



(12) **United States Patent**
Winkle et al.

(10) **Patent No.:** **US 10,332,407 B2**
(45) **Date of Patent:** **Jun. 25, 2019**

(54) **SYSTEMS AND METHODS FOR PROVIDING EMERGENCY ALERTS AT EMERGENCY LANDING AREAS OF UNMANNED AERIAL VEHICLES**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 22 days.

(21) Appl. No.: **16/011,932**

(22) Filed: **Jun. 19, 2018**

(65) **Prior Publication Data**
US 2019/0014461 A1 Jan. 10, 2019

Related U.S. Application Data
(60) Provisional application No. 62/529,653, filed on Jul. 7, 2017.

(51) **Int. Cl.**
G08G 5/00 (2006.01)

(52) **U.S. Cl.**
CPC **G08G 5/0069** (2013.01); **G08G 5/0056** (2013.01); **B64C 2201/14** (2013.01); **B64C 2201/141** (2013.01); **B64C 2201/146** (2013.01)

(58) **Field of Classification Search**
CPC **B64C 2201/00**; **B64C 2201/14**; **B64C 2201/141**; **B64C 2201/143**;

(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

1,001,746 A * 8/1911 English G11B 3/00 369/169
7,167,782 B2 * 1/2007 Humbar G01C 23/00 340/961

(Continued)

FOREIGN PATENT DOCUMENTS

WO 2016026023 2/2016

OTHER PUBLICATIONS

“Drones for Emergency Alerts?”; <http://www.hyperreach.com/dronesforemergencyalerts/>; 2016; pp. 1-3.

(Continued)

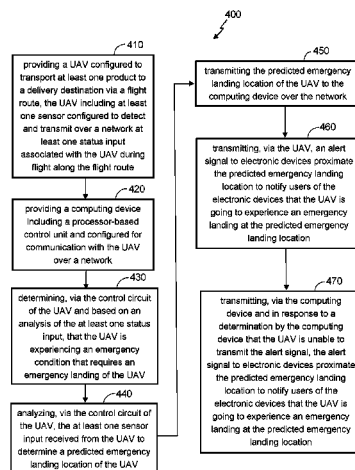
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(57) **ABSTRACT**

In some embodiments, methods and systems are provided that provide for controlling unmanned aerial vehicles (UAVs) experiencing emergency landings and providing emergency alerts to the predicted emergency landing locations of the UAV. Each UAV includes sensors configured to detect at least one status input associated with the UAV during flight along its flight route. Each UAV analyzes the status inputs while in flight in order to predict an emergency landing location where the UAV would land if unable to fly due to an emergency condition. The UAV is configured to transmit an alert signal to electronic devices proximate the predicted emergency landing location to notify users of the electronic devices that the unmanned aerial vehicle is going to experience an emergency landing at the predicted emergency landing location.

20 Claims, 4 Drawing Sheets



(58) **Field of Classification Search**

CPC B64C 2201/145; B64C 2201/146; B64C
 2201/148; B64C 2201/182; B64C
 2201/185; B64C 39/02; B64C 39/024;
 B60D 45/00; B60D 45/0045; B60D
 45/0005; G08B 5/0069

See application file for complete search history.

2016/0257401 A1 9/2016 Buchmueller
 2017/0004714 A1 1/2017 Rhee
 2017/0110017 A1 4/2017 Kimchi
 2017/0369183 A1* 12/2017 Tarimala B64D 45/0015

OTHER PUBLICATIONS

(56) **References Cited**

U.S. PATENT DOCUMENTS

8,032,267 B1* 10/2011 Simon G05D 1/105
 701/4
 9,274,529 B2 3/2016 Ben-Shachar
 9,466,218 B2 10/2016 Jarrell
 9,483,950 B2 11/2016 Wang
 9,524,648 B1 12/2016 Gopalakrishnan
 9,550,577 B1 1/2017 Beckman
 9,573,684 B2 2/2017 Kimchi
 10,061,746 B2* 8/2018 Yount G06F 9/30036
 2003/0060940 A1* 3/2003 Humbard G01C 23/00
 701/3
 2015/0120094 A1 4/2015 Kimchi
 2015/0277440 A1 10/2015 Kimchi
 2016/0196755 A1 7/2016 Navot

Faheem, Rao Muhammad, et al.; "UAV Emergency Landing Site Selection System using Machine Vision"; Journal of Machine Intelligence, vol. 1, No. 1; 2016; pp. 13-20.

Fikri, Rafid, et al.; "SmartDrone for Emergency Alert, Guide & Searching"; <http://unicefchallenge.com/smartdroneforemergencyalarmguidingsearching/>; Nov. 24, 2014; pp. 1-12.

Levy, Nat; "Amazon drones could hitch rides on trucks or buses en route to delivery location, patent filing shows"; <http://www.geekwire.com/2016/amazondronescouldhitchridesontrucksorbusesenroutetodeliverylocationpatentshows/>; Sep. 8, 2016; pp. 1-7.

Limer, Eric; "A 1000W DIY Flashlight Turns a Drone Into a UFO"; <http://www.popularmechanics.com/flight/drones/a23401/dronedi1000wflashlight/>; Oct. 17, 2016; pp. 1-6.

PCT; App. No. PCT/US2018/040852; International Search Report and Written Opinion dated Sep. 28, 2018.

