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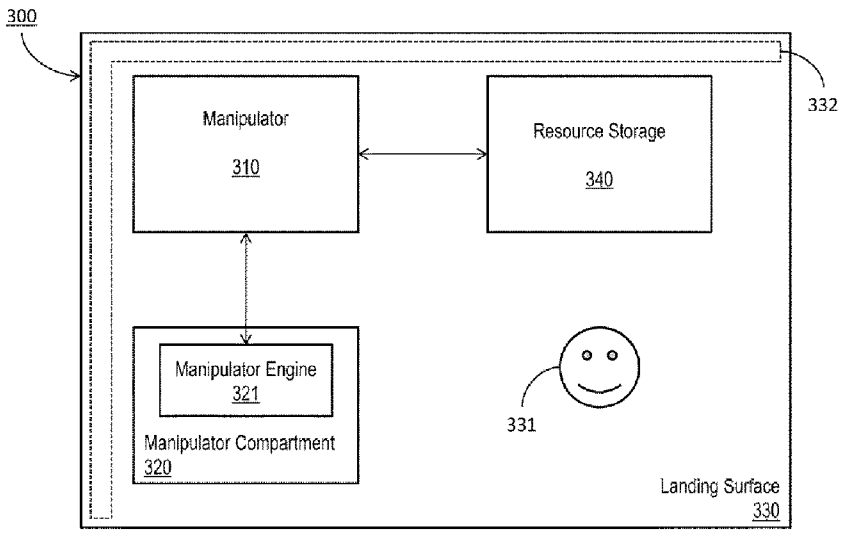
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(54) **Title**: SYSTEM AND METHOD FOR MANAGING UNMANNED AERIAL VEHICLES

[Fig. 2]



(57) **Abstract**: A base station for automated battery pack or payload exchange and methods for using the same. The base station provides a landing surface for receiving a mobile platform and includes a manipulator controlled by a manipulator compartment for accessing resource storage. The base station is operable to ascertain a location of the mobile platform on the landing surface and move the manipulator to the mobile platform. Thereby, the base station system advantageously accommodates low-accuracy landing of the mobile platform and further enables extended and autonomous operation of the mobile platform without the need for user intervention for exchanging battery packs and payloads.

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Description

Title of Invention: SYSTEM AND METHOD FOR MANAGING UNMANNED AERIAL VEHICLES

FIELD

[0001] The present disclosure relates generally to mobile platforms and more specifically, but not exclusively, to base stations for servicing mobile platforms, such as unmanned aerial vehicles (UAVs).

BACKGROUND

[0002] Conventional unmanned aerial vehicles (UAVs) have limited flight time because their battery life is often limited to ten to thirty minutes at the most. When a battery is expended, the UAV must land, and the expended battery must be exchanged by a user or recharged before the UAV can operate again. Similarly, each UAV may carry a payload configured to perform a specific function such as capturing images of the operating environment, spreading pesticides, or transporting fuel. For each of these payloads, regular maintenance is required that typically involves frequent user interaction (e.g., users required to download captured images or refill a pesticide spray tank).

[0003] The necessity for frequent user interaction to maintain and exchange the batteries and payloads of the UAVs is not beneficial where extended duty times are required or where extended autonomous operation is desired for a fleet of UAVs.

[0004] Some conventional systems require the UAV to land on, or be moved to (manually or automatically), a position on a landing pad for autonomous operation on the UAV. For a larger UAV with low landing accuracy, the resources and cost required to move the larger UAV to the desired position on the landing pad is not practical for autonomous operation on the larger UAV.

[0005] In view of the foregoing, a need exists for an improved UAV base station system and method for autonomous exchange of UAV batteries in an effort to overcome the aforementioned obstacles and deficiencies of conventional UAV systems.

[0006] SUMMARY

[0007] The present disclosure relates to a base station for automated battery pack or payload exchange and methods for using the same. The base station provides a landing surface for receiving a mobile platform, such as an unmanned aerial vehicle (UAV). The base station system advantageously accommodates low-accuracy landing of the mobile platform and further enables extended and autonomous operation of the mobile platform without the need for user intervention for exchanging battery packs and payloads.

[0008] In accordance with a first aspect disclosed herein, there is set forth a method for managing a payload or a battery of a mobile platform positioned on a landing surface, the method comprising:

[0009] ascertaining a location of the mobile platform; and

[0010] moving a maintenance system relative to the mobile platform based on the ascertained location of the mobile platform.

[0011] In some embodiments of the disclosed method, moving the maintenance system comprises moving the maintenance system translationally along at least one of an X-axis, a Y-axis, and a Z-axis or rotationally to the mobile platform based on the ascertained location of the UAV.

[0012] In some embodiments of the disclosed method, the method further comprises interacting with a selected payload or a selected battery of the mobile platform via the maintenance system, wherein said interacting optionally occurs automatically and without user interaction.

[0013] In some embodiments of the disclosed method, interacting with the selected payload or the selected battery of the mobile platform comprises at least one of removing the selected battery and recharging the selected battery.

[0014] In some embodiments of the disclosed method, interacting with the selected payload or the selected battery of the mobile platform comprises interacting with at least one of fuel, parcels, cargo, water, pesticides, fertilizer, and a data storage unit of the mobile platform.

[0015] In some embodiments of the disclosed method, the method further comprises inserting a replacement payload or replacement battery into the mobile platform.

[0016] In some embodiments of the disclosed method, the method further comprises actuating a power switch of the mobile platform.

[0017] In some embodiments of the disclosed method, the method further comprises connecting a physical cable assembly to the mobile platform.

[0018] In some embodiments of the disclosed method, connecting the physical cable assembly comprises at least one of connecting a first physical communication cable assembly for transmitting data from the base station to the mobile platform, connecting a second physical communication cable assembly for transmitting data from the mobile platform to the base station, connecting a power cable for providing electrical power to the mobile platform, and connecting a fuel line for refueling the mobile platform.

[0019] In some embodiments of the disclosed method, connecting the first physical communication cable assembly and connecting the second physical communication cable assembly comprise connecting a common physical communication cable assembly for exchanging data between the mobile platform and the base station.

[0020] In some embodiments of the disclosed method, the method further comprises

wirelessly providing power to the mobile platform.

[0021] In some embodiments of the disclosed method, ascertaining the location of the mobile platform comprises receiving position information from one or more sensors, and

[0022] wherein said one or more sensors comprise at least one of an optical sensor, a contact image sensor, an electro-optical sensor, an infra-red sensor, a kinetic inductance detector, a light-emitting diode (LED) as light sensor, a fiber optic sensor, an optical position sensor, a photodetector, a pressure sensor, a photoresistor, a phototransistor, a thermal or temperature sensor, a proximity sensor, an electric current sensor, a magnetic sensor, and a radio sensor.

[0023] In some embodiments of the disclosed method, the mobile platform remains stationary on the landing surface.

[0024] In some embodiments of the disclosed method, the method further comprises moving the mobile platform from the ascertained location to a predetermined location on the landing surface.

[0025] In some embodiments of the disclosed method, moving the mobile platform to the predetermined location results in one or more landing legs of the mobile platform each engaging a corresponding receiving cavity defined on a predetermined surface of the landing surface.

[0026] In some embodiments of the disclosed method, the method further comprises ascertaining a second location of a second mobile platform.

[0027] In some embodiments of the disclosed method, the mobile platform is an unmanned aerial vehicle (UAV).

[0028] In accordance with a another aspect disclosed herein, there is set forth a base station for a mobile platform having a payload or a battery, comprising:

[0029] a landing surface; and

[0030] a maintenance system operable to ascertain a location of the mobile platform on the landing surface and move to the mobile platform based on the ascertained location of the mobile platform.

[0031] In some embodiments of the disclosed system, the maintenance system is operable to move translationally along an X-axis, a Y-axis, and a Z-axis or rotationally to the mobile platform based on the ascertained location of the mobile platform.

[0032] In some embodiments of the disclosed system, the maintenance system is operable to interact with a selected replacement payload and the payload of the mobile platform and optionally is configured to operate automatically and without user interaction.

[0033] In some embodiments of the disclosed system, at least one of the selected replacement payload and the payload comprises at least one of a data storage unit, a predetermined quantity of fuel, a predetermined quantity of fertilizer, a predetermined

quantity of water, one or more parcels, cargo, and a predetermined quantity of pesticides.

[0034] In some embodiments of the disclosed system, the maintenance system is operable to interact with a selected replacement battery and the battery of the mobile platform and optionally is configured to operate automatically and without user interaction.

[0035] In some embodiments of the disclosed system, the maintenance system is further operable to at least one of remove the battery from the mobile platform, recharge the removed battery, and insert the selected replacement battery into the mobile platform.

[0036] In some embodiments of the disclosed system, the maintenance system is further operable to ascertain a distance between the mobile platform and a second base station located on a flight path of the mobile platform.

[0037] In some embodiments of the disclosed system, the maintenance system is further operable to provide a signal to the mobile platform, the signal instructing the mobile platform to land on the landing surface or travel to the second base station.

[0038] In some embodiments of the disclosed system, the maintenance system is further operable to actuate a power switch of the mobile platform.

[0039] In some embodiments of the disclosed system, the maintenance system is further operable to connect a physical cable assembly to the mobile platform.

[0040] In some embodiments of the disclosed system, said physical cable assembly comprises at least one of a first communication cable assembly for transmitting data from the base station to the mobile platform, a second communication cable assembly for transmitting data from the mobile platform to the base station, a power cable for providing electrical power to the mobile platform, and a fuel line for refueling the mobile platform.

[0041] In some embodiments of the disclosed system, the first communication cable assembly and the second communication cable assembly comprise a common physical communication cable assembly for exchanging data between the mobile platform and the base station.

[0042] In some embodiments of the disclosed system, the maintenance system is operable to wirelessly provide power to the mobile platform.

[0043] In some embodiments of the disclosed system, the landing surface comprises a charging pad for wirelessly providing the power to the mobile platform.

[0044] In some embodiments of the disclosed system, the power provided to the mobile platform comprises electrical power.

[0045] In some embodiments of the disclosed system, the landing surface comprises an electric coil system for wirelessly providing the power to the mobile platform.

[0046] In some embodiments of the disclosed system, the maintenance system is operable to move the mobile platform from the ascertained location to a predetermined location on

the landing surface.

[0047] In some embodiments of the disclosed system, the predetermined location comprises one or more receiving cavities defined on a predetermined surface of the landing surface and being operable to receive one or more landing legs of the mobile platform.

[0048] In some embodiments of the disclosed system, the maintenance system is operable to ascertain a second location of a second mobile platform on the landing surface and move to the second mobile platform based on the ascertained second location of the second mobile platform.

[0049] In some embodiments of the disclosed system, the maintenance system comprises at least two manipulator carriages optionally operable to move simultaneously for moving to the first and second mobile platform.

[0050] In some embodiments of the disclosed system, one of the manipulator carriages comprises a power transmitter for wirelessly providing power to the mobile platform.

[0051] In some embodiments of the disclosed system, the power transmitter comprises an electric coil system for wirelessly providing the power to the mobile platform.

