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UAV Enabled Vehicle Perimeters

Abstract

Perimeter devices, vehicles, including autonomous vehicles and human-controlled vehicles, UAVs, and related systems and methods are described. Perimeter devices respond to triggering events, such as vehicle-immobilizing events, GPS-based events, and environment-based events, to establish a perimeter adjacent a vehicle such that observers can visually detect the presence of a signal member, such as a warning triangle having a reflective surface. An example vehicle includes a tractor unit, a trailer connected to the tractor unit, a storage enclosure associated with the tractor unit, and a plurality of perimeter devices disposed in the chamber. Each perimeter device is adapted to deploy from the vehicle and establish a perimeter by the vehicle in response to a triggering event, such as parking of the vehicle in a location for which a perimeter must be established, impact of the vehicle with another object, rollover, or mechanical and/or electrical failure of the vehicle.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application is a continuation of U.S. application Ser. No. 17/184,010, filed on Feb. 24, 2021 and issued as U.S. Pat. No. 11,939,057, which claims priority to U.S. Provisional Application No. 63/112,439, filed on Nov. 11, 2020, and U.S. Provisional Application No. 63/114,219, filed on Nov. 16, 2020. The entire contents of each of these related applications are incorporated into this disclosure by reference.

FIELD
[0002] The disclosure relates to the field of perimeters for vehicles. More particularly, the disclosure relates to vehicle perimeters established by unmanned aerial vehicles (UAVs), such as autonomous drones. Specific examples described herein relate to perimeter devices, vehicles, including autonomous vehicles and human-controlled vehicles, UAVs, and related systems and methods. The perimeters enabled by the various inventions can be established for various purposes, including safety, security, data collection, communications, logistical delivery and/or resupply, and environmental control
BACKGROUND
[0003] Vehicles of all types are in continuous development, with sizes, weights, and configurations changing frequently. Furthermore, autonomous functionality is available or in late-stage development for many types of vehicles, including passenger cars, delivery vans and trucks, and cargo trucks. As vehicles change, and as roads, sidewalks, and safety support systems change in response, traditional perimeters for vehicles will become inadequate for establishing effective perimeters when such vehicles become disabled or otherwise temporarily immobile. Furthermore, the development of new perimeter technology provides an opportunity to extend the function of vehicle perimeters beyond those typically served by conventional perimeters.
[0004] A need exists, therefore, for improved perimeters for vehicles and related devices, systems, and methods.
BRIEF SUMMARY OF SELECTED EXAMPLES
[0005] Various example perimeter devices are described.
[0006] An example perimeter device comprises a signal member, a base member movably connected to the signal member, a connector disposed on the signal member, and a UAV connected to the connector. The perimeter device has a non-deployed configuration and a deployed configuration.
[0007] Another example perimeter device comprises a signal member, a base member movably connected to the signal member, a connector disposed on the signal member, and a UAV connected to the connector such the UAV is movable from a first position that is substantially within an opening defined by the signal member to a second position that is substantially external to the opening. The perimeter device has a non-deployed configuration and a deployed configuration.
[0008] Another example perimeter device comprises a signal member and a UAV that includes a

frame that provides a base member. The signal member is movably connected to the frame of the UAV. The signal member has multiple sides, and the frame of the UAV has multiple sides. The UAV has propellers positioned at the vertices formed by the sides of the frame. The perimeter device has a non-deployed configuration and a deployed configuration.

[0009] Another example perimeter device comprises a UAV having a triangular frame defined by first, second, and third sides that cooperatively define an opening. The UAV has propellers positioned at the vertices formed by the sides of the frame. The UAV includes a storage bay positioned in the opening defined by sides of the frame and covering. A hook is attached to the covering and extends downward. A plurality of signal members is positioned in the storage bay, arranged as a stack with individual signal members positioned in a plane that is parallel to the plane in which the frame is disposed. Each signal member of the plurality of signal members includes a loop through which the hook extends. Individual signal members of the plurality of signal members are adapted to be released from the hook and storage bay for deployment and include support legs that extend outward upon release of the signal member.

[0010] Various vehicles are described.

[0011] An example vehicle comprises a passenger automobile and includes a storage enclosure disposed on the undercarriage of the vehicle and defining a chamber. A movable door provides selective ingress and egress to the chamber. A perimeter device according to an embodiment is positioned within the chamber when the vehicle is in a perimeter device storage configuration. The perimeter device is secured to the storage enclosure.