* cited by examiner

FIG. 1

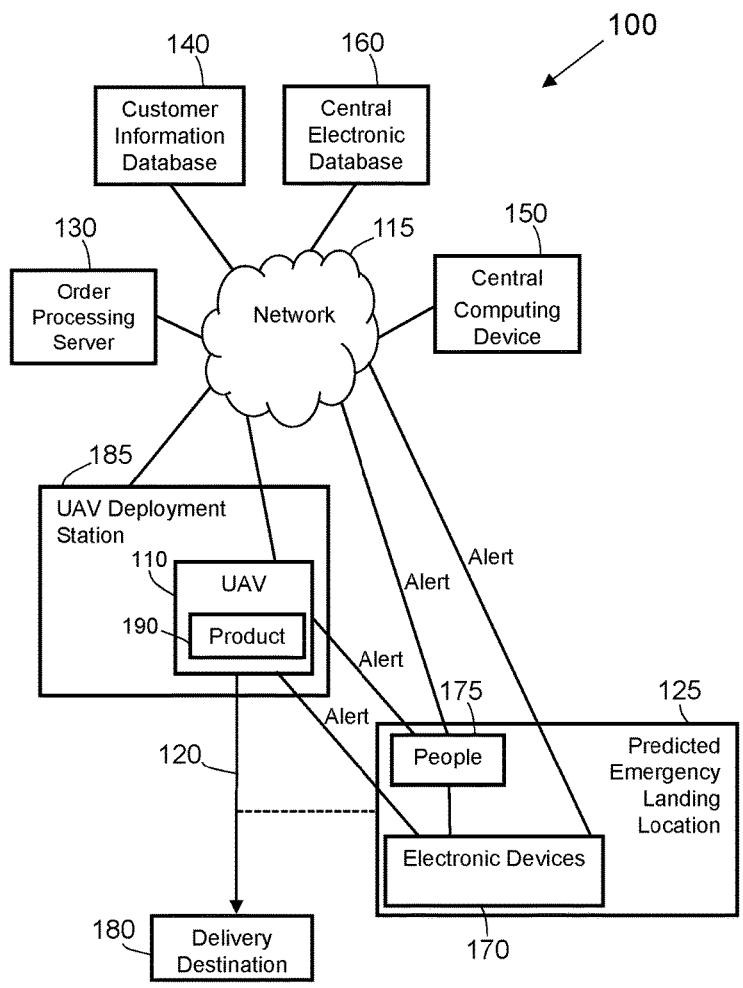


FIG. 2

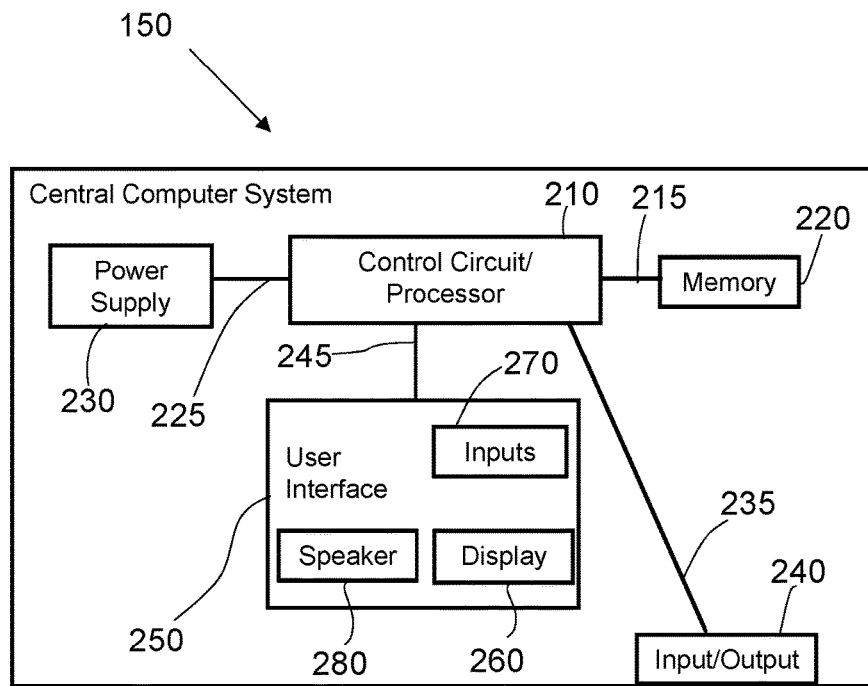


FIG. 3

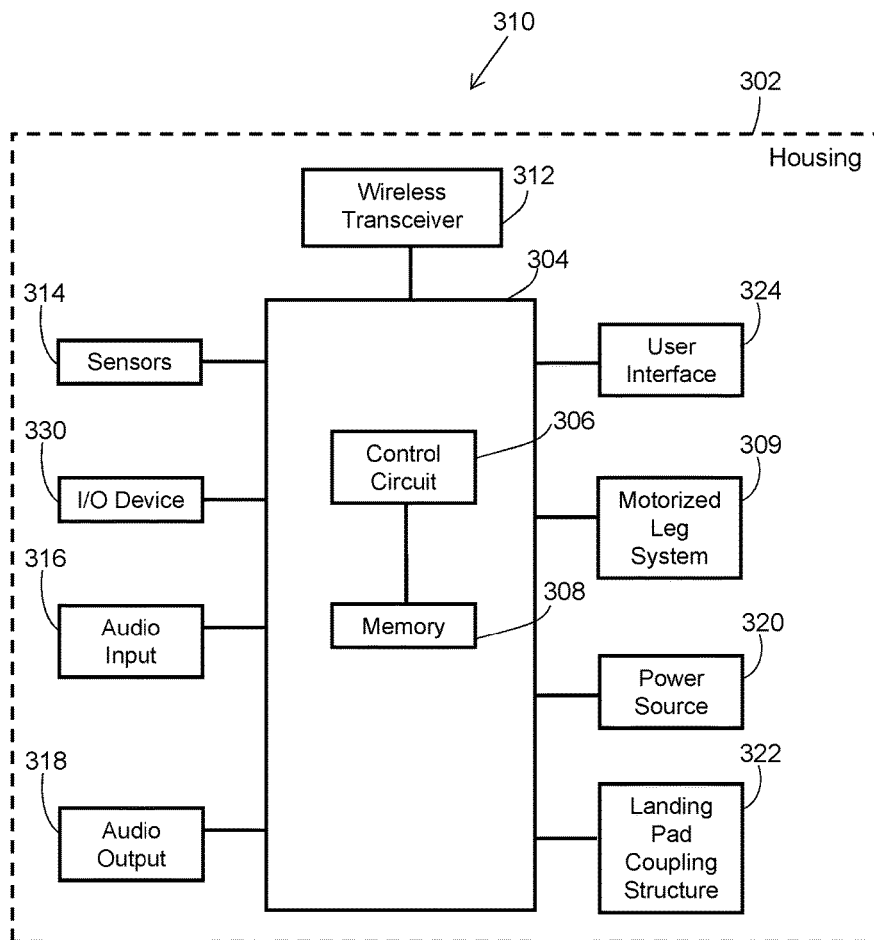
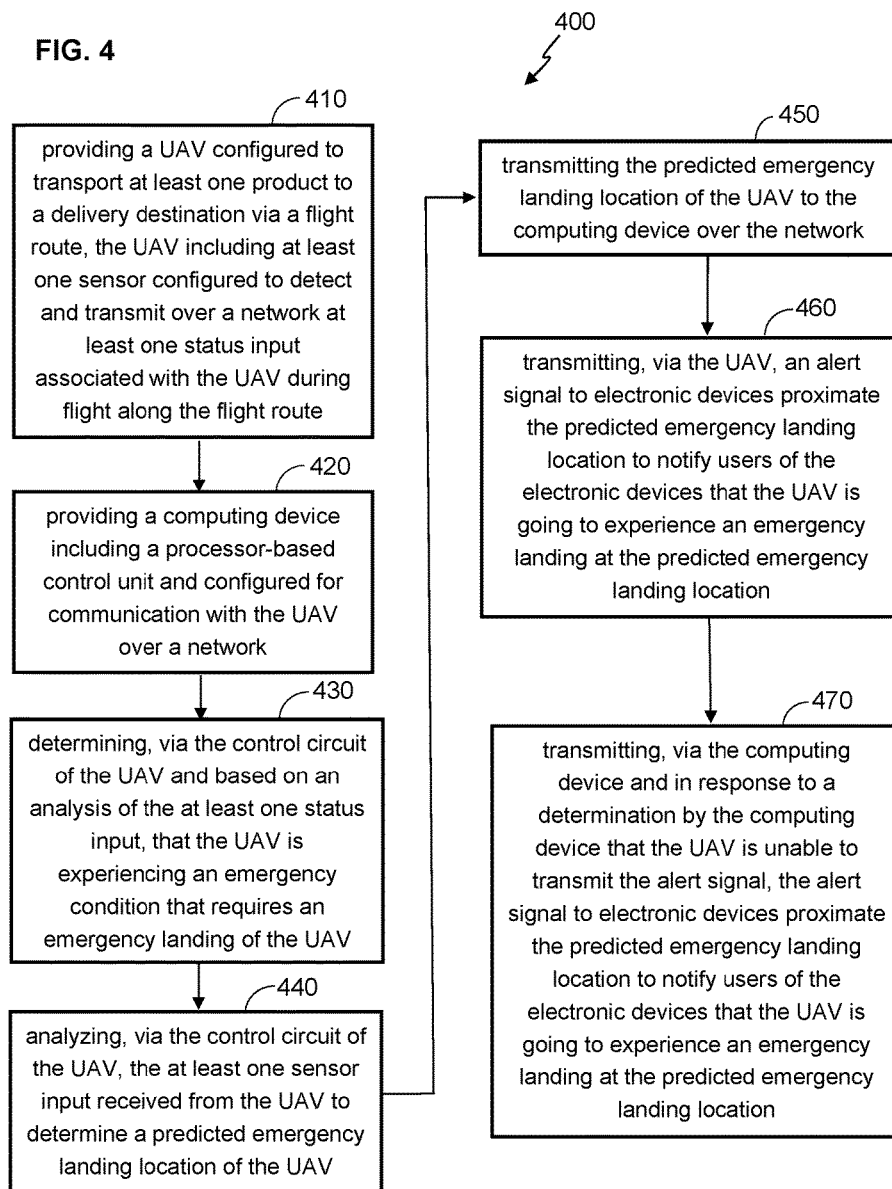


FIG. 4



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**SYSTEMS AND METHODS FOR PROVIDING
EMERGENCY ALERTS AT EMERGENCY
LANDING AREAS OF UNMANNED AERIAL
VEHICLES**

RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 62/529,653, filed Jul. 7, 2017, which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

This disclosure relates generally to facilitating the landings of unmanned aerial vehicles and, in particular, to providing emergency alerts to computing devices and/or people proximate predicted emergency landing locations of unmanned aerial vehicles.

BACKGROUND

Transporting products via unmanned aerial vehicles (UAVs) over populated areas such as towns and cities requires UAV operators to consider the risks associated with unexpected malfunctions, in-air collisions, and/or other emergency events that may lead to emergency crash landings of the UAVs. Given that the UAVs, both when empty and when carrying cargo, can present a significant injury risk to people and animals on the ground as well as a personal property risk to buildings and cars on the ground in the event that the UAVs crash land, especially in a densely populated area such as a city, early warnings of such potential crash landings is desirable.

BRIEF DESCRIPTION OF THE DRAWINGS

Disclosed herein are embodiments of systems, apparatuses, and methods pertaining to controlling an unmanned aerial vehicle experiencing an emergency landing and providing an emergency alert to an area proximate a predicted emergency landing location of the unmanned aerial vehicle. This description includes drawings, wherein:

FIG. 1 is a diagram of a system for controlling an unmanned aerial vehicle experiencing an emergency landing and providing an emergency alert to an area proximate a predicted emergency landing location of the UAV in accordance with some embodiments;

FIG. 2 is a functional diagram of an exemplary computing device usable with the system of FIG. 1 in accordance with some embodiments;

FIG. 3 comprises a block diagram of an unmanned aerial vehicle as configured in accordance with some embodiments; and

FIG. 4 is a flow chart diagram of a process of controlling an unmanned aerial vehicle experiencing an emergency landing and providing an emergency alert to an area proximate a predicted emergency landing location of the UAV in accordance with some embodiments.

Elements in the figures are illustrated for simplicity and clarity and have not been drawn to scale. For example, the dimensions and/or relative positioning of some of the elements in the figures may be exaggerated relative to other elements to help to improve understanding of various embodiments of the present invention. Also, common but well-understood elements that are useful or necessary in a commercially feasible embodiment are often not depicted in order to facilitate a less obstructed view of these various

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embodiments of the present invention. Certain actions and/or steps may be described or depicted in a particular order of occurrence while those skilled in the art will understand that such specificity with respect to sequence is not actually required. The terms and expressions used herein have the ordinary technical meaning as is accorded to such terms and expressions by persons skilled in the technical field as set forth above except where different specific meanings have otherwise been set forth herein.

DETAILED DESCRIPTION

The following description is not to be taken in a limiting sense, but is made merely for the purpose of describing the general principles of exemplary embodiments. Reference throughout this specification to “one embodiment,” “an embodiment,” or similar language means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, appearances of the phrases “in one embodiment,” “in an embodiment,” and similar language throughout this specification may, but do not necessarily, all refer to the same embodiment.

Generally speaking, pursuant to various embodiments, systems, apparatuses, and methods are provided for providing emergency warnings to computing devices and/or people located proximate a predicted emergency landing location of a UAV. In some embodiments, the UAVs are configured to send out an emergency signal to electronic devices in the area after the UAV determines that an emergency landing becomes inevitable. In some embodiments, if the UAV is unable to transmit such an emergency signal, a central computing device is configured to transmit such an emergency signal. The emergency signal may be in the form of an electronic message (e.g., text message), an audible alert (e.g., a siren), and/or a visual alert (e.g., a flare, a light-generating device, smoke-generating device, or the like).

In some embodiments, a system for controlling an unmanned aerial vehicle experiencing an emergency landing and providing an emergency alert to an area proximate a predicted emergency landing location of the unmanned aerial vehicle is provided. The system includes an unmanned aerial vehicle configured to transport at least one product to a delivery destination via a flight route. The unmanned aerial vehicle includes at least one sensor configured to detect and transmit over a network at least one status input associated with the unmanned aerial vehicle during flight along the flight route. The system also includes a computing device including a processor-based control unit and configured for communication with the unmanned aerial vehicle over a network. The unmanned aerial vehicle includes a processor-based control circuit configured to: determine, based on an analysis of the at least one status input, that the unmanned aerial vehicle is experiencing an emergency condition that requires an emergency landing of the unmanned aerial vehicle; analyze the at least one sensor input in order to determine a predicted emergency landing location of the unmanned aerial vehicle; and transmit the predicted emergency landing location of the unmanned aerial vehicle to the computing device over the network. The unmanned aerial vehicle is configured to transmit an alert signal to electronic devices proximate the predicted emergency landing location to notify users of the electronic devices that the unmanned aerial vehicle is going to experience an emergency landing at the predicted emergency landing location. In response to a determination by the computing device that the unmanned aerial vehicle is unable to transmit the alert signal, the

computing device is configured to transmit the alert signal to electronic devices proximate the predicted emergency landing location to notify users of the electronic devices that the unmanned aerial vehicle is going to experience an emergency landing at the predicted emergency landing location.