[0052] In some embodiments of the disclosed system, the mobile platform is an unmanned aerial vehicle (UAV).

[0053] In accordance with a another aspect disclosed herein, there is set forth a base station for a mobile platform having a payload or a battery, comprising:

[0054] a landing surface configured for the mobile platform to land thereon; and

[0055] a maintenance system comprising:

[0056] a sensor apparatus for ascertaining a location of the mobile platform on the landing surface;

[0057] a resource supply for defining a plurality of resource-slots each configured to removably hold a replacement payload or replacement battery; and

[0058] one or more mechanical manipulators for moving to the mobile platform based on the ascertained location of the mobile platform and optionally interacting with a selected replacement payload, a selected replacement battery, the payload, or the battery.

[0059] In some embodiments of the disclosed system, the maintenance system is operable to move translationally along an X-axis, a Y-axis, and a Z-axis or rotationally to the ascertained location of the mobile platform.

[0060] In some embodiments of the disclosed system, the mechanical manipulators are operable to:

[0061] move along an X-axis and Y-axis to the selected replacement payload or replacement battery positioned in a selected resource-slot;

[0062] extend a resource-carriage along a Z-axis;

[0063] grasp the selected replacement payload or replacement battery;

[0064] retract the resource-carriage along the Z-axis to remove the replacement payload or replacement battery from the resource-slot;

[0065] move the removed replacement payload or removed replacement battery proximate to the ascertained location of the mobile platform; and

[0066] insert the replacement payload or replacement battery into a mobile platform resource-slot provided on the mobile platform and decouple from the replacement payload.

[0067] In some embodiments of the disclosed system, the sensor apparatus comprises first and second optical sensors operable to respectively locate the mobile platform along respective perpendicular axes, and wherein the sensor apparatus optionally is configured to operate automatically and without user interaction.

[0068] In some embodiments of the disclosed system, the first and second optical sensors are respectively located on first and second location arms each extending substantially perpendicularly to a respective axis.

[0069] In some embodiments of the disclosed system, at least one of the payload and the replacement payload comprises at least one of a data storage unit, a predetermined quantity of fuel, a predetermined quantity of fertilizer, a predetermined quantity of water, a parcel, cargo, and a predetermined quantity of pesticides.

[0070] In some embodiments of the disclosed system, the mechanical manipulators are operable to actuate a power switch of the mobile platform.

[0071] In some embodiments of the disclosed system, the mechanical manipulators are operable to connect a physical cable assembly to the mobile platform.

[0072] In some embodiments of the disclosed system, the physical cable assembly is a power cable for providing electrical power to the mobile platform.

[0073] In some embodiments of the disclosed system, the physical cable assembly is a communication cable for exchanging data between the base station and the mobile platform.

[0074] In some embodiments of the disclosed system, the physical cable assembly is a fuel line for filling a fuel tank of the mobile platform.

[0075] In some embodiments of the disclosed system, the maintenance system is configured to operate automatically and without user interaction.

[0076] In some embodiments of the disclosed system, at least one of said resource-slots is operable to charge a battery.

[0077] In some embodiments of the disclosed system, the mobile platform remains stationary on the landing surface.

[0078] In some embodiments of the disclosed system, the mechanical manipulators are operable to move the mobile platform from the ascertained location to a predetermined location on the landing surface.

[0079] In some embodiments of the disclosed system, the predetermined location defines one or more receiving cavities operable to receive one or more landing legs of the mobile platform.

[0080] In some embodiments of the disclosed system, the sensor apparatus is operable to ascertain a second location of a second mobile platform on the landing surface.

[0081] In some embodiments of the disclosed system, the mechanical manipulators are operable to move to the second mobile platform based on the ascertained second location.

[0082] In some embodiments of the disclosed system, the mobile platform is an unmanned aerial vehicle (UAV).

[0083] In accordance with a another aspect disclosed herein, there is set forth a maintenance system of a base station for a mobile platform having a payload or a battery, comprising:

[0084] a sensor apparatus for ascertaining a location of the mobile platform on a landing surface;

[0085] a resource supply for defining a plurality of resource-slots each configured to removably hold a replacement payload or replacement battery; and

[0086] one or more mechanical manipulators for moving to the mobile platform based on the ascertained location of the mobile platform and optionally interacting with a selected replacement payload, a selected replacement battery, the payload, or the battery.

[0087] In some embodiments of the disclosed system, the maintenance system is operable to move translationally along an X-axis, a Y-axis, and a Z-axis or rotationally to the ascertained location of the mobile platform.

[0088] In some embodiments of the disclosed system, the mechanical manipulators are operable to:

[0089] move along an X-axis and Y-axis to the selected replacement payload or replacement battery positioned in a selected resource-slot;

[0090] extend a resource-carriage along a Z-axis;

[0091] grasp the selected replacement payload or replacement battery;

[0092] retract the resource-carriage along the Z-axis to remove the replacement payload or replacement battery from the resource-slot;

[0093] move the removed replacement payload or removed replacement battery proximate to the ascertained location of the mobile platform; and

[0094] insert the replacement payload or replacement battery into a mobile platform resource-slot provided on the mobile platform and decouple from the replacement payload.

[0095] In some embodiments of the disclosed system, the sensor apparatus comprises first

and second optical sensors operable to respectively locate the mobile platform along respective perpendicular axes, and wherein the sensor apparatus optionally is configured to operate automatically and without user interaction.

[0096] In some embodiments of the disclosed system, the first and second optical sensors are respectively located on first and second location arms each extending substantially perpendicularly to a respective axis.

[0097] In some embodiments of the disclosed system, at least one of the payload and the replacement payload comprises at least one of a data storage unit, a predetermined quantity of fuel, a predetermined quantity of fertilizer, a predetermined quantity of water, a parcel, cargo, and a predetermined quantity of pesticides.

[0098] In some embodiments of the disclosed system, the mechanical manipulators are operable to actuate a power switch of the mobile platform.

[0099] In some embodiments of the disclosed system, the mechanical manipulators are operable to connect a physical cable assembly to the mobile platform.

[0100] In some embodiments of the disclosed system, the physical cable assembly is a power cable for providing electrical power to the mobile platform.

[0101] In some embodiments of the disclosed system, the physical cable assembly is a communication cable for exchanging data between the base station and the mobile platform.

[0102] In some embodiments of the disclosed system, the physical cable assembly is a fuel line for filling a fuel tank of the mobile platform.

[0103] In some embodiments of the disclosed system, the maintenance system is configured to operate automatically and without user interaction.

[0104] In some embodiments of the disclosed system, at least one of said resource-slots is operable to charge a battery.

[0105] In some embodiments of the disclosed system, the mobile platform remains stationary on the landing surface.

[0106] In some embodiments of the disclosed system, the mechanical manipulators are operable to move the mobile platform from the ascertained location to a predetermined location on the landing surface.

[0107] In some embodiments of the disclosed system, the predetermined location comprises one or more receiving cavities operable to receive one or more landing legs of the mobile platform.

[0108] In some embodiments of the disclosed system, the sensor apparatus is operable to ascertain a second location of a second mobile platform on the landing surface.

[0109] In some embodiments of the disclosed system, the mechanical manipulators are operable to move to the second mobile platform based on the ascertained second location.

[0110] In some embodiments of the disclosed system, the mobile platform is an unmanned aerial vehicle (UAV).

[0111] In accordance with a another aspect disclosed herein, there is set forth a method of inserting a replacement payload or battery into a mobile platform, comprising:

[0112] ascertaining a location of the mobile platform on a landing surface, optionally with the aid of a sensor apparatus;

[0113] grasping the replacement payload or the replacement battery positioned in a selected resource-slot;

[0114] moving the grasped replacement payload or replacement battery to the mobile platform based on the ascertained location of the mobile platform, optionally with an aid of a maintenance system;

[0115] inserting the replacement payload or replacement battery into a payload-slot or a battery-slot positioned on the mobile platform; and

[0116] decoupling the replacement payload or replacement battery.

[0117] In some embodiments of the disclosed method, moving the grasped replacement payload or replacement battery further comprises moving the maintenance system translationally along an X-axis, a Y-axis, and a Z-axis or rotationally of the landing surface to the mobile platform based on the ascertained location of the mobile platform.

[0118] In some embodiments of the disclosed method, grasping the replacement payload or replacement battery further comprises moving a mechanical manipulator of the maintenance system along the X-axis, the Y-axis, and the Z-axis.

[0119] In some embodiments of the disclosed method, the mobile platform is an unmanned aerial vehicle (UAV).

[0120] In accordance with a another aspect disclosed herein, there is set forth a method of storing a payload or battery removed from a mobile platform, comprising:

[0121] ascertaining a location of the mobile platform on a landing surface of a maintenance system;

[0122] a mechanical manipulator of the maintenance system moving proximate to the mobile platform having the payload or the battery positioned thereon in a resource-slot of the mobile platform;

[0123] grasping the payload or the battery positioned in the resource-slot;

[0124] retractably removing the payload or the battery from the resource-slot; and

[0125] inserting the payload or battery in a selected resource storage slot of the maintenance system.

[0126] In some embodiments of the disclosed method, at least one of grasping, retractably moving, and inserting optionally occurs with an aid of the mechanical manipulator.

[0127] In accordance with a another aspect disclosed herein, there is set forth a method of

managing a payload or a battery of a mobile platform, comprising:

[0128] determining a first distance between the mobile platform and a first base station;

[0129] determining a second distance between the mobile platform and a second base station;

[0130] signaling to the mobile platform to land on a selected one of the first and second base stations based on the determined first and second distances;

[0131] landing the mobile platform on a landing surface of the selected base station;

[0132] ascertaining a location of the landed mobile platform on the landing surface; and

[0133] moving a maintenance system relative to the mobile platform based on the ascertained location of the mobile platform.

[0134] In some embodiments of the disclosed method, moving the maintenance system comprises moving the maintenance system translationally along at least one of an X-axis, a Y-axis, and a Z-axis or rotationally to the mobile platform based on the ascertained location of the mobile platform.

[0135] In some embodiments of the disclosed method, the method further comprises interacting with a selected payload or a selected battery of the mobile platform via the maintenance system, wherein said interacting optionally occurs automatically and without user interaction.

[0136] In some embodiments of the disclosed method, the mobile platform is an unmanned aerial vehicle (UAV).

BRIEF DESCRIPTION OF THE DRAWINGS

[0137] Fig. 1 is an exemplary top-level block diagram illustrating an embodiment of a mobile platform management system.

[0138] Fig. 2 is an exemplary top-level block diagram illustrating one embodiment of a base station of the mobile platform management system of Fig. 1.

[0139] Fig. 3 is an exemplary top-view illustrating an embodiment of the manipulator of the base station of Fig. 2 in a first position.

[0140] Fig. 4 is an exemplary top-view illustrating an embodiment of the manipulator of Figs. 2 and 3 in a second position.

[0141] Fig. 5 is an exemplary perspective view illustrating the second position of the manipulator of Fig. 4.

[0142] Fig. 6 is an exemplary perspective view illustrating an embodiment of the manipulator of Fig. 2 returning a battery to a resource compartment.

