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Kucik

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(54) **COMMUNICATIONS USING UNMANNED SURFACE VEHICLES AND UNMANNED MICRO-AERIAL VEHICLES**

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(73) Assignee: **The United States of America as represented by the Secretary of the Navy**, Washington, DC (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 474 days.

This patent is subject to a terminal disclaimer.

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(51) **Int. Cl.**
H04B 1/034 (2006.01)

(52) **U.S. Cl.** .... **455/96**; 455/97; 455/98; 455/99; 244/190; 244/3.11; 244/3.14; 244/3.19; 342/60; 342/26 B; 701/35; 701/36

(58) **Field of Classification Search** .... 455/66.1, 455/517, 3.01–3.03, 427–431, 12.1, 13.3, 455/96–99; 342/58, 60, 26 B, 27, 28, 36, 342/37, 89, 357.1, 357.09; 701/1, 2, 35, 701/36, 200, 201, 220
See application file for complete search history.

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(57) **ABSTRACT**

A communications system and method utilizes an unmanned surface vehicle (USV) capable of collecting data about an environment in which the USV resides. At least one micro-aerial vehicle (MAV), equipped for unmanned flight after a launch thereof, is mounted on the USV. Each MAV has onboard radio frequency (RF) communications. Each MAV launched into the air transmits the data collected by the USV using the MAV's RF communications.

