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(54) **Title**: SYSTEM FOR PROVIDING LAND VEHICLE SUPPORT OPERATIONS USING AN UNMANNED AUTONOMOUS VEHICLE

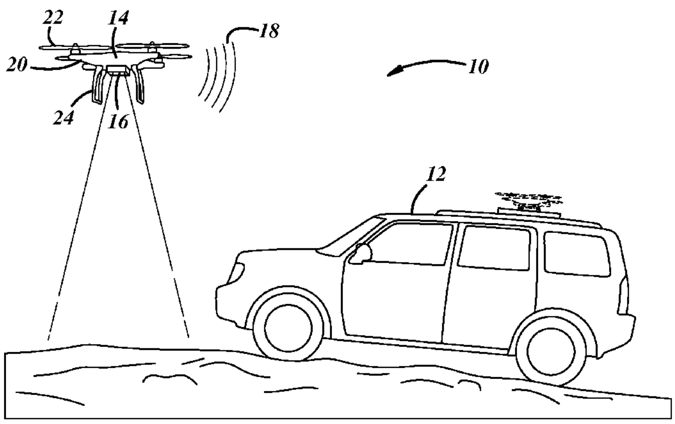

FIG. 1

(57) **Abstract**: A system provides one or more support operations for a land vehicle using an unmanned autonomous vehicle (UAV) such as an aerial drone. The support operations are provided via operation of a UAV accessory or accessory module while the UAV is deployed away from the land vehicle. The UAV accessory can obtain information pertaining to the terrain at a terrain mapping zone, and this information can assist in guiding the land vehicle along a selected path to safely traverse the terrain. Wade depth mapping of a water feature is an example of terrain mapping that can be performed by the system. Other types of support operations include emergency support operations, extending the effective reach of wireless signals to and from the land vehicle, and capturing recreational images of the land vehicle.

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SYSTEM FOR PROVIDING LAND VEHICLE SUPPORT OPERATIONS USING AN UNMANNED AUTONOMOUS VEHICLE

TECHNICAL FIELD

The present disclosure relates to a system for enhancing the operation of a land vehicle using an unmanned autonomous vehicle. Aspects of the invention relate to a system and to methods.

BACKGROUND

A large portion of land-based vehicles in operation today are in use primarily on paved streets or roads, representing a somewhat predictable terrain over which any particular vehicle travels. However, it is sometimes desirable or necessary for a land vehicle to traverse relatively unpredictable terrain. For instance, some vehicles may be driven off-road where the terrain is uneven or includes obstacles such as trees, water features, cliffs, etc. Efforts have been made to equip land vehicles with sensors or other components intended to provide the driver or a vehicle system with information about the terrain beneath or in front of the vehicle so that appropriate vehicle or driving adjustments can be made. The available information from such vehicle-mounted components is limited at least by the distance from the vehicle. It is an aim of the present invention to address disadvantages associated with the prior art.

SUMMARY OF THE INVENTION

Aspects and embodiments of the invention provide a system, a land vehicle, and methods as claimed in the appended claims.

According to an aspect of the invention, there is provided an unmanned autonomous vehicle system for use with a land vehicle. The system comprises an unmanned autonomous vehicle (UAV) that is deployable from a docked position on the land vehicle. The UAV is configured to releasably attach to the land vehicle in the docked position and move autonomously away from the land vehicle when deployed. The system further comprises at least one UAV accessory attached to the UAV and configured to operate while the UAV is deployed. The UAV and the at least one UAV accessory together provide one or more support operations for the land vehicle at a location remote of the land vehicle.

In an embodiment, the UAV comprises an accessory module port, the system comprises an accessory module removably attached to the UAV via the accessory module port, and the accessory module comprises the at least one UAV accessory.

In an embodiment, the system comprises a plurality of accessory modules. Each accessory module includes at least one UAV accessory and is interchangeable with an accessory module that is removably attached to the UAV via an accessory module port. The removably attached accessory module is one of the plurality of accessory modules, and each UAV accessory is configured to operate when attached to the UAV while the UAV is deployed to, together with the UAV, provide one or more support operations for the land vehicle.

In an embodiment, the system comprises a module changer carried by the land vehicle. The module changer removably holds each of a plurality of accessory modules when not attached to the UAV. The module changer is configured to detach any one of the plurality of accessory modules from an accessory module port and to attach any one of the plurality of accessory modules to the UAV via the accessory module port while the UAV is not deployed.

In an embodiment, the at least one UAV accessory is permanently attached to the UAV.

In an embodiment, the at least one UAV accessory includes a signal receiver and a signal transmitter. The signal receiver is configured to receive a first information-containing signal originating from a location other than the land vehicle, and the signal transmitter is configured to transmit a second information-containing signal to the land vehicle. The information contained in the second signal is usable by the land vehicle to provide one or more support operations for the land vehicle.

In an embodiment, the at least one UAV accessory comprises an antenna configured to receive a telecommunications signal that is relayed to the land vehicle via a second information-containing signal.

In an embodiment, the system comprises a processor that processes information contained in a first information-containing signal to provide one or more support operations for the land vehicle.

In an embodiment, the UAV includes a processor, whereby information contained in a first information-containing signal can be processed at the UAV and a signal transmitter transmits the UAV-processed information to the land vehicle via a second information-containing signal.

In an embodiment, the land vehicle includes a processor, whereby a signal transmitter transmits information contained in a first information-containing signal to the land vehicle via a second information-containing signal to be processed by the land vehicle.

In an embodiment, the at least one UAV accessory includes a terrain sensor operable to obtain information pertaining to the terrain at a terrain mapping zone located away from the land vehicle.

In an embodiment, the at least one UAV accessory comprises a camera operable to obtain imagery of the terrain at a terrain mapping zone.

In an embodiment, the at least one UAV accessory comprises a camera operable to obtain information pertaining to a UAV landing location at the land vehicle.

In an embodiment, the at least one UAV accessory comprises a sonar module operable to obtain information pertaining to the contour of the terrain at a terrain mapping zone.

In an embodiment, the at least one UAV accessory comprises a lidar module operable to obtain information pertaining to the contour of the terrain at a terrain mapping zone.

In an embodiment, the at least one UAV accessory comprises a fluid flow rate sensor operable to obtain information pertaining to the flow rate of a water feature at a terrain mapping zone.

In an embodiment, the at least one UAV accessory comprises a terrain sensor that is deployable from a stowed position on the UAV and spaced away from the UAV when deployed, the terrain sensor being in communication with the UAV while deployed.

In an embodiment, the at least one UAV accessory comprises a water sensor operable to obtain information pertaining to the presence of a water feature at a terrain mapping zone.

In an embodiment, the at least one UAV accessory comprises an ultrasonic transducer.

In an embodiment, the at least one UAV accessory comprises a distress beacon operable to emit a distress signal while the UAV is deployed.

In an embodiment, the system comprises an attachment mechanism that releasably attaches the UAV to the land vehicle while in the docked position.

In an embodiment, the system comprises an attachment mechanism comprising a magnet carried by the UAV and/or carried by the land vehicle, whereby the UAV is magnetically attached to the land vehicle while in the docked position.

In an embodiment, the system comprises a replenishable energy source carried by the UAV that powers the UAV and/or the at least one UAV accessory while the UAV is deployed. The system further comprises an energy source replenisher carried by the land vehicle and configured to replenish the energy source when the energy source is attached to the land vehicle.

In an embodiment, an energy source replenisher carried by the land vehicle is configured to replenish a replenishable energy source carried by the UAV while the UAV is in the docked position.

In an embodiment, an energy source replenisher carried by the land vehicle is configured to replenish a replenishable energy source while the UAV is deployed.

In an embodiment, the system comprises a docking pad attached to the land vehicle, the docking pad being moveable between a stowed position and an extended position. The UAV can be deployed from and landed on the docking pad when the docking pad is in the extended position, and the UAV cannot be deployed from or landed on the docking pad when the docking pad is in the stowed position.

In an embodiment, the system comprises a docking pad attached to the land vehicle, and the at least one UAV accessory includes a camera. The system is configured to locate the docking pad via imagery obtained by the camera when returning to the land vehicle from deployment.

In an embodiment, the at least one UAV accessory includes an image projector configured to project an image onto the terrain in front of the land vehicle, wherein the image includes information pertaining to the terrain at a terrain mapping zone.

In an embodiment, the system comprises a visual display carried by the land vehicle and visible to an occupant of the land vehicle, wherein the visual display displays information pertaining to the terrain in front of the land vehicle and at a terrain mapping zone.

In an embodiment, the UAV comprises a navigation receiver that receives a navigation signal from the land vehicle, the navigation signal being used by the UAV to change the position of the UAV with respect to the terrain.

In an embodiment, a navigation receiver of the UAV wirelessly receives a navigation signal from the land vehicle.

In an embodiment, the at least one UAV accessory includes a terrain sensor, and the system further comprises a processor configured to determine a path along the terrain along which a self-steering system of the land vehicle can navigate the land vehicle, the path being based at least in part on information obtained by the terrain sensor.

In an embodiment, the UAV is an aerial vehicle.

According to another aspect of the invention, there is provided a land vehicle comprising a system including any combination of the aforementioned features.

According to another aspect of the invention, there is provided a method of using an unmanned autonomous vehicle (UAV) to provide one or more support operations for a land vehicle. The method includes deploying the UAV from a docked position on the land vehicle and operating a UAV accessory carried by the UAV while the UAV is away from the land vehicle. The UAV is configured to releasably attach to the land vehicle in the docked position and move autonomously away from the land vehicle when deployed. The UAV and the UAV accessory together provide one or more support operations for the land vehicle from a location remote of the land vehicle.

In an embodiment, the method comprises detaching the UAV accessory from an accessory module port of the UAV and attaching a different UAV accessory to the UAV via the accessory module port.

In an embodiment, detaching the UAV accessory and attaching a different UAV accessory are performed using a module changer while the UAV is in the docked position.

In an embodiment, the method comprises receiving a first information-containing signal at the UAV, the first signal originating from one of: the land vehicle or a location away from the land vehicle. The method further comprises transmitting a second information-containing signal from the UAV to be received at the other one of: the land vehicle or the location away from the land vehicle.

In an embodiment, the method comprises receiving at the UAV a telecommunications signal originating from a location away from the land vehicle, and relaying the telecommunications signal to the land vehicle.

In an embodiment, the land vehicle is at a location at which a telecommunications signal cannot be received directly from an originating location, whereby receiving the telecommunications signal at and transmitting the telecommunications signal from the UAV effectively increases the wireless telecommunications range of the land vehicle.

In an embodiment, the method comprises processing information contained in a first information-containing signal at the UAV, wherein information contained in a second information-containing signal is processed information.

In an embodiment, the method comprises processing information contained in a second information-containing signal at the land vehicle.

In an embodiment, operating the UAV accessory comprises obtaining information via operation of the UAV accessory, said information pertaining to the terrain at a terrain mapping zone located away from the land vehicle.

In an embodiment, operating the UAV accessory comprises obtaining imagery of the terrain at a terrain mapping zone.

In an embodiment, operating the UAV accessory comprises obtaining information pertaining to the contour of the terrain at a terrain mapping zone.

In an embodiment, operating the UAV accessory comprises obtaining information pertaining to the depth of a water feature at a terrain mapping zone.

In an embodiment, operating the UAV accessory comprises obtaining information pertaining to the flow rate of a water feature at a terrain mapping zone.

In an embodiment, operating the UAV accessory comprises obtaining information pertaining to the presence of a water feature at a terrain mapping zone.

In an embodiment, operating the UAV accessory comprises deploying the UAV accessory toward the terrain and away from the UAV from a stowed position on the UAV, and receiving at the UAV an information-containing signal from the deployed UAV accessory, the information contained in the signal being usable to provide the one or more support operations when said information is processed.

In an embodiment, a sensor of the UAV accessory is located in a water feature when the UAV accessory is deployed from a stowed position on the UAV.

In an embodiment, operating the UAV accessory includes emitting a distress signal from the UAV accessory.

In an embodiment, the method comprises releasably attaching the UAV to the land vehicle after deploying the UAV and operating the UAV accessory.

In an embodiment, the method comprises magnetically attaching the UAV to the land vehicle.

In an embodiment, the method comprises replenishing an energy source carried by the UAV while the UAV is attached to the land vehicle.

In an embodiment, the method comprises moving a docking pad carried by the land vehicle between a stowed position and an extended position while the UAV is attached to the land vehicle via the docking pad.

In an embodiment, the method comprises using the UAV accessory to locate a docking pad carried by the land vehicle after deploying the UAV and operating the UAV accessory while the UAV is away from the land vehicle, and landing the UAV at the docking pad.

In an embodiment, the UAV accessory is a camera and the method comprises using the camera to locate a docking pad via recognition of the docking pad from imagery obtained by the camera.

In an embodiment, the method comprises operating the UAV accessory to obtain information pertaining to the terrain at a terrain mapping zone located away from the vehicle, processing the obtained information to select a path along the terrain along which it is desired to guide the land vehicle, and providing guidance to help guide the land vehicle along the path.

In an embodiment, the method comprises projecting an image onto the terrain in front of the land vehicle, the image being visible to a driver of the land vehicle and indicating a selected path so that the driver can use the image to guide the land vehicle along the path.

