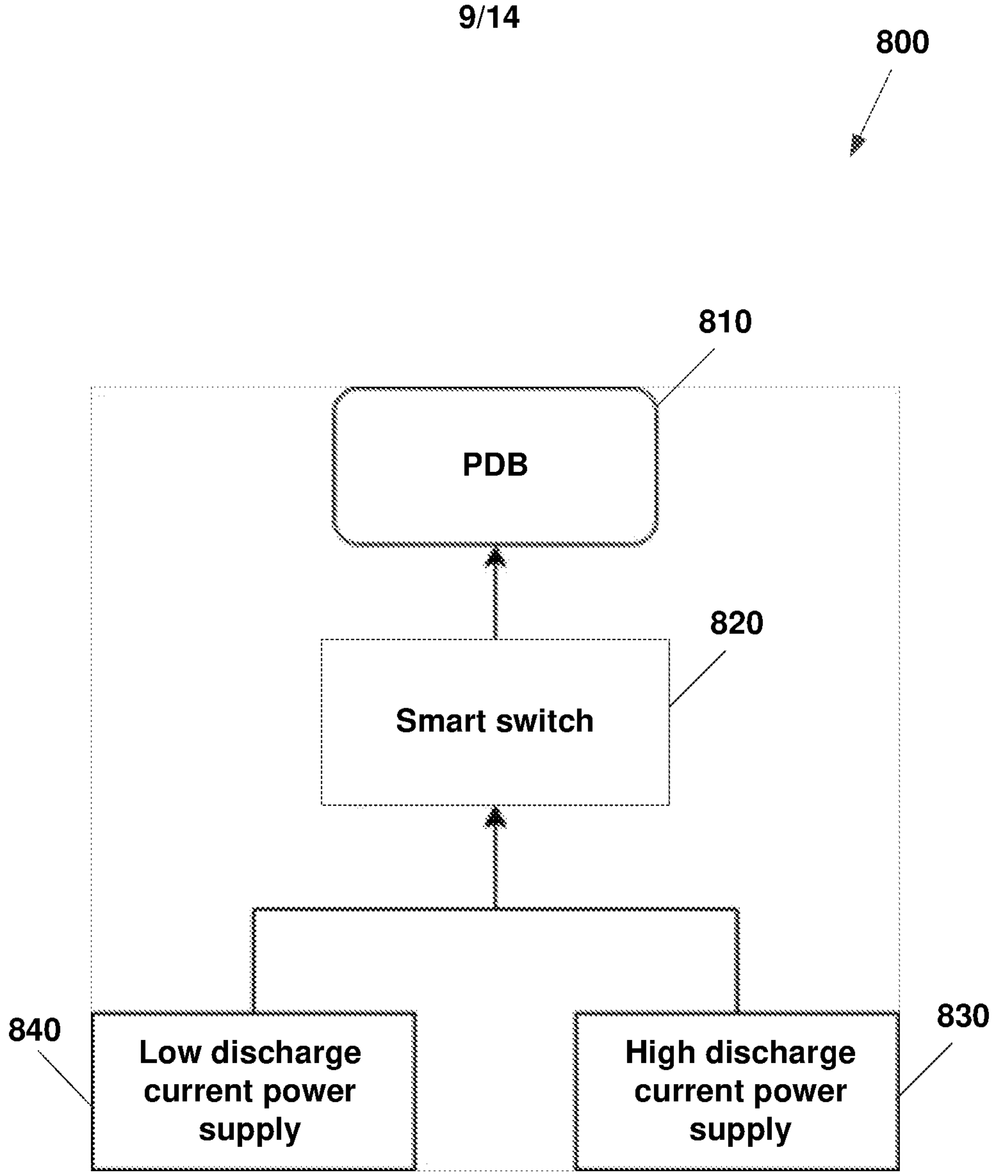
800
810
PDB
820
Smart switch
840
Low discharge current power supply
High discharge current power supply
830