14 Claims, 3 Drawing Sheets

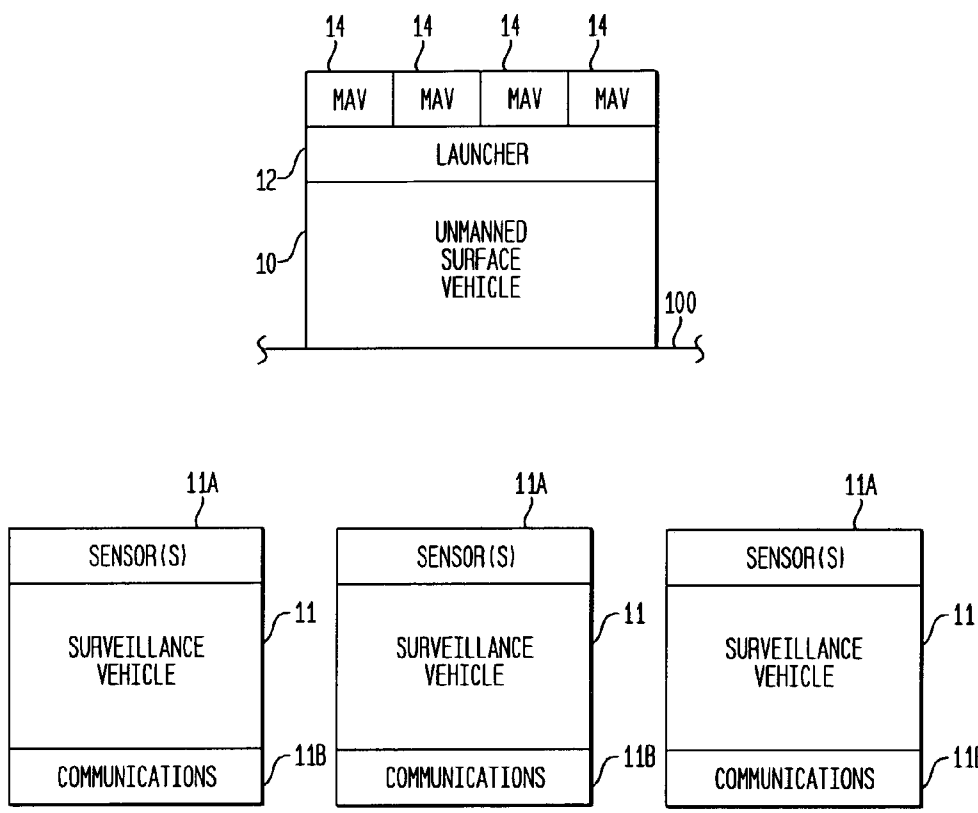


FIG. 1A

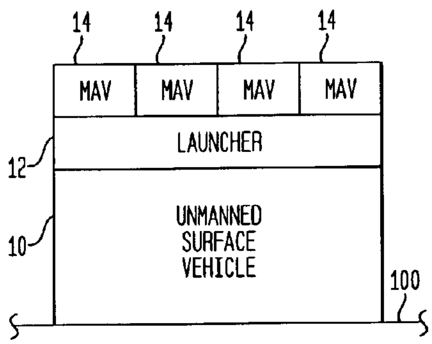


FIG. 1B

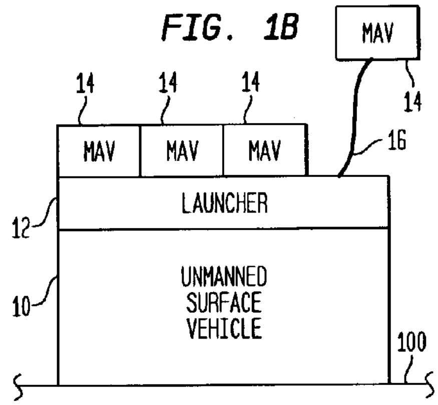


FIG. 1C

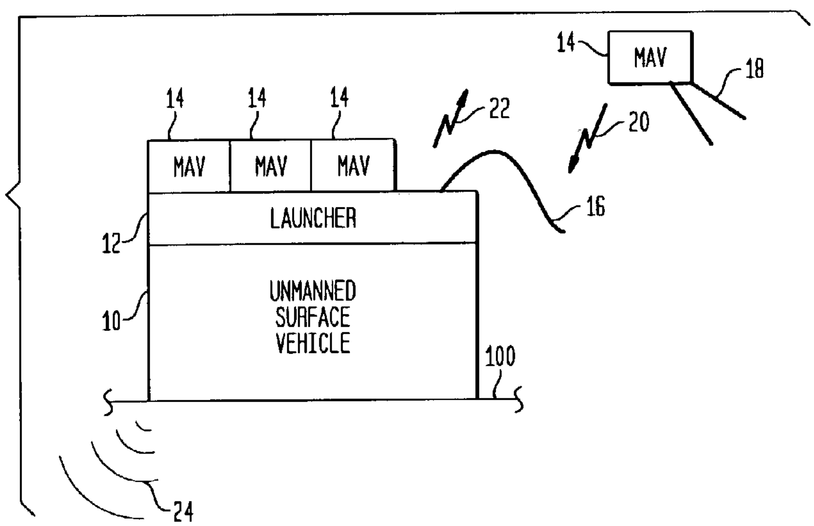


FIG. 1D

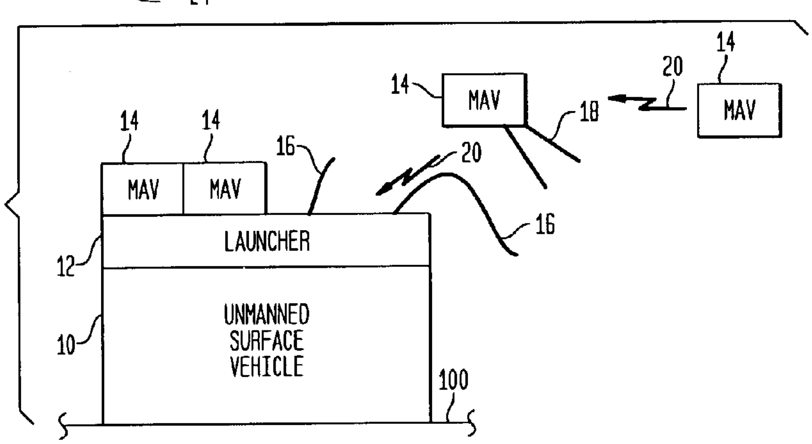