In an embodiment, the method comprises displaying an image on a visual display visible to a driver of the land vehicle, the image indicating a selected path so that the driver can use the image to guide the land vehicle along the path.

In an embodiment, the method comprises navigating the UAV along a selected path, the UAV being visible to a driver of the land vehicle so that the driver can follow the UAV to guide the land vehicle along the path.

In an embodiment, the method comprises operating a self-steering system of the land vehicle to guide the land vehicle along a selected path.

In an embodiment, the method comprises selecting a path along the terrain along which the land vehicle is to be guided, and presenting a visual indicator pertaining to the location of the path with respect to the terrain such that the visual indicator is visible to a driver of the land vehicle.

In an embodiment, the method comprises selecting a path along the terrain along which the land vehicle is to be guided, the selecting being performed by a user via a user input device.

In an embodiment, the method comprises selecting a path along the terrain along which the land vehicle is to be guided, the selecting being performed by a processor based at least in part on information obtained by the UAV accessory while the UAV is deployed, said information pertaining to the terrain at a terrain mapping zone.

In an embodiment, the method comprises projecting an image onto the terrain in front of the land vehicle, the image being visible to a driver of the land vehicle and indicating a selected path so that the driver can use the image to guide the land vehicle along the path.

In an embodiment, the method comprises displaying an image on a visual display carried by the land vehicle, the image indicating a selected path so that the driver can use the image to guide the land vehicle along the path.

In an embodiment, the UAV accessory comprises a camera and the method comprises capturing images of the land vehicle while the UAV is deployed and while the land vehicle is being guided along a path.

According to another aspect of the invention, there is provided a method comprising maneuvering an unmanned autonomous vehicle (UAV) over terrain at a terrain mapping zone located away from a land vehicle, obtaining information pertaining to the terrain at the terrain mapping zone using one or more UAV accessories, and processing the information to determine whether a path along the terrain mapping zone can be selected such that the land vehicle can safely traverse the terrain mapping zone by following the path.

In an embodiment, the method comprises providing guidance to help guide the land vehicle along the path if the path can be selected.

In an embodiment, the method comprises providing an indication to a driver of the land vehicle that no safe path can be selected.

In an embodiment, processing the information comprises mapping the depth of a water feature located at the terrain mapping zone.

In an embodiment, the one or more UAV accessories includes a sonar device in communication with the UAV.

Within the scope of this application it is expressly intended that the various aspects, embodiments, examples and alternatives set out in the preceding paragraphs, in the claims and/or in the following description and drawings, and in particular the individual features thereof, may be taken independently or in any combination. That is, all embodiments and/or features of any embodiment can be combined in any way and/or combination, unless such features are incompatible. The applicant reserves the right to change any originally filed claim or file any new claim accordingly, including the right to amend any originally filed claim to depend from and/or incorporate any feature of any other claim although not originally claimed in that manner.

BRIEF DESCRIPTION OF THE DRAWINGS

One or more embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

FIG. 1 is a side view of an example of a UAV system for providing support operations for a land vehicle, the system including an unmanned autonomous vehicle (UAV);

FIG. 2 is a perspective view of the UAV of FIG. 1, illustrating an interchangeable accessory module;

FIG. 3 is a plan view of the system of FIG. 1, illustrating the UAV deployed at a terrain mapping zone;

FIG. 4 depicts the UAV equipped with an image projector projecting an image along the terrain representing a selected path for the land vehicle to be guided along;

FIG. 5 is a side view of the system of FIG. 1 performing a wade depth measurement, the UAV being equipped with a sonar module;

FIG. 6 depicts the land vehicle in a valley and the UAV in a deployed position relaying information-containing signals to and/or from a location away from the land vehicle;

FIG. 7 depicts the land vehicle in distress in the valley and the UAV in a deployed position operating a distress beacon;

FIG. 8 depicts the UAV equipped with a projector and projecting an image along the terrain representing a suitable camping area;

FIG. 9 is a cutaway view of a pod for mounting to the land vehicle, including an accessory module changer, an elevator, and a docking pad;

FIG. 10 is a schematic side view of a pair of accessory modules being installed in the UAV;

FIG. 11 is an end view of a portion of 4-way rotating accessory module changer; and

FIG. 12 is a perspective view of a portion of 2-way rotating accessory module changer.

DETAILED DESCRIPTION

The system, system components, and methods described below can be used to enhance the operation of a land vehicle through the use of an unmanned autonomous vehicle (UAV), such as an aerial drone. The system can enhance the operation of the land vehicle by providing one or more support operations for the land vehicle from or at a location remote of the land vehicle. Such support operations may include the use of a UAV accessory carried by the UAV to obtain information pertaining to the terrain at a location away from the land vehicle. The obtained information can assist a driver and/or a system of the land vehicle in selecting or guiding the vehicle along a path to traverse the terrain. Use of the UAV enables the collection and use of information at distances away from the land vehicle far beyond the useful distance of land vehicle-mounted information-gathering components. Other support operations include use of the UAV system in emergency situations, use of the UAV system to extend the effective reach of wireless signals to and from the land vehicle, and use of the UAV system to capture recreational images of the land vehicle, to name a few.

FIG. 1 illustrates one example of a system 10 for use with a land vehicle 12 to provide one or more support operations therefor. The illustrated system 10 includes a UAV 14 and a UAV accessory 16 operably attached to the UAV. The UAV 14 is deployable from a docked position on the land vehicle 12. The UAV may be configured to releasably attach to the land vehicle in the docked position and to move autonomously away from the land vehicle when deployed. In the example of FIG. 1, the UAV 14 is illustrated in a deployed position remote of the land vehicle 12. The UAV 14 is also shown in phantom view in the docked position. The particularly illustrated UAV 14 is an aerial drone in communication with the land vehicle 12 via a wireless signal 18 (e.g., WIFI) while deployed. Land-based or waterborne UAVs can also be configured to provide one or more support operations for the land vehicle 12 in certain embodiments, and communication with the land vehicle is not limited to wireless communication. For instance, the UAV 14 may collect and store information while deployed away from the land vehicle 12 and transmit information to the land vehicle via a hard electrical connection while in the docked position. As described further below, the land vehicle 12 may carry or include one or more components of the system 10 that remain with the land vehicle while the UAV 14 is deployed, and in some instances the entire system 10 may be considered part of the land vehicle 12.

The UAV 14 includes certain components that are considered necessary to its operation whether or not it is configured to provide support operations for the land vehicle 12. For example, the UAV 14 includes a body 20, a propulsion system 22, a maneuvering system, a guidance system, and a power source. The body 20 is a structure to which the other UAV components are attached and may include features such as legs 24 that support the UAV with respect to the ground when it is not deployed, protective guards for propulsion system components, etc. The propulsion system 22 functions to impart the UAV 14 with movement forces that allow the UAV to move with respect to the terrain. In the illustrated example, the propulsion system 22 includes propellers and unillustrated components such as electric motors that rotate the propellers. The maneuvering system includes components configured to change the position of the UAV with respect to the terrain, such as actuators that tilt the propellers and/or propeller speed controllers. The guidance system enables the unmanned vehicle to be autonomous, which means it can be maneuvered under the control of a processor (e.g., an electronic processor), which can be an on-board processor or a remote processor, without real-time human user input. The guidance system thus includes a positioning device (e.g., GPS component) that at least tracks the current position of the UAV with respect to a reference frame and/or home position. The power source provides power to operate at least these UAV systems and may be in the form of a battery, fuel cell, combustible fuel source, etc.

The UAV 14 may be configured so that the maneuvering system is remotely controlled, either by real-time human user input such as a hand-held remote controller or by a real-time controller carried by the land vehicle. In such cases, the UAV includes a navigation receiver that receives a navigation signal from the remote controller, the navigation signal being used by the UAV to change the position of the UAV with respect to the terrain.

The UAV accessory 16 is any component that is or can be operably attached to the UAV 14 and that provides functionality primarily for use in providing one or more support operations for the land vehicle from a location remote of the land vehicle. This functionality distinguishes the UAV accessory 16 from the above-described components that are considered necessary to operation of the UAV 14 whether or not the UAV is configured to provide support operations for the land vehicle 12. The illustrated UAV accessory 16 is a terrain sensor that obtains information pertaining to the terrain at a location away from the land vehicle. Some examples of suitable terrain sensors include a camera, a sonar module, a lidar module, a radar module, a fluid flow sensor, a water sensor, an ultrasonic transducer or module, or a night vision system, to name a few. Examples of manners in which some of these types of terrain sensors can be used to provide support operations for the land vehicle are discussed further below. Other types of UAV accessories include communication devices such as wireless or wired electronic transmitters or receivers, a communication antenna, an emergency beacon device, a processor configured to process information obtained via another UAV accessory, or an information storage device configured to store processed or unprocessed information obtained via another UAV accessory, to name a few examples. Some UAV accessories, such as a camera, can function as either a terrain sensor or as part of a vision system, as part of an image or video storage system, or as part of any combination of these or other systems. The system 10 may include more than one

UAV accessory 16, and each UAV accessory may be either permanently attached to the UAV 14 or removably attached to the UAV.

With reference to FIG. 2, the illustrated UAV 14 includes an accessory module port 26 configured to receive an accessory module 28 that includes two UAV accessories, which in this case are a camera 16 and a wireless communication device 16'. The accessory module 28 facilitates removable attachment and operable connection of one or more UAV accessories to the UAV 14 via the accessory module port 26. In some embodiments, the system 10 includes a plurality of accessory modules 28, each accessory module including at least one UAV accessory 16. Such modules 28 may be interchangeable – i.e., each module can be attached, detached, and replaced with a different module that includes the same or different combination of UAV accessories 16 via the accessory module port 26. The system can be configured for manual or automated interchanging of different accessory modules 28 and may include more than one accessory module port 26.

FIG. 3 is a plan view of the system of FIG. 1 with the land vehicle 12 located on terrain that includes examples of terrain features or obstacles such as a water feature 30, trees 32, and boulders 34, some of which are located at least partly in a terrain mapping zone 36. The UAV 14 is shown in the deployed position, away from the land vehicle 12 and over the terrain at the terrain mapping zone 36. In this particular example, the UAV 14 is deployed over the water feature 30, which is a stream or river in this case, where the UAV accessory can operate to help provide support operations for the land vehicle 12 by obtaining information pertaining to the portion of the water feature in the terrain mapping zone 36.

In one example, the UAV accessory includes a sensor capable of and configured to obtain information pertaining to the depth of the water feature 30 at a plurality of locations within the terrain mapping zone 36. The collected information can be processed in combination with information from the UAV positioning system or another positioning system to effectively map the depth of the water feature 30 within the terrain mapping zone 36. This technique may be referred to as wade depth mapping or wade depth measurement and offers several advantages over techniques that rely on land vehicle-bound sensors for such measurements. For instance, a land vehicle-bound water depth sensor may be limited to water depth measurements while the land vehicle is already at a location in or over the water feature, at which time it is too late to determine whether the water feature is sufficiently shallow at that location for the land vehicle to safely traverse the water feature along a path that includes the instant location. The illustrated system 10 is capable of water depth mapping while the land vehicle 12 is safely away from the water feature 30 as shown.

An illustrative method includes the steps of maneuvering the UAV 14 over terrain at the terrain mapping zone 36, which is located away from a land vehicle 12, obtaining information pertaining to the terrain at the terrain mapping zone using one or more UAV accessories operably attached to the UAV 14, and processing the information to determine whether a path 38 along the terrain mapping zone 36 can be selected such that the land vehicle 12 can safely traverse the terrain mapping zone by guidance along the path. In some embodiments, the UAV accessory includes a sonar device that is deployed from the UAV 14 while the UAV is deployed over the water feature. The sonar device may be lowered into the water while remaining tethered to the UAV 14, and the UAV 14 can be maneuvered over the water feature 30, thereby dragging the sonar device in and along the water feature to obtain depth information at a plurality of locations along the water feature. This depth information is then processed along with UAV positioning information to generate a depth map for some or all of the water feature 30 within the mapping zone 36. The system 10 may include a processor carried by the UAV 14 or by the land vehicle 12 that generates the depth map, or the water depth information may be processed by a processor located elsewhere (e.g., at a remote server, computer, handheld electronic device, etc.). The same processor or a different processor can be used to determine whether a traversable path 38 can be selected based at least in part on certain vehicle parameters or dimensions.

In the example of FIG. 3, such a path 38 can be selected and is illustrated. The path 38 may include a plurality of waypoints 40, as shown. Each waypoint 40 has a known position along the terrain. In this case, each of the waypoints 40 associated with the water feature 30 represents a location along the water feature where the water is sufficiently shallow for the land vehicle 12 to safely be over or in the water, and the path 38 has been selected such that the land vehicle can safely traverse the terrain mapping zone 36, including the portion of the water feature within the terrain mapping zone, by following the path.

In some cases, the step of processing the information obtained by the UAV accessory or accessories results in a determination that no path exists along which the land vehicle can safely traverse the terrain mapping zone or the water feature 30. In such cases, an indication can be provided to the driver so that the driver can possibly choose another location along the terrain and a different terrain mapping zone where the UAV can be used to help make a new determination.