Fig. 8

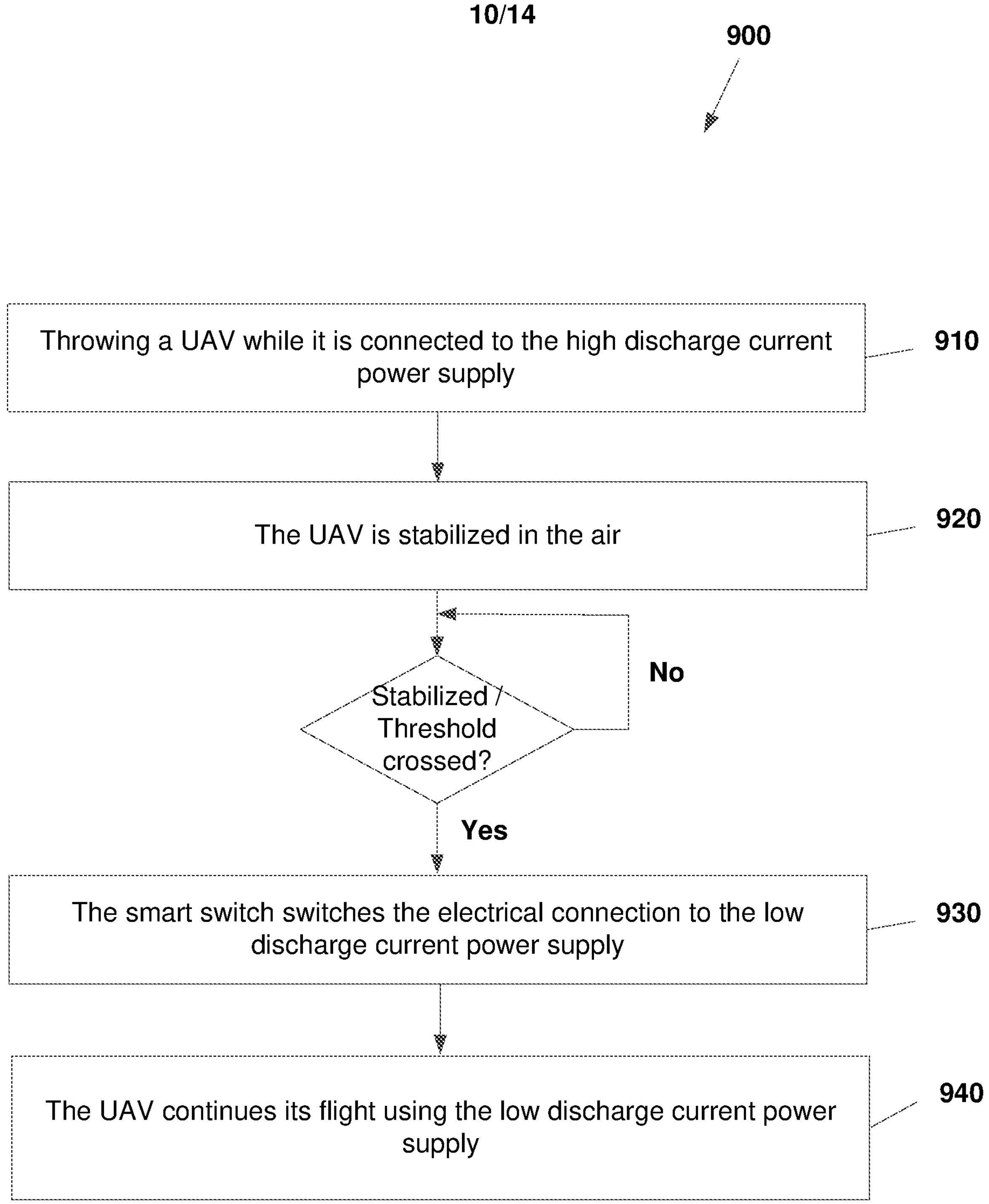
900
Throwing a UAV while it is connected to the high discharge current power supply
910
The UAV is stabilized in the air
920
Stabilized / Threshold crossed?
No
Yes
The smart switch switches the electrical connection to the low discharge current power supply
930
The UAV continues its flight using the low discharge current power supply
940