FIG. 2

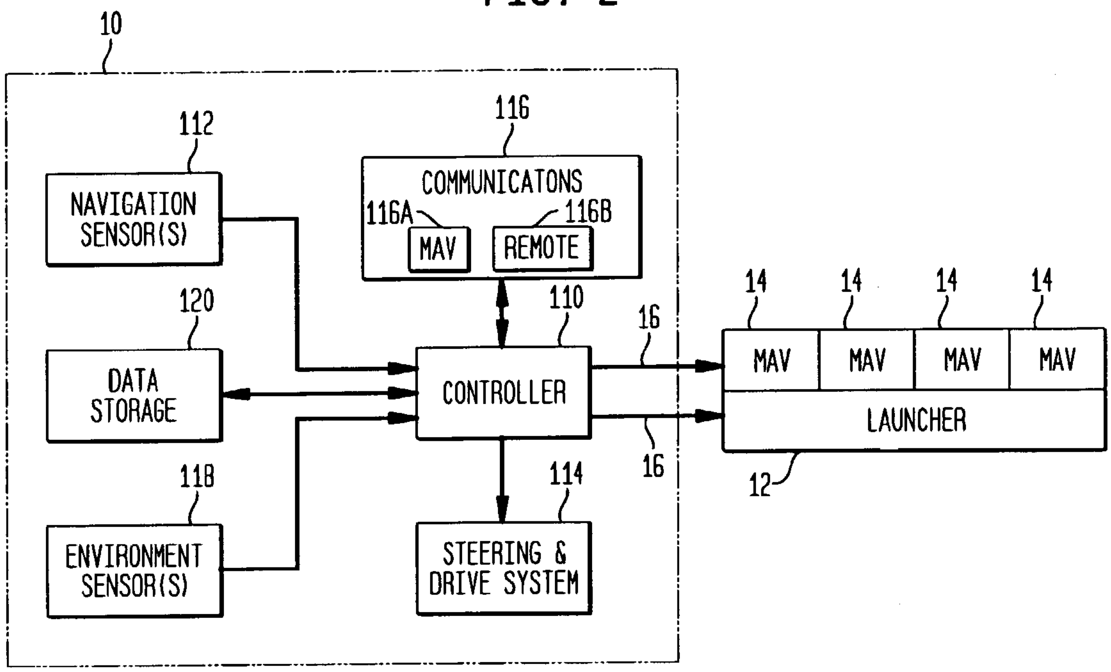

10
112
NAVIGATION SENSOR(S)
120
DATA STORAGE
118
ENVIRONMENT SENSOR(S)
116
COMMUNICATONS
116A
MAV
116B
REMOTE
110
CONTROLLER
114
STEERING & DRIVE SYSTEM
16
16
14
14
14
14
MAV
MAV
MAV
MAV
LAUNCHER
12