Guidance may be provided to a driver of the land vehicle 12 and/or to a guidance system of the land vehicle to help guide the land vehicle along the selected path 38. Where provided to the driver of the land vehicle, a visual indicator pertaining to the location of the path with respect to the terrain may be presented such that the visual indicator is visible to a driver. In one embodiment, the guidance is provided by a visual display that is visible to the driver while driving (e.g., an in-dash electronic screen or heads-up display). The visual display may display a depiction of the plan view of FIG. 3, for example, including the selected path 38 and an indicator of the current position and/or direction of the land vehicle 12 with respect to the path. In another example, the depiction is an aerial photograph obtained by a camera-type UAV accessory while the UAV was previously deployed, including the terrain mapping zone 36 with the selected path 38 and the current position and/or direction of the land vehicle 12 superimposed over the photograph. In another example, the visual display operates to display a real-time forward view from a land vehicle-based camera with the selected path 38 and/or a predicted vehicle path super-imposed thereover, where the predicted vehicle path is based on the real-time position of the steering wheel, for example, so that the driver can continuously adjust the steering wheel to maintain the position of the land vehicle along the selected path.

In another example, illustrated in FIG. 4, the UAV 14 is equipped with an image projector as the operating UAV accessory 16. The image projector 16 operates to provide guidance to the driver of the land vehicle and/or to a guidance system of the land vehicle to help guide the land vehicle along the selected path 38. The image projector 16 in this example projects a visible image, such as a laser light pattern 42, onto the terrain along which the driver can steer the land vehicle to safely traverse the illustrated water feature 30. Other types of images 42 can be projected onto the terrain as well, such as to indicate a larger region of the water feature 30 surrounding or adjacent to the selected path 38 where it is also safe to cross the water feature. The projected image 42 may also be detectable by a land vehicle-mounted sensor to assist an automatic steering system of the land vehicle in traversing the highlighted terrain, in which case the image 42 need not be projected with light in the visible portion of the spectrum.

Guidance can be provided in other ways as well. In one embodiment, guidance is provided by navigating the UAV 14 along the selected path 38 so that the UAV is visible to a driver of the land vehicle. For instance, the UAV may be navigated in front of the land vehicle or behind the land vehicle so that the driver can steer the land vehicle to follow the UAV 14 along the path 38. The UAV 14 may be navigated via a real-time navigation signal transmitted from the land vehicle and received at the UAV, or the UAV may autonomously navigate along the path using the processed information pertaining to the location of the path along the terrain combined with its own guidance system. In another example, the land vehicle is equipped with a self-steering system, and guidance is provided via operation of the self-steering system to guide the land vehicle along the selected path.

In some embodiments, system components may be employed to guide the land vehicle along a path selected at least in part by a system user. For example, the user may select the desired path via a user input device, such as an in-vehicle navigation system display or a mobile phone or tablet-based map application. The user may for example be presented with an aerial view of terrain near the land vehicle on a touch screen, such as imagery obtained by the UAV or database information, and trace the desired path on the screen. The system may then present a visual indicator (e.g., via a visual display, UAV-projected image, or a flashing LED on the UAV traveling along the path) pertaining to the location of the path with respect to the terrain for the user or driver to follow. The system may also be employed to determine if the user-selected path is traversable by the land vehicle based on information obtained by the UAV while deployed. If the system has not obtained sufficient information to make such a determination, the UAV can be deployed to attempt to obtain sufficient information before guiding the land vehicle along the selected path.

In one particular example, the system 10 can be operated in a racetrack or obstacle course mode in which the path 38 is selected by the user via a user input device or suggested by the system based on terrain information obtained by the UAV while deployed. A visual indicator is then provided to the driver to help the driver guide the land vehicle along the user-selected path. Where the visual indicator is provided by a land-vehicle mounted component, the UAV is available for other tasks. In one embodiment, the UAV accessory includes a camera and the UAV is deployed while the land vehicle is traversing the selected path 38. During this time, the UAV can capture images of the land vehicle while traversing the path, including video images and/or still images. For example, the UAV may be maneuvered to follow the land vehicle along the path while capturing rear, side, front, top, or offset view images of the land vehicle. Or the UAV may be maneuvered to a waypoint along the selected path which the land vehicle has not yet reached to capture images of the land vehicle as it approaches the waypoint.

Terrain mapping and guidance by the system 10 is not limited to water features. For example, the system 10 may include various types of UAV accessories including different types of terrain sensors capable of obtaining information pertaining to different types of terrain or different types of information about the same types of terrain. One type of sensor is a camera, and the information obtained by the camera includes imagery of the terrain at the terrain mapping zone 36. The above-described sonar device can be used to obtain information pertaining to the contour of the terrain at the terrain mapping zone 36 whether or not the terrain includes a water feature. In another example, the UAV accessory includes a lidar module or device that can obtain information pertaining to the contour of the terrain. The information obtained from these types of terrain sensors can be processed to determine the presence of and the location of terrain features or obstacles such as the trees 32 and boulders 34 of FIG. 3 or cliffs, drop-offs, ridges, etc.

A terrain map representing the contour of the terrain and/or the location and character of terrain features or obstacles in the terrain mapping zone 36 can be generated via processing of the information obtained by terrain sensors. In some embodiments, such terrain sensors may be forward-facing rather than downward-facing to obtain information pertaining to the terrain such as the width of a cave or the distance between two trees. This type of information can be processed to determine whether the land vehicle 12 can pass through or between such features and/or whether such terrain features can be included along a traversable path. As with the above-described wade depth mapping, terrain mapping can be used to determine whether a path can be selected such that the land vehicle can safely traverse the terrain mapping zone. If so, the same or similar types of guidance can be provided to assist in guiding the land vehicle along the selected path.

The system 10 may include other types of UAV accessories in the form of terrain sensors, such as a fluid flow rate sensor or a water sensor. A fluid flow rate sensor can obtain information pertaining to the flow rate of water in a water feature. This type of information may be useful to determine whether dangerously strong water current is present in the water feature. Information pertaining to water flow rate can also be determined at multiple depths along the water feature to detect the presence of an undertow or under current. A water sensor can be used to determine the presence of water along the terrain. One example is an ultrasonic sensor. Such a sensor can operate while the UAV is deployed to effectively scan the terrain in the terrain mapping zone for the presence of a water feature. When a water feature is detected, the system can then perform wade depth mapping if desired.

Any of these or other sensors can be operably attached to the UAV to be deployable from a stowed position on the UAV and spaced away from the UAV when deployed. The deployed sensor(s) can be configured to be in communication with the UAV while deployed via a wireless connection (e.g., WIFI, Bluetooth, etc.) or via a hard electrical connection. A hard electrical connection such as an electrical cable can double as a tether to keep the sensor attached to the UAV during sensor deployment and/or to ensure co-positioning of the sensor and the UAV along the terrain. Alternatively, the deployed sensor can be in wireless communication with the land vehicle.

As noted above, the system 10 can include more than one UAV accessory. In one example, the more than one UAV accessory includes a signal receiver and a signal transmitter. The receiver and transmitter may be integrated into a single bi-directional communication device, or they may be separately provided. The signal receiver may be configured to receive a first information-containing signal from a location other than the land vehicle, and the signal transmitter may be configured to transmit a second information-containing signal to the land vehicle. The information contained in the second signal may be generally the same information contained in the first signal so that the receiving and transmitting of the information at and from the UAV is performed in the manner of relaying the received information from the non-land vehicle source to the land vehicle via the UAV. This relayed information may then be processed by a processor away from the UAV, such as by a system processor carried by the land vehicle. Alternatively, the system may include a processor carried by the UAV that processes the information in the first signal and transmits the processed information to the land vehicle for use in providing support operations for the land vehicle or for further processing and operation-enhancing use.

An example of the receiver/transmitter system 10 is illustrated in FIG. 5 in the context of the above-described wade depth mapping. In this example, the system 10 includes the UAV 14 and an accessory module 28 operably attached to the UAV. The accessory module 28 includes a deployable sonar device 16, shown deployed in the water feature 30 of FIG. 5. The module 28 also includes a receiver 16' configured to receive the first information-containing signal 18 from the deployed sonar device and a transmitter 16" configured to transmit the second information-containing signal 18' to the land vehicle 12. In the illustrated example, the first and second signals 18, 18' are wireless signals. In other examples, the first and/or the second signals are respectively received and transmitted via a hard electrical connection. For instance, the illustrated tether 44 may include a hard electrical connection along which the first information-containing signal 18 may be received at the UAV 14. Additionally or alternatively, the received information may be stored and/or processed at the UAV 14 and subsequently transmitted from the UAV to the land vehicle 12 via a hard electrical connection when the UAV returns to the docked position at the land vehicle. This type of receiver/transmitter system 10 is thus useful with any type of UAV accessory 16 that is deployed away from a stowed position on the UAV 14 to provide a communication path that enables transmission of processed or unprocessed information initially obtained by the UAV accessory to the land vehicle 12.

Another example of the receiver/transmitter system 10 is illustrated in FIG. 6, which illustrates that the system is useful for more than obtaining and relaying information pertaining to the terrain at a terrain mapping zone. In this example, the land vehicle 12 is located in a valley, and the first signal 18 is a telecommunications signal that originates at a telecommunication tower 46. The relative locations of the vehicle 12 and the tower 46 are such that the first signal 18 cannot be received directly from the originating location 46. The UAV 14 is deployed to an altitude higher than that of the land vehicle 12, where the telecommunications signal 18 is received and re-transmitted to the land vehicle via the second signal 18', effectively increasing the strength of the telecommunications signal at the land vehicle compared to its strength at the land vehicle without the relaying function of the UAV. This mode of system operation is useful to extend the effective reach of wireless communication between the land vehicle 12 and any remote communication device, thereby providing a useful support operation for the land vehicle.

In the example of FIG. 7, the UAV accessory 16 is a distress beacon that is operable to emit a distress signal while the UAV 14 is deployed. The distress signal may be in any perceivable form, whether visual, audible, an electromagnetic carrier wave, etc. Examples of suitable distress beacons include a flashing LED light, a laser light beam, a flare, a smoke generator, a sound generator, or a continuous or intermittent radio wave configured to be received on a dedicated emergency frequency and carrying information such as the GPS location of the land vehicle 12.

FIG. 8 illustrates another use of the system 10 when equipped with an embodiment of the image projector 16. In this example, the image projector 16 operates to indicate the location of a section of terrain 48 that is suitable for a particular purpose. The section of terrain 48 located at or within the projected image 42 in FIG. 8 is sufficiently flat and/or devoid of unwanted terrain features to serve as a campsite or tent-pitching location. The indicated section of terrain 48 may be a clearing in a wooded area of the terrain, a relatively flat area along an otherwise uneven terrain, or a relatively elevated area along terrain with a high proportion of water features, for example. The section of terrain 48 may be identified and/or selected by or with the assistance of the system 10 in a manner similar to the above-described terrain mapping techniques. For example, whether a suitable section of terrain 48 exists within the terrain mapping zone can first be determined, followed by providing guidance regarding the location of the suitable section of terrain 48 to the driver or to the vehicle at least in the form of the projected image 42. In one embodiment, the system 10 operates to identify the suitable section of terrain 48 along with a suitable path along the terrain along which the vehicle can be guided to the selected section of terrain 48. The system 10 can be used to identify and indicate the location of sections of terrain suitable for other purposes as well, such as a campfire location, a water feature sufficiently deep for swimming, etc. The location of the desired section of terrain 48 may also be user-selected or selected from a database with the UAV 14 then being maneuvered to the section of terrain 48 and operating the image projector 16.

As noted above, the UAV accessory or accessories 16 operate in conjunction with the deployed UAV 14 to enhance the operation of and/or provide one or more support functions for the land vehicle 12, and the UAV may be releasably attached to the land vehicle 12 in a docked position. As such, the land vehicle 12 may carry additional components of the system 10 that remain with the land vehicle at or near the docked position of the UAV 14 when the UAV is deployed away from the land vehicle. FIG. 9 illustrates examples of such components as part of a cutaway view of a UAV pod 50. The pod 50 is configured for attachment to the land vehicle 12, such as along the roof of the land vehicle 12 at or near the docked position of the UAV illustrated in FIG. 1 in phantom. The illustrated pod 50 includes a UAV storage area 52, which is a hollow area within a protective housing 54. The housing 54 includes one or more panels or walls 56 that define the storage area 52, such as a bottom wall, sidewall(s), and top wall or lid. Where provided, the top wall or lid may be removable, retractable, hinged, or otherwise moveable away from a closed position to provide access to the storage area 52 from the top of the pod 50. The illustrated pod

50 also includes a docking pad 58, an attachment mechanism 60, an elevator 62, and a module changer 64, each located in the storage area 52 of the pod 50. While illustrated and described below as an integrated unit or subassembly that is attached to the land vehicle 12, the pod 50 may include only one of the illustrated components, one or more of the illustrated components may be omitted, or one or more additional components may be added.

The docking pad 58 supports the UAV when the UAV is in the docked position and cooperates with the attachment mechanism 60 to releasably attach the UAV to the land vehicle. The docking pad 58 may include alignment features 66 such as slots, grooves, or openings along a docking surface 68 that are complimentary in shape to features on the UAV body or legs to ensure that the UAV is properly positioned with respect to the attachment mechanism 60 and/or the module changer 64. The illustrated docking pad 58 also includes indicia 70 along the docking surface 68. The indicia 70 is useful in embodiments of the system in which the UAV is equipped with a camera and image recognition processing so that the UAV can locate the docking pad 58 when returning to the land vehicle from deployment. The illustrated indicia 70 is in an L-shape so that, prior to docking, the UAV can also be maneuvered to a desired rotational position with respect to a vertical axis for proper alignment with other pod components.