Fig. 9

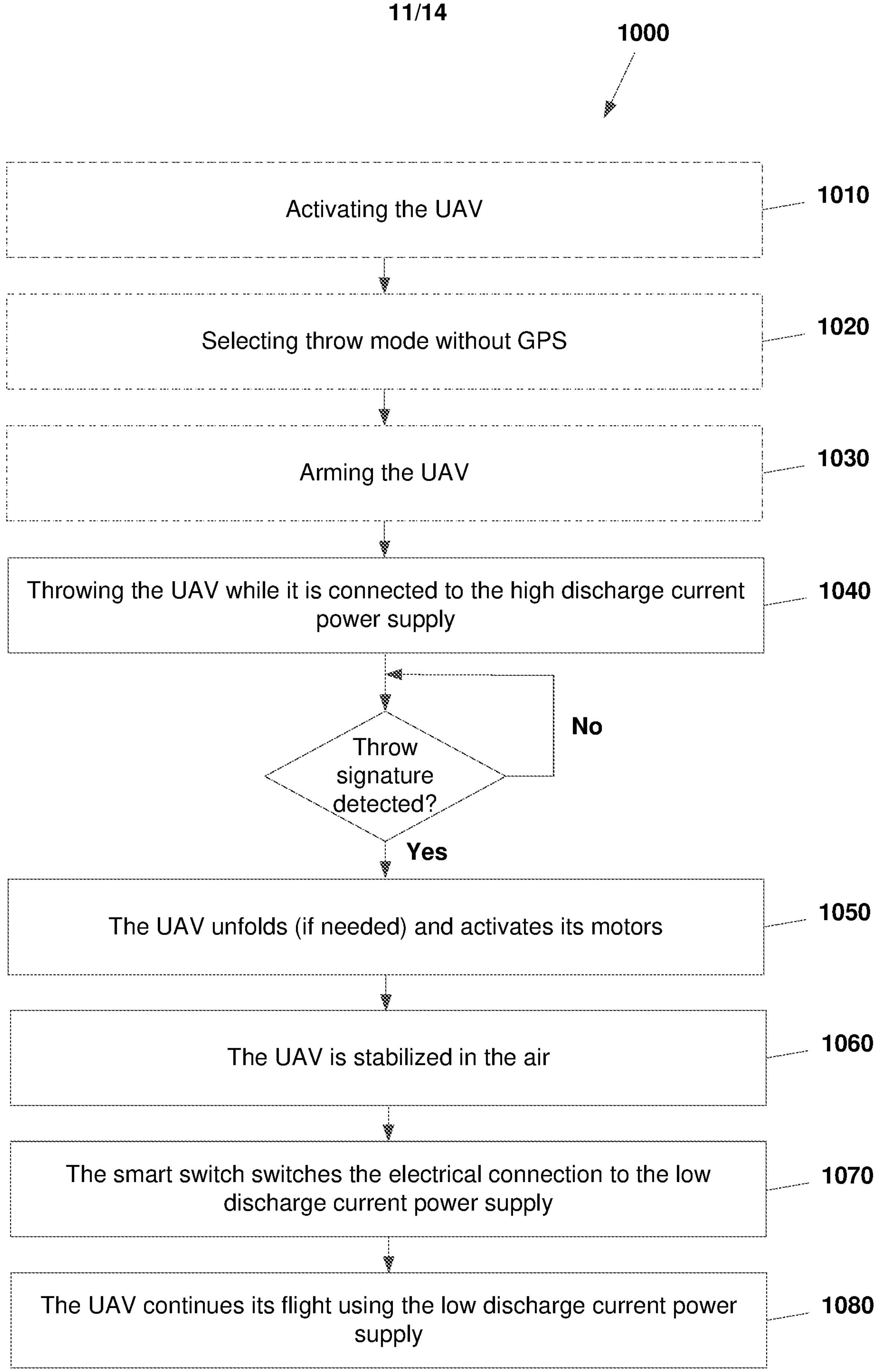
1000
Activating the UAV
1010
Selecting throw mode without GPS
1020
Arming the UAV
1030
Throwing the UAV while it is connected to the high discharge current power supply
1040
Throw signature detected?
No
Yes
The UAV unfolds (if needed) and activates its motors
1050
The UAV is stabilized in the air
1060
The smart switch switches the electrical connection to the low discharge current power supply
1070
The UAV continues its flight using the low discharge current power supply
1080