FIG. 3

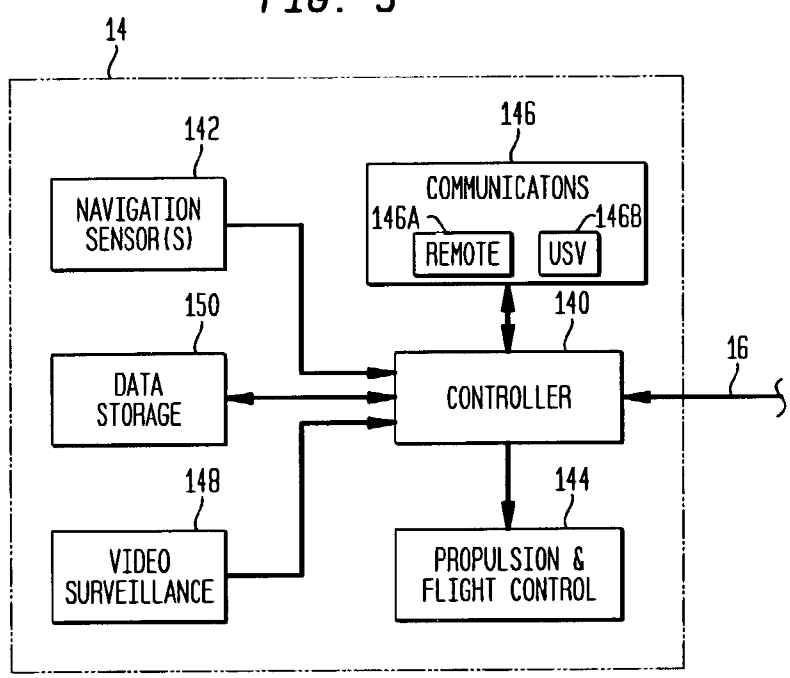
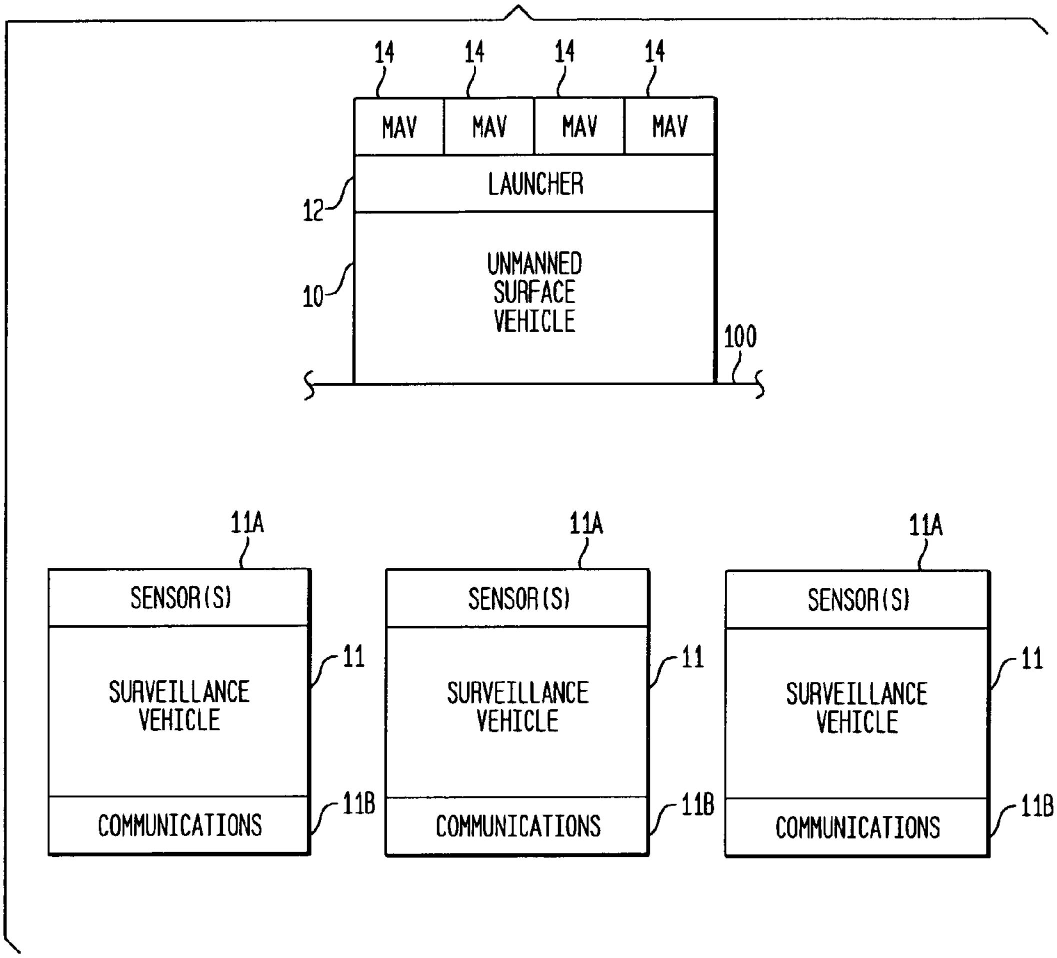

14
142
NAVIGATION SENSOR(S)
150
DATA STORAGE
148
VIDEO SURVEILLANCE
146
COMMUNICATONS
146A
REMOTE
146B
USV
140
CONTROLLER
16
144
PROPULSION & FLIGHT CONTROL

FIG. 4


14
14
14
14
MAV
MAV
MAV
MAV
LAUNCHER
12
UNMANNED SURFACE VEHICLE
10
100
11A
11A
11A
SENSOR(S)
SENSOR(S)
SENSOR(S)
SURVEILLANCE VEHICLE
SURVEILLANCE VEHICLE
SURVEILLANCE VEHICLE
11
11
11
COMMUNICATIONS
COMMUNICATIONS
COMMUNICATIONS
11B
11B
11B

COMMUNICATIONS USING UNMANNED SURFACE VEHICLES AND UNMANNED MICRO-AERIAL VEHICLES

ORIGIN OF THE INVENTION

The invention described herein was made in the performance of official duties by an employee of the Department of the Navy and may be manufactured, used, licensed by or for the Government for any governmental purpose without payment of any royalties thereon.

CROSS-REFERENCE TO RELATED PATENT APPLICATIONS

This patent application is co-pending with one related patent application entitled "RECONNAISSANCE USING UNMANNED SURFACE VEHICLES AND UNMANNED MICRO-AERIAL VEHICLES" Ser. No. 10/354,507, by the same inventor as this patent application.

FIELD OF THE INVENTION

The invention relates generally to communications systems and methods, and more particularly to a method and system of communication using unmanned surface vehicles and unmanned micro-aerial vehicles.