The illustrated attachment mechanism 60 includes clamps 72 adapted to restrain some portion of the UAV body with respect to the docking pad 58, for example by applying a clamping force to opposite sides of UAV legs between the docking surface 68 and clamping surfaces of the clamps. The clamps 72 in this example pivot between an illustrated open position, from which the UAV is releasable, and a closed position in which the UAV is attached to the land vehicle. The clamps 72 may be moved by electrically powered actuators or they may be configured for manual operation. In one embodiment, the attachment mechanism 60 includes one or more magnetic clamps, such as a magnet or electromagnet, that interact with another magnet or a ferromagnetic material attached to the UAV. Magnetic clamps can be positioned along the docking pad 58 at specific locations to ensure proper alignment or orientation of the UAV in the docked position or to help center the UAV on the docking pad 58. Alternatively, a magnetic attachment mechanism may include one or more portions of ferromagnetic material attached to the docking pad with corresponding magnets or electromagnets attached to the UAV.

The elevator 62 operates to move the docking pad 58 between a stowed position and an extended position. The extended position is characterized by the presence of a sufficient amount of space surrounding the UAV to facilitate deployment of the UAV when the UAV is in the docked position on the docking pad 58, and by the presence of a sufficient amount of space above the docking pad to facilitate landing the UAV on the docking pad. The stowed position is generally characterized by the docking pad 58 being closer to or further within the land vehicle than when in the extended position. In the illustrated embodiment, the stowed position is lower than the extended position, and the stowed position is characterized by the UAV being completely within the storage area 52 of the pod 50. The particular elevator 62 of FIG. 9 includes a scissor-lift mechanism that is operable to lift the docking pad 58 toward the extended position and lower the docking pad toward the stowed position. Elevator movement may be in one or more other directions, such as fore and aft or side-to-side. Or the docking pad 58 may be vertically oriented in the stowed position and pivot or otherwise move to be horizontally oriented in the extended position. Other movement mechanisms may be employed as well, such as rack-and-pinion gears, servo motors, power screws, pneumatic or hydraulic cylinders, solenoids, etc.

The module changer 64 is a mechanical or electromechanical mechanism that operates to attach and/or detach a UAV accessory module 28 to or from the UAV, such as via the accessory module port 26 illustrated in FIG. 2. In the example of FIG. 9, the system 10 includes a plurality of accessory modules 28, any one of which can be attached and/or detached to the UAV by the module changer 64 to render the one or more UAV accessories in each module 28 operable with the UAV while deployed. The illustrated module changer 64 carries up to four different accessory modules 28, each accessory module at a different module storage location 74 of the changer. During module detachment, an empty module storage location 74 is first moved into alignment with the occupied accessory port of the UAV. Then, the module changer 64 detaches the attached accessory module, rendering the accessory port unoccupied, and moves the detached module into the aligned storage location 74. During module attachment, a filled module storage location 74 is moved into alignment with an unoccupied accessory port of the UAV. Then, the module changer 64 moves the module in the aligned storage location 74 toward the unoccupied accessory port and attaches it to the UAV, rendering the aligned storage location empty. The combination of first detaching an accessory module from the UAV and then attaching a different accessory module to the UAV at the same accessory module port on the UAV is referred to as changing or interchanging accessory modules.

In the example of FIG. 9, each module storage location 74 is provided by a cartridge 76 adapted to fit the particular accessory module 28 that can be stored there. In this case, each cartridge 76 is cylindrical, and the individual accessory modules move horizontally out of the cartridge during UAV attachment and horizontally into the cartridge during detachment. Movement of the desired cartridge 76 into or out of alignment with the UAV accessory port of the UAV is achieved by simultaneous rotation of the multiple cartridges about a horizontal axis *A* of the changer 64. Each cartridge 76 may be self-leveling – i.e., the cartridge freely rotates about its own central axis during rotation about the changer axis and is weighted to maintain a constant angular orientation. Gearing, motors, or other mechanisms could also be used to maintain constant angular orientation. Other arrangements are possible, such as stationary cartridges with UAV movement to align accessory modules with the accessory port, attachment/detachment from beneath the UAV, or a pick-and-place mechanism, for example.

The module changer 64 can operate in an identical manner to attach and/or detach a UAV power module, such as a rechargeable battery or other replenishable energy source, to or from the UAV via a power port of the UAV. Any one or more of the storage locations 74 of the changer 64 may carry a power module and be brought into alignment with the UAV power port to attach the power module to the UAV after a different power module has been detached from the power port and moved into an empty storage location of the changer.

FIG. 10 is a side schematic view of the module changer 64 of FIG. 9 configured to simultaneously attach or detach a pair of modules, one of which is an accessory module 28, and one of which is a power module 78. In this example, the UAV 14 includes a power port 80 located above the accessory module port 26 so that the power module 78 is in a stacked arrangement over the accessory module 28 when installed together in the UAV. The module changer 64 is configured so that one of its cartridges 76 is aligned with the power port 80 when another one of its cartridges is aligned with the accessory module port 26. In the illustrated example, the accessory module 28 and the power module 78 are positioned to be moved toward and attached to the UAV at respectively unoccupied ports 26, 80. Each cartridge 76 in this example includes an actuator 82 configured to move the desired module 28, 78 toward or away from the UAV. The changer 64 may employ a key pin system to push and pull the modules into and out of their respective ports on the UAV.

FIG. 11 is a schematic end view of a portion of the 4-way module changer of FIG. 9 shown with all four of the illustrated cartridges 76 containing either an accessory module 28 or a power module 78. The four cartridges 76 are equally spaced around the axis *A* of the changer 64 and are configured to rotate together about the changer axis. A 90° rotation moves a different module 28, 78 into position for installation and attachment to the UAV. FIG. illustrates a similar arrangement in the form of a 2-way module changer. Each changer 64 can be configured to rotate the cartridges 76 in one or both rotational directions. Other changer configurations are possible, such as a changer having a plurality of cartridges 76 or other module storage locations arranged horizontally or vertically adjacent one another and configured to move the desired cartridge into alignment with the UAV port to attach or detach the appropriate accessory module.

In some embodiments, the power module 78 includes a replenishable energy source, such as a rechargeable battery. The system 10 may be equipped to replenish the energy source. For example, the UAV 14 and the docking pad 58 of FIG. 9 may each include electrical contacts that cooperate to connect a rechargeable battery installed in the UAV with a power source on the vehicle to recharge the battery while the UAV is in the docked position. In another example, a non-contact battery charger may be carried by the docking pad 58 and operate to recharge the battery while installed in the UAV while the UAV is in the docked position. Where a module changer such as those illustrated in FIGS. 9-12 is employed, each power module storage location of the changer may be equipped with charging components such as electrical contacts or induction units that are powered external to the UAV to allow replenishment of unused power modules even while the UAV is deployed.

One or more embodiments of the system described above may be used to carry out a method of using an unmanned autonomous vehicle (UAV) to provide one or more support operations for a land vehicle from a location remote of the land vehicle. The method may generally include deploying the UAV from a docked position on the land vehicle and operating a UAV accessory carried by the UAV while the UAV is away from the land vehicle. Several non-limiting examples are described below.

In one embodiment, illustrated by example in FIG. 6, the support operation provided by the UAV system to the land vehicle may include mobile telephone signal boosting. This type of support operation provides a stronger and/or more stable wireless telecommunications signal at the land vehicle than is available at the land vehicle without the UAV and effectively increases the wireless communications range of the land vehicle. In signal boost mode, the UAV may be deployed from the land vehicle using an in-vehicle or app-based button or other user input device. In this example, the UAV is an aerial drone that, when deployed, flies vertically upward and away from the land vehicle to a location at which a signal receiver or transceiver operably attached to the UAV can receive a desired telecommunications signal from a remote location that is sufficiently strong. The transceiver or a separate signal transmitter operably attached to the UAV can relay the received telecommunications signal to the land vehicle. The at least one UAV accessory in this case may include separate signal transmitters and receivers, a combined transceiver, one or more antennas, and/or a signal booster configured to amplify a telecommunications signal received from one location (i.e., the land vehicle or the communications tower) before relaying it to the other location via a different signal. The UAV can hover at the relaying location until the signal boost mode is deactivated, which may be accomplished via user input or by auto-deactivation when the UAV energy source is depleted to the minimum amount of power required to return to the land vehicle. The UAV may also be configured to measure and/or monitor the telecommunications signal strength to determine an optimum distance above the land vehicle and/or to navigate to another location if necessary to maintain sufficient signal strength, for example if the land vehicle moves. The UAV may also be configured to measure signal strength between the land vehicle or app-based device and the UAV to ensure a communication link with the UAV is not interrupted. Signal boost mode may be used in a similar manner to effectively increase the wireless communication range of any wireless communication device and is not limited to the land vehicle, nor is it limited to cellular telecommunications signals. The effective range of wi-fi or satellite signals could be increased as well, for example, such as in the case that a terrain obstruction (e.g. a cave wall) is blocking a GPS satellite signal.

In another embodiment, illustrated generally in FIG. 7, the at least one UAV accessory includes a distress beacon, and the support operation provided by the UAV system to the land vehicle is emergency assistance. In a specific example, the UAV system is configured to operate in an emergency mode and functions to visually and/or audibly provide or increase awareness regarding the location of the land vehicle and/or its passengers to a remote observer. The emergency mode can be activated when the vehicle is in distress (e.g., the land vehicle is damaged, inoperable, on non-navigable terrain, etc.) or when a vehicle occupant has experienced a medical emergency. When emergency mode is activated, the UAV may be deployed to a location upward and away from the land vehicle to deploy or activate the distress beacon. In one particular example, the distress beacon is an audio-visual flare that can be heard and/or seen by an observer located remote to the land vehicle. The UAV flight time and/or energy source power level may be monitored so that the UAV can periodically be deployed, activate the distress beacon, return to the land vehicle, and dock to replenish the energy source or to obtain a different non-depleted energy source stored at the land vehicle. These steps can be repeated until emergency mode is deactivated, for example by user input via an in-vehicle or app-based device button. The UAV system may also be configured so that an emergency service can remotely deploy the UAV in emergency mode to activate the distress beacon when emergency service personnel are in close proximity to the land vehicle. For example, in the event of an accident, the emergency service may be notified by a vehicle occupant and/or by a vehicle-based emergency service system. Upon approach to the land vehicle location, emergency personnel can initiate wireless communication with the UAV system to deploy the UAV to assist in determining a more precise location of the land vehicle. The system may be configured so that the emergency service can control the UAV remotely through an app-based device. In this case, when within range of the land vehicle, the application can notify the emergency service, and the UAV can be deployed by emergency service personnel, such as by pressing an app-based button. The UAV can then attempt to fly away from the land vehicle (e.g., vertically) and deploy the distress beacon to aid emergency personnel in the search for the land vehicle and/or its occupants.

The audio-visual flare distress beacon is configured to emit an audible sound and a visible light. The visible light can be produced via an LED, strobe, or laser source, for example. The distress beacon may also or alternatively be configured to emit a signal that is not detectable by human senses but detectable by other detection devices, such as light in the infrared spectrum, radio carrier waves, or ultrasonic sound waves. In one example, the distress beacon is configured to emit a signal containing the GPS coordinates of the UAV, the land vehicle, and/or the location at which the emergency mode was activated.

In other embodiments, the UAV system includes a terrain mapping mode in which the at least one UAV accessory includes a terrain sensor and the provided support operation includes obtaining information pertaining to the terrain that is usable by the UAV system to aid the UAV system, the land vehicle, and/or the driver in selecting a traversable path along the terrain. In a particular example, the UAV accessory includes a camera and/or lidar device that operates to obtain information pertaining to the contour or topography of the terrain at a terrain mapping zone. In this case, the UAV system also includes a processor configured to process the obtained information to provide the driver or system with comprehensive information useful to select a desired path or to otherwise inform the driver about the surrounding terrain and/or terrain features. For instance, the UAV system may include a camera, optical device, or lidar device that is operably attached to the UAV. When deployed, the UAV can autonomously navigate to a location ahead of the vehicle and scan the terrain to obtain topography information. The UAV can transmit the scanned image or information to the land vehicle via wireless communication to be processed. The processed image or information can alert or be used to alert the driver if the land vehicle will not be able to continue its forward motion. In some embodiments, a user can select an area to be scanned by the UAV (i.e., the terrain mapping zone) via an on-board mapping feature of the land vehicle or app-based device. The desired terrain mapping zone can be transmitted to the UAV via wireless communication, and the obtained images or information can be transmitted back to the user through an in-vehicle display device, such as an onboard screen. In other examples, the UAV can receive information regarding the desired terrain mapping zone and/or the UAV can transmit the obtained terrain information to the land vehicle while docked, either wirelessly or via wired electrical connection.