In another embodiment, a method for controlling an unmanned aerial vehicle experiencing an emergency landing and providing an emergency alert to an area proximate a predicted emergency landing location of the unmanned aerial vehicle includes: providing an unmanned aerial vehicle configured to transport at least one product to a delivery destination via a flight route, the unmanned aerial vehicle including at least one sensor configured to detect and transmit over a network at least one status input associated with the unmanned aerial vehicle during flight along the flight route; providing a computing device including a processor-based control unit and configured for communication with the unmanned aerial vehicle over a network; determining, via the control circuit of the unmanned aerial vehicle and based on an analysis of the at least one status input, that the unmanned aerial vehicle is experiencing an emergency condition that requires an emergency landing of the unmanned aerial vehicle; analyzing, via the control circuit of the unmanned aerial vehicle, the at least one sensor input received from the unmanned aerial vehicle in order to determine a predicted emergency landing location of the unmanned aerial vehicle; transmitting the predicted emergency landing location of the unmanned aerial vehicle to the computing device over the network; transmitting, via the unmanned aerial vehicle, an alert signal to electronic devices proximate the predicted emergency landing location to notify users of the electronic devices that the unmanned aerial vehicle is going to experience an emergency landing at the predicted emergency landing location; and transmitting, via the computing device and in response to a determination by the computing device that the unmanned aerial vehicle is unable to transmit the alert signal, the alert signal to electronic devices proximate the predicted emergency landing location to notify users of the electronic devices that the unmanned aerial vehicle is going to experience an emergency landing at the predicted emergency landing location.

FIG. 1 shows an embodiment of a system 100 for controlling an unmanned aerial vehicle 110 experiencing an emergency landing and providing an emergency alert to an area proximate a predicted emergency landing location 125 of the UAV 110, such that electronic devices and/or people in the predicted emergency landing location 125 are warned that a UAV 110 is going to experience an emergency landing in the predicted emergency landing location 125. It will be understood that the details of this example are intended to serve in an illustrative capacity and are not necessarily intended to suggest any limitations in regards to the present teachings. In some aspects, the exemplary UAV 110 of FIG. 1 is configured to transport one or more products 190 from one or more UAV deployment stations 185 to one or more delivery destinations 180 via the flight route 120. In other aspects, the UAV 110 is configured to fly along the flight route 120 from a UAV deployment station 185 to a product pick up location. In yet other aspects, the UAV 110 is configured to fly along the flight route 120 from a delivery destination 180 or a product pick up location back to the UAV deployment station 185.

A customer may be an individual or business entity. A delivery destination 180 may be a home, work place, or another location designated by the customer when placing the order. Exemplary products 190 that may be ordered by

the customer via the system 100 may include, but are not limited to, general-purpose consumer goods (retail products and goods not for sale) and consumable products (e.g., food items, medications, or the like). A UAV deployment station 185 can be mobile (e.g., vehicle-mounted) or stationary (e.g., installed at a facility of a retailer). A retailer may be any entity operating as a brick-and-mortar physical location and/or a website accessible, for example, via an intranet, internet, or another network, by way of which products 190 may be ordered by a consumer for delivery via a UAV 110.

The exemplary system 100 depicted in FIG. 1 includes an order processing server 130 configured to process a purchase order by a customer for one or more products 190. It will be appreciated that the order processing server 130 is an optional component of the system 100, and that some embodiments of the system 100 are implemented without incorporating the order processing server 130. The order processing server 130 may be implemented as one server at one location, or as multiple interconnected servers stored at multiple locations operated by the retailer, or for the retailer. As described in more detail below, the order processing server 130 may communicate with one or more electronic devices of system 100 via a network 115. The network 115 may be a wide-area network (WAN), a local area network (LAN), a personal area network (PAN), a wireless local area network (WLAN), Wi-Fi, Zigbee, Bluetooth, or any other internet or intranet network, or combinations of such networks. Generally, communication between various electronic devices of system 100 may take place over hard-wired, cellular, Wi-Fi or Bluetooth networked components or the like. In some embodiments, one or more electronic devices of system 100 may include cloud-based features, such as cloud-based memory storage.

In the embodiment of FIG. 1, the order processing server 130 communicates with a customer information database 140. In some embodiments, the customer information database 140 may be configured to store information associated with customers of the retailer who order products 190 from the retailer. In some embodiments, the customer information database 140 may store electronic information including but not limited to: personal information of the customers, including payment method information, billing address, previous delivery addresses, phone number, product order history, pending order status, product order options, as well as product delivery options (e.g., delivery by UAV) of the customer. The customer information database 140 may be stored, for example, on non-volatile storage media (e.g., a hard drive, flash drive, or removable optical disk) internal or external to the order processing server 130, or internal or external to computing devices separate and distinct from the order processing server 130. It will be appreciated that the customer information database 140 may likewise be cloud-based.

In the embodiment of FIG. 1, the order processing server 130 is in communication with a central electronic database 160 configured to store information associated with the inventory of products 190 made available by the retailer to the customer, as well as information associated with the UAVs 110 being deployed to deliver products 190 to the delivery destinations 180 specified by the customers. In some aspects, the central electronic database 160 stores information including but not limited to: information associated with the products 190 being transported by the UAV 110; inventory (e.g., on-hand, sold, replenishment, etc.) information associated with the products 190; flight status information associated with the UAV 110; information associated with predetermined flight routes 120 of the UAV 110;

status input information detected by one or more sensors of the UAV 110 during flight along the flight routes 120; information indicating the coordinates of the predicted emergency landing location 125; information indicating one or more electronic devices 170 and people 175 present at the predicted emergency landing location 125, and information indicating collateral damage associated with the predicted emergency landing location 125.

The central electronic database 160 may be stored, for example, on non-volatile storage media (e.g., a hard drive, flash drive, or removable optical disk) internal or external to the order processing server 130, or internal or external to computing devices separate and distinct from the order processing server 130. The central electronic database 160 may likewise be cloud-based. While the customer information database 140 and the central electronic database 160 are shown in FIG. 1 as two separate databases, it will be appreciated that the customer information database 140 and the central electronic database 160 can be incorporated into one database.

With reference to FIG. 1, the central computing device 150 may be a stationary or portable electronic device, for example, a desktop computer, a laptop computer, a tablet, a mobile phone, or any other electronic device including a processor-based control circuit (i.e., control unit). For purposes of this specification, the term “central computing device” will be understood to refer to a computing device owned by the retailer or any computing device owned and/or operated by an entity (e.g., delivery service) having an obligation to deliver products 190 for the retailer. In the embodiment of FIG. 1, the central computing device 150 is configured for data entry and processing as well as for communication with other devices of system 100 via the network 115 which, as described above. In some embodiments, as will be described below, the central computing device 150 is configured to access the central electronic database 160 and/or customer information database 140 via the network 115 to facilitate delivery of products 190 via UAVs 110 along flight routes 120 to delivery destinations 180, and to facilitate safe emergency landings of UAVs 110 in the event that the UAVs 110 are unable to continue flight along the flight routes 120.

In the system 100 of FIG. 1, the central computing device 150 is in two-way communication with the UAV 110 via the network 115. In some aspects, the central computing device 150 is configured to transmit at least one signal to the UAV 110 to cause the UAV 110 to fly along a flight route 120 determined by the central computing device 150 while transporting products 190 from the UAV deployment station 185 to the intended delivery destination 180 (e.g., to drop off a product 190 or to pick up a product 190), or while returning from the delivery destination 180 to the UAV deployment station 185 (e.g., after dropping off a product 190 or after picking up a product 190). In other aspects, after a customer places an order for one or more products 190 and specifies a delivery destination 180 for the products 190 via the order processing server 130, prior to and/or after the commencement of a delivery attempt of the products 190 ordered by the customer via a UAV 110 to the delivery destination 180, the central computing device 150 is configured to obtain GPS coordinates associated with the delivery destination 180 selected by the customer and GPS coordinates associated with the UAV deployment station 185 of the retailer (which houses the UAV 110 that will deliver the products 190), and to determine a flight route 120

for the UAV 110 in order to deliver the customer-ordered products 190 from the UAV deployment station 185 to the delivery destination 180.

In yet other aspects, if the computing device 150 determines that a UAV 110 is experiencing an inevitable emergency landing and that the UAV 110 is unable to transmit an alert signal to electronic devices 170 and/or people 175 at the predicted emergency landing location 125, the computing device 150 is configured to transmit (directly or via another computing device, sound-generating device, display device, or the like) an alert signal to electronic devices and/or people proximate the predicted emergency landing location 125, thereby notifying users of the electronic devices 170 and/or people 175 at the predicted emergency landing location 125 that the UAV 110 is going to emergency land at the predicted emergency landing location 125. In one approach, the computing device 150 may determine that UAV 110 is experiencing an emergency condition that will inevitably cause the UAV 110 to crash land after the computing device 150 receives an emergency (e.g., SOS) signal from the UAV 110. In one approach, the computing device 150 may determine that UAV 110 is experiencing an emergency condition that will inevitably cause the UAV 110 to crash land after the computing device 150 queries the UAV 110 as to flight status and receives no response from the UAV 110.

The UAV 110, which will be discussed in more detail below with reference to FIG. 3, is generally an unmanned aerial vehicle configured to autonomously traverse one or more intended environments in accordance with one or more flight routes 120 determined by the central computing device 150, and typically without the intervention of a human or a remote computing device, while retaining the products 190 therein and delivering the products 190 to the delivery destination 180. In some instances, however, a remote operator or a remote computer (e.g., central computing device 150) may temporarily or permanently take over operation of the UAV 110 using feedback information (e.g., audio and/or video content, sensor information, etc.) communicated from the UAV 110 to the remote operator or computer via the network 115, or another similar distributed network. While only one UAV 110 is shown in FIG. 1 for ease of illustration, it will be appreciated that in some embodiments, the central computing device 150 may communicate with, and/or provide flight route instructions to more than one (e.g., 5, 10, 20, 50, 100, 1000, or more) UAVs 110 simultaneously to guide the UAVs 110 to transport products 190 to their respective delivery destinations 180 and/or to facilitate safe emergency landings of the UAVs 110.