BACKGROUND OF THE INVENTION

A variety of unmanned surface vehicles (e.g., on the ground or water surface) are used to sense/collect data about an environment in which they reside. The data is then transmitted to a base station using radio frequency (RF) communications. However, the range of the RF communication is limited by the vehicle's line-of-sight due to its ground or water surface location. To improve the communication range, the vehicle could be equipped with satellite communications (or SATCOM as it is known) equipment. However, SATCOM equipment is big and heavy, consumes a lot of power, is expensive, is limited in bandwidth, and is subject to satellite availability and/or allocation problems.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide a method and system for improving communications from unmanned surface vehicles.

Another object of the present invention to provide a method and system for improving communications from unmanned surface vehicles using unmanned micro-aerial vehicles.

Other objects and advantages of the present invention will become more obvious hereinafter in the specification and drawings.

In accordance with the present invention, a communications system includes an unmanned surface vehicle (USV) capable of movement on an earth surface. The USV has data collection means for collecting data about an environment in which the USV resides. At least one micro-aerial vehicle (MAV), equipped for unmanned flight after a launch thereof, is mounted on the USV. Each MAV has radio frequency (RF) communication means mounted thereon. A launcher mounted on the USV is used to launch each MAV into the air where each MAV so-launched transmits the data using its RF communication means.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, features and advantages of the present invention will become apparent upon reference to the following description of the preferred embodiments and to the drawings, wherein corresponding reference characters indicate corresponding parts throughout the several views of the drawings and wherein:

FIG. **1** depicts an operational scenario of a system using an unmanned surface vehicle and micro-aerial vehicles in accordance with the present invention where FIGS. **1**A–**1**D depict a time progression in the operation scenario;

FIG. **2** is a functional block diagram of an unmanned surface vehicle for use in the present invention;

FIG. **3** is a functional block diagram of an unmanned micro-aerial vehicle for use in the present invention; and

FIG. **4** depicts another operational scenario in accordance with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the drawings, and more particularly to FIGS. **1**A–**1**D, an operational scenario is depicted for a system that can carry out reconnaissance and/or communications in accordance with the present invention. For simplicity of description, each of the reconnaissance and communications aspects of the present invention will be explained as separate operations. However, it is to be understood that the operations could be combined and provided by one system.

With respect to the reconnaissance aspect of the present invention, an unmanned surface vehicle (USV) **10** is provided and is capable of navigated movement on a surface **100** of the earth. Surface **100** can be the ground (to include dry land and the seafloor), or can be the surface of a body of water. Accordingly, USV **10** can be a ground-based vehicle or a floating vehicle without departing from the scope of the present invention. USV **10** can navigate autonomously to a desired location or can have its navigated movement controlled from a remote location.

Incorporated into or mounted on USV **10** is a launcher **12** for launching one or more micro-aerial vehicles (MAV) **14** from USV **10**. As is known in the art, each MAV **14** is a small, unmanned aircraft (e.g., wingspan on the order of 6 inches) capable of controllable flight using a gasoline or electric motor. See, for example, "New, Improved Plane Gives UF Tie at MAV Contest," The Florida Engineer, Summer **2002**. As will be explained further below, each MAV **14** is equipped with video surveillance equipment and wireless communication equipment, neither of which is shown in FIG. **1** for clarity of illustration.

When commanded to do so, launcher **12** applies a sufficient force to launch one of MAVs **14** into the air at which point the onboard propulsion system (not shown in FIG. **1**) of MAV **14** keeps it airborne. Given the minimal weight of each MAV **14**, launcher **12** can be realized of a variety of simple spring-loaded mechanical launchers (e.g., catapult), gas-powered launchers, or any other low-power launcher, the choice of which is not a limitation of the present invention. Such launchers, are well known in the art and, therefore will not be described further herein.

In operation, USV **10** navigates under autonomous or remote control to a desired location on earth surface **100** as shown in FIG. **1**A. USV **10** could remain on dry land at all times or could transition from a wet environment to a beach location for covert reconnaissance operations. When reconnaissance is needed, launcher **12** is commanded to launch one of MAVs **14** into the air as illustrated in FIG. **1**B. To check and initialize systems (e.g., flight propulsion and control systems, video surveillance systems, communication systems, etc.) prior to launch of one of MAVs **14**, a hardwire link **16** can be provided between USV **10** and each MAV **14**. Hardwire link **16** can be an umbilical-type of link/tether that remains coupled to MAV **14** prior to and during launch thereof, but then is uncoupled from MAV **14** once the MAV's propulsion and flight control systems are operational and the MAV has been launched.