In another example of the terrain mapping mode, the UAV and UAV accessory can be used to monitor upcoming terrain and adjust vehicle settings before the vehicle reaches the terrain. This type of support operation may be provided as part of a terrain forecast mode. In a particular example, a user in the vehicle initiates the terrain forecast mode via a user interface such as an in-vehicle or app-based button. The UAV is then deployed from the vehicle by a particular distance (e.g., up to 10 meters) ahead of the land vehicle and scans the terrain for changes in the terrain, terrain features, or obstacles. When a change in terrain is detected, the UAV system informs an onboard computer or processor of the land vehicle via wireless transmission. The transmitted information includes a combination of the location of the terrain and the terrain type. The processor is configured to split the data and use the location portion of the data to alter the vehicle set-up, if necessary, through an onboard vehicle network at the appropriate location along the path along which the land vehicle is traveling. The terrain type portion of the data is used to select the terrain response setting needed at that location (e.g., ride height, suspension stiffness, etc.).

In another example, the UAV system is used to measure the flow of a body of water. In this case, the UAV accessory or module includes a flow meter that is deployable from the UAV to be suspended below the UAV. In a particular example, a user in the vehicle initiates the water feature assessment mode via a user interface such as an in-vehicle or app-based button. The

UAV navigates to a location above the water feature, similar to the illustration in FIG. 5. The flow meter is then deployed from the UAV, for example by a second user input from the land vehicle, and lowered into the water. The flow meter sends data to the land vehicle via wireless transmission either directly or via the UAV. The data is processed at the vehicle or the UAV, and the system informs the driver if the flow of the water is too fast for the land vehicle to cross.

In another example, the UAV system is used to measure the depth of a body of water, as generally illustrated in FIG. 5. In this case, the UAV accessory or module includes a sonar module that is deployable from the UAV to be suspended below the UAV. In a particular example, a user in the vehicle initiates the water depth assessment mode via a user interface such as an in-vehicle or app-based button. The UAV navigates to a location above the water feature, and the sonar module is then deployed from the UAV, for example by a second user input from the land vehicle, and lowered into the water. The sonar module sends data to the land vehicle via wireless transmission either directly or via the UAV. The data is processed at the vehicle or the UAV, and the system informs the driver if the depth of the water is too great for the land vehicle to cross the water feature.

In another example, the UAV system is used to measure the flow rate of a water feature via optical information. In this case, the UAV accessory or module includes a camera or other optical device to obtain sequentially timed images of the surface of the water feature. The images can be compared and correlated by a system processor to determine the flow rate of the water in the water feature, and the system can inform the driver if the flow rate is too fast and/or unsafe for the vehicle to traverse the water feature. The UAV may hover over the water feature near the surface of the water feature to obtain the optical information, or an optical device can be deployed and suspended over the surface of the water feature to obtain the information.

In another example, the UAV system can operate in a terrain projection mode to provide guidance to the driver or land vehicle for traversing the terrain. In this case, the UAV accessory or module includes an image projector to provide the guidance information. In a particular example, a user in the vehicle initiates the terrain projection mode via a user interface such as an in-vehicle or app-based button. Via wireless communication between the land vehicle and the UAV, the user can choose the particular terrain mapping zone, and the UAV projects information pertaining to the selected terrain onto the ground. In some embodiments, onboard guidance settings allow the user to select a “drone view” mode, in which the UAV is deployed and directed to hover just in front of the vehicle above the driver view of the driver. The UAV can receive previously obtained terrain information from the land vehicle and project the information on the ground in front of vehicle to assist the driver in traversing the terrain.

In another example, the UAV system can operate in a racetrack or obstacle course mode. In this case, the UAV accessory of module includes a camera. In a particular example, a user in the vehicle initiates the racetrack mode via a user interface such as an in-vehicle or app-based button. The UAV is deployed and navigates to a maximum height (e.g. a maximum distance from the land vehicle at which communication to and from the land vehicle can be maintained) and obtains imagery of the terrain below. The imagery is transmitted to the land vehicle or app-based device. In one embodiment, the user can select a desired route or path on a touch-screen input device by tracing the desired route on the touch-screen while the screen displays the obtained imagery. A UAV system processor then determines or suggests interesting points of view based on the traced route, measuring an average change of bearing between pairs of waypoints determined along the route and using the greatest average to determine an image collection viewpoint between waypoints. The UAV then operates to travel ahead of the land vehicle to each image collection viewpoint to obtain imagery that includes the land vehicle as it moves along the selected route. The UAV system may also operate to calculate time between waypoints or viewpoints via use of GPS information. Using the known UAV position, altitude, and camera field of view, the instant distance to one of the waypoints or viewpoints can be determined, and UAV speed can be used to then calculate an instant time-to-reach each point.

In another example, the UAV system can operate in a landing mode in which a landing or docking location at the land vehicle is tracked. In a particular example, the UAV accessory or module includes a camera or other optical device that provides imagery for an image recognition function of the system to recognize the landing site when the UAV reaches a location over the site while returning to the land vehicle from deployment. The UAV (e.g., the legs of the UAV) may be fitted with magnetic or electromagnetic elements and the docking location may be fitted with similar elements of opposite polarity. In one embodiment, the landing pad has a conical shape with magnetic elements arranged about a base edge of the landing pad. When the UAV is in close proximity, the magnetic elements facilitate proper alignment of the UAV with the landing pad. The landing mode may also include use of a near-field communication device to deactivate the propulsion system of the UAV as the UAV approaches the docked position from deployment and, in particular, when the UAV reaches a position on or just above (e.g., on the millimeter scale) the landing pad.

The UAV system may also operate in a docking pad configuration mode to move the above-described docking pad between the extended and stowed positions. In a particular example, the elevator may operate to move the docking pad from the stowed position to the extended position upon initiation via in-vehicle or app-based user input while the UAV is attached to the land vehicle at the docking pad. The attachment mechanism is then deactivated for UAV deployment. Upon UAV deployment, the elevator may operate to return the docking pad to the stowed position upon user input or upon system detection that the UAV is no longer on the docking pad, such as via a weight sensor or proximity sensor. In-vehicle or app-based information is made available to the user indicating the present position of the docking pad (i.e., extended, stowed, or in transition).

In another example, the UAV system operates in an accessory module changing mode via the above-described accessory module changer. The accessory module changer includes a plurality of self-leveling cartridges and a powered sliding mechanism (e.g., an actuator) that extends and retracts a cartridge shelf that holds a UAV accessory module. The accessory module may be selected via user-input (e.g., in-vehicle or app-based), and the accessory module changer operates to position the desired accessory module in alignment with the appropriate accessory module port of the UAV. The actuator can then push the desired accessory module into the accessory module port and/or remove an accessory module from the UAV when required.

It is to be understood that the foregoing description is not a definition of the invention, but is a description of one or more preferred exemplary embodiments of the invention. The invention is not limited to the particular embodiment(s) disclosed herein, but rather is defined solely by the claims below. Furthermore, the statements contained in the foregoing description relate to particular embodiments and are not to be construed as limitations on the scope of the invention or on the definition of terms used in the claims, except where a term or phrase is expressly defined above. Various other embodiments and various changes and modifications to the disclosed embodiment(s) will become apparent to those skilled in the art. All such other embodiments, changes, and modifications are intended to come within the scope of the appended claims.

As used in this specification and claims, the terms “for example,” “e.g.,” “for instance,” “such as,” and “like,” and the verbs “comprising,” “having,” “including,” and their other verb forms, when used in conjunction with a listing of one or more components or other items, are each to be construed as open-ended, meaning that that the listing is not to be considered as excluding other, additional components or items. Other terms are to be construed using their broadest reasonable meaning unless they are used in a context that requires a different interpretation.

CLAIMS

1. An unmanned autonomous vehicle system for use with a land vehicle, the system comprising:

an unmanned autonomous vehicle (UAV) that is deployable from a docked position on the land vehicle, wherein the UAV is configured to releasably attach to the land vehicle in the docked position and move autonomously away from the land vehicle when deployed; and

at least one UAV accessory attached to the UAV and configured to operate while the UAV is deployed, wherein the UAV and the at least one UAV accessory together provide one or more support operations for the land vehicle at a location remote of the land vehicle.

2. The system as defined in claim 1, wherein the UAV comprises an accessory module port and the system comprises an accessory module removably attached to the UAV via the accessory module port, the accessory module comprising the at least one UAV accessory.

3. The system as defined in claim 2, comprising a plurality of accessory modules, each accessory module including at least one UAV accessory and being interchangeable with the accessory module that is removably attached to the UAV via the accessory module port, wherein the removably attached accessory module is one of the plurality of accessory modules, each UAV accessory being configured to operate when attached to the UAV while the UAV is deployed to, together with the UAV, provide one or more support operations for the land vehicle.

4. The system as defined in claim 3, comprising a module changer carried by the land vehicle, wherein the module changer removably holds each of the plurality of accessory modules when not attached to the UAV, the module changer being configured to detach any one of the plurality of accessory modules from the accessory module port and to attach any one of the plurality of accessory modules to the UAV via the accessory module port while the UAV is not deployed.

5. The system as defined in any one of the preceding claims, wherein the at least one UAV accessory is permanently attached to the UAV.

6. The system as defined in any one of the preceding claims, wherein the at least one UAV accessory includes a signal receiver and a signal transmitter, the signal receiver being

configured to receive a first information-containing signal originating from a location other than the land vehicle, and the signal transmitter being configured to transmit a second information-containing signal to the land vehicle, the information contained in the second signal being usable by the land vehicle to provide one or more support operations for the land vehicle.

7. A system as defined in claim 6, wherein the signal receiver comprises an antenna configured to receive a telecommunications signal that is relayed to the land vehicle via the second information-containing signal.

8. A system as defined in claim 6 or claim 7, comprising a processor that processes the information contained in the first signal to provide one or more support operations for the land vehicle.

9. A system as defined in claim 8, wherein the UAV includes the processor, whereby the information contained in the first signal can be processed at the UAV and the signal transmitter transmits the UAV-processed information to the land vehicle via the second signal.

10. A system as defined in claim 8, wherein the land vehicle includes the processor, whereby the signal transmitter transmits the information contained in the first signal to the land vehicle via the second signal to be processed by the land vehicle.

11. A system as defined in any one of the preceding claims, wherein the at least one UAV accessory includes a terrain sensor operable to obtain information pertaining to the terrain at a terrain mapping zone located away from the land vehicle.

12. A system as defined in claim 11, wherein the terrain sensor comprises a camera, said information including imagery of the terrain at the terrain mapping zone.

13. A system as defined in claim 12, wherein the camera is further operable to obtain information pertaining to a UAV landing location at the land vehicle.

14. A system as defined in claim 11, wherein the terrain sensor comprises a sonar module, said information pertaining to the topography of the terrain at the terrain mapping zone.

15. A system as defined in claim 11, wherein the terrain sensor comprises a lidar module, said information pertaining to the topography of the terrain at the terrain mapping zone.

16. A system as defined in claim 11, wherein the terrain sensor comprises a fluid flow rate sensor, said information pertaining to the flow rate of a water feature at the terrain mapping zone.

17. A system as defined in any one of claims 11 to 15, wherein the terrain sensor is deployable from a stowed position on the UAV and spaced away from the UAV when deployed, the terrain sensor being in communication with the UAV while deployed.

18. A system as defined in claim 11, wherein the terrain sensor comprises a water sensor, said information pertaining to the presence of a water feature at the terrain mapping zone.

19. A system as defined in claim 18, wherein the water sensor comprises an ultrasonic transducer.

20. A system as defined in any one of the preceding claims, wherein the at least one UAV accessory includes a distress beacon operable to emit a distress signal while the UAV is deployed.

21. A system as defined in any one of the preceding claims, comprising an attachment mechanism that releasably attaches the UAV to the land vehicle while in the docked position.

22. A system as defined in claim 21, wherein the attachment mechanism comprises a magnet carried by the UAV and/or carried by the land vehicle, whereby the UAV is magnetically attached to the land vehicle while in the docked position.

23. A system as defined in any one of the preceding claims, comprising:

a replenishable energy source carried by the UAV that powers the UAV and/or the at least one UAV accessory while the UAV is deployed; and

an energy source replenisher carried by the land vehicle and configured to replenish the energy source when the energy source is attached to the land vehicle.

24. A system as defined in claim 23, wherein the energy source replenisher is configured to replenish the energy source while the UAV is in the docked position.

25. A system as defined in claim 23, wherein the energy source replenisher is configured to replenish the energy source while the UAV is deployed.

26. A system as defined in any one of the preceding claims, comprising a docking pad attached to the land vehicle, the docking pad being moveable between a stowed position and an extended position, wherein the UAV can be deployed from and landed on the docking pad when the docking pad is in the extended position, and wherein the UAV cannot be deployed from or landed on the docking pad when the docking pad is in the stowed position.

27. A system as defined in any one of the preceding claims, comprising a docking pad attached to the land vehicle, wherein the at least one UAV accessory includes a camera and the system is configured to locate the docking pad via imagery obtained by the camera when returning to the land vehicle from deployment.

28. A system as defined in any one of the preceding claims, wherein the at least one UAV accessory includes an image projector configured to project an image onto the terrain in front of the land vehicle, wherein the image includes information pertaining to the terrain at a terrain mapping zone.

29. A system as defined in any one of the preceding claims, comprising a visual display carried by the land vehicle and visible to an occupant of the land vehicle, wherein the visual display displays information pertaining to the terrain in front of the land vehicle and at a terrain mapping zone.