[0143] Fig. 7 is an exemplary top-view illustrating an embodiment of the manipulator of Fig. 6.

[0144] Fig. 8 is an exemplary view illustrating one embodiment of the undercarriage of a selected mobile platform interfacing with the manipulator of Fig. 2.

[0145] Fig. 9 is another view illustrating an embodiment of the undercarriage of the selected

mobile platform of Fig. 8 interfacing with the manipulator of Fig. 2.

[0146] Fig. 10 is an exemplary flowchart illustrating one embodiment of a method of mobile platform management using the mobile platform management system of Fig. 1.

[0147] Fig. 11 is an exemplary flowchart illustrating one embodiment of a method of battery or payload exchange using the mobile platform management system of Fig. 1.

[0148] Fig. 12 is an exemplary flowchart illustrating one embodiment of a method of coupling a physical cable using the mobile platform management system of Fig. 1.

[0149] It should be noted that the figures are not drawn to scale and that elements of similar structures or functions are generally represented by like reference numerals for illustrative purposes throughout the figures. It also should be noted that the figures are only intended to facilitate the description of the preferred embodiments. The figures do not illustrate every aspect of the described embodiments and do not limit the scope of the present disclosure.

DETAILED DESCRIPTION

[0150] Since currently-available mobile platform management systems are deficient because they fail to accommodate larger mobile platforms, a mobile platform base station that provides autonomous maintenance (e.g., battery/payload swapping) can prove desirable and provide a basis for a wide range of mobile platform applications, such as the ability for unmanned aerial vehicle (UAV) systems to perform longer autonomous missions. This result can be achieved, according to one embodiment disclosed herein, by a mobile platform management system 100 as illustrated in Fig. 1.

[0151] Turning to Fig. 1, the mobile platform management system 100 is shown as including a base station 300 for management of a mobile platform 200. The mobile platform management system 100 is suitable for use with a wide range of mobile platforms. In one embodiment, the mobile platform management system 100 can be suitable for sure with multiple mobile platforms 200, such as one or more UAVs 201. For example, one popular UAV type is an aerial rotorcraft that is propelled by multiple rotors. A rotorcraft having four rotors is known as a quadcopter, quadrotor helicopter, or quad rotor. Such a rotorcraft provides the UAV with a high range of motion, allowing, e.g., vertical takeoff and landing as well as the ability to hover in mid-air for still aerial image acquisition or fly over large fields to spray pesticides. Various UAV types are suitable for the mobile platform management systems and methods, including other rotor designs, e.g., single rotor (e.g., helicopter), dual rotor, trirotor, hexarotor, and octorotor designs. Fixed-wing and hybrid rotorcraft-fixed wing UAVs can also be used.

[0152] The UAVs 201 of the mobile platform management system 100 can have features that allow the UAVs 201 to be remotely controlled by a user and/or autonomously piloted. In many mobile platform management applications, it can be advantageous

that UAVs 201 be capable of both remote and autonomous control so that the UAVs 201 can be switched between remote and autonomous control as needed. During flight, it can be advantageous for a user to have some degree of control of the UAV 201. The UAV 201 thereby can be directed to regions of interest to the user and acquire desired data regarding the region of interest. However, should the UAV 201 lose communication with the base station 300 and/or require fueling/battery replacement, autonomous piloting can take over control of the UAV 201, directing the UAV 201 to follow a pre-set course and/or to return to a home location, such as the base station 300 for routine maintenance. For example, some quadcopter models have automatic homing features that use global positioning systems (GPS) systems to allow the quadcopter to return to its ground location as the need arises. Similarly, under certain routine deployment circumstances, e.g., deployment to a given region of interest prior to the time that the user takes control and/or during redeployment to a different ground station, it may be advantageous that the UAV 201 have some degree of autonomous control.

[0153] The UAVs 201 associated with the mobile platform management system 100 can be equipped with various control systems and sensors (not shown) for controlling flight operations and returning to a selected base station 300. The control systems can, for example, control flight characteristics such as attitude (pitch, roll, and yaw), velocity, and so on of the UAVs 201. Exemplary sensors relating to flight operations include inertial sensors such as inertial measurement units (IMUs) that typically rely on a combination of accelerometers, gyroscopes, and sometimes magnetometers to report on a selected UAV's velocity, orientation, and gravitational forces. The UAV 201 can rely on other sensors, e.g., pressure sensors, temperature, wind speed, and altitude sensors, to assist in its flight operations. Through various computational operations—such as integral operations—a position of the UAV 201 can be extrapolated from such sensor data. Alternatively, the UAVs 201 can sense their own position, for example, through a global positioning system (GPS). In some embodiments, the UAVs 201 are equipped with both inertial sensors and GPS systems, which can be used in complement with one another.

[0154] In some embodiments, the UAVs 201 of the mobile platform management system 100 can be equipped with appropriate instruments (not shown) that may require management at the base station 300, such as for capturing data regarding a region of interest for virtual sightseeing. It is generally advantageous that the instruments be lightweight and able to provide high-frequency data feeds to other components of mobile platform management system 100 to facilitate real-time collection of visual and non-visual data and/or presentation of the collected data in real time. In some embodiments, the UAVs 201 can be equipped with various instruments for collecting

visual data, such as a variety of conventional cameras for image and/or video acquisition. Additionally and/or alternatively, the UAVs 201 can be equipped with thermographic cameras for thermal imaging, spectrum cameras for spectral imaging, and so on. The UAVs 201 can be uniformly and/or differently equipped.

[0155] Additionally and/or alternatively, the UAVs 201 can also be equipped with various instruments for other flight tasks relating to transportation of a variety of payloads (e.g., fuel, a parcel and/or cargo), agriculture (e.g., spraying water, fertilizer, and/or pesticides over a farm), fire-fighting, and so on. Some examples of instruments for transportation of payloads include, but are not limited to, fuel tanks, spray tanks, centrifugal pumps, spray booms, check valves, spray nozzles, and so on.

[0156] The UAVs 201 of the mobile platform management system 100 and method 1000 (shown in Fig. 10) can be uniformly equipped and/or differently equipped. A selected UAV 201 equipped in a particular manner can be selected for deployment based upon a flight task criterion (e.g., an agricultural task, a transportation expedition, a sightseeing request, a characteristic of the region of interest, other sightseeing variables, and so on). For example, the selected UAV 201 can include both virtual sightseeing equipment and pesticide spraying systems for precision agriculture. Advantageously, such combination equipment can reduce over spraying and spreading on farms by determining specific areas of the farms that need more attention.

[0157] As an additional example, the selected UAV 201 can be equipped with floodlights and/or night vision for use during night sightseeing or cave-exploration. In another example, the selected UAV 201 can be equipped with specialized cold-weather proofing and used for exploration of cold regions. In some cases, each geographical sightseeing area can be assigned a group of UAVs 201 that are specially equipped for the characteristics that area. Alternatively, it may be advantageous to equip each UAV 201 uniformly, or have some overlap of functionality capacity, so that the UAVs 201 are interchangeable in case of one of the UAVs 201 experiences a malfunction and requires management at the base station 300.

[0158] The UAVs 201 of the mobile platform management system 100 can be equipped to communicate wirelessly with the base station 300. A selected UAV 201 associated with the mobile platform management system 100 can be likened to a communications endpoint, e.g., a cell phone, within a wireless communications network. Thus, any conventional wireless communication protocol appropriate for communications endpoints can be suitable for use to facilitate communications between the UAVs 201, the base station 300, and any other components of the mobile platform management system 100. For example, the UAV 201 can establish data uplink and/or downlink channels with the base station 300 for navigation, localization, data transmission, and the like. Suitable wireless communication media can include any category of conventional

wireless communications, for example, radio, Wireless Fidelity (Wi-Fi), cellular, satellite, and broadcasting. Exemplary suitable wireless communication technologies include, but are not limited to, Global System for Mobile Communications (GSM), General Packet Radio Service (GPRS), Code Division Multiple Access (CDMA), Wideband CDMA (W-CDMA), CDMA2000, IMT Single Carrier, Enhanced Data Rates for GSM Evolution (EDGE), Long-Term Evolution (LTE), LTE Advanced, Time-Division LTE (TD-LTE), High Performance Radio Local Area Network (HiperLAN), High Performance Radio Wide Area Network (HiperWAN), High Performance Radio Metropolitan Area Network (HiperMAN), Local Multipoint Distribution Service (LMDS), Worldwide Interoperability for Microwave Access (WiMAX), ZigBee, Bluetooth, Flash Orthogonal Frequency-Division Multiplexing (Flash-OFDM), High Capacity Spatial Division Multiple Access (HC-SDMA), iBurst, Universal Mobile Telecommunications System (UMTS), UMTS Time-Division Duplexing (UMTS-TDD), Evolved High Speed Packet Access (HSPA+), Time Division Synchronous Code Division Multiple Access (TD-SCDMA), Evolution-Data Optimized (EV-DO), Digital Enhanced Cordless Telecommunications (DECT) and others.

[0159] In certain embodiments, the UAVs 201 and the base station 300 of the mobile platform management system 100 mutually communicate via 3G or 4G (i.e., third generation or fourth generation) mobile telecommunications technologies. In other embodiments, UAVs 201 can use 5G (i.e., fifth generation) mobile telecommunications networks to facilitate communications between the relevant subsystems of the mobile platform management system.

[0160] In some embodiments, the wireless communications between the subsystems of the mobile platform management system 100 can be encrypted, as may be advantageous for secure flight task applications. Suitable encryption methods include, but are not limited to, internet key exchange, Internet Protocol Security (IPsec), Kerberos, point-to-point protocol, transport layer security, SSID hiding, MAC ID filtering, Static IP addressing, 802.11 security, Wired Equivalent Privacy (WEP), Wi-Fi Protected Access (WPA), WPA2, Temporal Key Integrity Protocol (TKIP), Extensible Authentication Protocol (EAP), Lightweight Extensible Authentication Protocol (LEAP), Protected Extensible Authentication Protocol (PEAP), and the like. Encryption methods specifically designed for mobile platform management systems may also be suitable.

[0161] Thus, existing wireless technologies for use by current telecommunications endpoints can be readily adapted for use by the UAVs 201. For example, by outfitting each UAV 201 with a wireless card like those used for mobile phones, or other suitable wireless communications hardware, the UAVs 201 can easily be integrated into existing networks. Alternatively, and/or additionally, proprietary communications hardware can

be used as needed.

[0162] As shown in Fig. 1, the base station 300 can cooperate with the mobile platform 200. While the base station 300 and the mobile platform 200 are represented schematically as single subsystems of the mobile platform management system 100, more than one base station 300 can cooperate with a selected mobile platform 200. Similarly, more than one mobile platform 200 can cooperate with a selected base station 300. In certain embodiments, a selected base station 300 is associated with a geographical location where the UAVs 201 can land, thereby providing anchor or "home" locations for the UAVs 201. For example, each UAV 201 can be programmed to return to a selected base station 300 as a matter of default when, for example, the UAV 201 is low on power, flies out of range, requires a payload drop-off and/or pick-up, completes a flight task, encounters unexpected operating conditions, and so on. In some embodiments, the base station 300 can be a vacant land area where the UAV 201 is allowed to land safely until it can be manually located, recharged, and/or maintained for further operation. In other embodiments, the base station 300 can include additional support systems, which will be further described below.