[0012] Another example vehicle comprises a semi-trailer truck, and includes a tractor unit and a trailer. The vehicle also includes a storage enclosure disposed on a surface of the tractor unit, such as the uppermost surface. The storage enclosure defines a chamber and a movable door that provides selective ingress and egress to the chamber. A plurality of perimeter devices is positioned within the chamber when the vehicle is in a perimeter device storage configuration. Each perimeter device of the plurality of perimeter devices is a perimeter device according to an embodiment of the invention and is secured to the storage enclosure.

[0013] Various vehicle perimeter systems are described herein.

[0014] An example vehicle perimeter system comprises a vehicle, a remote computing resource, and at least one UAV adapted to be mounted on and deployed from the vehicle and to communicate with the remote computing resource. The UAV is a component of a perimeter device according to an embodiment.

[0015] Another example vehicle perimeter system comprises a vehicle and at least one UAV mounted on the vehicle in a designated mounting area. The UAV is deployable from the vehicle when the vehicle, or a driver or remote operator of the of the vehicle, transmits a signal to the UAV indicating that the vehicle is temporarily immobilized, such as during a rollover or other event. The UAV is configured to survey the environment immediately surrounding the vehicle and determine optimal positioning for one or more perimeter devices near the vehicle during its period of immobilization. In some embodiments, the UAV is configured to fly to the determined position, or one of the determined positions, and to release a perimeter device it is carrying, such as a cone, reflective triangle, flare, light, communications beacon, or the like, at the determined position. In other embodiments, the UAV has a configuration in which it functions as a perimeter device. In these embodiments, the UAV is configured to fly to the determined position, or one of the determined positions, and to adopt its perimeter device configuration, and then place itself at the determined position. The UAV is configured to leave the determined position, and leave its perimeter device configuration if appropriate, when the vehicle, or a driver or remote operator of the vehicle, transmits a signal to the UAV indicating that the vehicle is no longer temporarily immobilized. Once this signal is received, the UAV leaves the determined position and flies to the vehicle, ultimately mounting itself on the designated mounting area on the vehicle.

[0016] Various methods of establishing a vehicle perimeter are described herein.

[0017] An example method of establishing a vehicle perimeter comprises operating a vehicle having at least one perimeter device associated with the vehicle according to an embodiment; deploying the perimeter device from the vehicle by operating the UAV component of the perimeter device; and positioning the perimeter device at a predetermined location relative to the vehicle to establish the safety perimeter. An optional step comprises returning the perimeter device to the vehicle such that the perimeter device is again associated with the vehicle. The steps of deploying the perimeter device and positioning the perimeter device at the predetermined location can be repeated any suitable number of times, each using a new and different predetermined location, based on the number of perimeter devices associated with the vehicle.
[0018] Another example method of establishing a vehicle perimeter comprises operating a vehicle having at least one perimeter device associated with the vehicle according to an embodiment; deploying the perimeter device from the vehicle by operating the UAV component of the perimeter device; acquiring information relating to one or more situational parameters by the UAV component of the perimeter device; and positioning the perimeter device at a predetermined location relative to the vehicle to establish the safety perimeter. An optional step comprises returning the perimeter device to the vehicle such that the perimeter device is again associated with the vehicle. The steps of deploying the perimeter device and positioning the perimeter device at the predetermined location can be repeated any suitable number of times, each using a new and different predetermined location, based on the number of perimeter devices associated with the vehicle.
[0019] Another example method of establishing a vehicle perimeter comprises operating a vehicle having at least one perimeter device associated with the vehicle according to an embodiment; deploying the perimeter device from the vehicle by operating the UAV component of the perimeter device; acquiring information relating to one or more situational parameters by the UAV component of the perimeter device; positioning the perimeter device at a predetermined location relative to the vehicle to establish the safety perimeter; and acquiring information relating to one or more safety perimeter parameters by the UAV component of the perimeter device. An optional step comprises returning the perimeter device to the vehicle such that the perimeter device is again associated with the vehicle. The steps of deploying the perimeter device and positioning the perimeter device at the predetermined location can be repeated any suitable number of times, each using a new and different predetermined location, based on the number of perimeter devices associated with the vehicle.
[0020] Additional understanding of the inventive improved perimeters for vehicles and related devices, methods, and systems can be obtained by reviewing the detailed description of selected examples, below, with reference to the appended drawings.