Fig. 10

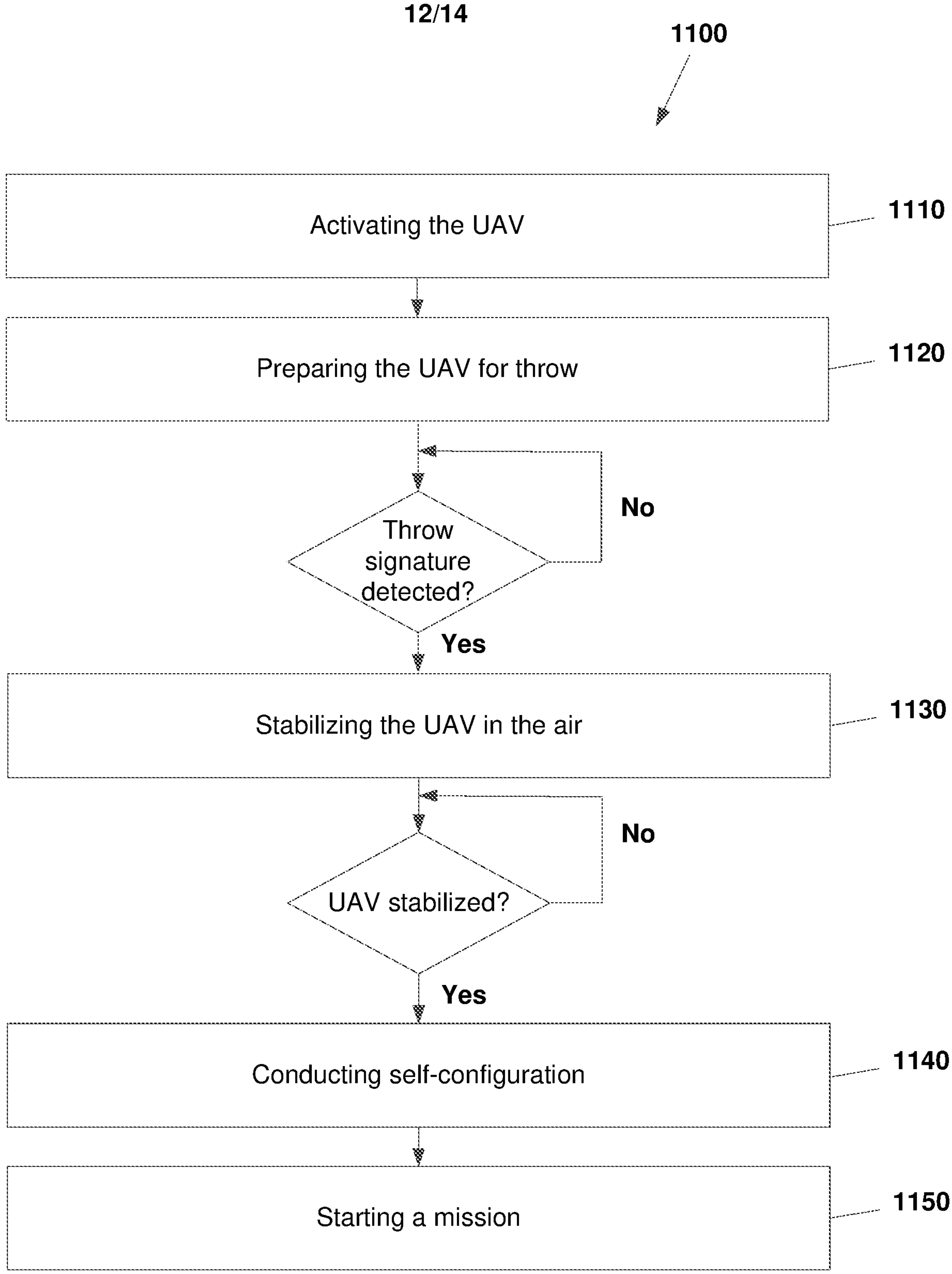
1100
Activating the UAV
1110
Preparing the UAV for throw
1120
Throw signature detected?
No
Yes
Stabilizing the UAV in the air
1130
UAV stabilized?
No
Yes
Conducting self-configuration
1140
Starting a mission
1150