[0163] In some embodiments, each base station 300 is configured to accommodate a single UAV 201; however, in other embodiments, each base station 300 is configured to simultaneously accommodate a plurality of the UAVs 201.

[0164] Turning now to Fig. 2, an exemplary embodiment of the base station 300 is illustrated in further detail. The base station 300 can be lightweight and portable so as to be unobtrusive and easily moved when relocation of the base station 300 is desired. The base station 300 can include a manipulator 310 operated by a manipulator compartment 320. In some embodiments, the manipulator compartment 320 includes a hardware and software infrastructure for providing a mobile platform management user interface (not shown). For example, the mobile platform management user interface can include a display and/or input system (not shown) for enabling a user to interact with the base station 300 and/or a selected UAV 201 associated with the base station 300. Exemplary interactions can include setting a flight parameter and/or reading a status of the base station 300 and/or the selected UAV 201. In one embodiment, the display and input system can be at least partially integrated as a touchscreen system. The users can also communicate with the base station 300 with a user device (e.g., smartphone, tablet, personal computer) via wireless and/or wired (e.g., universal serial bus) communications. Therefore, the users can monitor the status of a flight task, set flight task parameters, and/or manually override the control of a selected UAV 201. The manipulator compartment 320 thereby provides various input and output functions for the mobile platform management system 100 (shown in Fig. 1). The manipulator compartment 320 can perform many of the input and output functions for a user

interface, including functions related to maintenance of the UAVs 201, data output/ presentation, and support.

[0165] Additionally and/or alternatively, the manipulator compartment 320 can perform the control functions for the manipulator 310. Thus, the manipulator compartment 320 further includes a manipulator engine 321 for driving physical movements of the manipulator 310. In some embodiments, the manipulator engine 321 is configured to drive the manipulator 310 with at least four degrees of freedom. For example, the manipulator 310 is operable to translate linearly along an axis X (shown in Fig. 5) and an axis Y (shown in Fig. 5) that extends substantially perpendicularly to the axis X. The manipulator engine 321 can also adjust the height of the manipulator 310 along an axis Z (shown in Fig. 5), which is normal to the axis X and the axis Y, and rotate the manipulator 310 at least 360 degrees. In some embodiments, the control functions for the manipulator 310 can operate without user interaction. Such functions of the manipulator compartment 320 are described in more detail below with reference to Figs. 3-7.

[0166] The manipulator 310 provides resources to the mobile platform 200 from resource storage 340. In some embodiments, the resource storage 340 includes a charging station for recharging and storing batteries that power the UAVs 201 (shown in Fig. 6), power stations (not shown) for providing power sources (e.g., other than electricity) to the UAVs 201, fuel stations, payload (e.g., pesticides) replacements, data storage transmission systems (e.g., hard disks, universal serial bus (USB) adapters, Ethernet coupling systems, machines having combinations thereof, and so on), combinations of any of the preceding, and the like. In some embodiments, the resource storage 340 can provide power, such as electrical power and/or operating power, to the UAVs 201 via wired and/or wireless power transmission. The power provided by the resource storage 340 can be used to replenish one or more resources, such as a rechargeable battery system, of a relevant UAV 201. The resources available from resource storage 340 can vary to accommodate for various flight tasks of the mobile platform 200.

[0167] While shown and described as comprising a single manipulator 310 and a single resource storage 340 for purposes of illustration only, the base station 300 can comprise more than one manipulator 310 and/or more than one resource storage 340 that can cooperate with a selected mobile platform 200. For example, two manipulators 310 simultaneously can cooperate with the selected mobile platform 200 for exchanging a battery and unloading cargo from the resource storages 340 at the same time.

[0168] As shown in Fig. 2, the base station 300 can further provide a landing surface 330 for receiving the mobile platform 200 (e.g., UAVs 201). To aid the UAVs 201 in landing on the landing surface 330, communication between the UAVs 201 and the base

station 300 may be used to direct the UAVs 201 to the general location of the landing surface 330. As discussed above, the communication between the UAVs 201 and the base station 300 may occur wirelessly. In one example, the UAV 201 may employ GPS or other location-based software to locate the base station 300. The GPS or other location-based techniques can be used to get a selected UAV 201 to the vicinity of the base station 300. The wireless communication directs the UAV 201 within a predetermined range of the base station 300, wherein the UAV 201 can sense one or more elements/subsystems of the base station 300. For instance, the UAV 201 may be brought into a line-of-sight of the manipulator compartment 320. A landing area marker 331, or any unique landing marker, may aid in further pinpointing the location of the landing surface 330. As desired, the landing area marker 331 can be provided on the landing surface 330 and may serve as a confirmation of the landing surface 330 on which the UAV 201 may land. The landing area marker 331 may also differentiate the landing surface 330 from other objects or regions.

[0169] In some embodiments, the landing area marker 331 may indicate a landing position of the UAV 201 on the landing surface 330. The landing area marker 331 may be used as a fiducial marker, which may aid the UAV 201 in navigating to a proper landing position on the landing surface 330. In some examples, multiple landing area markers 331 may be provided, which may aid the UAV 201 to land in a desired position. For example, multiple landing area markers 331 can be used for a larger landing surface 330 that accommodates multiple UAVs 201 and/or provide boundaries for a single UAV 201. In some instances, it may also be desirable for the UAV 201 to have a particular orientation when docking with the base station 300. In one example, the landing area marker 331 may include an asymmetric image, a letter of the alphabet, and/or code that may be discernible by the UAV 201. The landing area marker 331 may be indicative of the orientation of the base station 300 relative to the UAV 201. Thus, the UAV 201 can find proper orientation when landing on the landing surface 330.

[0170] The landing area marker 331 may also be indicative of a distance of the base station 300 relative to the UAV 201. The distance may be used separate from or in combination with one or more other sensors of the UAV 201 to determine the altitude of the UAV 201. For example, if the size of the landing area marker 331 is known, the distance from the UAV 201 to the landing area marker 331 may be gauged depending on a size of the landing area marker 331 showing up in the sensors (not shown) of the UAV 201.

[0171] In one example, the landing area marker 331 may be provided at a particular location relative to a desired landing spot of the UAV 201 on the landing surface 330. The UAV 201 may be capable of landing on the landing surface 330 with great precision.

The landing area marker 331 may help guide the UAV 201 to the desired landing spot. For instance, the landing area marker 331 may be located 10 cm in front of the center of the desired landing point of the UAV 201. Alternatively, multiple landing area markers 331 may be provided such that the desired landing spot may fall between the multiple landing area markers 331. The UAV 201 may use the markers to help orient the UAV 201 and/or position its landing between the markers. Distance between the markers may aid the UAV 201 in gauging the distance from the UAV 201 to the landing surface 330.

[0172] The landing area marker 331 may be placed in a location that is easily discernable from flight (e.g., aerial top-view). In some instances, the landing area marker 331 may be provided on an exterior surface of the base station 300 (e.g., on an external surface of the manipulator 310 and/or manipulator compartment 320). The landing area marker 331 may include a transmitter (not shown) for relaying a wireless signal being emitted by the base station 300. The origin of the signal may be from outside the base station 300 and/or within the base station 300 (e.g., manipulator compartment 320). Alternatively, the base station 300 may emit signals in the infrared (IR), ultraviolent (UV), radio, and/or audio frequency band.

[0173] In one example, the landing area marker 331 may be positioned less than about 100 cm, 90 cm, 80 cm, 75 cm, 70 cm, 65 cm, 60 cm, 55 cm, 50 cm, 45 cm, 40 cm, 35 cm, 30 cm, 25 cm, 20 cm, 15 cm, 12 cm, 10 cm, 8 cm, 7 cm, 6 cm, 5 cm, 4 cm, 3 cm, 2 cm, or 1 cm from where the UAV 201 should attempt to land on the landing surface 330.

[0174] Data pertaining to the detected landing area marker 331 may be provided to one or more processors (not shown). The processors may be on board the UAV 201. Based on the received information about the detected landing area marker 331, the processors may, individually or collectively, generate a command signal. The command signal may drive propulsion units (not shown) of the UAV 201. For example, the propulsion units may be driven to cause the UAV 201 to land on the landing surface 330 adjacent to the detected landing area marker 331, when the detected landing area marker 331 is determined to be associated with the base station 300. The detected landing area marker 331 may indicate the state of charge of the stored batteries (not shown) at the base station 300. For example, if the base station 300 has a fully-charged battery available, the detected landing area marker 331 may result in a command from the processor to land the UAV 201. In another example, if the base station 300 does not have a charged battery available, the detected landing area marker 331 may result in a command from the processor to continue traveling to the next-closest base station 300 with an available charged battery. Thus, a UAV 201 may be able to land in an autonomous or semi-autonomous fashion in response to a detected landing area marker 331. The UAV 201 may be capable of landing without receiving any commands or

manual input from the user.

[0175] In some embodiments, the sensors (not shown) on board the UAV 201 may be used to detect the landing area marker 331 and processing may occur on-board the UAV 201. The UAV 201 may be capable of landing itself on the landing surface 330 without requiring further guidance or information from the base station 30 once the UAV 201 has confirmed that the landing area marker 331 is associated with the base station 300.

[0176] The base station 300 may send information about its location to a selected UAV 201 (or broadcast the location information to all UAVs 201). The base station 300 may have a location unit (not shown) capable of determining positional information. The base station 300 may receive information from the UAV 201 about the location of the UAV 201, the state of the battery on board the UAV 201, and/or the level of fuel remaining on the UAV 201. For example, coordinate information, such as GPS co-ordinates, for the UAV 201 may be provided to the base station 300. In another example, the UAV 201 may communicate the remaining charge percentage of the battery currently in use on the UAV 201. The base station 300 may have a communication unit (e.g., manipulator compartment 320) capable of communicating with the UAV 201. The base station 300 may have a processor (not shown) capable of identifying and/or calculating a location of the UAV 201.

[0177] Additionally and/or alternatively, the processor of the base station 300 may be capable of identifying and/or calculating a location of the next nearest battery exchange station (not shown). For example, the UAV 201 may communicate to the base station 300 that the battery currently on board the UAV 201 has a remaining charge percentage of 18%. In some embodiments, the processor of the base station 300 can calculate a distance to the next nearest battery exchange station in the flight path of a particular UAV 201 to determine whether the UAV 201 should stop at the base station 300 for maintenance or continue to the next nearest battery exchange station with an available charged battery.

[0178] Once the UAV 201 has landed, the specific landing accuracy of the UAV 201 on the landing surface 330 can depend on a number of landing properties (e.g., weather, sensor accuracy, and so on). As discussed above, conventional mobile platform management systems require movement of the UAV 201 to a specific position on the landing surface 330 for autonomous operation on the UAV 201. However, for larger UAVs 201, the resources and cost required to move the larger UAV 201 to the desired position on the landing surface 330 is not practical for autonomous operation on the larger UAV 201. Accordingly, the base station 300 can accommodate for low-accuracy landing of the UAV 201.