Description

DESCRIPTION OF FIGURES
[0021] FIG. **1** is a top view of an example perimeter device. The perimeter device is illustrated in a non-deployed configuration.
[0022] FIG. **2** is a bottom view of the perimeter device illustrated in FIG. **1**. The perimeter device is illustrated in a non-deployed configuration.
[0023] FIG. **3** is a side view of the perimeter device illustrated in FIG. **1**. The perimeter device is illustrated in a non-deployed configuration.
[0024] FIG. **4** is a perspective view of the perimeter device illustrated in FIG. **1**. The perimeter device is illustrated in a deployed configuration.
[0025] FIG. **5** is a top view of another example perimeter device. The perimeter device is illustrated in a non-deployed configuration.

[0026] FIG. **6** is a bottom view of the perimeter device illustrated in FIG. **5**. The perimeter device is illustrated in a non-deployed configuration.
[0027] FIG. **7** is a side view of the perimeter device illustrated in FIG. **5**. The perimeter device is illustrated in a non-deployed configuration.
[0028] FIG. **8** is a perspective view of the perimeter device illustrated in FIG. **5**. The perimeter device is illustrated in a deployed configuration.
[0029] FIG. **9** is a top view of another example perimeter device. The perimeter device is illustrated in a non-deployed configuration.
[0030] FIG. **10** is a bottom view of the perimeter device illustrated in FIG. **9**. The perimeter device is illustrated in a non-deployed configuration.
[0031] FIG. **11** is a side view of the perimeter device illustrated in FIG. **9**. The perimeter device is illustrated in a non-deployed configuration.
[0032] FIG. **12** is a side view of the perimeter device illustrated in FIG. **9**. The perimeter device is illustrated in a deployed configuration.
[0033] FIG. **13** is a top view of another example perimeter device. The perimeter device is illustrated in a non-deployed configuration.
[0034] FIG. **14** is a perspective view of the perimeter device illustrated in FIG. **13**. The perimeter device is illustrated in a deployed configuration.
[0035] FIG. **15** is a top view of an example UAV. The UAV is illustrated in a non-flying configuration.
[0036] FIG. **16** is a side view of the UAV illustrated in FIG. **15**. The UAV is illustrated in a flying configuration.
[0037] FIG. **17** is a side view of an example vehicle and associated perimeter devices and UAV.
[0038] FIG. **18** is a side view of an example vehicle.
[0039] FIG. **19** is a bottom view of the vehicle illustrated in FIG. **18**.
[0040] FIG. **20** is a side view of the vehicle illustrated in FIG. **18**. The associated perimeter device is illustrated as deployed from the vehicle.
[0041] FIG. **21** is a perspective view of another example vehicle.
[0042] FIG. **22** is a side view of the cab portion of the vehicle illustrated in FIG. **21**.
[0043] FIG. **23** is a top view of the storage enclosure of the vehicle illustrated in FIG. **21**.
[0044] FIG. **24** is a side view of the cab portion of the vehicle illustrated in FIG. **21**. The associated perimeter devices are illustrated as deployed from the vehicle.
[0045] FIG. **25** is a perspective view of the vehicle illustrated in FIG. **21**. The associated perimeter devices are illustrated as deployed from the vehicle.
[0046] FIG. **26** is a perspective view of another example vehicle.
[0047] FIG. **27** is a perspective view of the vehicle illustrated in FIG. **26**. A UAV associated with the vehicle is transporting a perimeter device associated with the vehicle.
[0048] FIG. **28** is a perspective view of the vehicle illustrated in FIG. **26**. A UAV associated with the vehicle is approaching a monitoring station positioned on the vehicle.
[0049] FIG. **29** is a schematic illustration of an example vehicle perimeter system.
[0050] FIG. **30** is a perspective view of an example vehicle and deployed vehicle safety perimeter.
[0051] FIG. **31** is a top view of the vehicle and deployed vehicle perimeter illustrated in FIG. **30**.
[0052] FIG. **32** is another top view of the vehicle and deployed vehicle perimeter illustrated in FIG. **30**.
[0053] FIG. **33** is a perspective view of another example vehicle and components of a vehicle perimeter during deployment.
[0054] FIG. **34** is a top view of the vehicle illustrated in FIG. **33** following deployment of the vehicle safety perimeter.
[0055] FIG. **35** is a flowchart illustration of an example method of establishing a vehicle safety perimeter.