Fig. 11

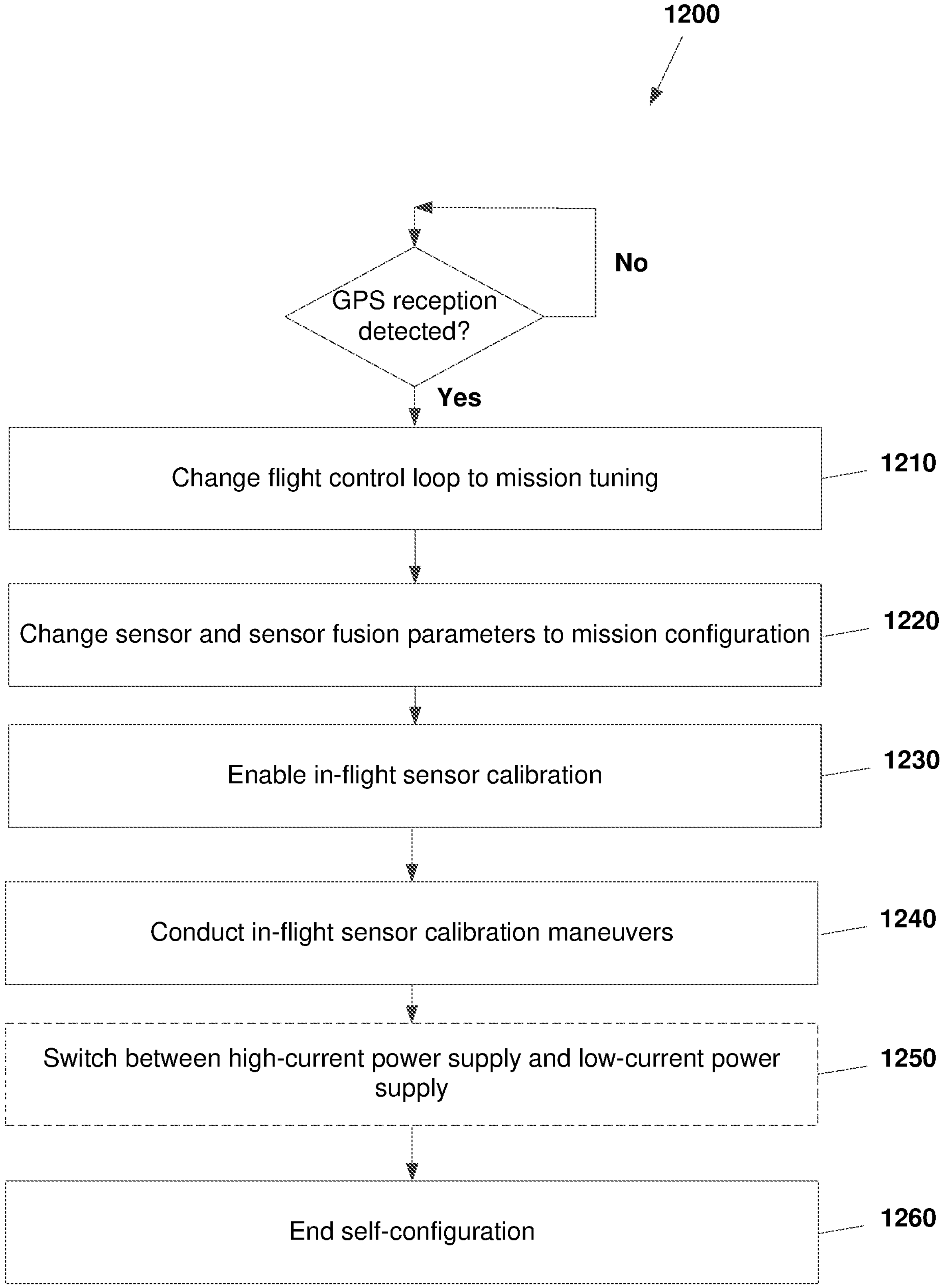
1200
GPS reception detected?
No
Yes
Change flight control loop to mission tuning
1210
Change sensor and sensor fusion parameters to mission configuration
1220
Enable in-flight sensor calibration
1230
Conduct in-flight sensor calibration maneuvers
1240
Switch between high-current power supply and low-current power supply
1250
End self-configuration
1260