[0179] With reference now to Fig. 3, the UAV 201 lands on the landing surface 330, for example, within 20 cm of the landing marker 330 (shown in Fig. 2). As shown in Fig.

3, prior to and during the UAV 201 landing, the manipulator 310 is coupled to the manipulator compartment 320 on the lower left of the landing surface 330 to provide for a landing area on the landing surface 330 that is free of physical interference. Similarly, the resource storage 340 is situated away from the landing surface 330 while being accessible to the manipulator 310. As used herein, the position of the manipulator 310, the manipulator compartment 320, and the resource storage 340 relative to the landing surface 330 that is shown in Fig. 3 is referred to as a "home" position of the base station 300.

[0180] After the UAV 201 lands, a sensor 332 (shown in Fig. 2) on the base station 300 can determine the location of the landed UAV 201 on the landing surface 330. As a non-limiting example, the sensor 332 can include first and second optical sensors, located on respective perpendicular axes relative to the landing surface 330, and can ascertain position information of the UAV 201. Accordingly, each optical sensor can provide a Cartesian coordinate on a horizontal plane parallel to the landing surface 330. With the first and second optical sensor located on respective perpendicular axes, the coordinates can represent the position of the perpendicular projection of the UAV 201 onto the two axes, expressed as signed distances from a predetermined point, such as the manipulator compartment 320. Additionally and/or alternatively, the sensor 332 can include, but is not limited to, any number of contact image sensors, electro-optical sensors, infra-red sensors, kinetic inductance detectors, light-emitting diode (LED) as light sensors, fiber optic sensors, optical position sensors, photodetectors, pressure sensors, photoresistors, phototransistors, thermal or temperature sensors, proximity sensors, electric current sensors, magnetic sensors, radio sensors, and so on.

[0181] The manipulator compartment 320 can use the position information of the UAV 201 to control the manipulator 310 via the manipulator engine 321 to move from the home position to the UAV 201.

[0182] Turning to Fig. 4, the manipulator 310 is shown as including a manipulator arm system 311 having a manipulator carriage 312 on a distal end of the manipulator arm system 311. The manipulator arm system 311 can be directly and/or indirectly coupled to the manipulator engine 321. In some embodiments, a manipulator rail system (not shown) can be used to provide a drive path for the manipulator arm system 311.

[0183] As shown in Fig. 4, the manipulator engine 321 has extended the manipulator arm system 311 away from the manipulator compartment 320. Stated in another way, the manipulator carriage 312 has translated from the home position along the axis X and the axis Y to the UAV 201 based on ascertained position information of the UAV 201. To accommodate for UAVs 201 that may require unique maintenance at one or more positions of the UAV 201, the manipulator carriage 312 can elevate and/or lower to a desired height, such as along the axis Z shown in Fig. 5.

[0184] In some embodiments, the UAV 201 includes one or more service markers (not shown), each on a predetermined and unique location of the UAV 201 to indicate service locations on the UAV 201. For example, a selected UAV 201 may include a unique code or asymmetric shape on its battery compartment (not shown) such that the manipulator compartment 320 can identify the service marker for a precise service area. The service marker for the battery compartment thereby can be distinguished from a different service marker on the UAV 201 that is used to indicate a payload storage compartment. Thus, similar to the function of the landing area marker 331, once the manipulator compartment 320 locates the desired service marker on the UAV 201, the manipulator engine 321 can direct the manipulator carriage 312 to the specific location of the battery compartment.

[0185] In other embodiments, the service locations on the UAV 201 are known to the base station 300. For example, a fleet of UAVs 201 can each have a battery compartment in a predetermined position that is common to the other UAVs 201 of the fleet. Thus, once the location of the UAV 201 on the landing surface 330 is determined, the manipulator engine 321 can direct the manipulator carriage 312 to the battery compartment without the need for service markers.

[0186] Even further, the manipulator carriage 312 rotates, for example, with 360-degrees of freedom, to accommodate maintenance that requires varying angles of operation. In one example, the manipulator carriage 312 can grasp a battery 345 (shown in Fig. 8 and Fig. 9) situated in the UAV 201, remove the battery 345 from the UAV 201, insert a charged battery into the UAV 201, and place the removed battery 345 in a battery compartment (shown in Fig. 6) for charging. Depending on the particular UAV 201, removing the battery 345 may require rotation of the manipulator carriage 312 to free the battery 345 from the UAV 201. In another example, the manipulator carriage 312 can be configured to provide fuel for a particular UAV 201 that includes an engine, such as an internal combustion engine, that can require refueling). In this manner, the base station 300 advantageously can operate as a gas (or refueling) station for the UAV 201. The varying degrees of freedom of the manipulator 310 advantageously accommodate maintenance relating to a number of flight tasks (e.g., replacing fuel, replacing pesticides, and transmission of electronic data including bidirectional data transfer).

[0187] Once the battery 345 has been removed from the UAV 201, the battery 345 can be placed in the resource storage 340 for recharging. One example is shown in Figs. 6 and 7. With specific reference to Fig. 6, the resource storage 340 is illustrated as including a battery-matrix that forms a plurality of battery-charging slots 341. Each battery-charging slot 341 is configured to store a respective battery 345. As depicted in Fig. 6, the battery-matrix comprises two stacked rows of battery-charging slots 341, where

each row comprises five battery-charging slots 341.

[0188] Although a specific configuration of the battery-matrix is shown and described with reference to Fig. 6, for purposes of illustration only, any suitable arrangement of battery-charging slots 341 within the battery-matrix may be provided. The battery matrix can include any suitable number of battery-charging slots 341. The number of battery-charging slots 341 can depend on the number of UAVs 201 in the mobile platform management system 100, charging time of the battery pack 345, desired mission time, or the like. For example, some embodiments of the base station 300 may include fewer battery-charging slots 341 or may include many more battery-charging slots 341. The battery-charging slots 341 may have any suitable size and/or shape based on the type of the battery-pack 345 to be held therewithin, and, in some embodiments, the battery-matrix may be configured to hold a plurality of uniform and/or different battery pack types, which may include different shapes, cross sections, voltages, currents, or the like. In some embodiments, there may be any suitable number of rows and/or columns in the battery-matrix, and further embodiments may include battery-charging slots 341 in any other suitable regular or non-regular configuration, that may or may not include rows or columns. In some embodiments, there may be a plurality of battery-matrices and/or the battery-matrix may be three dimensional compared to the two dimensional arrangement depicted herein (i.e., a first dimension of rows, and a second dimension of columns).

[0189] After maintenance on the UAV 201 is completed, the manipulator 310 can return to the home position, and the UAV 201 is ready to fly again.

[0190] The mobile platform management system 100 can manage the mobile platforms in any suitable manner discussed above, including via an exemplary process 1000 for mobile platform management, shown in Fig. 10. With reference to Fig. 10, the exemplary process 1000 for mobile platform management of the UAVs 201 is shown as including a plurality of processes, which need not be performed in the order depicted.

[0191] At 1001, the landing surface 330 (shown in Figs. 2-7) receives the mobile platform 200 (shown in Figs. 3-5). As discussed in more detail above, a variety of methods are suitable for assisting the mobile platform 200 in locating the landing surface 330 (shown in Figs. 2-7) of the base station 300. Once the mobile platform 200 has landed, the base station 300 acquires the position of the mobile platform 200, at 1002, in any manner described herein.

[0192] Based on the acquired position, the manipulator 310, at 1003, moves to the location of the mobile platform 200 (shown in Figs. 4 and 5) and performs one or more management functions, at 1004. In the examples described above, the base station 300 is operable for payload and battery maintenance. Furthermore, the mobile platform

management system 100 is operable to perform any suitable task discussed above to the mobile platforms, including, for example, an exemplary process 1100 for payload and battery maintenance (shown in Fig. 11) and an exemplary process 1200 for coupling a physical cable to the mobile platform 200 (shown in Fig. 12).

[0193] Turning to Fig. 11, the exemplary process 1100 for payload and battery maintenance is shown. At 1101, the battery/payload compartment of the mobile platform 200 is located, and the manipulator carriage 312 moves to the located position at 1102. As discussed above, the battery/payload is removed and stored at 1103 in the resource storage 340, for example, to recharge. In another example, a selected UAV 201 suited for agriculture can exchange a spray tank including pesticides with a full tank of pesticides for a subsequent flight task. Once removed, a replacement battery/payload optionally can be returned to the UAV 201, at 1104.

[0194] In the preceding examples, a physical payload/battery is exchanged with the base station 300. Additionally and/or alternatively, the base station 300 can be configured for providing non-physical exchange/communication with the mobile platform 200.

[0195] With reference now to Fig. 12, for example, the exemplary process 1200 for coupling a physical cable to the mobile platform 200 is shown.

[0196] The process 1200 begins, at 1201, with locating a coupling port on the mobile platform 200. For instance, a UAV 201 that is assigned for virtual sightseeing and/or capturing various videos/images can include an on-board data storage system (not shown) with the captured videos/images. Similarly, data can be provided from the base station 300 to the UAV 201 for software/firmware updates. Accordingly, at 1201, the base station 300 locates a data exchange port (e.g., Universal Serial Bus (USB), Ethernet, and so on) on the UAV 201 for providing bidirectional data transfer between the base station 300 and the mobile platform 200. In other examples, the coupling port can include fuel lines, for UAVs 201 that include an engine that can require refueling as discussed above, and/or other non-electronic data ports. Once the desired coupling port has been identified, the process 1202 can move the manipulator 310 to the desired coupling port, at 1202, and a physical cable (e.g., Ethernet cable, USB cable, fuel line, power cable, and so on) of the base station 300 is coupled to the mobile platform 200, at 1203. Data/fuel and the like thereby can be exchanged between the base station 300 and the mobile platform 200, at 1204, and, once the exchange is complete, the physical cable is removed and returned to the home position, at 1205.

[0197] In some embodiments, the base station 300 can be configured for providing power, such as electrical operating power, to the mobile platform 200. In process 1200, a physical communication cable, such as an alternating current (AC) adapter, can be used to transfer power from a power source (e.g., resource storage 340) of the base station 300 to the mobile platform 200. Thereby, the base station 300 advantageously

can recharge a rechargeable battery (not shown) of the mobile platform 200 without a need to physically remove the battery and/or exchange batteries (e.g., process 1100).

[0198] In other embodiments, the base station 300 can be configured for supporting wireless power and/or wireless energy exchange with the mobile platform 200. The base station 300, for example, can be equipped with an electric coil system (not shown) for acting as a power transmitter. Stated somewhat differently, the landing surface 330 of the base station 300 can function as a charging pad for the mobile platform 200. Additionally and/or alternatively, the manipulator 310 can be equipped with the coil system. Accordingly, power can be transferred from the base station 300 to the mobile platform 200 via coupled inductors (e.g., direct induction followed by resonant magnetic induction). Similarly, electromagnetic radiation, electrical conduction, and so on can be used for wireless power transmission between the base station 300 and the mobile platform 200.