In some embodiments, as will be discussed in more detail below, the UAV 110 is equipped with one or more sensors configured to detect and transmit (e.g., internally to the UAV 110 and/or over the network 115) at least one status input associated with the UAV 110 during flight along the flight route 120. In addition, in some configurations, the UAV 110 includes a processor-based control circuit configured to determine, based on an analysis of the status input, that the UAV 110 is experiencing an emergency condition that requires an emergency landing of the UAV 110 and a predicted emergency landing location 125 of the UAV 110, as well as to transmit the predicted emergency landing location 125 of the UAV 110 over the network 115, for example, to the central computing device 150. In some aspects, the UAV 110 is configured to transmit an alert signal to electronic devices 170 (and/or people 175) proximate the predicted emergency landing location 125 to notify users of

the electronic devices 170 (and/or people not having electronic devices 170) that the UAV 110 is going to crash land at the predicted emergency landing location 125.

With reference to FIG. 2, an exemplary central computing device 150 configured for use with the systems and methods described herein may include a control unit or control circuit 210 including a processor (for example, a microprocessor or a microcontroller) electrically coupled via a connection 215 to a memory 220 and via a connection 225 to a power supply 230. The control circuit 210 can comprise a fixed-purpose hard-wired platform or can comprise a partially or wholly programmable platform, such as a microcontroller, an application specification integrated circuit, a field programmable gate array, and so on. These architectural options are well known and understood in the art and require no further description here.

The control circuit 210 of the central computing device 150 can be configured (for example, by using corresponding programming stored in the memory 220 as will be well understood by those skilled in the art) to carry out one or more of the steps, actions, and/or functions described herein. In some embodiments, the memory 220 may be integral to the processor-based control circuit 210 or can be physically discrete (in whole or in part) from the control circuit 210 and is configured non-transitorily store the computer instructions that, when executed by the control circuit 210, cause the control circuit 210 to behave as described herein. (As used herein, this reference to “non-transitorily” will be understood to refer to a non-ephemeral state for the stored contents (and hence excludes when the stored contents merely constitute signals or waves) rather than volatility of the storage media itself and hence includes both non-volatile memory (such as read-only memory (ROM)) as well as volatile memory (such as an erasable programmable read-only memory (EPROM))). Thus, the memory and/or the control circuit may be referred to as a non-transitory medium or non-transitory computer readable medium.

The control circuit 210 of the central computing device 150 is also electrically coupled via a connection 235 to an input/output 240 that can receive signals from the UAV 110 and/or order processing server 130 and/or customer information database 140 and/or central electronic database 160. For example, in some approaches, the computing device 150 receives sensor data representing at least one status input associated with the UAV 110 during flight of the UAV 110 along the flight route 120, electronic emergency (e.g., SOS) signals from the UAV 110 indicating that the UAV 110 is experiencing an emergency condition (including an identification of the emergency condition) that requires an emergency landing of the UAV 110, and data relating to an order for a product 190 placed by the customer, location data (e.g., GPS coordinates) associated with the delivery destination 180 selected by the customer, or from any other source that can communicate with the central computing device 150 via a wired or wireless connection.

The input/output 240 of the computing device 150 can also send signals to the UAV 110 (e.g., a control signal indicating a flight route 120 determined by the computing device 150 for the UAV 110 in order to deliver the product 190 from the UAV deployment station 185 to the delivery destination 180). The input/output 240 of the central computing device 150 can also send signals to the order processing server 130 (e.g., notification indicating that the UAV 110 was unable to successfully deliver the product 190 to the delivery destination 180 due to an emergency landing). In some aspects, the computing device 150 is configured to transmit, via the input/output 240 and over the network 115,

an alert signal to electronic devices 170 and/or people 175 at the predicted emergency landing location 125 to notify users of electronic devices 170 and/or people 175 that the UAV 110 is going to crash land at the predicted emergency landing location 125.

In the embodiment of FIG. 2, the processor-based control circuit 210 of the central computing device 150 is electrically coupled via a connection 245 to a user interface 250, which may include a visual display or display screen 260 (e.g., LED screen) and/or button input 270 that provide the user interface 250 with the ability to permit an operator of the central computing device 150 to manually control the central computing device 150 by inputting commands via touch-screen and/or button operation and/or voice commands to, for example, to transmit a control signal to the UAV 110 in order to provide the UAV 110 with the flight route 120 from the UAV deployment station 185 to the delivery destination 180, or to transmit an alert signal to electronic devices 170 and/or people 175 proximate the predicted emergency landing location 125 to provide a warning to the users of the electronic devices 170 and/or people 175 at the emergency landing location 125 that the UAV 110 is going to emergency land at the predicted emergency landing location 125. It will be appreciated that the performance of such functions by the processor-based control circuit 210 of the central computing device 150 is not dependent on a human operator, and that the control circuit 210 may be programmed to perform such functions without a human operator.

In some aspects, the display screen 260 of the central computing device 150 is configured to display various graphical interface-based menus, options, and/or alerts that may be transmitted to the central computing device 150 and displayed on the display screen 260 in connection with various aspects of the delivery of the products 190 ordered by the customers by the UAVs 110, as well as various aspects of predicted and actual emergency landings of the UAV 110. The inputs 270 of the central computing device 150 may be configured to permit an operator to navigate through the on-screen menus on the central computing device 150 and change and/or update the flight route 120 of the UAV 110 toward or away from the delivery destination 180 and/or to guide a UAV 110 experiencing an emergency landing toward a predicted emergency landing location 125, and/or to cause the UAV 110 and/or computing device 150 to generate an alert signal to electronic devices 170 and/or people 175 at the predicted emergency landing location 125 to notify users of the electronic devices 170 and/or people 175 at the predicted emergency landing location 125 that the UAV 110 is going to emergency land at the predicted emergency landing location 125. It will be appreciated that the display screen 260 may be configured as both a display screen and an input 270 (e.g., a touch-screen that permits an operator to press on the display screen 260 to enter text and/or execute commands.)

In some embodiments, after an order for one or more products 190 is placed by a customer via the order processing server 130, and prior to commencement of the delivery attempt of one or more products 190 via the UAV 110 to the delivery destination 180 designated by the customer, the control circuit 210 of the central computing device 150 is programmed to obtain the GPS coordinates of the delivery destination 180 where the product 190 is to be delivered by the UAV 110. For example, in embodiments, where the customer requested delivery of a product 190 or products 190 to a delivery destination 180 associated with a specific geographic location (e.g., home address, work address, etc.),

the control circuit **210** of the central computing device **150** obtains the GPS coordinates associated with the delivery destination **180**, for example, from the customer information database **140**, or from another source configured to provide GPS coordinates associated with a given physical address.

In some embodiments, the control circuit **210** of the central computing device **150** is configured to analyze the GPS coordinates of both the UAV deployment station **185** and the delivery destination **180**, and to determine and generate a flight route **120** for the UAV **110**. In one aspect, the flight route **120** determined by the central computing device **150** is based on a starting location of the UAV **110** (e.g., a UAV deployment station **185**) and the intended destination of the UAV **110** (e.g., delivery destination **180** and/or product pick up destination). In some aspects, the central computing device **150** is configured to calculate multiple possible flight routes **120** for the UAV **110**, and then select a flight route **120** determined by the central computing device **150** to provide an optimal flight time and/or optimal predicted emergency landing locations **125** for the UAV **110** while flying along the original flight route **120**. In some embodiments, after the control circuit **210** of the central computing device **150** determines and generates a flight route **120** for the UAV **110**, the central computing device **150** transmits, via the output **240** and over the network **115**, a signal including the flight route **120** to the UAV **110** assigned to deliver one or more products **190** from the UAV deployment station **185** to the delivery destination **180**.

In some aspects, prior to the UAV **110** being deployed from the UAV deployment station **185**, the control circuit **210** of the central computing device **150** and/or the control circuit **306** of the UAV **310** (which will be discussed in more detail below) is programmed to analyze the determined flight route **120** of the UAV **110** and to predict an emergency landing location **125** where the UAV **110** would land if the UAV **110** is unable to fly due to one or more emergency conditions (that force the UAV **110** to crash land) at any given point along the flight route **120**. In some embodiments, after the UAV **110** has been deployed and while the UAV **110** is in flight along a flight route **120** predetermined by the central computing device **150**, the control circuit **210** of the central computing device **150** is programmed predict, in real time, emergency landing locations **125** where the UAV **110** would land if the UAV **110** is unable to fly due to one or more emergency conditions at any point along the flight route **120**.

In some embodiments, the central computing device **150** is capable of integrating 2D and 3D maps of the navigable space of the UAV **110** along the flight route **120** determined by the central computing device **150**, complete with topography data comprising: no fly zones along the flight route **120** and on-ground buildings, hills, bodies of water, power lines, roads, vehicles, people, and/or known safe landing points for the UAV **110** along the flight route **120**. After the central computing device **150** maps all in-air and on-ground objects along the flight route **120** of the UAV **110** to specific locations using algorithms, measurements, and GPS geo-location, for example, grids may be applied sectioning off the maps into access ways and blocked sections, enabling the UAV **110** to use such grids for navigation and recognition. The grids may be applied to 2D horizontal maps along with 3D models. Such grids may start at a higher unit level and then can be broken down into smaller units of measure by the central computing device **150** when needed to provide more accuracy. In some aspects, for various on-ground facilities (e.g., residential or commercial buildings, schools, parks/recreation, etc.) determined by the computing device

150 proximate the predicted emergency landing location **125**, the computing device **150** is configured to analyze the working hours at such buildings (in order to assess potential personal injury risk in the event of a UAV **110** crashing at such facilities), as well as to obtain information regarding electronic devices **170** (e.g., central computers, mobile phones, etc.) present at such facilities (in order to enable the UAV **110** and/or the computing device **150**) to transmit an emergency alert signal to such electronic devices **170** and warn the users of the electronic devices **170** and/or other people **175** at such facilities that a UAV **110** is going to crash land into or near such facilities.

FIG. **3** presents a more detailed exemplary embodiment of the UAV **310** of FIG. **1**.

In this example, the UAV **310** has a housing **302** that contains (partially or fully) or at least supports and carries a number of components. These components include a control unit **304** comprising a control circuit **306** that, like the control circuit **210** of the central computing device **150**, controls the general operations of the UAV **310**. The control unit **304** includes a memory **308** coupled to the control circuit **306** for storing data such as operating instructions and/or useful data.