30. A system as defined in any one of the preceding claims, wherein the UAV comprises a navigation receiver that receives a navigation signal from the land vehicle, the navigation signal being used by the UAV to change the position of the UAV with respect to the terrain.

31. A system as defined in claim 30, wherein the navigation receiver wirelessly receives the navigation signal from the land vehicle.

32. A system as defined in any one of the preceding claims, wherein the at least one UAV accessory includes a terrain sensor, the system further comprising a processor configured to determine a path along the terrain along which a self-steering system of the land vehicle can navigate the land vehicle, the path being based at least in part on information obtained by the terrain sensor.

33. A system as defined in any one of the preceding claims, wherein the UAV is an aerial vehicle.

34. A land vehicle comprising the system as defined in any one of the preceding claims.

35. A land vehicle for use in the system defined in any one of the preceding claims, the land vehicle comprising:

means configured to dock a UAV,

means configured to receive and process a signal from at least one UAV accessory attached to the UAV

36. A UAV for use in the system defined in any one of the preceding claims for use with a land vehicle, the UAV comprising:

means configured to releasably attach to the land vehicle

means configure to move autonomously away from the land vehicle when deployed; and

at least one UAV accessory configured to operate while the UAV is deployed.

37. A method of using an unmanned autonomous vehicle (UAV) to provide one or more support operations for a land vehicle, the method comprising:

deploying the UAV from a docked position on the land vehicle, wherein the UAV is configured to releasably attach to the land vehicle in the docked position and move autonomously away from the land vehicle when deployed; and

operating a UAV accessory carried by the UAV while the UAV is away from the land vehicle, wherein the UAV and the UAV accessory together provide one or more support operations for the land vehicle from a location remote of the land vehicle.

38. The method of claim 37, further comprising:

detaching the UAV accessory from an accessory module port of the UAV and attaching a different UAV accessory to the UAV via the accessory module port.

39. The method of claim 38, wherein detaching the UAV accessory and attaching the different UAV accessory are performed using a module changer while the UAV is in the docked position.

40. The method of any one of claims 37 to 39, further comprising:

receiving a first information-containing signal at the UAV, the first signal originating from one of: the land vehicle or a location away from the land vehicle; and

transmitting a second information-containing signal from the UAV to be received at the other one of: the land vehicle or said location away from the land vehicle.

41. The method of claim 40, wherein the land vehicle is at a location at which the first signal cannot be received directly from the said originating location, whereby relaying the signal effectively increases the wireless telecommunications range of the land vehicle.

42. The method of claim 40 or claim 41, further comprising processing the information contained in the first signal at the UAV, wherein the information contained in the second signal is processed information.

43. The method of any one of claims 38 to 42, further comprising processing the information contained in the second signal at the land vehicle.

44. The method of any one of claims 37 to 43, wherein operating the UAV accessory comprises obtaining information via operation of the UAV accessory, said information pertaining to the terrain at a terrain mapping zone located away from the land vehicle.

45. The method of claim 44, wherein said information includes imagery of the terrain at the terrain mapping zone.

46. The method of claim 44, wherein said information pertains to the topography of the terrain at the terrain mapping zone.

47. The method of claim 44, wherein said information pertains to the depth of a water feature at the terrain mapping zone.

48. The method of claim 44, wherein said information pertains to the flow rate of a water feature at the terrain mapping zone.

49. The method of claim 44, wherein said information pertains to the presence of a water feature at the terrain mapping zone.

50. The method of any one of claims 37 to 49, wherein operating the UAV accessory comprises:

deploying the UAV accessory toward the terrain and away from the UAV from a stowed position on the UAV; and

receiving at the UAV an information-containing signal from the deployed UAV accessory, the information contained in the signal being usable to provide the one or more support operations when said information is processed.

51. The method of claim 50, wherein a sensor of the UAV accessory is located in a water feature when the UAV accessory is deployed.

52. The method of any one of claims 37 to 51, wherein operating the UAV accessory includes emitting a distress signal from the UAV accessory.

53. The method of any one of claims 37 to 52, further comprising: releasably attaching the UAV to the land vehicle after deploying the UAV and operating the UAV accessory.

54. The method of claim 53, wherein releasably attaching the UAV includes magnetically attaching.

55. The method of any one of claims 37 to 54, further comprising: replenishing an energy source carried by the UAV while the UAV is attached to the land vehicle.

56. The method of any one of claims 37 to 55, further comprising: moving a docking pad carried by the land vehicle between a stowed position and an extended position while the UAV is attached to the land vehicle via the docking pad.

57. The method of any one of claims 37 to 54, further comprising:

using the UAV accessory to locate a docking pad carried by the land vehicle after deploying the UAV and operating the UAV accessory while the UAV is away from the land vehicle; and

landing the UAV at the docking pad.

58. The method of claim 57, wherein the UAV accessory is a camera, using the UAV accessory to locate the docking pad includes recognition of the docking pad from imagery obtained by the camera.

59. The method of claim any one of claims 37 to 58, further comprising:

operating the UAV accessory to obtain information pertaining to the terrain at a terrain mapping zone located away from the vehicle;

processing said information to select a path along the terrain along which it is desired to guide the land vehicle; and

providing guidance to help guide the land vehicle along the path.

60. The method of claim 59, wherein providing guidance includes projecting an image onto the terrain in front of the land vehicle, the image being visible to a driver of the land vehicle and indicating the selected path so that the driver can use the image to guide the land vehicle along the path.

61. The method of claim 59, wherein providing guidance includes displaying an image on a visual display visible to a driver of the land vehicle, the image indicating the selected path so that the driver can use the image to guide the land vehicle along the path.

62. The method of claim 59, wherein providing guidance includes navigating the UAV along the selected path, the UAV being visible to a driver of the land vehicle so that the driver can follow the UAV to guide the land vehicle along the path.

63. The method of claim 59, wherein providing guidance includes operating a self-steering system of the land vehicle to guide the land vehicle along the selected path.

64. The method of any one of claims 37 to 63, further comprising:

selecting a path along the terrain along which the land vehicle is to be guided; and

presenting a visual indicator pertaining to the location of the path with respect to the terrain such that the visual indicator is visible to a driver of the land vehicle.

65. The method of claim 64, wherein selecting the path is performed by a user via a user input device.

66. The method of claim 64, wherein selecting the path is performed by a processor based at least in part on information obtained by the UAV accessory while the UAV is deployed, said information pertaining to the terrain at a terrain mapping zone.

67. The method of claim 64, wherein presenting the visual indicator includes projecting an image onto the terrain in front of the land vehicle, the image being visible to a driver of the land vehicle and indicating the selected path so that the driver can use the image to guide the land vehicle along the path.

68. The method of claim 64, wherein presenting the visual indicator includes displaying an image on a visual display carried by the land vehicle, the image indicating the selected path so that the driver can use the image to guide the land vehicle along the path.

69. The method of claim 68, wherein the UAV accessory comprises a camera and the method comprises capturing images of the land vehicle while the UAV is deployed and while the land vehicle is being guided along the path.

70. A method comprising:

maneuvering an unmanned autonomous vehicle (UAV) over terrain at a terrain mapping zone located away from a land vehicle;

obtaining information pertaining to the terrain at the terrain mapping zone using one or more UAV accessories; and processing the information to determine whether a path along the terrain mapping zone can be selected such that the land vehicle can safely traverse the terrain mapping zone by following the path.

71. The method of claim 70, further comprising: providing guidance to help guide the land vehicle along the path if the path can be selected.

72. The method of claim 70, further comprising: providing an indication to a driver of the land vehicle that no safe path can be selected.

73. The method of claim 70, wherein processing the information comprises mapping the depth of a water feature located at the terrain mapping zone.

74. The method of claim 73, wherein the one or more UAV accessories includes a sonar device in communication with the UAV.