[0199] In some other embodiments, the base station 300 is configured for tasks that do not involve physical or non-physical exchange with the mobile platform 200. As a non-limiting example, the base station 300 locates a power switch (not shown) on a selected UAV 201. The base station 300 can actuate (e.g., turn on or off) the power switch on the UAV 201 to restart, power-on, power-down, and/or enter a dormant mode.

[0200] In yet another embodiment, the landing surface 330 includes a plurality of landing guides (not shown), such as receiving cavities for guiding landing equipment of the mobile platform 200 (shown in Fig. 1). The receiving cavities can facilitate landing and ensure that the mobile platform 200 is in a proper orientation. For example, while the base station 300 may know the predetermined location of particular service areas on a selected UAV 201 as discussed above, the receiving cavities can be used to confirm that the selected UAV 201 did not land at an angle relative to the manipulator compartment 320 that requires additional movement of the manipulator carriage 312. The number of receiving cavities of the landing surface 330 (shown in Figs. 2-7) can vary to accommodate the UAVs 201 having a predetermined number of landing legs (not shown). When the UAV 201 lands on the landing surface such that the landing legs of the UAV 201 are not received by a respective receiving cavity (not shown), a sensor (not shown) can obtain a spatial relationship between the landing legs of the UAV 201 and corresponding receiving cavities. Thus, the manipulator 310 is configured to assist the UAV 201 into the corresponding cavities based on the obtained spatial relationship. Advantageously, maintenance of the UAV 201 can proceed as discussed above with UAVs 201 having limited landing accuracy.

[0201] The described embodiments are susceptible to various modifications and alternative forms, and specific examples thereof have been shown by way of example in the

drawings and are herein described in detail. It should be understood, however, that the described embodiments are not to be limited to the particular forms or methods disclosed, but to the contrary, the present disclosure is to cover all modifications, equivalents, and alternatives.

Claims

[Claim 1] A method of managing a payload or a battery of a mobile platform positioned on a landing surface, comprising:
ascertaining a location of the mobile platform; and
moving a maintenance system relative to the mobile platform based on the ascertained location of the mobile platform.

[Claim 2] The method of claim 1, wherein said moving the maintenance system comprises moving the maintenance system translationally along at least one of an X-axis, a Y-axis, and a Z-axis or rotationally to the mobile platform based on the ascertained location of the UAV.

[Claim 3] The method of claim 1 or claim 2, further comprising interacting with a selected payload or a selected battery of the mobile platform via the maintenance system, wherein said interacting optionally occurs automatically and without user interaction.

[Claim 4] The method of claim 3, wherein said interacting with the selected payload or the selected battery of the mobile platform comprises at least one of removing the selected battery and recharging the selected battery.

[Claim 5] The method of claim 3, wherein said interacting with the selected payload or the selected battery of the mobile platform comprises interacting with at least one of fuel, parcels, cargo, water, pesticides, fertilizer, and a data storage unit of the mobile platform.

[Claim 6] The method of any one of the above claims, further comprising inserting a replacement payload or replacement battery into the mobile platform.

[Claim 7] The method of any one of the above claims, further comprising actuating a power switch of the mobile platform.

[Claim 8] The method of any one of the above claims, further comprising connecting a physical cable assembly to the mobile platform.

[Claim 9] The method of claim 8, wherein said connecting the physical cable assembly comprises at least one of connecting a first physical communication cable assembly for transmitting data from the base station to the mobile platform, connecting a second physical communication cable assembly for transmitting data from the mobile platform to the base station, connecting a power cable for providing electrical power to the mobile platform, and connecting a fuel line for refueling the mobile platform.

[Claim 10] The method of claim 9, wherein said connecting the first physical communication cable assembly and said connecting the second physical communication cable assembly comprise connecting a common physical communication cable assembly for exchanging data between the mobile platform and the base station.

[Claim 11] The method of any one of the above claims, further comprising wirelessly providing power to the mobile platform.

[Claim 12] The method of any one of the above claims,
wherein said ascertaining the location of the mobile platform comprises receiving position information from one or more sensors, and
wherein said one or more sensors comprise at least one of an optical sensor, a contact image sensor, an electro-optical sensor, an infra-red sensor, a kinetic inductance detector, a light-emitting diode (LED) as light sensor, a fiber optic sensor, an optical position sensor, a photodetector, a pressure sensor, a photoresistor, a phototransistor, a thermal or temperature sensor, a proximity sensor, an electric current sensor, a magnetic sensor, and a radio sensor.

[Claim 13] The method of any one of the above claims, wherein the mobile platform remains stationary on the landing surface.

[Claim 14] The method of any one of claims 1-12, further comprising moving the mobile platform from the ascertained location to a predetermined location on the landing surface.

[Claim 15] The method of claim 14, wherein said moving the mobile platform to the predetermined location results in one or more landing legs of the mobile platform each engaging a corresponding receiving cavity defined on a predetermined surface of the landing surface.

[Claim 16] The method of any one of the above claims, further comprising ascertaining a second location of a second mobile platform.

[Claim 17] The method of any one of the above claims, wherein the mobile platform is an unmanned aerial vehicle (UAV).

[Claim 18] A base station for a mobile platform having a payload or a battery, comprising:
a landing surface; and
a maintenance system operable to ascertain a location of the mobile platform on the landing surface and move to the mobile platform based on the ascertained location of the mobile platform.

[Claim 19] The base station of claim 18, wherein said maintenance system is operable to move translationally along an X-axis, a Y-axis, and a Z-axis

or rotationally to the mobile platform based on the ascertained location of the mobile platform.

[Claim 20] The base station of claim 18 or claim 19, wherein said maintenance system is operable to interact with a selected replacement payload and the payload of the mobile platform and optionally is configured to operate automatically and without user interaction.

[Claim 21] The base station of any one of claims 18-19, wherein at least one of the selected replacement payload and the payload comprises at least one of a data storage unit, a predetermined quantity of fuel, a predetermined quantity of fertilizer, a predetermined quantity of water, one or more parcels, cargo, and a predetermined quantity of pesticides.

[Claim 22] The base station of any one of claims 18-21, wherein said maintenance system is operable to interact with a selected replacement battery and the battery of the mobile platform and optionally is configured to operate automatically and without user interaction.

[Claim 23] The base station of claim 22, wherein said maintenance system is further operable to at least one of remove the battery from the mobile platform, recharge the removed battery, and insert the selected replacement battery into the mobile platform.

[Claim 24] The base station of any one of claims 18-23, wherein the maintenance system is further operable to ascertain a distance between the mobile platform and a second base station located on a flight path of the mobile platform.

[Claim 25] The base station of claim 24, wherein the maintenance system is further operable to provide a signal to the mobile platform, the signal instructing the mobile platform to land on the landing surface or travel to the second base station.

[Claim 26] The base station of any one of claims 18-25, wherein the maintenance system is further operable to actuate a power switch of the mobile platform.

[Claim 27] The base station of any one of claims 18-26, wherein the maintenance system is further operable to connect a physical cable assembly to the mobile platform.

[Claim 28] The base station of claim 27, wherein said physical cable assembly comprises at least one of a first communication cable assembly for transmitting data from the base station to the mobile platform, a second communication cable assembly for transmitting data from the mobile platform to the base station, a power cable for providing electrical

power to the mobile platform, and a fuel line for refueling the mobile platform.

[Claim 29] The base station of claim 28, wherein said first communication cable assembly and said second communication cable assembly comprise a common physical communication cable assembly for exchanging data between the mobile platform and the base station.

[Claim 30] The base station of any one of claims 18-29, wherein said maintenance system is operable to wirelessly provide power to the mobile platform.

[Claim 31] The base station of claim 30, wherein said landing surface comprises a charging pad for wirelessly providing the power to the mobile platform.

[Claim 32] The base station of claim 31, wherein the power provided to the mobile platform comprises electrical power.

[Claim 33] The base station of claim 31 or claim 32, wherein said landing surface comprises an electric coil system for wirelessly providing the power to the mobile platform.

[Claim 34] The base station of any one of claims 18-33, wherein said maintenance system is operable to move the mobile platform from the ascertained location to a predetermined location on the landing surface.

[Claim 35] The base station of claim 34, wherein the predetermined location comprises one or more receiving cavities defined on a predetermined surface of the landing surface and being operable to receive one or more landing legs of the mobile platform.

[Claim 36] The base station of any one of claims 18-35, wherein said maintenance system is operable to ascertain a second location of a second mobile platform on the landing surface and move to the second mobile platform based on the ascertained second location of the second mobile platform.

[Claim 37] The base station of claim 36, wherein said maintenance system comprises at least two manipulator carriages optionally operable to move simultaneously for moving to the first and second mobile platform.

[Claim 38] The base station of claim 37, wherein at least one of said manipulator carriages comprises a power transmitter for wirelessly providing power to the mobile platform.

[Claim 39] The base station of claim 38, wherein the power provided to the mobile platform comprises electrical power.

[Claim 40] The base station of claim 38 or claim 39, wherein said power transmitter comprises an electric coil system for wirelessly providing

the power to the mobile platform.

[Claim 41] The base station of any one of claims 18-40, wherein the mobile platform is an unmanned aerial vehicle (UAV).

[Claim 42] A base station for a mobile platform having a payload or a battery, comprising:
a landing surface configured for the mobile platform to land thereon; and
a maintenance system comprising:
a sensor apparatus for ascertaining a location of the mobile platform on the landing surface;
a resource supply for defining a plurality of resource-slots each configured to removably hold a replacement payload or replacement battery; and
one or more mechanical manipulators for moving to the mobile platform based on the ascertained location of the mobile platform and optionally interacting with a selected replacement payload, a selected replacement battery, the payload, or the battery.

[Claim 43] The base station of claim 42, wherein said maintenance system is operable to move translationally along an X-axis, a Y-axis, and a Z-axis or rotationally to the ascertained location of the mobile platform.

[Claim 44] The base station of claim 42 or claim 43, wherein the mechanical manipulators are operable to:
move along an X-axis and Y-axis to the selected replacement payload or replacement battery positioned in a selected resource-slot;
extend a resource-carriage along a Z-axis;
grasp the selected replacement payload or replacement battery;
retract the resource-carriage along the Z-axis to remove the replacement payload or replacement battery from the resource-slot;
move the removed replacement payload or removed replacement battery proximate to the ascertained location of the mobile platform; and
insert the replacement payload or replacement battery into a mobile platform resource-slot provided on the mobile platform and decouple from the replacement payload.

[Claim 45] The base station of any one of claims 42-44, wherein said sensor apparatus comprises first and second optical sensors operable to respectively locate the mobile platform along respective perpendicular axes, and wherein the sensor apparatus optionally is configured to

operate automatically and without user interaction.

[Claim 46] The base station of claim 45, wherein the first and second optical sensors are respectively located on first and second location arms each extending substantially perpendicularly to a respective axis.

[Claim 47] The base station of any one of claims 42-46, wherein at least one of the payload and the replacement payload comprises at least one of a data storage unit, a predetermined quantity of fuel, a predetermined quantity of fertilizer, a predetermined quantity of water, a parcel, cargo, and a predetermined quantity of pesticides.