[0056] FIG. **36** is a flowchart illustration of another example method of establishing a vehicle safety perimeter.

DESCRIPTION OF SELECTED EXAMPLES

[0057] The following detailed description and the appended drawings describe and illustrate various example vehicle perimeters and related devices systems, and method. The description and illustration of these examples enable one skilled in the art to make and use examples of the inventive devices and systems, and to perform the inventive methods. They do not limit the scope of the claims in any manner.

[0058] As used herein, the term “associated with,” and related grammatical terms, refers to one object being permanently or non-permanently in a structural contact interface with another object. For example, a first object is associated with a second object when the first object is positioned on the second object such that surfaces of each object contact each other. Also, the first object is associated with the second object when the first object is releasably connected to the second object, such as by a mechanical connection, a direct magnetic connection, or other physical connection between the two objects.

[0059] As used herein, the term “autonomous,” in relation to vehicles, refers to an ability of a vehicle to drive itself. The term is not absolute as vehicles can have varying levels of autonomy. The Society of Automotive Engineers (SAE) defines 6 levels of driving automation ranging from 0 (fully manual; requiring full human control of the vehicle for driving) to 5 (fully autonomous; requiring no human control for driving). These levels have been adopted by the U.S. Department of Transportation. As used herein, the term “fully autonomous,” and related grammatical terms, refers to a vehicle at level 5 on the SAE scale (full driving automation). As used herein, the term “partially autonomous,” and grammatically related terms, refer to a vehicle at one of levels 1 (driver assistance) to level 4 (high driving automation). on the SAE scale. As used herein, the term “manual controlled,” “human driven,” “human controlled,” and grammatically related terms refer to a vehicle at level 0 (no driving automation) on the SAE scale. The inventions described herein are considered particularly critical for autonomous vehicles, and advantageous for partially autonomous vehicles and human controlled vehicles.

[0060] As used herein, the term “base member” refers to a structural member adapted to provide support to another component or components associated with the base member.

[0061] As used herein, the term “signal member” refers to a structural member adapted to provide a signal to a human observing the signal member. For example, a signal member can include a reflective surface, light reflective tape, a powered light or lights, a sound-emitting component, or other. Signal members can have any suitable size, shape, and structural configuration, including a triangular configuration, which is conventional and required by many laws and regulations applicable to vehicle perimeters.

[0062] As used herein, the term “unmanned aerial vehicle” refers to an aircraft that does not require a human pilot on board to operate the aircraft. An unmanned aerial vehicle is a component of an unmanned aircraft system; which includes a UAV, a controller, which can be ground-based, and a communication system that operably connects the UAV and the controller. The terms “unmanned aerial vehicle,” “UAV,” and “drone” are used interchangeably herein and all refer to an unmanned aerial vehicle.

[0063] As used herein, the term “vehicle” and grammatically related terms refers to a machine used for transporting people or cargo. The term does not require any specific type or category of vehicle, and includes wheeled vehicles, such as cars, trucks, tractors, and railroad engines and cars, for transportation across surfaces, such as roads, paths, tracks, lots, fields, and undeveloped planetary surfaces; marine vehicles, such as boats and ships; and aerial vehicles, such as aircraft.

[0064] As used herein, the term “vehicle perimeter” refers to a demarcation of an area adjacent a vehicle created by placement of one or more perimeter devices by the vehicle. Accordingly, an established vehicle perimeter demarcates an area relative to a vehicle. A vehicle perimeter can be continuous or non-continuous, and can comprise any suitable geometric configuration, including a single point defined by a single perimeter device positioned adjacent a vehicle, a line segment defined by two perimeter devices positioned adjacent a vehicle, two or more line segments defined by three or more vehicle perimeter devices positioned adjacent a vehicle, a circle, an oval, a regular polygon, an irregular polygon, or any other suitable geometric configuration defined by a suitable number of perimeter devices positioned adjacent a vehicle. A vehicle perimeter can be static or dynamic, can be deployed in response to a triggering event, and can be deployed from a stationary or moving vehicle.