Fig. 12

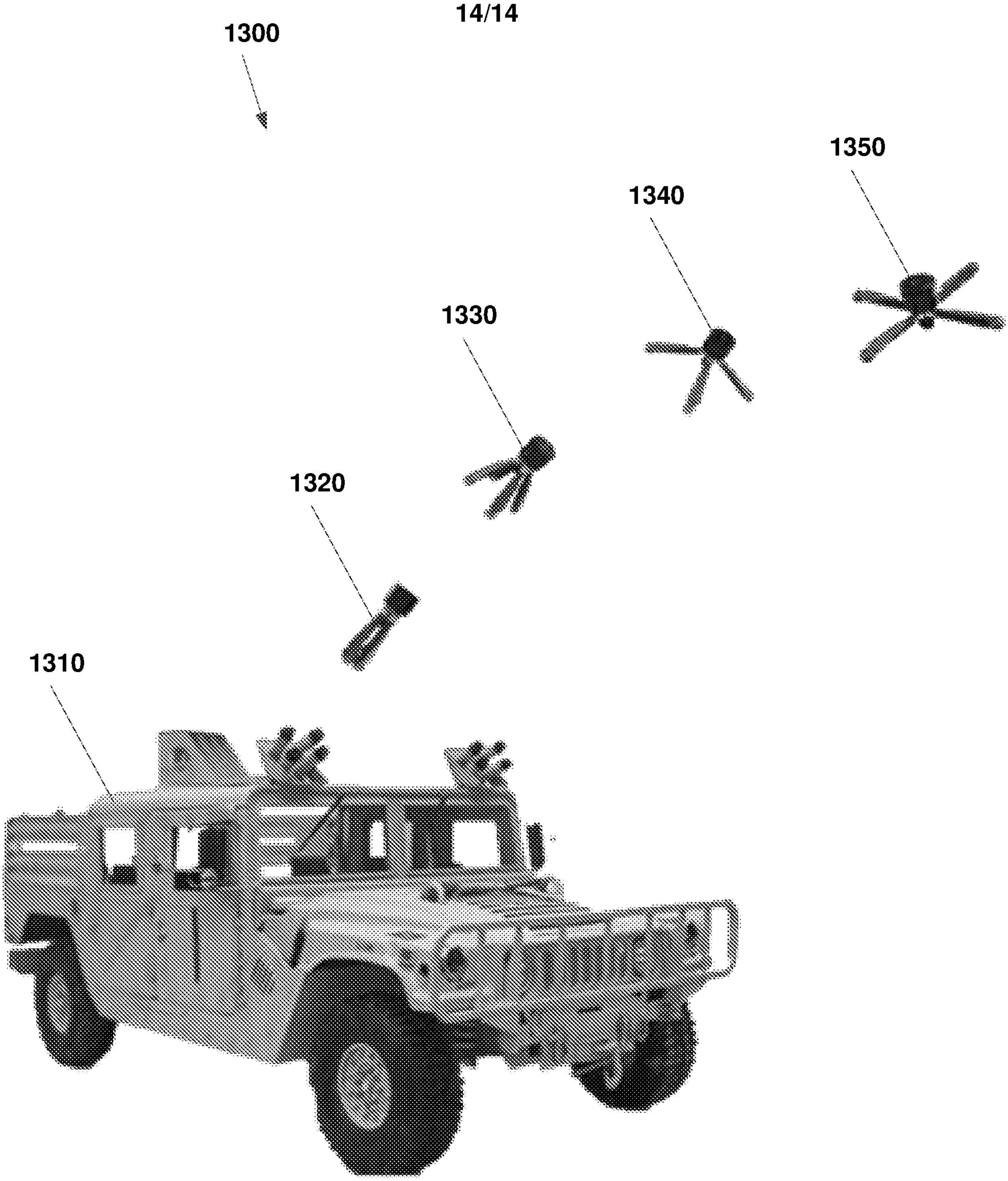

Fig. 13

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL2020/050036

A. CLASSIFICATION OF SUBJECT MATTER
IPC (20200101) B64C 39/00, B64F 1/06
CPC (20200101) B64C 39/00, B64C 2201/08, B64C 2201/06, B64F 1/06
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC (20200101) B64C 39/00, B64F 1/06, B60L 58/20
CPC (20200101) B64C 39/00, B64C 2201/08, B64C 2201/06, B64F 1/06, B60L 58/20

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Databases consulted: Esp@cenet, Google Patents, FamPat database

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2017269609 A1 LILY ROBOTICS INC [US] 21 Sep 2017 (2017/09/21) Entire document	1-18
A	US 2017144078 A1 CASIO COMPUTER CO LTD [JP] 25 May 2017 (2017/05/25) Entire document	1-3,6-12,15-18
A	US 9632501 B1 ZEROTECH (SHENZHEN) INTELLIGENCE ROBOT CO LTD [CN] 25 Apr 2017 (2017/04/25) Entire document	1-3,6-12,15-18
A	WO 2018106235 A1 INTEL CORP [US] 14 Jun 2018 (2018/06/14) Entire document	1-3,6-12,15-18
X	US 2018364695 A1 AUTEL EUROPE GMBH [DE] 20 Dec 2018 (2018/12/20) Entire document	19

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 Apr 2020	23 Apr 2020

Name and mailing address of the ISA:	Authorized officer
Israel Patent Office Technology Park, Bldg.5, Malcha, Jerusalem, 9695101, Israel Email address: pctoffice@justice.gov.il	ORGAD Yaniv Telephone No. 972-73-3927151

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL2020/050036

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	Entire document	20
Y	WO 2018229747 A1 SPEAR UAV LTD [IL] 20 Dec 2018 (2018/12/20) Entire document	20

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

See extra sheet.

1. [X] As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. [ ] As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. [ ] As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. [ ] No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

[ ] The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

[ ] The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

[X] No protest accompanied the payment of additional search fees.

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet):

* This International Searching Authority found multiple inventions in this international application, as follows:

Invention/s 1	This invention relates to a thrown UAV having an internal throwing recognition.	Claim/s 1-3,6-12,15-18
Invention/s 2	This invention relates to a throwing UAV with a "hybrid" power supply designed to supply high current during the stabilization phase and low current during normal flight.	Claim/s 4,5,13,14,19,20

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Information on patent family members

International application No.
PCT/IL2020/050036

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