In some embodiments, the control circuit **306** operably couples to a motorized leg system **309**. This motorized leg system **309** functions as a locomotion system to permit the UAV **310** to land onto the ground or onto a landing pad at the delivery destination **180** and/or to move laterally at the delivery destination **180** or at an emergency landing location **125** after the UAV **110** crash lands. Various examples of motorized leg systems are known in the art. Further elaboration in these regards is not provided here for the sake of brevity save to note that the control circuit **306** may be configured to control the various operating states of the motorized leg system **309** to thereby control when and how the motorized leg system **309** operates.

In the exemplary embodiment of FIG. **3**, the control circuit **306** operably couples to at least one wireless transceiver **312** that is configured as a two-way transceiver and operates according to any known wireless protocol. This wireless transceiver **312** can comprise, for example, a cellular-compatible, Wi-Fi-compatible, and/or Bluetooth-compatible transceiver that can wirelessly communicate with the central computing device **150** via the network **115**. These teachings will accommodate using any of a wide variety of wireless technologies as desired and/or as may be appropriate in a given application setting. These teachings will also accommodate employing two or more wireless transceivers **312**. So configured, the control circuit **306** of the UAV **310** can provide information (e.g., sensor input) to the central computing device **150** (via the network **115**) and can receive information and/or movement (e.g., routing and rerouting) instructions from the central computing device **150**.

In some embodiments, the wireless transceiver **312** is configured to receive a signal containing instructions including the flight route **120** and/or rerouting information transmitted from the central computing device **150**, and that can transmit one or more signals to the central computing device **150**. For example, the control circuit **306** of the UAV **310** can receive control signals from the central computing device **150** via the network **115** containing instructions regarding directional movement of the UAV **310** along a specific, central computing device-determined flight route **120** when, for example: flying from the UAV deployment station **185** to the delivery destination **180** to drop off and/or pick up a product **190**, when returning from the delivery destination **180** after dropping off or picking up a product

190 to the UAV deployment station 185, or when experiencing an emergency landing toward the predicted emergency landing location 125. In particular, as discussed above, the central computing device 150 can be configured to analyze GPS coordinates of the delivery destination 180 designated by the customer, determine a flight route 120 for the UAV 110 to the delivery destination 180, and transmit to the wireless transceiver 312 of the UAV 110 a first control signal including the flight route 120 over the network 115. The UAV 110, after receipt of the first control signal from the central computing device 150, is configured to navigate along the flight route 120, based on the route instructions in the control signal, to the delivery destination 180.

In some embodiments, the UAV 310 is configured to transmit, via the transceiver 312, electronic emergency (e.g., SOS) signals indicating that the UAV 110 is experiencing an emergency condition that requires an emergency landing of the UAV 310. In one approach, the electronic emergency signal transmitted by the UAV 310 includes an identification of the emergency condition (e.g., rock, bird, another UAV, electrical/mechanical failure, etc.) In some embodiments, the UAV 310 is configured to generate and transmit an alert to electronic devices 170 and/or people 175 at the predicted emergency landing location 125. In one aspect, as will be described in more detail below, the UAV 310 generates an audible alert (e.g., a siren or verbal warning) via the audio output 318, thereby warning people 175 in the predicted emergency landing location 125 that a UAV 310 is going to crash land nearby. In another aspect, the UAV 310 is configured to transmit the alert via the transceiver 312 (directly or indirectly) to electronic devices 170 (e.g., in text message and/or audible alert form) in the predicted emergency landing area 125.

In some aspects, the UAV 310 is configured to transmit an alert signal to electronic devices other than the central computing device 150, for example, ground vehicles, emergency alert stations, emergency alert-generating devices, and/or other computing devices that are coupled, or are otherwise configured, to audibly and/or visually generate and transmit an emergency alert to the electronic devices 170 and/or people 175 in the emergency landing location 125. For example, after receiving the SOS signal from the UAV 310, one or more ground vehicles, emergency alert stations, and emergency alert-generating devices generate an audible alert signal and/or a visual alert signal configured to be displayed on electronic devices 170 and/or perceived (visually and/or audibly) by people 175 at the predicted emergency landing location 125 without assistance from their electronic devices. In some aspects, after the UAV 310 lands at the predicted emergency landing location 125, the UAV 310 is configured to transmit an electronic emergency signal to the central computing device 150 and/or other electronic devices via the transceiver 312 of the UAV 310 and the network 115 in order to facilitate the recovery of the UAV 310. For example, in some aspects, the electronic emergency signal can include electronic data identifying the UAV 310, task data associated with the UAV 310 during the flight mission, as well as electronic data identifying the type of products 190 (e.g., grocery, frozen, fragile, dry goods, bio-hazard, hazardous materials classification, etc.) contained in the UAV 310 to identify possible hazards associated with recovery operations and/or to facilitate proper response requirements and/or proper handling of the UAV 310 during the recovery operations.

With reference to FIG. 3, the control circuit 306 of the UAV 310 also couples to one or more on-board sensors 314 of the UAV 310. These teachings will accommodate a wide

variety of sensor technologies and form factors. In some embodiments, the on-board sensors 314 can comprise any relevant device that detects and/or transmits at least one status of the UAV 310 during flight of the UAV 110 along the flight route 120. The sensors 314 of the UAV 310 can include but are not limited to: altimeter, velocimeter, thermometer, photocell, battery life sensor, video camera, radar, lidar, laser range finder, and sonar. In some embodiments, the information obtained by one or more sensors 314 of the UAV 310 is used by the UAV 310 and/or the central computing device 150 in functions including but not limited to: navigation, landing, on-the-ground object/people detection, potential in-air threat detection, crash damage assessments, distance measurements, topography mapping, location determination, emergency detection.

In some aspects, the status input detected and/or transmitted by one or more sensors 314 of the UAV 310 includes but is not limited to location data associated with the UAV 310. Such location data can include, for example GPS coordinates of the UAV 310, marker beacon data along the flight route 120, and way point data along the flight route 120, all of which enable the control circuit 210 of the central computing device 150 and/or the control circuit 306 of the UAV 310, based on an analysis of at least such location data, to predict an emergency landing location 125 where the UAV 310 would land if unable to fly due to an emergency condition at a given point along the flight route 120. In some embodiments, the status input detected and/or transmitted by the at least one sensor 314 of the UAV 310 includes UAV status data including but not limited to propeller status, electronics status, communication status, interfering radio frequency (RF) status. For example, the UAV 310 can include at least one sensor 314 configured to monitor the function of, and to detect any malfunction of, any mechanical or electronic component of the UAV 310.

In some aspects, the sensors 314 of the UAV 310 are configured to detect rotation speed of the propellers of the UAV 310, detect directional movement of the UAV 310, measure ambient temperature surrounding the UAV 310, capture images and/or video in the air around the UAV 310 or on the ground below the UAV 310 along the flight route 120 of the UAV 310, capture thermographic, infrared, and/or multi spectral images of such in-air or on ground objects, capture images of entities attempting to tamper with UAV 310. Such sensors 314 include but are not limited to one or more accelerometers, gyroscopes, odometers, location sensors, microphones, distance measurement sensors (e.g., laser sensors, sonar sensors, sensors that measure distance by emitting and capturing a wireless signal (which can comprise light and/or sound) or the like), 3D scanning sensors, other such sensors, or a combination of two or more of such sensors.

In some embodiments, the status input detected and/or transmitted by the at least one sensor 314 of the UAV 310 includes flight mission data of the UAV 310. Such flight mission data can include but is not limited to: dimensional characteristics of the product(s) 190 being transported by the UAV 310; weight of the product(s) 190 being transported by the UAV 310; total weight of the UAV 310; component configuration of the UAV 310; altitude of the UAV 310; speed of the UAV 310; ambient wind speed; ambient temperature; ambient light level, in-air objects proximate the UAV 310 along the flight route 120; RF signal strengths prior to onset of emergency conditions, last recognized wireless (e.g., Wi-Fi) networks prior to emergency condition, last visual imaged captured prior to onset of emergency condition and/or prior to crash landing; distance of the UAV

310 to the in-air objects; angle of incidence of the UAV 310 relative to the in-air objects; last command received by the UAV 310 prior to onset of emergency condition, remaining battery life of the UAV 310; start- and end-points of the UAV 310 along the flight route 120; last known mission status of the UAV 310 (on route to delivery destination 185, returning to the UAV deployment station 185, delivery cancelled, etc.), original path of the UAV 310 along the flight route 120; location of one or more mobile relay stations along the flight route 120; location of at least one facility of the retailer having a safe landing point along the flight route 120; total dollar value of the products 190 being transported by the UAV 310; and total dollar value of the UAV 310. In some embodiments, such data obtained by the sensors 314 can be used to locate and/or recover the drone post-crash at the predicted emergency landing location 125. In some aspects, such data may be used to enable post-crash UAV recovery 310 and/or post-crash forensics/diagnostics, for example, to determine the cause of the emergency condition (e.g., in-air object, RF signal jamming, electrical, mechanical, or electronic malfunction, or the like) that caused the UAV 310 to crash.

For example, in some aspects, the sensors 314 include one or more devices that can be used to capture data related to one or more in-air objects (e.g., other UAVs 310, helicopters, birds, rocks, etc.) located within a threshold distance relative to the UAV 310. For example, the UAV 310 includes at least one on-board sensor 314 configured to detect at least one obstacle between the UAV 310 and the delivery destination 180 designated by the customer and/or the predicted emergency landing location 125. Based on the detection of one or more obstacles by such a sensor 314, the UAV 310 is configured to avoid the obstacle(s). In some aspects, the UAV 310 may attempt to avoid detected obstacles, and if unable to avoid, to notify the central computing device 150 of such a condition. In some aspects, using on-board sensors 314 (such as distance measurement units, e.g., laser or other optical-based distance measurement sensors), the UAV 310 detects obstacles in its path, and flies around such obstacles or stops until the obstacle is clear.

In some aspects, the UAV 310 includes sensors 314 configured to recognize environmental elements along the flight route 120 of the UAV 310 toward and/or away from the delivery destination 180. Such sensors 314 can provide information that the control circuit 306 and/or the central computing device 150 can employ to determine a present location, distance, and/or orientation of the UAV 310 relative to one or more in-air objects and/or objects and surfaces at the delivery destination 180, and/or at the predicted emergency landing location 125. These teachings will accommodate any of a variety of distance measurement units including optical units and sound/ultrasound units. A sensor 314 may comprise an altimeter and/or a laser distance sensor device capable of determining a distance to objects in proximity to the sensor 314. Such information obtained by sensors 314 may be processed by the control circuit 306 of the UAV 310 and/or the control circuit 210 of the central computing device 150 to determine, for example, the objects (buildings, cars, bus stops, parks, schools, etc.) that may be damaged and/or people that may be injured by the crashing of the UAV 310 at the predicted emergency landing location 125.