[0065] Example perimeter devices include a signal member, a base member, and a UAV. In some examples, the signal member, base member, and UAV comprise individual structural members connected to in some manner to form the perimeter device. In other examples, a portion of the UAV, such as a frame, provides the base member or the signal member. In these examples, the UAV is connected to the other, non-UAV component (e.g., the base member or signal member not formed by a portion of the UAV). Once deployed and positioned appropriately, inventive perimeter devices can remain in a fixed location relative to a static (e.g., parked) or dynamic (e.g., moving) vehicle for which a perimeter has been established, or the devices can be dynamic relative to the vehicle (e.g., circling the vehicle), adjusting position relative to the vehicle based on role, environment, events, or other parameters.

[0066] FIGS. **1**, **2**, **3**, and **4** illustrate an example perimeter device **100**. The perimeter device **100** has a non-deployed configuration, illustrated in FIGS. **1**, **2**, and **3**, and a deployed configuration, illustrated in FIG. **4**.

[0067] The perimeter device **100** includes a signal member **110**, a base member **112** movably connected to the signal member **110**, a connector **114** disposed on the signal member **110**, and a UAV **116** connected to the connector **114** such that the UAV **116** is movable from a first position that is substantially within an opening **130** defined by the signal member **110** to a second position that is substantially external to the opening **130**. In the non-deployed configuration, illustrated in FIGS. **1**, **2**, and **3**, the signal member **110** and base member **112** are disposed on parallel planes and the housing **170** of the UAV **116** is disposed within the central opening **130** defined by the signal member **110**. In the deployed configuration, illustrated in FIG. **4**, the signal member **110** is disposed on a plane that is disposed at a non-parallel angle to a plane within which the base member **112** is disposed. The perimeter device **100** transitions between the non-deployed and deployed configurations through movement of the signal member **110** relative to the base member **112** and movement of the UAV relative to the signal member **110** and the base member **112**.

[0068] The signal member **110** is a structural member having first **120** and second **122** opposing surfaces, multiple sides **124**, **126**, **128** that cooperatively define an opening **130**. A reflective surface **132** is disposed on the first surface **120** and is adapted to reflect light, such as light directed at the first surface from a vehicle headlight or other light source. In this example, the signal member **110** is a triangular member having first **124**, second **126**, and third **128** sides. The signal member **110** can comprise a traffic warning triangle, adapted as needed to be incorporated into the inventive perimeter device **100**. A second reflective surface can be disposed on the second **122** surface, if desired, to provide reflectivity and visibility from both opposing surfaces **120**, **122** of the signal member **110**.

[0069] The base member **112** is a structural member having a generally complimentary structural configuration to that of the signal member **110**, which is considered advantageous at least because it provides for a low profile during aerial movement of the perimeter device **100**. Accordingly, in this example, the base member is a structural member having first **140** and second **142** opposing surfaces, multiple sides **144**, **146**, **148** that cooperatively define an opening **150**. In this example, the base member **112** is a triangular member having first **144**, second **146**, and third **148** sides. In the deployed configuration, the base member **112** provides stability to the deployed perimeter device **100**. Accordingly, the base member **112** advantageously has a mass that is greater than the mass of the signal member **110**. Also, the base member **112** has a thickness, measured from the first surface **140** to the second surface **142**, that is greater than the thickness of the signal member **110**, measured from its first surface **120** to its second surface **122**.

[0070] The base member **112** is movably connected to the signal member **110** such that the signal member **110** is able to rotate about an axis relative to the base member **112** as the perimeter device **100** moves from the first configuration to the second configuration. Accordingly, a connector **160** is attached to both the signal member **110** and the base member **112** and disposed adjacent sides **124**, **144** of the signal member **110** and the base member **112** that are disposed adjacent each in both the non-deployed and deployed configurations. Any suitable connector **160** can be used to form the movable connection between the signal member **110** and the base member **112**, and a skilled artisan will be able to select a suitable connector for use in a perimeter device according to a particular embodiment based on various considerations, including incremental mass and any desired resistance to movement between the non-deployed and deployed configurations and/or vice-versa. Examples of suitable connectors include hinges, including single hinges that extend along the entire length of the sides **124**, **144**, single hinges that extend along a portion of the length of the sides **124**, **144**, and multiple hinges, each of which extend along a portion of the length of the sides **124**, **144**.