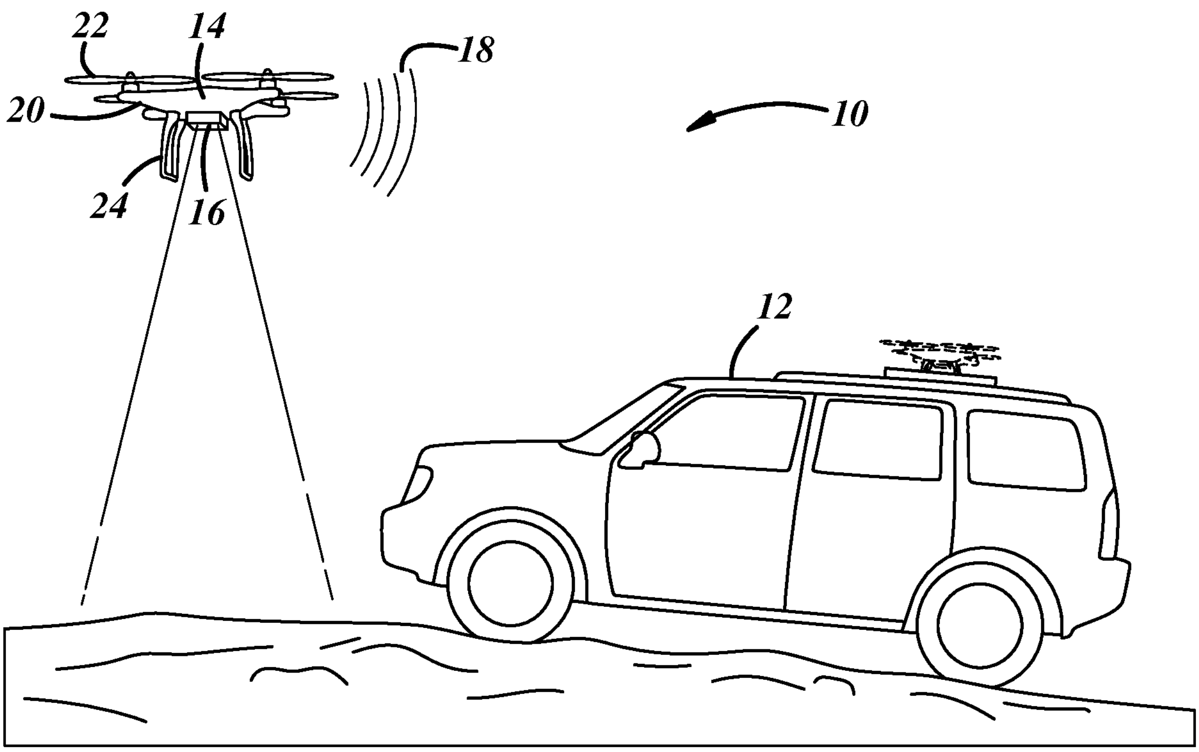

FIG. 1

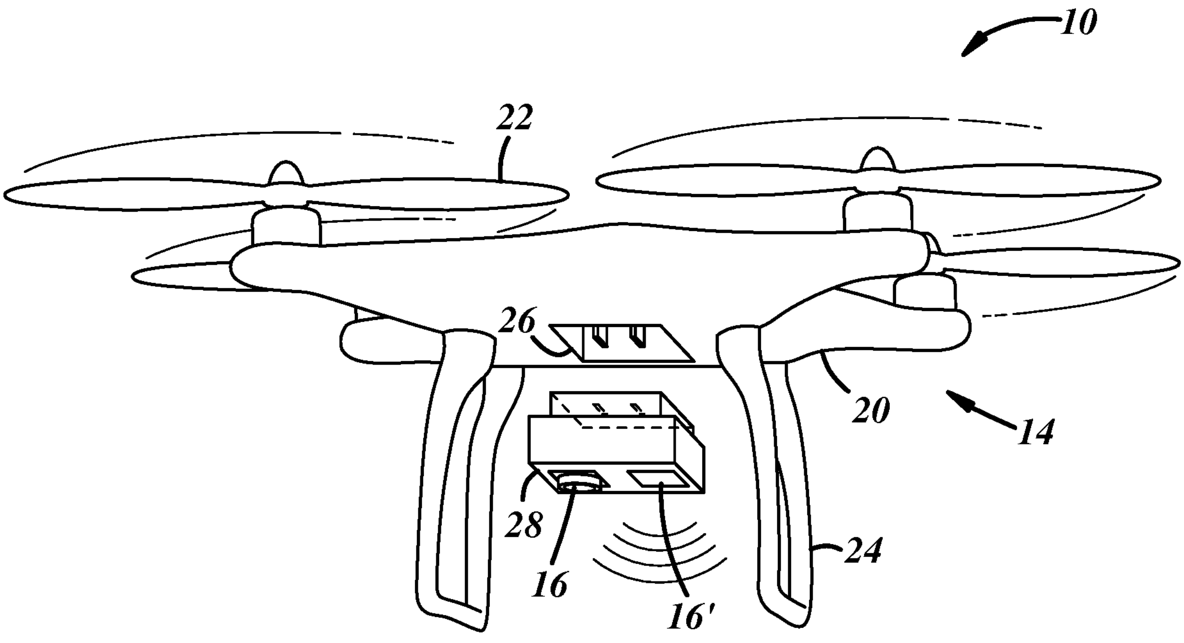

FIG. 2

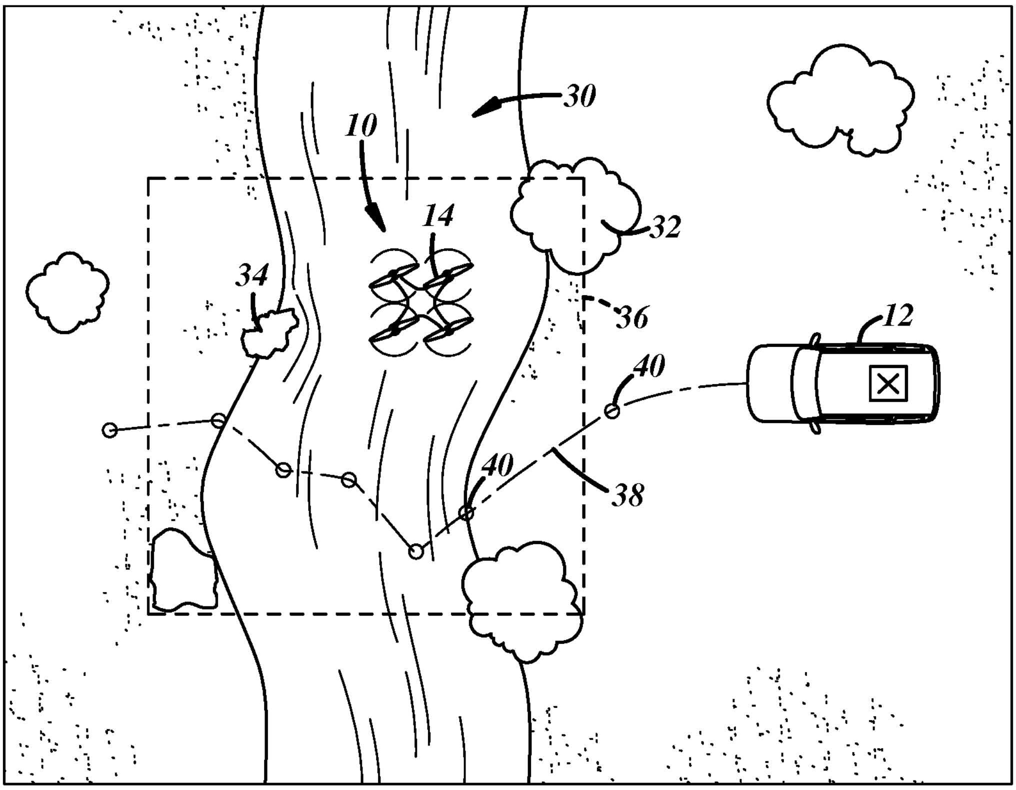

FIG. 3

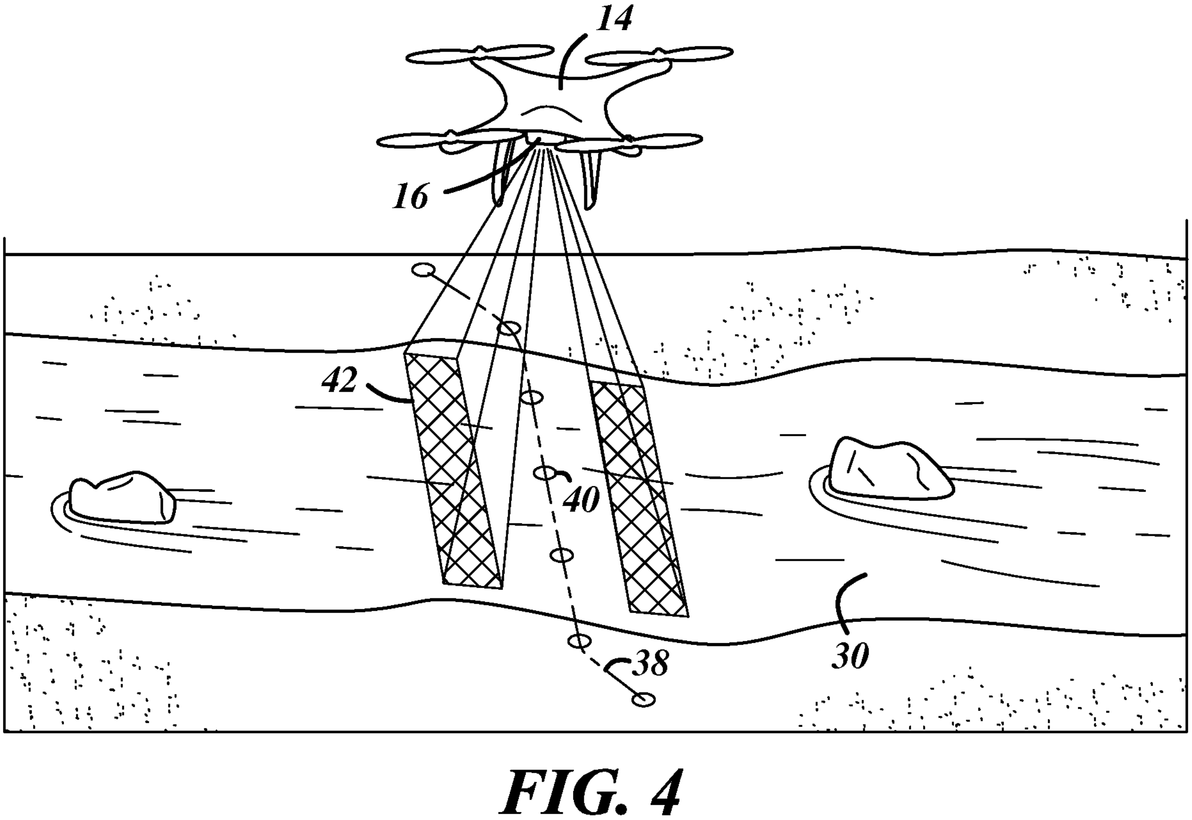

FIG. 4

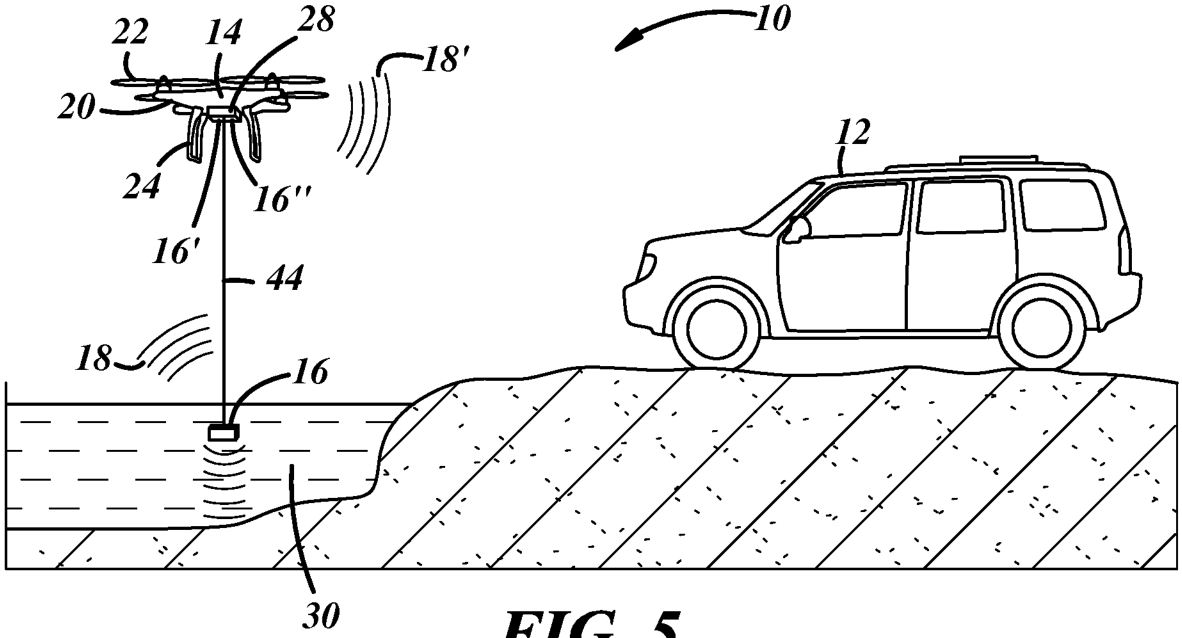

FIG. 5

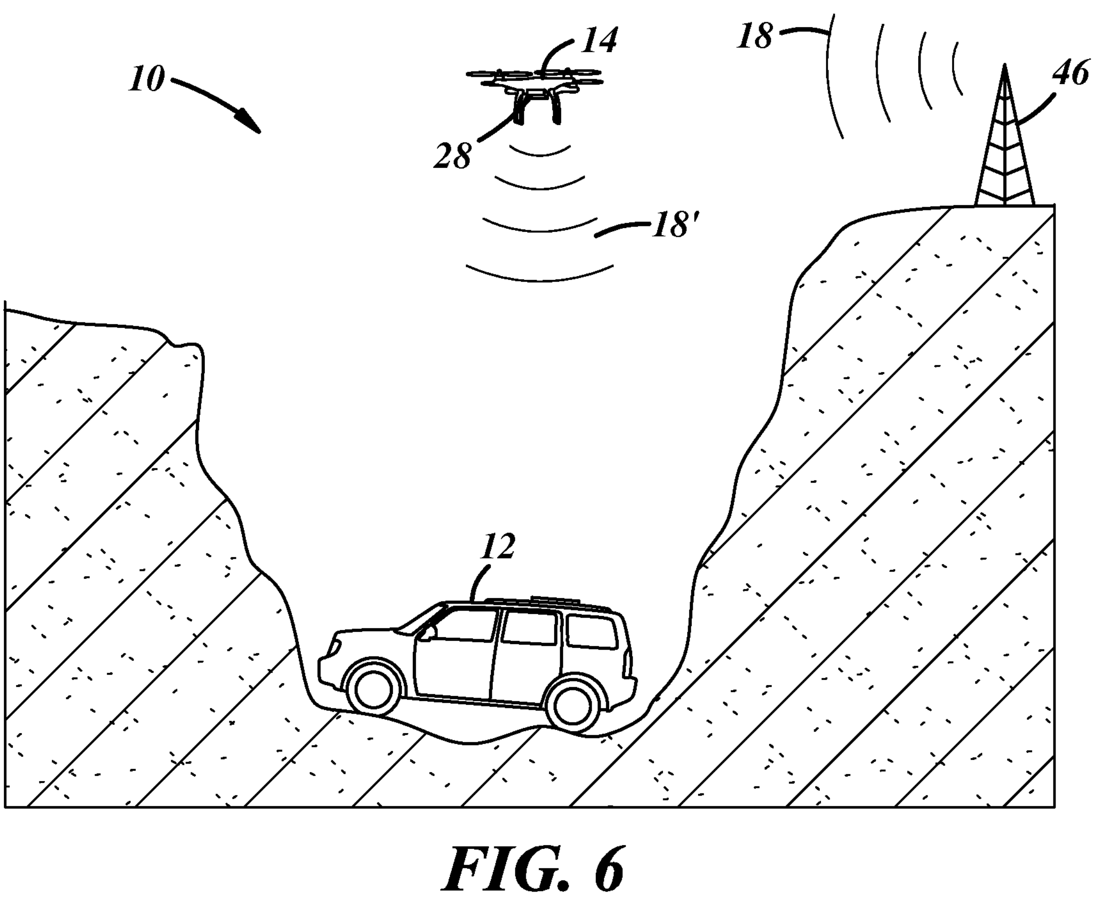

FIG. 6

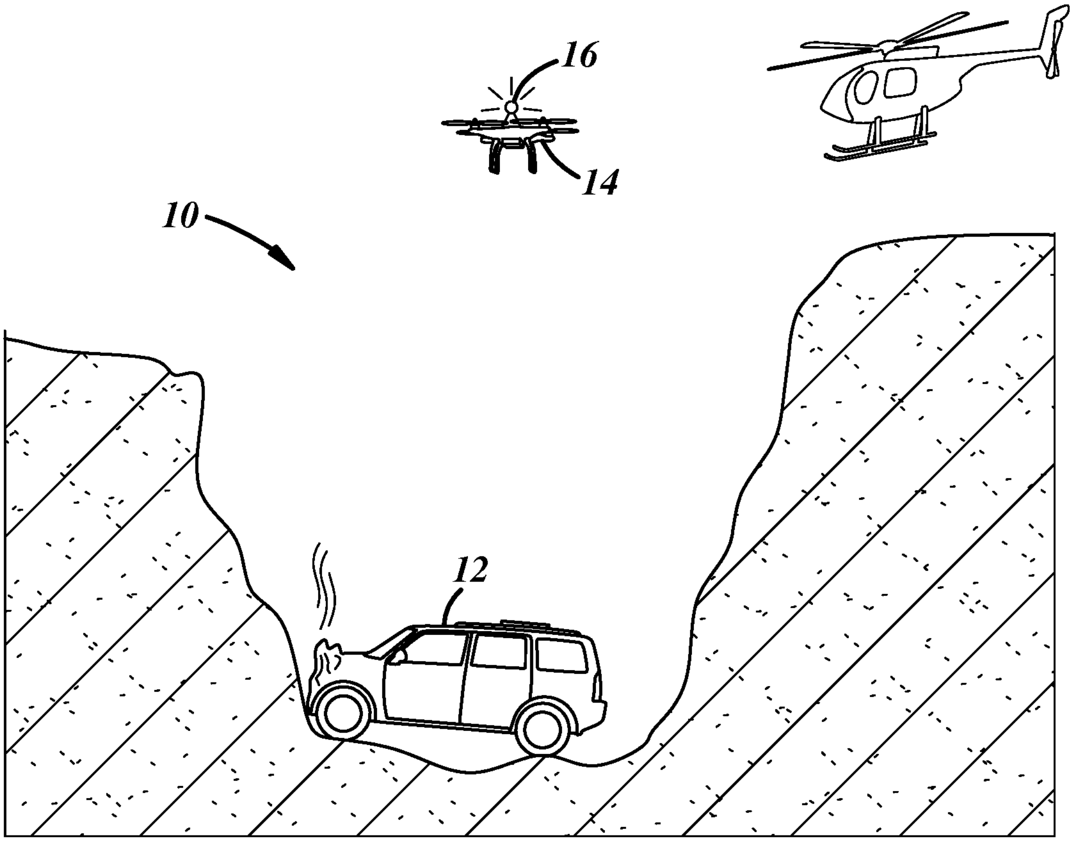

FIG. 7

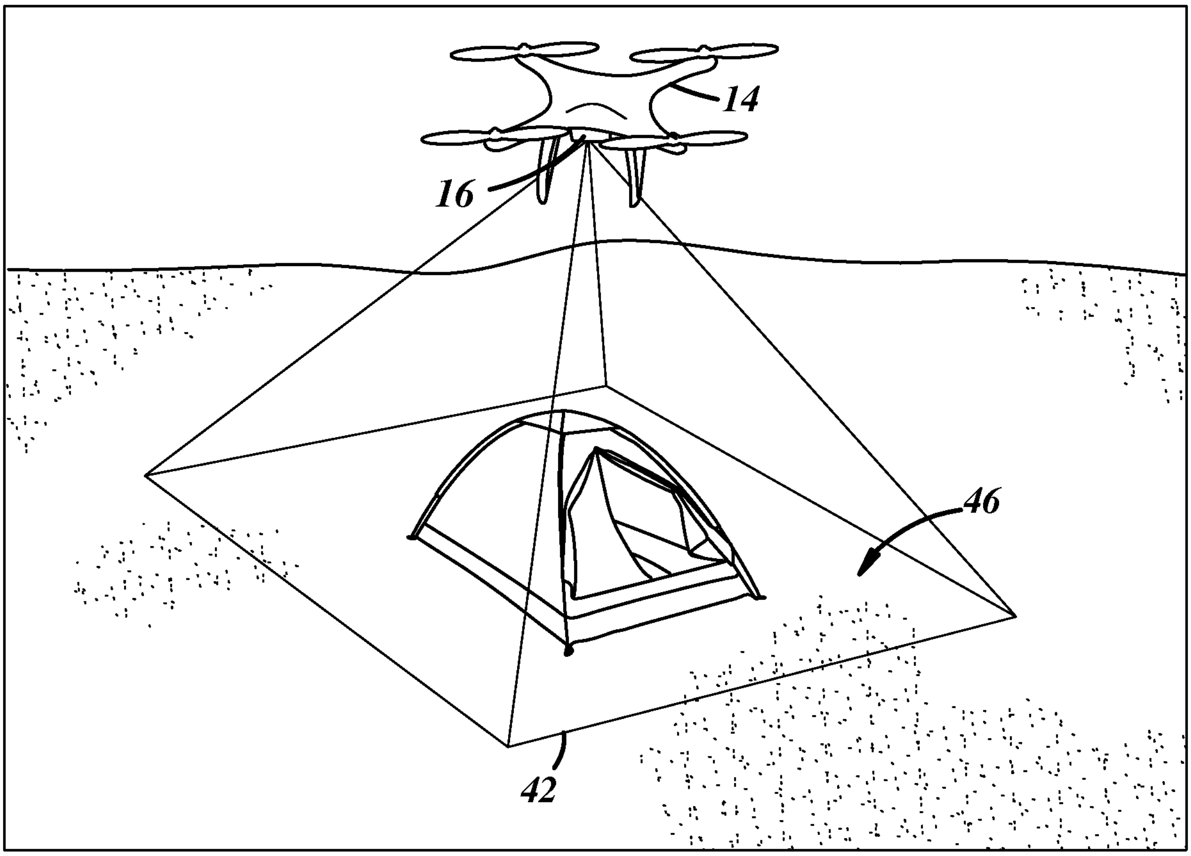

FIG. 8

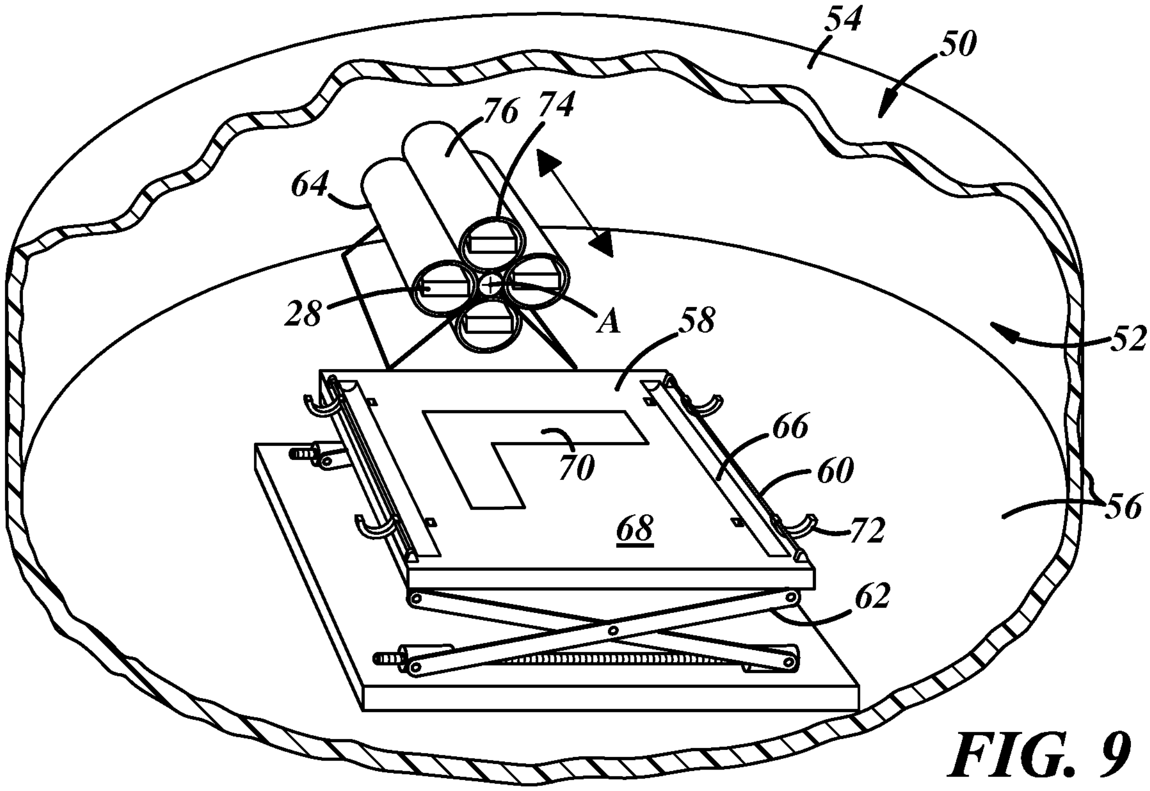

FIG. 9

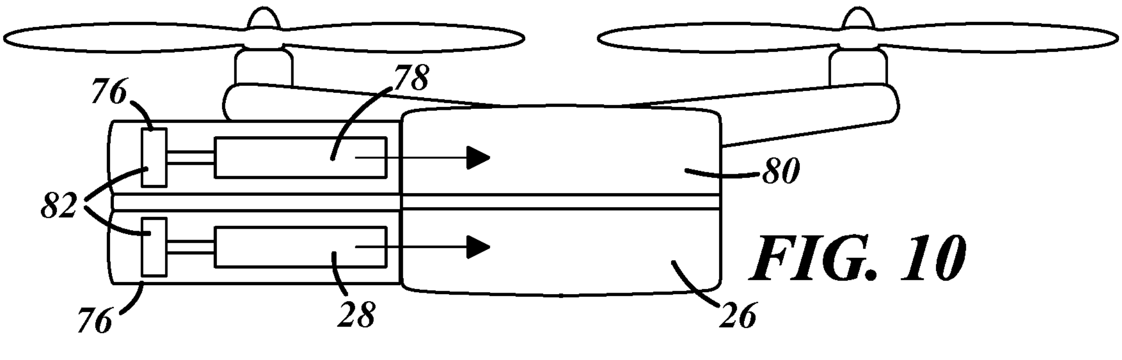

FIG. 10

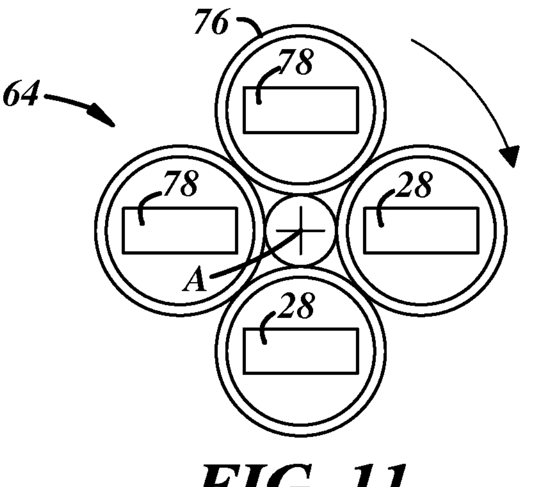

FIG. 11

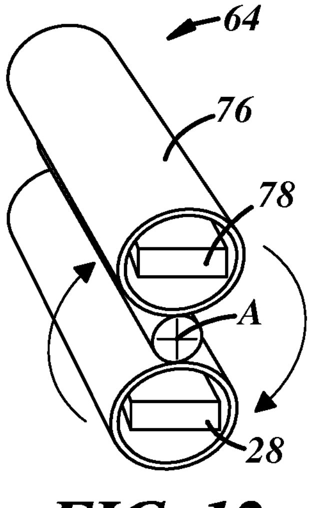

FIG. 12

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/055862

A. CLASSIFICATION OF SUBJECT MATTER
INV. G05D1/00 G08G1/0962
ADD.

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)
G05D G08G

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)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 10 2011 106170 A1 (DAIMLER AG [DE]) 2 February 2012 (2012-02-02)	1-15, 17-27, 29-46, 49-59, 61-66, 68-72,74
A	the whole document -----	16,28, 47,48, 60,67,73
X	WO 2015/180180 A1 (SZ DJI TECHNOLOGY CO LTD [CN]) 3 December 2015 (2015-12-03) the whole document ----- -/--	1-15, 17-27, 29-46, 49-59, 61-66, 68-72,74

[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

"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
3 May 2017	10/05/2017

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Thomann, Jérôme

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2015/321758 A1 (SARNA II PETER CHRISTOPHER [US]) 12 November 2015 (2015-11-12)	1