Referring now to FIG. **1**C, the one MAV **14** launched into the air by launcher **12** is illustrated as being uncoupled from hardwire link **16** and flying under its own power. The video surveillance performed by the airborne one of MAVs **14** is indicated by field-of-view **18** while the wireless transmission of the video data captured is field-of-view **18** is indicated by arrow **20**. Typically, wireless transmission **20** is a radio frequency (RF) transmission that can either be received at a remote location or by USV **10** for storage and/or re-transmission as indicated by arrow **22**. If USV **10** is to re-transmit the video data, USV **10** could be equipped with higher power SATCOM or RF transmission means. Further, if surface **100** is a water surface, USV **10** could be equipped with acoustic or other underwater communications systems capable of transmitting signals **24** under (water) surface **100**.

The above-described process can be repeated for each of the remaining MAVs **14** that are still coupled to USV **10**. As illustrated in FIG. **1**D, a second MAV **14** can be launched into the air when, for example, i) video reconnaissance of a different area is required, ii) the first launched MAV **14** runs out of power or otherwise fails, or iii) a communication relay/is needed to support transmission of video data **20** from the first and/or second launched MAV **14**.

Referring additionally now to FIG. **2**, an embodiment of USV **10** for supporting the above-described operational scenario is shown in block diagram form. At the heart of USV **10** is a controller **110** that orchestrates all activity onboard USV **10**. More specifically, controller **110** performs navigation functions, controls motion of USV **10**, commands launches of MAVs **14**, oversees image data communications and video data transmissions, and controls video data storage/retrieval. Controller **110** can be realized by one central control computer or by individual control computers for each major function performed by USV **10**.

In terms of navigation and motion of USV **10**, navigation sensor(s) **112** are coupled to controller **110** and can include a compass for reading vehicle headings, wheel encoders for measuring distance traveled, a GPS receiver, and inertial sensors. Readings from these sensor/receivers are used by controller **110** in ways well known in the art (e.g., GPS receiver provides long baseline navigation while compass, wheel encoders and inertial sensors are used for dead reckoning) to determine an accurate position of USV **10** at all times. Controller **110** uses the determined position to adjust a steering and drive system **114** so that USV **10** is navigated along a desired path to a destination. The desired path and destination can be pre-programmed into controller **110** in which case USV **10** moves in a completely autonomous fashion. Another option is to control USV **10** from a remote location. Accordingly, a communications module **116** can include separate communications **116**A and **116**B where communications **116**A is used to communicate between MAVs **14** and communications **116**B is used to communicate with a remote location. Ideally, both communications can occur simultaneously and uninterrupted.

Environmental sensor(s) **118** can include sensors for collecting data about the environment in which USV **10** resides (e.g., motion, acoustic, seismic, temperature, video, etc.) as well as sensors used during the movement of USV **10** (e.g., collision sensing, collision avoidance, video, etc.). For example, once USV **10** reaches its desired destination, controller **110** can place itself and systems coupled thereto in a "sleep" mode to conserve power while environmental sensor(s) **118** "listen" for environment changes that signal the need for reconnaissance, at which point controller **110** wakes the needed onboard systems. The collected data could also be stored onboard USV **10** using data storage **120**.

Controller **110** is coupled to launcher **12** and is also coupled to each MAV **14** (only one of which is shown in FIG. **2**) via hardwire link **16**. As mentioned above, hardwire link **16** is used to activate and check the various flight systems onboard MAV **14** prior to the launching thereof by launcher **12**.

Referring to FIG. **3**, an embodiment of MAV **14** for supporting the reconnaissance aspect of the present invention is shown in block diagram form. A controller **140** oversees all of the functions of MAV **14** that can include autonomous flight control, remote-operator controlled flight, communications, video surveillance and data storage. In terms of its flying operations, MAV **14** includes navigation sensor(s) **142** (e.g., compass, altimeter, GPS, inertial, etc.) for providing position information to controller **140** which, in turn, uses such position to implement a flight plan using the MAV's propulsion and flight control **144** (e.g., motor or engine, propeller, control surfaces, etc.) The flight plan can be pre-programmed into controller **140** or could be provided remotely from USV **10** or some other location. Accordingly, a communications module **146** can include communications **146**A for communication with a remote base location (that can be in the air, on the ground or on the water) and communications **146**B for communication with just USV **10**. Since two-way communication would be required, each of communications **146**A and **146**B can be realized by an RF transceiver.