[0071] The connector **114** connects the signal member **110** and the UAV **116** such that the UAV is able to move from a first position that is substantially within an opening **130** defined by the signal member **110** to a second position that is substantially external to the opening **130** as the perimeter device **100** moves from the non-deployed configuration to the deployed configuration. Any suitable connector **114** can be used as the connector **114**, and a skilled artisan will be able to select a suitable connector for use in a perimeter device according to a particular embodiment based on various considerations, including the materials used in the signal member and UAV of the embodiment, and points of attachment on each of these structures. In this example, the connector **114** is a hinge connected to one side **124** of the signal member and to one propeller shields of the UAV.

[0072] The UAV **116** is a multi-propeller drone adapted for remote control operation, including remote control of takeoff, flying, maneuvering, and movement necessary to move the perimeter device **100** from the non-deployed configuration to the deployed configuration. The UAV **116** includes a housing **170**, multiple support arms **172**, **174**, **176**, multiple propellers **178**, **180**, **182**, and multiple propeller shields **184**, **186**, **188**. Each of the support arms **172**, **174**, **176** extends from the housing **170** to one of the propellers **178**, **180**, **182**, and each of the propeller shields **184**, **186**, **188** is disposed around one of the propellers **178**, **180**, **182**. The propeller shields **184**, **186**, **188** have a diameter sufficient to extend circumferentially around the propellers at their maximum diameter, typically during flight. The UAV **116** includes a power supply, such as a removable and/or rechargeable battery, electronics adapted to control flight operations, and can include memory for storing images and/or video, cameras, such as a still image camera and/or a video camera, sensors, such as proximity sensors, gyroscopic sensors, temperature sensors, other suitable or desirable sensors, and any other suitable or desirable accessories. The UAV **116** need only be suitable for structural securement in and operation of the perimeter device as described herein. In this example, inclusion of at least one propeller shield **184**, **186**, **188** is considered critical as it provides a desirable point of attachment for the connector **114**. Also, the UAV **116** can include a remote control **190** that enables remote operation. Alternatively, the UAV can be adapted for remote control via a computing device adapted to communicate with the UAV via any suitable communication link, including one or more of computer networking connections, WiFi connections, Bluetooth connections, satellite connections, cellular connections, and any other suitable connections capable of transmitting data to and from a remote computing device and the UAV **116**. The propellers **178**, **180**, **182** and the driving motors can comprise any suitable propellers and motors known in the UAV art. It is noted, though, that foldable or collapsible propellers that orient to a flying orientation in response to centripetal force as the motor initiates rotary motion, are considered particularly advantageous at least because these propellers fold to a relatively low-profile configuration when the motor is not powered, reducing the potential for lift to occur by wind or other air movement against the propeller when the perimeter device is in a deployed configuration, which could cause unwanted movement of the perimeter device.

[0073] The UAV can include any suitable number and type of sensors, including visual sensors such as cameras, infrared sensors, such as IR cameras, radar sensors, LIDAR sensors, temperature sensors, noise sensors, atmospheric sensors, specific chemical sensors, such as carbon monoxide sensors, and any other sensors for which sensor data is desired. Furthermore, any suitable number of sensors can be included, and a skilled artisan will be able to select an appropriate number of sensors for a perimeter device according to a particular embodiment based on various considerations, including a balance between desired sensor data and weight and overall size of the perimeter device. Perimeter devices according to particular embodiments can include various additional functionalities and/or structural adaptions that make a particular perimeter device suitable for a particular use and/or function. For example, the signal member **110** can include one or more lights, such as an LED panel, adapted to project light from the first surface **120** of the signal member **110** and/or the second surface **122**. In these perimeter devices, a power supply, such as a removable and/or rechargeable battery can be included to power the lights. Also in these embodiments, the perimeter device and/or signal device can include a photosensor or other appropriate sensor to determine when lighting is appropriate and activate the light(s) of the signal member when desirable or necessary. Also, one or more solar panels can be associated with the signal member **110** and/or the base member **112** to provide power to the lights, such as through suitable wiring that operably connects the solar panel(s) to the light(s). Also in this embodiment, the connector **114** can be adapted to operate as a switch such that establishes electrical communication between the power supply and/or the solar panel(s) and the light(s) as the perimeter device **100** moves from the non-deployed configuration to the deployed configuration. Also, the UAV can include additional structural elements and functionality to impact its environment in response to appropriate events, such as fire retardant, fertilizer, and spray paint for marking vehicles that enter an established perimeter.