[Claim 48] The base station of any one of claims 42-47, wherein said mechanical manipulators are operable to actuate a power switch of the mobile platform.

[Claim 49] The base station of any one of claims 42-48, wherein said mechanical manipulators are operable to connect a physical cable assembly to the mobile platform.

[Claim 50] The base station of claim 49, wherein the physical cable assembly is a power cable for providing electrical power to the mobile platform.

[Claim 51] The base station of claim 49, wherein the physical cable assembly is a communication cable for exchanging data between the base station and the mobile platform.

[Claim 52] The base station of claim 49, wherein the physical cable assembly is a fuel line for filling a fuel tank of the mobile platform.

[Claim 53] The base station of any one of claims 42-52, wherein the mechanical manipulators are operable to wirelessly provide power to the mobile platform.

[Claim 54] The base station of any one of claims 42-53, wherein the maintenance system is configured to operate automatically and without user interaction.

[Claim 55] The base station of any one of claims 42-54, wherein at least one of said resource-slots is operable to charge a battery.

[Claim 56] The base station of any one of claims 42-55, wherein the mobile platform remains stationary on the landing surface.

[Claim 57] The base station of any one of claims 42-56, wherein said mechanical manipulators are operable to move the mobile platform from the ascertained location to a predetermined location on the landing surface.

[Claim 58] The base station of claim 57, wherein the predetermined location defines one or more receiving cavities operable to receive one or more landing legs of the mobile platform.

[Claim 59] The base station of any one of claims 42-58, wherein said sensor apparatus is operable to ascertain a second location of a second mobile platform on the landing surface.

[Claim 60] The base station of claim 59, wherein said mechanical manipulators are operable to move to the second mobile platform based on the ascertained second location.

[Claim 61] The base station of any one of claims 42-60, wherein the mobile platform is an unmanned aerial vehicle (UAV).

[Claim 62] A maintenance system of a base station for a mobile platform having a payload or a battery, comprising:
a sensor apparatus for ascertaining a location of the mobile platform on a landing surface;
a resource supply for defining a plurality of resource-slots each configured to removably hold a replacement payload or replacement battery; and
one or more mechanical manipulators for moving to the mobile platform based on the ascertained location of the mobile platform and optionally interacting with a selected replacement payload, a selected replacement battery, the payload, or the battery.

[Claim 63] The maintenance system of claim 62, wherein said maintenance system is operable to move translationally along an X-axis, a Y-axis, and a Z-axis or rotationally to the ascertained location of the mobile platform.

[Claim 64] The maintenance system of claim 62 or claim 63, wherein the mechanical manipulators are operable to:
move along an X-axis and Y-axis to the selected replacement payload or replacement battery positioned in a selected resource-slot;
extend a resource-carriage along a Z-axis;
grasp the selected replacement payload or replacement battery;
retract the resource-carriage along the Z-axis to remove the replacement payload or replacement battery from the resource-slot;
move the removed replacement payload or removed replacement battery proximate to the ascertained location of the mobile platform; and
insert the replacement payload or replacement battery into a mobile platform resource-slot provided on the mobile platform and decouple from the replacement payload.

[Claim 65] The maintenance system of any one of claims 62-64, wherein said sensor apparatus comprises first and second optical sensors operable to

respectively locate the mobile platform along respective perpendicular axes, and wherein the sensor apparatus optionally is configured to operate automatically and without user interaction.

[Claim 66] The maintenance system of claim 65, wherein the first and second optical sensors are respectively located on first and second location arms each extending substantially perpendicularly to a respective axis.

[Claim 67] The maintenance system of any one of claims 62-66, wherein at least one of the payload and the replacement payload comprises at least one of a data storage unit, a predetermined quantity of fuel, a predetermined quantity of fertilizer, a predetermined quantity of water, a parcel, cargo, and a predetermined quantity of pesticides.

[Claim 68] The maintenance system of any one of claims 62-67, wherein said mechanical manipulators are operable to actuate a power switch of the mobile platform.

[Claim 69] The maintenance system of any one of claims 62-68, wherein said mechanical manipulators are operable to connect a physical cable assembly to the mobile platform.

[Claim 70] The maintenance system of claim 69, wherein the physical cable assembly is a power cable for providing electrical power to the mobile platform.

[Claim 71] The maintenance system of claim 69, wherein the physical cable assembly is a communication cable for exchanging data between the base station and the mobile platform.

[Claim 72] The maintenance system of claim 69, wherein the physical cable assembly is a fuel line for filling a fuel tank of the mobile platform.

[Claim 73] The maintenance system of any one of claims 62-72, wherein said mechanical manipulators are operable to wirelessly provide power to the mobile platform.

[Claim 74] The maintenance system of any one of claims 62-73, wherein the maintenance system is configured to operate automatically and without user interaction.

[Claim 75] The maintenance system of any one of claims 62-74, wherein at least one of said resource-slots is operable to charge a battery.

[Claim 76] The maintenance system of any one of claims 62-75, wherein the mobile platform remains stationary on the landing surface.

[Claim 77] The maintenance system of any one of claims 62-76, wherein said mechanical manipulators are operable to move the mobile platform from the ascertained location to a predetermined location on the landing

surface.

[Claim 78] The maintenance system of claim 77, wherein the predetermined location comprises one or more receiving cavities operable to receive one or more landing legs of the mobile platform.

[Claim 79] The maintenance system of any one of claims 62-78, wherein said sensor apparatus is operable to ascertain a second location of a second mobile platform on the landing surface.

[Claim 80] The maintenance system of claim 79, wherein said mechanical manipulators are operable to move to the second mobile platform based on the ascertained second location.

[Claim 81] The maintenance system of any one of claims 62-80, wherein the mobile platform is an unmanned aerial vehicle (UAV).

[Claim 82] A method of inserting a replacement payload or battery into a mobile platform, comprising:
ascertaining a location of the mobile platform on a landing surface, optionally with the aid of a sensor apparatus;
grasping the replacement payload or the replacement battery positioned in a selected resource-slot;
moving the grasped replacement payload or replacement battery to the mobile platform based on the ascertained location of the mobile platform, optionally with an aid of a maintenance system;
inserting the replacement payload or replacement battery into a payload-slot or a battery-slot positioned on the mobile platform; and
decoupling the replacement payload or replacement battery.

[Claim 83] The method of claim 82, wherein said moving the grasped replacement payload or replacement battery further comprises moving the maintenance system translationally along an X-axis, a Y-axis, and a Z-axis or rotationally of the landing surface to the mobile platform based on the ascertained location of the mobile platform.

[Claim 84] The method of claim 82 or claim 83, wherein said grasping the replacement payload or replacement battery further comprises moving a mechanical manipulator of the maintenance system along the X-axis, the Y-axis, and the Z-axis.

[Claim 85] The method of any one of claims 82-84, wherein the mobile platform is an unmanned aerial vehicle (UAV).

[Claim 86] A method of storing a payload or battery removed from a mobile platform, comprising:
ascertaining a location of the mobile platform on a landing surface of a

maintenance system;
a mechanical manipulator of the maintenance system moving proximate to the mobile platform having the payload or the battery positioned thereon in a resource-slot of the mobile platform;
grasping the payload or the battery positioned in the resource-slot;
retractably removing the payload or the battery from the resource-slot; and
inserting the payload or battery in a selected resource storage slot of the maintenance system.

[Claim 87] The method of claim 86, wherein at least one of said grasping, said retractably moving, and inserting optionally occurs with an aid of the mechanical manipulator.

[Claim 88] A method of managing a payload or a battery of a mobile platform, comprising:
determining a first distance between the mobile platform and a first base station;
determining a second distance between the mobile platform and a second base station;
signaling to the mobile platform to land on a selected one of the first and second base stations based on the determined first and second distances;
landing the mobile platform on a landing surface of the selected base station;
ascertaining a location of the landed mobile platform on the landing surface; and
moving a maintenance system relative to the mobile platform based on the ascertained location of the mobile platform.

[Claim 89] The method of claim 88, wherein said moving the maintenance system comprises moving the maintenance system translationally along at least one of an X-axis, a Y-axis, and a Z-axis or rotationally to the mobile platform based on the ascertained location of the mobile platform.

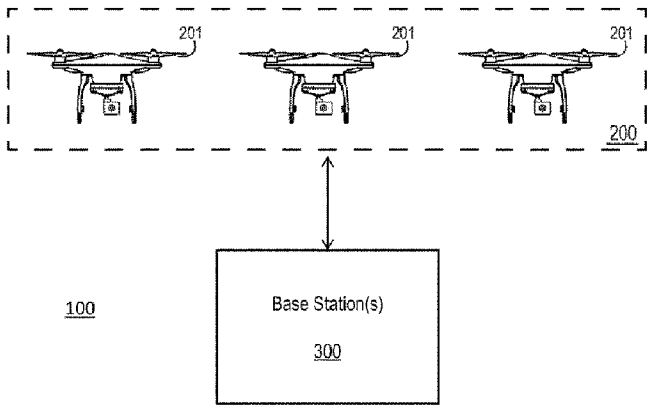
[Claim 90] The method of claim 88 or claim 89, further comprising interacting with a selected payload or a selected battery of the mobile platform via the maintenance system, wherein said interacting optionally occurs automatically and without user interaction.

[Claim 91] The method of claim 90, wherein said interacting with the selected payload or the selected battery occurs wirelessly.

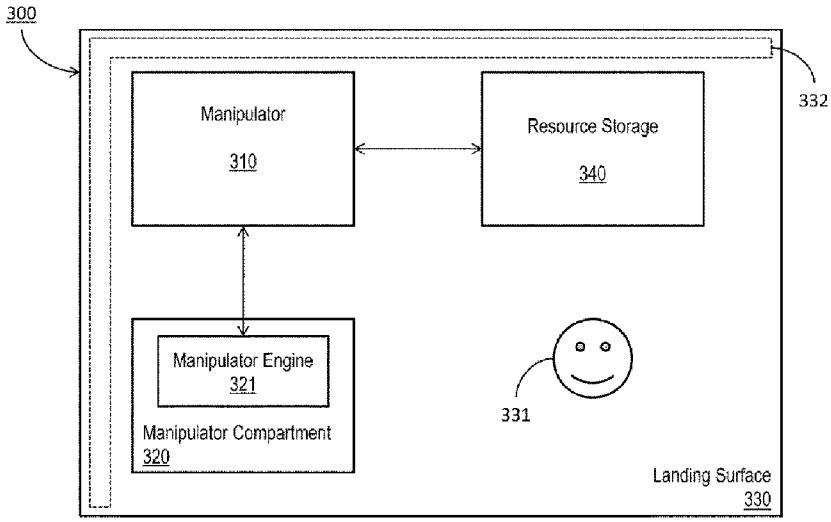
[Claim 92] The method of any one of claims 88-91, wherein the mobile platform is

an unmanned aerial vehicle (UAV).