Once MAV **14** is airborne, controller **140** activates video surveillance **148** which typically includes a miniature camera (e.g., standard image, thermal starlight, etc.) and video processor. The video data is passed to controller **140** which can store some or all thereof at data storage **150** and/or have some transmitted from MAV **14** using communications module **146**.

Controller **140** is also coupled to hardwire link **16** as described above. Just prior to launch of MAV **14**, controller **140** receives wake commands via hardwire link **16**. Such wake commands could be detailed with respect to each system onboard MAV **14** or could simply be one command that triggers that start of an operational program stored on controller **140**. At a minimum, navigation sensor (s) **142** and propulsion/flight control **144** are activated prior to launch of MAV **14**. Note that hardwire link **16** could also be used to check the integrity of each system onboard MAV **14** prior to launch thereof. Then, if a failure is detected, another one of the MAVs **14** could be launched.

As mentioned above, the present invention could also function as a communications system with the hardware provided on each of USV **10** and MAVs **14** being the same as the already described. Accordingly, simultaneous reference will be made to FIGS. **1**–**3** in order to explain the operation of the present invention's use as a communications system. In essence, data collected autonomously by USV **10** over a period of time is transmitted by an airborne one of MAVs **14**. Thus, no personnel need be present to perform data collection and line-of-sight transmission distance is greatly increased by the airborne MAV **14**.

The data collected by USV **10** (e.g., by its environmental sensor(s) **118**) can be transferred to one of MAVs **14** for airborne transmission therefrom in one of two ways. First, collected data could be stored onboard USV **10** using data storage **120**. Then, when one of MAVs **14** is airborne, the collected data could be transmitted thereto using the communications link formed by the combination of communications **116**A and **146**B. MAV **14** would then re-transmit the data using communications **146**A. Note that the use of separate communications links allows the data to be relayed nearly simultaneously.

The second way collected data could be transferred to one of MAVs **14** involves storing the collected data onboard MAV **14** (using data storage **150**) prior to launching MAV **14**. Then, at a predetermined time, or when data storage **150** is at capacity, MAV **14** is launched into the air where transmission to a remote location occurs using communications **146**A. Once airborne, transfer of collected data to MAV **14** could then occur as described in the first method. Note that USV **10** could simultaneously store the collected data using data storage **120** for archive purposes, for re-transmission, or if the airborne one of MAVs **14** experiences a failure.

The present invention's communication aspect could also use USV **10** as a data collection node for a large number of surface-based reconnaissance vehicles. This scenario is depicted in FIG. **4** where USV **10** is deployed at earth surface **100** and is equipped as previously described. Deployed on surface **100** (or under surface **100** in the case of a water environment) are a number of surveillance vehicles **11**, each of which is equipped with sensor(s) **11**A for sensing information such as environmental conditions and communications **11**B for transferring sensed information to USV **10**. In situations where surveillance vehicles **11** are on a ground or water surface, communications **11**B can be RF communications that transmit the information for receipt by (RF) communications **116**B onboard USV **10**. However, if surveillance vehicles are deployed underwater, communications **11**B can be an acoustic transmitter and communications **116**B can be an acoustic receiver (or transceiver if two-way communication with surveillance vehicles **11** is required). The information collected by USV **10** in this fashion can then be transferred to an MAV **14** for airborne transmission thereof as described above.

The advantages of the present invention are numerous. Personnel are kept out of dangerous, remote and/or time consuming data reconnaissance situations. Thus, the present invention is safer and cheaper than existing personnel-based reconnaissance and/or communications system. The use of high-cost satellite communications is not required. Further, by equipping each USV with multiple MAVs, the present invention presents a long-term solution to providing covert reconnaissance and improved long-range communications with unmanned reconnaissance vehicle(s).

Although the invention has been described relative to a specific embodiment thereof, there are numerous variations and modifications that will be readily apparent to those skilled in the art in light of the above teachings. For example, USV **10** could remain underwater at all times with launcher **12** being a buoyant platform that could be released from USV **10**. Upon such release, the buoyant launching platform would float to the water's surface, launch it's MAV(s), and then be scuttled and sink below the water's surface. It is therefore to be understood that, within the scope of the appended claims, the invention may be practiced other than as specifically described.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. A communications system, comprising:

an unmanned surface vehicle (USV) capable of movement on an earth surface, said USV having data collection means for collecting data about an environment in which said USV resides;

at least one micro-aerial vehicle (MAV) equipped for unmanned flight after a launch thereof, said MAV mounted on said USV and having radio frequency (RF) communication means mounted thereon; and

launching means mounted on said USV for launching said MAV into the air, wherein said MAV so-launched into the air transmits said data using said RF communication means.