[0074] In operation, the perimeter device **100** initiates flight by taking off from a storage location in the non-deployed configuration and flies to a desired deployment location, such as a roadside position adjacent a disabled vehicle. When the perimeter device **100** reaches a location above the desired deployment location, the perimeter device **100** lowers to the ground such that the base member **112** is positioned on the ground at the desired deployment location. The UAV **116** then initiates a movement to rotate the signal member **110** relative to the base member **112** via the connection between these two members, leaving the base member **112** in its position on the ground and the signal member **110** in an angled position relative to the base member **112** such that the signal member **110** is disposed upright relative to the ground at the desired deployment location. Lastly, the UAV **116** initiates a movement to rotate relative to the signal member **110** to place itself on the ground opposite the base member **112** relative to the signal member. At this point, the perimeter device **100** is in the deployed configuration and the base member **112** and UAV **116** are positioned to cooperatively act as a base for the signal member **110**, which is disposed at an angle to the ground, extending upwardly from the ground. Thus, during deployment, the UAV **116** effectively flips, having a first surface **192** of the housing **170** upward while the perimeter device **100** is in the non-deployed configuration and having an opposite second surface **194** of the housing **170** upward while the perimeter device **100** is in the deployed configuration. When necessary or desired, these actions can be reversed to transition the perimeter device **100** from the deployed configuration to the non-deployed configuration, which may be desirable when the need for the perimeter device **100** has passed and a return to storage is desired. The perimeter device **100** can be adapted to initiate deployment in response to any suitable signal, including a signal transmitted to the perimeter device by a human operator, which can be an operator of the vehicle or another human that is near the vehicle or distant to the vehicle (i.e., beyond visual line of sight of the vehicle). In particularly advantageous embodiments, though, the perimeter device **100** is adapted to initiate deployment in response to event-based signaling in which a triggering event relating to a status of the vehicle or its environment is transmitted to the perimeter device to initiate its deployment. Examples of suitable triggering events include vehicle immobilizing events, such as vehicle rollover, vehicle impact, vehicle inoperability, vehicle parking, and the like. Further examples of suitable events include image recognition by artificial intelligence and/or machine learning (e.g., recognition of a roadside ditch directly in front of the vehicle, recognition of a rotated horizon relative to the vehicle, etc.), GPS-based events (e.g. the vehicle being in a position sufficiently separated from the location of the edge of a road, positioning or change in positioning of the vehicle relative to a GPS-defined area, i.e., geo-fence related events), environment-based events (e.g., detection of a hazardous material in the environment, detection of rapid temperature elevation in the vehicle environment, etc.), and other suitable events. It is noted that transition of the perimeter device **100** from the deployed configuration to the non-deployed configuration can also be initiated in response to suitable events.

[0075] FIGS. **5**, **6**, **7**, and **8** illustrate another example perimeter device **200**. The perimeter device **200** has a non-deployed configuration, illustrated in FIGS. **5**, **6**, and **7**, and a deployed configuration, illustrated in FIG. **8**.

[0076] The perimeter device **200** is similar to the perimeter device **100** described above, except as detailed below. Thus, the perimeter device **200** includes a signal member **210**, a base member **212** movably connected to the signal member **210**, first **214** and second connectors **215** disposed on the signal member **210**, and a UAV **216** connected to the connectors **214**, **215** such that the UAV **216** is movable from a first position that is substantially within an opening **230** defined by the signal member **210** to a second position that is substantially external to the opening **230**. In the non-deployed configuration, illustrated in FIGS. **5**, **6**, and **7**, the signal member **210** and base member **212** are disposed on parallel planes and the housing **270** of the UAV **216** is disposed entirely within the central opening **230** defined by the signal member **210**. In the deployed configuration, illustrated in FIG. **8**, the signal member **210** is disposed on a plane that is disposed at a non-parallel angle to a plane within which the base member **212** is disposed. The perimeter device **200** transitions between the non-deployed and deployed configurations through movement of the signal member **210** relative to the base member **212** and movement of the UAV **216** relative to the signal member **210** and the base member **212**.