In some embodiments, such information obtained by sensors 314 is used by the computing device 150 and/or the UAV 110 to calculate a predicted casualty radius within which people 175 can be injured and property can be damaged by the emergency landing of the UAV 110 at the

predicted emergency landing location 125. In some aspects, the control circuit 210 of the computing device 150 and/or the control circuit 306 of the UAV 310 are programmed to determine the presence of: electronic devices 170 (e.g., mobile phones, personal computers, loudspeakers, etc.) located within the predicted casualty radius and/or otherwise configured to display/transmit information to people 175 located in the predicted emergency landing location 125; and in-air electronic devices located proximate a descent path of the UAV 310, from a given point of the flight route 120 where the emergency condition occurred, toward the predicted emergency landing location 125. Furthermore, in some aspects, the computing device 150 and the UAV 310 are configured to transmit the alert signal to the detected electronic devices of humans located within the predicted casualty radius, detected electronic devices associated with vehicles located within the predicted casualty radius, detected electronic devices associated with privately owned facilities located within the predicted casualty radius, detected electronic devices associated with public facilities located within the predicted casualty radius, and/or detected electronic devices associated with in-air objects located proximate the descent path of the UAV 310.

In some embodiments, the UAV 310 includes an on-board sensor 314 (e.g., a video camera) configured to detect map reference and/or topography and/or people and/or objects at the predicted emergency landing location 125. For example, in some aspects, one or more map reference or topography data acquired by one or more sensors 314 of the UAV 310 includes but is not limited to: no fly zones along the flight route 120, known safe emergency landing points along the flight route 120, on-the-ground people, buildings, vehicles and/or other objects, as well as hills, bodies of water, power lines, roads, and other environmental factors along the flight route 120 and/or at the predicted emergency landing location 125. As mentioned above, in some embodiments, a video camera-based sensor 314 on-board the UAV 310 may transmit images during the emergency descent of the UAV 310 all the way to the point of ground impact, thereby facilitating post-crash recovery of the UAV 310 in the predicted emergency landing location 125.

In some aspects, the sensor 314 of the UAV 310 is configured to transmit (e.g., via internal circuitry and/or via the transceiver 312) still and/or moving images of the predicted emergency landing location 125 to the control circuit 306 of the UAV 110 and/or the control circuit 210 of the central computing device 150, which allows the control circuit 306 of the UAV 310 and/or the control circuit 210 of the central computing device 150 to not only analyze the detected environmental elements and assess a personal injury risk and/or property damage risk associated with the crash landing of the UAV 310 at the predicted emergency landing location 125, but also to determine which electronic devices in the predicted emergency landing location 125 can be warned with an emergency alert signal indicating that a UAV 310 is going to crash land in the predicted emergency landing location 125. In one aspect, such analysis by the control circuit 210 of the central computing device 150 and/or the control circuit 306 of the UAV 310 can include obtaining information indicating a number of people and/or cars and/or buildings and/or other structures in a predicted casualty radius associated with the crash landing of the UAV 310.

In some embodiments, after the control circuit 210 of the central computing device 150 and/or control circuit 306 of the UAV 310 determines a predicted emergency landing location 125, the control circuit 210 of the central computing

device **150** and/or control circuit **306** of the UAV **310** is programmed to detect, based on the data obtained by the sensors **314** and/or via further communications with on-ground electronic devices proximate the predicted emergency landing location **125**, electronic devices that are configured for receiving (either directly or via another electronic device, emergency station, loudspeaker, electronic display, or the like) an emergency alert signal generated by the UAV **310** and/or the central computing device **150**.

In some embodiments, an audio input **316** (such as a microphone) and/or an audio output **318** (such as a speaker) can also operably couple to the control circuit **306** of the UAV **310**. So configured, the control circuit **306** can provide for a variety of audible sounds to enable the UAV **310** to communicate with, for example, the central computing device **150** or other UAVs, or electronic devices at the emergency landing location **125**. Such sounds can include any of a variety of tones and/or sirens and/or other non-verbal sounds. Such audible sounds can also include, in lieu of the foregoing or in combination therewith, pre-recorded or synthesized speech. In some embodiments, the UAV **310** can be configured with one or more devices capable of generating (instead of or in addition to the audible alert) a visual alert (e.g., flare, smoke, flashing lights, etc.) that would be perceivable by people **175** at the predicted emergency landing location **125** without requiring assistance from their personal electronic devices.

In the embodiment illustrated in FIG. 3, the UAV **310** includes a rechargeable power source **320** such as one or more batteries. The power provided by the rechargeable power source **320** can be made available to whichever components of the UAV **310** require electrical energy. By one approach, the UAV **310** includes a plug or other electrically conductive interface that the control circuit **306** can utilize to automatically connect to an external source of electrical energy (e.g., a charging dock) to recharge the rechargeable power source **320**.

The exemplary UAV **310** of FIG. 3 also includes an input/output (I/O) device **330** that is coupled to the control circuit **306**. The I/O device **330** allows an external device to couple to the control unit **304**. The function and purpose of connecting devices will depend on the application. In some examples, devices connecting to the I/O device **330** may add functionality to the control unit **304**, allow the exporting of data from the control unit **304**, allow the diagnosing of the UAV **310**, and so on.

The exemplary UAV **310** of FIG. 3 also includes a user interface **324** including for example, user inputs and/or user outputs or displays depending on the intended interaction with a user (e.g., a worker of a retailer, UAV delivery service or customer, and/or a rescue operations worker or robot). For example, user inputs could include any input device such as buttons, knobs, switches, touch sensitive surfaces or display screens, and so on. Example user outputs include lights, display screens, and so on. The user interface **324** may work together with or separate from any user interface implemented at an optional user interface unit (such as a smart phone or tablet device) usable by the worker.

In some embodiments, the UAV **310** may be controlled by a user in direct proximity to the UAV **310**, for example, an operator of the UAV deployment station **185** (e.g., a driver of a moving vehicle), or by a user at any location remote to the location of the UAV **310** (e.g., regional or central hub operator). This is due to the architecture of some embodiments where the central computing device **150** outputs control signals to the UAV **310**. These controls signals can

originate at any electronic device in communication with the central computing device **150**. For example, the signals sent to the UAV **310** may be movement instructions determined by the central computing device **150** and/or initially transmitted by a device of a user to the central computing device **150** and in turn transmitted from the central computing device **150** to the UAV **310**.

The control unit **304** of the UAV **310** includes a memory **308** coupled to a control circuit **306** and storing data such as operating instructions and/or other data. The control circuit **306** can comprise a fixed-purpose hard-wired platform or can comprise a partially or wholly programmable platform. These architectural options are well known and understood in the art and require no further description. This control circuit **306** is configured (e.g., by using corresponding programming stored in the memory **308** as will be well understood by those skilled in the art) to carry out one or more of the steps, actions, and/or functions described herein. The memory **308** may be integral to the control circuit **306** or can be physically discrete (in whole or in part) from the control circuit **306** as desired. This memory **308** can also be local with respect to the control circuit **306** (where, for example, both share a common circuit board, chassis, power supply, and/or housing) or can be partially or wholly remote with respect to the control circuit **306**. This memory **308** can serve, for example, to non-transitorily store the computer instructions that, when executed by the control circuit **306**, cause the control circuit **306** to behave as described herein. It is noted that not all components illustrated in FIG. 3 are included in all embodiments of the UAV **310**. That is, some components may be optional depending on the implementation.

As referenced above, in some aspects, after receiving one or more sensor inputs detected by one or more sensors **314** of the UAV **310** while the UAV **310** is in flight along the flight route **120** determined by the central computing device **150**, the control circuit **210** of the central computing device **150** is programmed to analyze one or more of the received status inputs in order to determine a predicted emergency landing location **125** where the UAV **310** would land if unable to fly due to an emergency condition at a given point along the flight route **120**. Similarly, in some embodiments, the control circuit **306** of the UAV **310** is programmed to analyze one or more status inputs obtained by one or more sensors **314** while the UAV **310** is in normal flight mode and/or facing an imminent emergency condition in order to determine the emergency landing location **125** where the UAV **110** would land if unable to fly due to the emergency condition at a given point along the flight route **120**.

For example, in some aspects, the control circuit **306** of the UAV **310** and/or the control circuit **210** of the central computing device **150** is programmed to predict possible emergency landing locations **125** of the UAV **310** based on possible emergency conditions occurring at any given point along the flight route **120** of the UAV **310**, which include analysis of emergency landing locations **125** including but not limited to: an emergency landing location **125** resulting from an unguided ballistic trajectory of the UAV **310** if the UAV **310** loses all power (e.g., the battery of the UAV **310** dies or is otherwise disabled) at any point along the flight route **120**; an emergency landing location **125** resulting from a collision of the UAV **310** with an in-air object (e.g., bird, rock, other UAV, etc.) that causes the UAV **310** to veer off the flight route **120** and/or malfunction such that the UAV **310** is not controllable; an emergency landing location **125** resulting from a guided ballistic trajectory of the UAV **310** if the UAV **310** malfunctions or collides with an object at

any point along the flight route **120** but does not lose power and remains controllable by the central computing device **150** and/or the control circuit **306** of the UAV **310** from the point along the flight route **120** where the emergency condition occurred to the emergency landing location **125** where the UAV **310** is guided to.

FIG. **4** shows an embodiment of an exemplary method **400** of controlling an UAV **110** experiencing an emergency landing and providing an emergency alert to an area proximate a predicted emergency landing location **125** of the UAV **110**. The embodiment of the method **400** illustrated in FIG. **4** includes providing a UAV **110** configured to transport at least one product **190** to a delivery destination **180** via a flight route **120**, with the UAV **110** including at least one sensor **314** configured to detect and transmit over a network **115** at least one status input associated with the UAV **110** during flight along the flight route **120** (step **410**). The method **400** further includes providing a computing device **150** including a processor-based control circuit **210** and in communication with the UAV **110** over the network **115** (step **420**).