2. A communications system as in claim **1** wherein said USV further comprises an RF transceiver for transmitting said data to said RF communications means associated with said MAV so-launched.

3. A communications system as in claim **2** further comprising surveillance vehicles in the vicinity of said USV, each of said surveillance vehicles being equipped with means for transferring information therefrom to said USV wherein said information becomes at least a portion of said data so-collected by said USV.

4. A communications system as in claim **2** wherein said earth surface is a water surface, said USV further including acoustic communication means coupled to said RF transceiver, and said communications system further comprising unmanned underwater vehicles (UUVs) under the water surface and in the vicinity of said USV, each of said UUVs being equipped with an acoustic transmitter for transmitting information therefrom through the water to said acoustic communication means of said USV wherein said information becomes at least a portion of said data so-collected by said USV.

5. A communications system as in claim **2** further comprising surveillance vehicles in the vicinity of said USV, each of said surveillance vehicles being equipped with an RF transmitter for transmitting information therefrom to said RF transceiver of said USV wherein said information becomes at least a portion of said data so-collected by said USV.

6. A communications system as in claim **2** wherein said RF communications means comprises:

a first RF transceiver for two-way communication with said RF transceiver of said USV; and

a second RF transceiver for two-way communication with a location that is remote with respect to said USV, wherein said first RF transceiver and said second RF transceiver can operate simultaneously.

7. A communications system as in claim **1** wherein said MAV further includes data storage means coupled to said data collection means and to said RF communications means, wherein said data is transferred from said data collection means to said data storage means prior to launching said MAV and wherein, after launching said MAV, said data is transmitted from said data storage means associated with said MAV so-launched using said RF communication means associated with said MAV so-launched.

8. A method of communication between an unmanned surface vehicle (USV) and a location that is remote with respect to USV, comprising the steps of:

using said USV as a node for the collection of data;

providing at least one micro-aerial vehicle (MAV) on said USV, said MAV being equipped for unmanned flight after a launch thereof, said MAV having radio frequency (RF) communication means mounted thereon;

launching said MAV into the air from said USV; and

transmitting said data using said RF communication means on said MAV so-launched into the air.

9. A method according to claim **8** wherein said step of transmitting comprises the steps of:

providing an RF transceiver on said USV; and

transmitting said data to said RF communications means associated with said MAV so-launched into the air using said RF transceiver on said USV.

10. A method according to claim **9** further comprising the steps of:

providing surveillance vehicles in the vicinity of said USV, each of said surveillance vehicles being equipped with means for transmitting information therefrom; and

transmitting said information from each of said surveillance vehicles to said USV wherein said information becomes at least a portion of said data so-collected by said USV.

11. A method according to claim **9** wherein said earth surface is a water surface, said method further comprising the steps of:

providing said USV with acoustic communication means coupled to said RF transceiver;

providing unmanned underwater vehicles (UUVs) under the water surface and in the vicinity of said USV, each of said UUVs being equipped with an acoustic transmitter; and

transmitting information from each said acoustic transmitter through the water to said acoustic communication means of said USV wherein said information becomes at least a portion of said data so-collected by said USV.

12. A method according to claim **9** further comprising the steps of:

providing surveillance vehicles in the vicinity of said USV, each of said surveillance vehicles being equipped with an RF transmitter; and

transmitting information from each of said surveillance vehicles to said RF transceiver of said USV wherein said information becomes at least a portion of said data so-collected by said USV.

13. A method according to claim **9** wherein said RF communications means comprises a first RF transceiver for two-way communication with said RF transceiver of said USV and a second RF transceiver for two-way communication with a location that is remote with respect to said USV, said method further comprising the step of operating said first RF transceiver and said second RF transceiver simultaneously.

14. A method according to claim **8** further comprising the steps of:

providing said MAV with data storage means coupled to said RF communications means and to said data collection means of said USV prior to launching said MAV;

transferring said data from said data collection means to said data storage means prior to launching said MAV; and transmitting with said MAV so-launched.

* * * * *