A	the whole document	2-74
X	FR 2 986 647 A3 (RENAULT SAS [FR]) 9 August 2013 (2013-08-09)	1
A	the whole document	2-74
X	US 2011/068224 A1 (KANG BEOM-SOO [KR] ET AL) 24 March 2011 (2011-03-24)	1
A	the whole document	2-74
X	US 2016/016663 A1 (STANEK JOE F [US] ET AL) 21 January 2016 (2016-01-21)	1
A	the whole document	2-74
X	WO 2014/080385 A2 (ALSHDAIFAT WASFI [AE]; ALMUHAIRBI EIDA [AE]; KASSAB FARAH AFIF [AE]) 30 May 2014 (2014-05-30)	1
A	the whole document	2-74
X	US 2015/102154 A1 (DUNCAN WILLIAM D [US] ET AL) 16 April 2015 (2015-04-16)	1
A	the whole document	2-74

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2017/055862

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 102011106170 A1	02-02-2012	NONE	
WO 2015180180 A1	03-12-2015	CN 105517664 A	20-04-2016
		EP 2976687 A1	27-01-2016
		JP 6062079 B2	18-01-2017
		JP 2016535879 A	17-11-2016
		US 9056676 B1	16-06-2015
		US 2015353206 A1	10-12-2015
		US 2016023762 A1	28-01-2016
		US 2016332748 A1	17-11-2016
		WO 2015180180 A1	03-12-2015
US 2015321758 A1	12-11-2015	NONE	
FR 2986647 A3	09-08-2013	NONE	
US 2011068224 A1	24-03-2011	KR 20110024616 A	09-03-2011
		US 2011068224 A1	24-03-2011
US 2016016663 A1	21-01-2016	CN 105302152 A	03-02-2016
		DE 102015110812 A1	21-01-2016
		RU 2015128817 A	18-01-2017
		US 2016016663 A1	21-01-2016
		US 2016347452 A1	01-12-2016
WO 2014080385 A2	30-05-2014	NONE	
US 2015102154 A1	16-04-2015	EP 3057857 A1	24-08-2016
		US 2015102154 A1	16-04-2015
		US 2016176523 A1	23-06-2016
		WO 2015057832 A1	23-04-2015