As discussed above, the central computing device **150** is configured to obtain and analyze the relative locations of the UAV deployment station **185** and delivery destination **180** in order to determine a flight route **120** for the UAV **110** from the UAV deployment station **185** to the delivery destination **180**. For example, in some embodiments, the central computing device **150** obtains GPS data associated with the delivery destination **180** from the customer information database **140** and GPS data associated with the UAV deployment station **185** from the central electronic database **160**. As discussed above, the customer information database **140** and the central electronic database **160** may be implemented as a single database.

As discussed above, while the UAV **110** is in flight along the flight route **120** from the UAV deployment station **185** to the delivery destination **180**, the onboard sensors **314** of the UAV **310** monitor various parameters relating to the flight mission of the UAV **310** and the status of the UAV **310**. While the data detected by the sensors **314** is expected to, in most cases, indicate that the flight mission is going as planned, in certain situations, the sensors **314** may provide information regarding a possible and/or imminent emergency condition that may cause the UAV **310** to experience an emergency landing. For example, a sensor **314** may detect a malfunction (e.g., power loss, electrical short-circuit, mechanical (e.g., propeller) problem, or the like) or an imminent collision with an in-air object (e.g., a rock or another device launched from the ground, a bird, another UAV, a helicopter, or the like) that would be expected by the analyzing processor (e.g., control circuit **210** of the central computing device and/or control circuit **306** of the UAV **310**) to cause the UAV **310** to experience an emergency landing. To that end, the method **400** includes determining, via the control circuit of the UAV **310** and based on an analysis of the at least one status input, that the UAV **310** is experiencing an emergency condition that requires an emergency landing of the UAV **310** (step **430**).

As discussed above, the on-board sensors **314** of the UAV **310** may include but are not limited to: altimeter, velocimeter, thermometer, photocell, battery life sensor, video camera, radar, lidar, laser range finder, and sonar, and the information obtained by the sensors **314** of the UAV **310** while the UAV **310** is in flight is used by the control circuit **306** of the UAV **310** and/or the control circuit **210** of the central computing device **150** in functions including but not limited to: navigation, landing, on-the-ground object/people

detection, potential in-air threat detection, crash damage assessments, distance measurements, topography mapping, location determination, emergency detection. In some aspects, the status input detected and/or transmitted by one or more sensors **314** of the UAV **310** includes but is not limited to location data associated with the UAV **310** and data relating to potential obstacles, in-air objects, and UAV status information that may be relevant to analysis, by the control circuit **306** of the UAV **310**, of potential emergency conditions that may force the UAV **310** to experience a forced emergency landing, as well as of predicted emergency landing location **125** where the UAV **310** would land if unable to fly due to an emergency condition at a given point along the flight route **120**.

As discussed above, in some embodiments, the control circuit **306** of the UAV **310** analyzes one or more status inputs obtained by one or more sensors **314** while the UAV **110** is in normal flight mode and/or facing an imminent emergency condition in order to determine the emergency landing location **125** where the UAV **110** would land if unable to fly due to the emergency condition at a given point along the flight route **120**. To that end, the method **400** further includes analyzing, via a processor-based control circuit **306** of the UAV **310**, one or more of the status inputs (acquired by the sensors **314** of the UAV **310**) in order to determine a predicted emergency landing location **125** where the UAV **310** would land if unable to fly due to the detected emergency condition at a given point along the determined flight route **120** (step **440**).

In some embodiments, after the control circuit **210** of the central computing device **150** and/or control circuit **306** of the UAV **310** predicts the emergency landing location **125** of the UAV **310** as a result of the emergency condition, the control circuit **306** of the UAV **310** is programmed to cause the UAV **310** to transmit an emergency signal (e.g., SOS) indicating that a crash of the UAV **310** is unavoidable and, optionally, indicating the emergency condition that caused the UAV **310** to go down. In the exemplary embodiment of FIG. **4**, the method **400** of FIG. **4** includes transmitting the predicted emergency landing location **125** of the UAV **310** to the computing device **150** over the network **115** (step **450**). It will be appreciated that the control circuit **306** of the UAV **310** can be programmed not only to analyze the data obtained by the sensors **314** in order to predict an emergency landing location **125** of the UAV **310** only after an emergency condition actually occurs, but also to analyze the data obtained by the sensors **314** in real-time while the UAV **310** is in flight in order to continuously predict emergency landing locations **125** of the UAV **310** if a crash-causing emergency were to occur at a given point along the route **120** of the UAV **310** toward the delivery destination **180**.

Generally, determining a predicted emergency landing location **125** after the emergency condition occurs and before the UAV **310** crash lands enables the UAV **310** and/or central computing device **150** to provide a warning (directly or via another computing device) to people **175** and/or electronic devices **170** in the predicted emergency landing location **125** of the UAV **310**, thereby reducing the possible personal injury and/or property damage that may result from the crash landing of the UAV **310** at the predicted emergency landing location **125**. More specifically, the exemplary method **400** of FIG. **4** further includes transmitting, via the UAV **310**, an alert signal to electronic devices **170** proximate the predicted emergency landing location **125** to notify users of the electronic devices that the UAV **310** is going to experience an emergency landing at the predicted emergency landing location **125** (step **460**).

In some embodiments, the UAV 310 is configured to send out an emergency signal to electronic devices 170 in the predicted emergency landing area 125 via a text message. For example, the UAV 310 may transmit (via the transceiver 312 and over the network 115) an alert that the UAV 310 is crashing in the predicted emergency landing area 125 to an emergency signal station configured to transmit emergency signals (e.g., akin to kidnapped child alerts) to all mobile phones detected in an area that includes the predicted emergency landing location 125 and is serviced by the emergency signal station. In one aspect, after such an emergency signal station receives the alert from the UAV 310 over the network 115, the emergency signal station relays the alert (e.g., via a text message and/or accompanying audible alert) to the electronic devices 170 (e.g., mobile phones) located in the area covering the predicted emergency landing location 125 of the UAV 310, thereby providing a warning to users of such electronic devices 170 that a UAV 310 is imminently going to crash land at the predicted emergency landing location 125.

In another aspect, instead of sending an alert signal to an emergency signal station and relying on the emergency signal station to relay the alert signal to the electronic devices 170 in the area that covers the predicted landing location 125 of the UAV 310, the UAV 310 obtains network permission and/or electronic device information from the emergency signal station, enabling the UAV 310 to transmit (via the transceiver 312 and over the network 115) the alert signal via a text message and/or an accompanying audible alert directly to the electronic devices 170 located in the predicted landing location 125. For purposes of this disclosure, the term emergency signal station will be understood to refer to a communication hub (which may comprise a single computing device or multiple networked computing devices) having permission to transmit electronic emergency communications to electronic devices in an area serviced by the communications hub.

As discussed above, in some aspects, the alert signal generated by the UAV 310 is configured to provide an audible and/or a visual warning to the users of the electronic devices 170 and/or other people 175 located proximate the emergency landing location 125 where the UAV 310 is going to crash land. In some aspects, the UAV 310 is configured to emit sounds (e.g., variety of tones and/or sirens and/or other non-verbal sounds) that are loud enough for people 175 at the predicted emergency landing location 125 to hear well before the UAV 310 crash lands at the predicted emergency landing location 125, thereby providing such people 175 with enough time to escape from the potential casualty radius associated with the crash landing of the UAV 310. Instead of, or in addition to generating sound-based alerts, the UAV 310 is configured, in some embodiments, to generate a visual alert (e.g., flare, smoke, flashing lights, etc.) that would be perceivable by humans at the predicted emergency landing location 125 (as the UAV 310 is going down but prior to the crash landing of the UAV 310) without requiring assistance from their personal electronic devices.

In some aspects, the UAV 310 is configured to transmit the crash landing alert to an emergency service computing device (akin to college campus emergency warning systems and/or kidnapped children alert communication hubs) that is communicatively coupled to informational displays and/or loudspeakers in the predicted emergency landing location 125, thereby enabling the emergency service computing device to either relay the alert received from the UAV 310 to a loudspeaker and/or a visual display in the predicted

emergency landing location 125 in order to warn people 175 at that location that a UAV 310 is imminently crashing nearby. Such a notification may enable the people 175 receiving such a warning pre-crash to escape the casualty radius of the crash and may enable the people 175 receiving such a warning post-crash to avoid the UAV 310 crash area, thereby facilitating UAV 310 recovery from the predicted emergency landing location 125.

In certain situations, an emergency condition may disable the UAV 310 to a degree where the UAV 310 is unable to transmit any emergency alerts. For example, a collision of the UAV 310 with another UAV may cause such physical damage to the UAV 310 that the UAV 310 loses all power and/or the transceiver 312 is damaged and unable to transmit signals. In such situations, the central computing device 150 provides a reserve warning system to electronic devices 170 and/or people 175 located in the predicted emergency landing location 125. In other words, in some embodiments, upon obtaining information indicating that the UAV 310 is unable to send or receive signals, the control circuit 210 of the computing device 150 is configured to cause the computing device 150 to transmit an audible and/or visual alert signal to electronic devices 170 and/or people 175 located proximate the predicted emergency landing location 125, thereby notifying the users of the electronic devices 170 and/or other people 175 that the UAV 310 is going to crash at the predicted emergency landing location 125. To that end, the method 400 of FIG. 4 includes transmitting, via the computing device 150 and in response to a determination by the computing device 150 that the UAV 310 is unable to transmit the alert signal, the alert signal to electronic devices 170 proximate the predicted emergency landing location 125 to notify users of the electronic devices that the UAV 310 is going to experience an emergency landing at the predicted emergency landing location 125 (step 470).

The systems and methods described herein advantageously provide for emergency alerts that warn users of electronic devices and/or others that a UAV is going to experience an emergency landing in a location where the users and/or other people would be within the predicted casualty radius of the crash landings. In addition, the systems and methods described herein advantageously provide for post-crash emergency alerts that may facilitate the recovery of the UAVs from the crash sites. As such, the systems and methods described herein not only advantageously provide an early warning to people, thereby reducing possible personal injury and/or property damage associated with a UAV crash landing, but also advantageously provide for post-crash recovery of the UAV and warn others to avoid the crash area while UAV recovery and/or crash site cleanup is in progress.

Those skilled in the art will recognize that a wide variety of other modifications, alterations, and combinations can also be made with respect to the above described embodiments without departing from the scope of the invention, and that such modifications, alterations, and combinations are to be viewed as being within the ambit of the inventive concept.