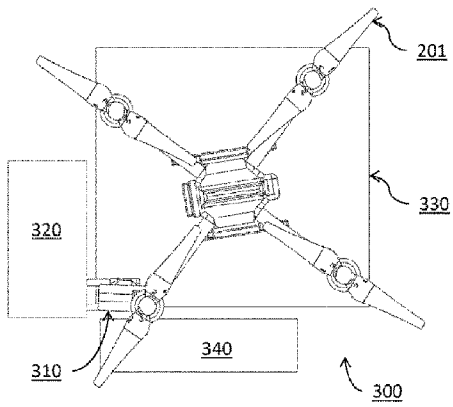
[Fig. 1]



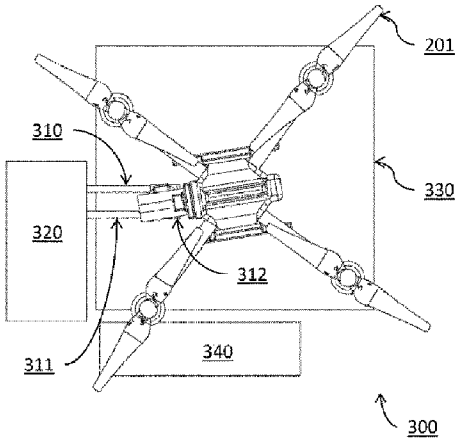
[Fig. 2]


300
332
Manipulator
310
Resource Storage
340
Manipulator Engine
321
Manipulator Compartment
320
331
Landing Surface
330

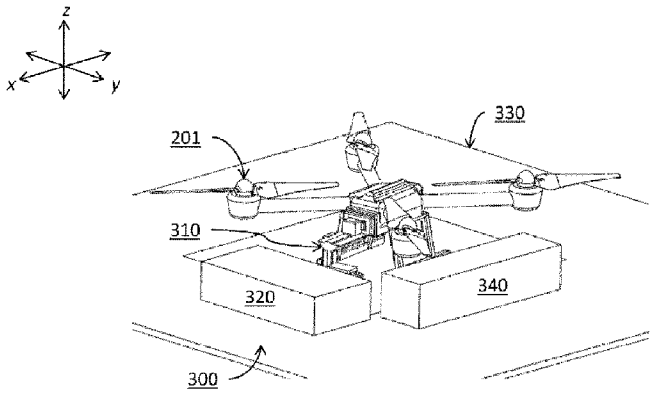
[Fig. 3]



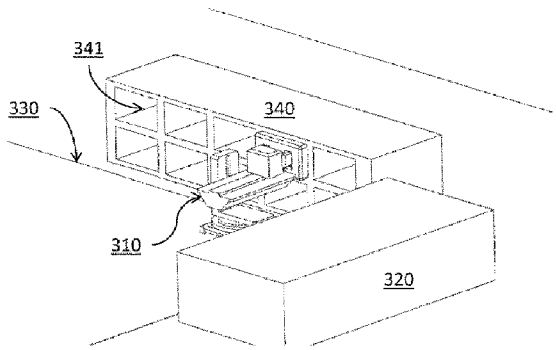
[Fig. 4]



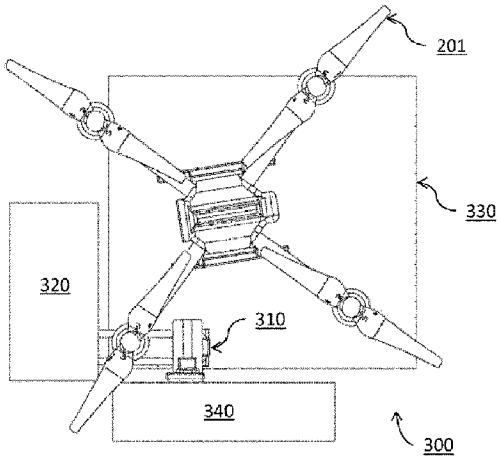
[Fig. 5]



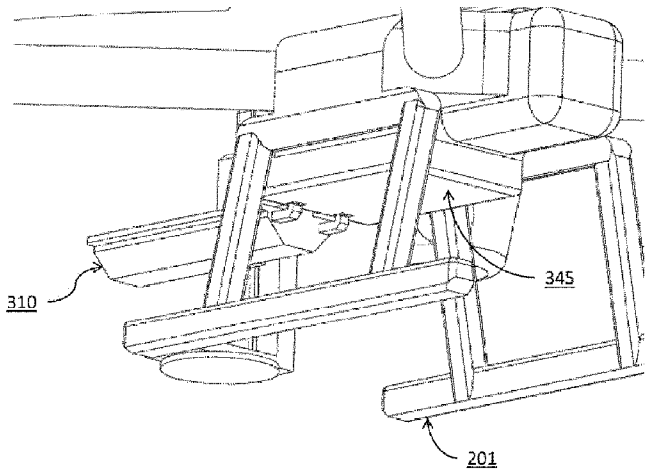
[Fig. 6]



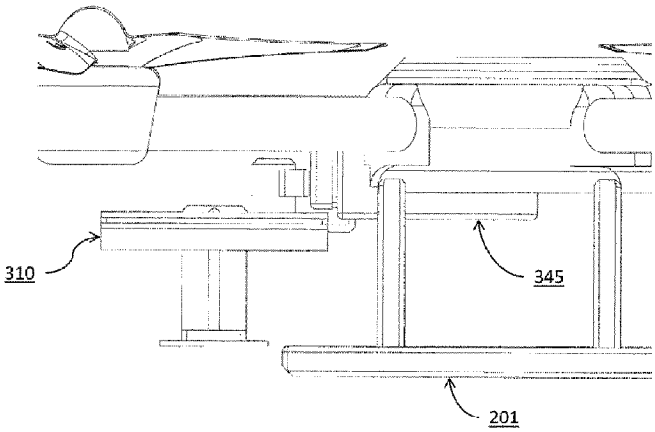
[Fig. 7]



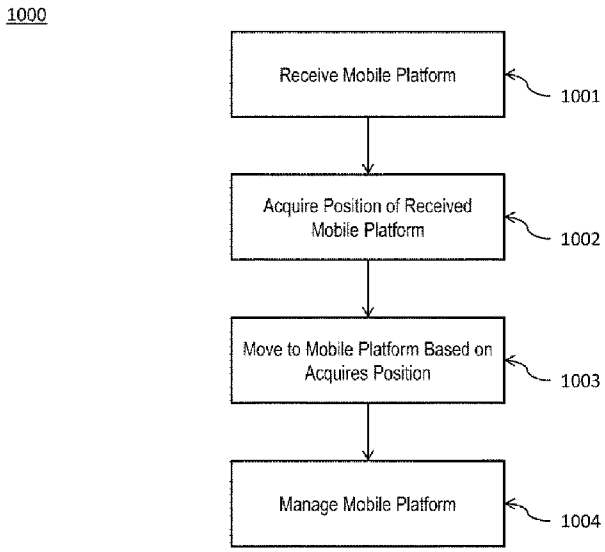
[Fig. 8]



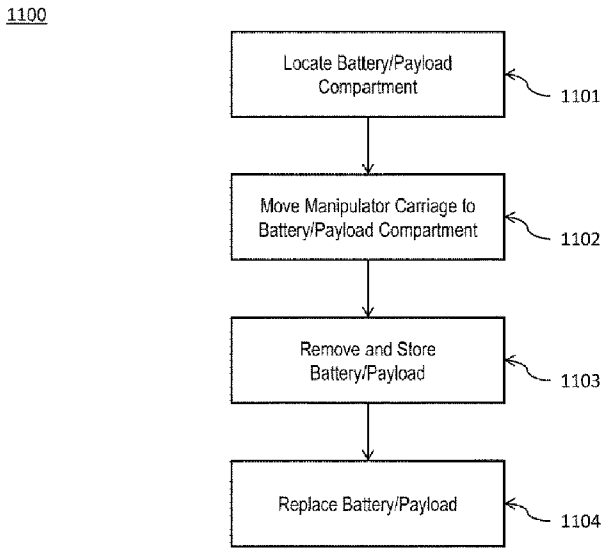
[Fig. 9]



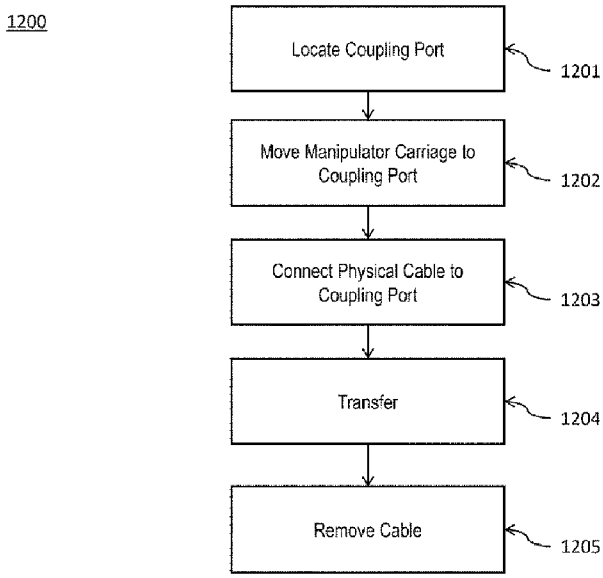
[Fig. 10]


1000
Receive Mobile Platform
1001
Acquire Position of Received Mobile Platform
1002
Move to Mobile Platform Based on Acquires Position
1003
Manage Mobile Platform
1004

[Fig. 11]


1100
Locate Battery/Payload Compartment
1101
Move Manipulator Carriage to Battery/Payload Compartment
1102
Remove and Store Battery/Payload
1103
Replace Battery/Payload
1104

[Fig. 12]


1200
Locate Coupling Port
1201
Move Manipulator Carriage to Coupling Port
1202
Connect Physical Cable to Coupling Port
1203
Transfer
1204
Remove Cable
1205

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2014/091939

A. CLASSIFICATION OF SUBJECT MATTER

B64F 5/00(2006.01)i

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)

B64F

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)

CNPAT, CNKI, DWPI:change, cell, replace, charge, load, UAV, remov+, unmanned, battery, renew

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 2799336 A1 (BOEING CO) 05 November 2014 (2014-11-05) pages 3-5, figs. 1-8	1-92
X	US 2013081245 A1 (BOEING COET AL.) 04 April 2013 (2013-04-04) pages 2-7, figs. 1-10	1-92
X	CN 202922160 U (NANJING INFORMATION SCI & TECHNOLOG) 08 May 2013 (2013-05-08) pages 3-5, figs. 1-11	1-92
X	CN 102909540 A (NANJING INFORMATION SCI & TECHNOLOG) 06 February 2013 (2013-02-06) pages 3-5, figs. 1-11	1-92
A	CN 203845022 U (ZHAO ZIBIN) 24 September 2014 (2014-09-24) the whole document	1-92

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:

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"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
12 March 2015	**25 March 2015**

Name and mailing address of the ISA/CN	Authorized officer
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2014/091939

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
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CN 202922160 U	08 May 2013	None	
CN 102909540 A	06 February 2013	CN 102909540 B	10 December 2014
CN 203845022 U	24 September 2014	None	