What is claimed is:

1. A system for controlling an unmanned aerial vehicle experiencing an emergency landing and providing an emergency alert to an area proximate a predicted emergency landing location of the unmanned aerial vehicle, the system comprising:
 - an unmanned aerial vehicle configured to transport at least one product to a delivery destination via a flight route, the unmanned aerial vehicle including at least one

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sensor configured to detect and transmit over a network at least one status input associated with the unmanned aerial vehicle during flight along the flight route;

a computing device including a processor-based control unit and configured for communication with the unmanned aerial vehicle over the network;

wherein the unmanned aerial vehicle includes a processor-based control circuit configured to:

determine, based on an analysis of the at least one status input, that the unmanned aerial vehicle is experiencing an emergency condition that requires an emergency landing of the unmanned aerial vehicle;

analyze the at least one sensor input in order to determine a predicted emergency landing location of the unmanned aerial vehicle; and

transmit the predicted emergency landing location of the unmanned aerial vehicle to the computing device over the network;

wherein the unmanned aerial vehicle is configured to transmit an alert signal to electronic devices proximate the predicted emergency landing location to notify users of the electronic devices that the unmanned aerial vehicle is going to experience an emergency landing at the predicted emergency landing location; and

wherein, in response to a determination by the computing device that the unmanned aerial vehicle is unable to transmit the alert signal, the computing device is configured to transmit the alert signal to electronic devices proximate the predicted emergency landing location to notify users of the electronic devices that the unmanned aerial vehicle is going to experience an emergency landing at the predicted emergency landing location.

2. The system of claim 1, wherein the computing device is configured to receive, over the network, an electronic signal from the unmanned aerial vehicle indicating that the unmanned aerial vehicle is experiencing an emergency condition that requires an emergency landing of the unmanned aerial vehicle, and including an identification of the emergency condition.

3. The system of claim 1, wherein the control circuit of the unmanned aerial vehicle is configured to determine the predicted emergency landing location of the unmanned aerial vehicle based on an analysis of at least one sensor input comprising: global positioning system (GPS) coordinates of the unmanned aerial vehicle; altitude of the unmanned aerial vehicle; speed of the unmanned aerial vehicle; wind speed; weight of the unmanned aerial vehicle; component configuration of the unmanned aerial vehicle; weight of the at least one product; safe landing points along the flight route; topography of the predicted emergency landing location; buildings, trees, power lines, roads, vehicles, and people at the predicted emergency landing location, in-air objects along an emergency descent of the unmanned aerial vehicle from the flight route toward the predicted emergency landing location; distance to the in-air objects; angle of incidence relative to the in-air objects; distance to objects on the ground at the predicted emergency landing location; remaining battery life of the unmanned aerial vehicle; mission status of the unmanned aerial vehicle; RF signal strengths; detectable WiFi networks; and last command received by the unmanned aerial vehicle.

4. The system of claim 1, wherein the at least one sensor comprises an altimeter, velocimeter, thermometer, photocell, battery life sensor, camera, radar, lidar, laser range finder, and sonar.

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5. The system of claim 1, wherein the control circuit of the unmanned aerial vehicle is configured to analyze the at least one sensor input in order to determine a predicted emergency landing location resulting from an unguided ballistic trajectory of the unmanned aerial vehicle if the unmanned aerial vehicle loses all power at a given point along the flight route due to the emergency condition, and a predicted emergency landing location resulting from a computing device-guided trajectory of the unmanned aerial vehicle from the given point along the flight route due to the emergency condition.

6. The system of claim 1, wherein at least one of the unmanned aerial vehicle and the computing device is configured to calculate a predicted casualty radius within which humans can be injured and property can be damaged by the emergency landing of the unmanned aerial vehicle.

7. The system of claim 6, wherein the at least one of the unmanned aerial vehicle and the computing device is configured to detect at least one of: electronic devices of humans located within the predicted casualty radius; electronic devices associated with the property located within the predicted casualty radius; and in-air electronic devices located proximate a descent path of the unmanned aerial vehicle from a given point of the flight route where the emergency condition occurred toward the predicted emergency landing condition.

8. The system of claim 7, wherein the at least one of the unmanned aerial vehicle and the computing device is configured to transmit the alert signal to at least one of: detected electronic devices of humans located within the predicted casualty radius; detected electronic devices associated with vehicles located within the predicted casualty radius; detected electronic devices associated with privately owned facilities located within the predicted casualty radius; detected electronic devices associated with public facilities located within the predicted casualty radius; and detected electronic devices associated with in-air objects located proximate the descent path of the unmanned aerial vehicle.

9. The system of claim 1, wherein at least one of the unmanned aerial vehicle and the computing device is configured to generate at least one of an audible alert signal and a visual alert signal configured to be perceived by humans at the predicted emergency landing location without assistance from their electronic devices.

10. The system of claim 1, wherein at least one of the unmanned aerial vehicle and the computing device is configured to transmit the alert signal to at least one of a ground vehicle, an emergency alert station, and an emergency alert-generating device, and wherein the at least one of the ground vehicle, emergency alert station, and emergency alert-generating device, after receipt of the alert signal from the computing device, generates at least one of an audible alert signal and a visual alert signal configured to be perceived by humans at the predicted emergency landing location without assistance from their electronic devices.

11. A method for controlling an unmanned aerial vehicle experiencing an emergency landing and providing an emergency alert to an area proximate a predicted emergency landing location of the unmanned aerial vehicle, the method comprising:

providing an unmanned aerial vehicle configured to transport at least one product to a delivery destination via a flight route, the unmanned aerial vehicle including at least one sensor configured to detect and transmit over a network at least one status input associated with the unmanned aerial vehicle during flight along the flight route;

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providing a computing device including a processor-based control unit and configured for communication with the unmanned aerial vehicle over the network; determining, via the control circuit of the unmanned aerial vehicle and based on an analysis of the at least one status input, that the unmanned aerial vehicle is experiencing an emergency condition that requires an emergency landing of the unmanned aerial vehicle; analyzing, via the control circuit of the unmanned aerial vehicle, the at least one sensor input received from the unmanned aerial vehicle in order to determine a predicted emergency landing location of the unmanned aerial vehicle; transmitting the predicted emergency landing location of the unmanned aerial vehicle to the computing device over the network; transmitting, via the unmanned aerial vehicle, an alert signal to electronic devices proximate the predicted emergency landing location to notify users of the electronic devices that the unmanned aerial vehicle is going to experience an emergency landing at the predicted emergency landing location; and transmitting, via the computing device and in response to a determination by the computing device that the unmanned aerial vehicle is unable to transmit the alert signal, the alert signal to electronic devices proximate the predicted emergency landing location to notify users of the electronic devices that the unmanned aerial vehicle is going to experience an emergency landing at the predicted emergency landing location.

12. The method of claim **11**, wherein the determining step further comprises receiving, at the computing device and over the network, an electronic signal from the unmanned aerial vehicle indicating that the unmanned aerial vehicle is experiencing an emergency condition that requires an emergency landing of the unmanned aerial vehicle, and including an identification of the emergency condition.

13. The method of claim **11**, wherein the determining step further comprises determining, via control circuit of the unmanned aerial vehicle, the predicted emergency landing location of the unmanned aerial vehicle based on at least one sensor input comprising: global positioning system (GPS) coordinates of the unmanned aerial vehicle; altitude of the unmanned aerial vehicle; speed of the unmanned aerial vehicle; wind speed; weight of the unmanned aerial vehicle; component configuration of the unmanned aerial vehicle; weight of the at least one product; safe landing points along the flight route; topography of the predicted emergency landing location; buildings, trees, power lines, roads, vehicles, and people at the predicted emergency landing location, in-air objects along an emergency descent of the unmanned aerial vehicle from the flight route toward the predicted emergency landing location; distance to the in-air objects; angle of incidence relative to the in-air objects; distance to objects on the ground at the predicted emergency landing location; remaining battery life of the unmanned aerial vehicle; mission status of the unmanned aerial vehicle; RF signal strengths; detectable WiFi networks; and last command received by the unmanned aerial vehicle.

14. The method of claim **11**, wherein the at least one sensor comprises an altimeter, velocimeter, thermometer, photocell, battery life sensor, camera, radar, lidar, laser range finder, and sonar.

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15. The method of claim **11**, wherein the analyzing step further comprises analyzing, via the control circuit of the unmanned aerial vehicle, the at least one sensor input in order to determine a predicted emergency landing location resulting from an unguided ballistic trajectory of the unmanned aerial vehicle if the unmanned aerial vehicle loses all power at a given point along the flight route due to the emergency condition, and a predicted emergency landing location resulting from a computing device-guided trajectory of the unmanned aerial vehicle from the given point along the flight route due to the emergency condition.

16. The method of claim **11**, wherein the analyzing step further comprises calculating, via at least one of the unmanned aerial vehicle and the computing device, a predicted casualty radius within which humans can be injured and property can be damaged by the emergency landing of the unmanned aerial vehicle.

17. The method of claim **16**, further comprising detecting, via the at least one of the unmanned aerial vehicle and the computing device, at least one of: electronic devices of humans located within the predicted casualty radius; electronic devices associated with the property located within the predicted casualty radius; and in-air electronic devices located proximate a descent path of the unmanned aerial vehicle from a given point of the flight route where the emergency condition occurred toward the predicted emergency landing condition.

18. The method of claim **17**, wherein the transmitting step further comprises transmitting, via the at least one of the unmanned aerial vehicle and the computing device, the alert signal to at least one of: detected electronic devices of humans located within the predicted casualty radius; detected electronic devices associated with vehicles located within the predicted casualty radius; detected electronic devices associated with privately owned facilities located within the predicted casualty radius; detected electronic devices associated with public facilities located within the predicted casualty radius; and detected electronic devices associated with in-air objects located proximate the descent path of the unmanned aerial vehicle.

19. The method of claim **11**, wherein the transmitting step further comprises generating, via at least one of the unmanned aerial vehicle and the computing device, at least one of an audible alert signal and a visual alert signal configured to be perceived by humans at the predicted emergency landing location without assistance from their electronic devices.

20. The method of claim **11**, wherein the transmitting step further comprises transmitting, via at least one of the unmanned aerial vehicle and the computing device, the alert signal to at least one of a ground vehicle, an emergency alert station, and an emergency alert-generating device, and generating, via the at least one of the ground vehicle, emergency alert station, and emergency alert-generating device, at least one of an audible alert signal and a visual alert signal configured to be perceived by humans at the predicted emergency landing location without assistance from their electronic devices.

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