[0077] In this example, the UAV **216** is disposed entirely within the opening **230** defined by the sides **224**, **226**, **228** of the signal member **210**. Also, the UAV **216** is connected to the signal member **210** by first **214** and second **215** connectors, each of which comprises a hinge attached to the signal member **210** and one of the propeller shields **284**, **286**, **288** disposed around the propellers **278**, **280**, **282** of the UAV **216**. This structural arrangement is considered advantageous at least because the positioning of the UAV **216** entirely within the opening **230** of the signal member **210** provides a low profile to the perimeter device **200**, which can improve aerodynamics and maneuverability, and because the inclusion of two connectors **214**, **215** eliminates a degree of freedom in movement of the UAV **216** relative to the signal member **210** during deployment, which may lead to improved accuracy in final positioning of the perimeter device **200** relative to a desired deployment location.

[0078] FIGS. **9**, **10**, **11**, and **12** illustrate another example perimeter device **300**. The perimeter device **300** has a non-deployed configuration, illustrated in FIGS. **9**, **10**, and **11**, and a deployed configuration, illustrated in FIG. **12**.

[0079] The perimeter device **300** is similar to the perimeter device **100** described above, except as detailed below. Thus, the perimeter device **300** includes a signal member **310** and a UAV **316** that includes a frame **312** that provides a base member.

[0080] In this example, the signal member **310** is movably connected to the frame **312** of the UAV

316, which functions as the base member. First **314** and second **315** connectors are attached to the signal member **310** and frame **312** to form the connection between the signal member **310** and frame **312**. In this example, each of the connectors **314**, **315** comprises a hinge. Also in this example, the signal member **310** has multiple sides **324**, **326**, **328**. Similarly, the frame **312** of the UAV has multiple sides **344**, **346**, **348**. In this example, the signal member is a triangle having first **324**, second **326**, and third **328** sides the cooperatively define an opening **330**. Similarly, the base member **312** is a triangular member having first **344**, second **346**, and third **348** sides.

[0081] The UAV **316** has propellers **378**, **380**, **382** positioned at the vertices formed by the sides **344**, **346**, **348** of the frame **312**. Propeller shields **384**, **386**, **388** are individually disposed around the propellers **378**, **380**, **382** of the UAV **316**. This configuration is considered advantageous at least because it leverages the structure of the base member as a frame **312** for the UAV **316**, effectively eliminating support arms, which ultimately provides a more compact structure. Furthermore, the positioning of the propellers at the vertices formed by the sides **344**, **346**, **348** of the frame **312** is expected to enhance stability of the perimeter device **300** during flight.

[0082] In this embodiment, the signal member **310** includes a light **389**, such as a LED. Also, the perimeter device **300** includes a solar panel **391** operably connected to the light or its battery to provide power to the light when the perimeter device is in the deployed configuration. Also, a battery **393** is operably connected to the solar panel **391** and to the UAV **316** to provide power to the UAV **316**. A first camera **351** is disposed on a vertice of the warning member **310**, and first **353**, second **355**, and third **357** sensors, which can be cameras or another type of sensor, are mounted on sides of the frame **312** of the UAV **316**.

[0083] FIGS. **13** and **14** illustrate another example perimeter device **400**. The perimeter device **400** has a non-deployed configuration, illustrated in FIG. **13**, and a deployed configuration, illustrated in FIG. **14**.

[0084] In this example, the UAV **416** includes a frame **410** that also functions as the signal member of the perimeter device **400**. A base member **412** is movably attached to the frame **410** by first **415**, **416** connectors. Thus, in this example, the perimeter device **400** includes a base member **410** and a UAV **416** that includes a frame **410** that provides a signal member. The base member **412** is movably connected to the frame **410** of the UAV **416**, which functions as the signal member. Each of the connectors **414**, **415** comprises a hinge. The frame **410** has multiple sides **424**, **426**, **428**. Similarly, the base member **412** has multiple sides **444**, **446**, **448**. In this example, the frame **410** is a triangle having first **424**, second **426**, and third **428** sides that cooperatively define an opening **430**. Similarly, the base member **412** is a triangular member having first **444**, second **446**, and third **448** sides. The UAV **416** includes multiple extensions **475**, **477**, **479**, each of which is pivotably attached to one of the sides **424**, **426**, **428** of the frame **410**. A propeller **478**, **480**, **482** is positioned at the end of each of the extensions. This configuration is considered advantageous at least because it leverages the structure of the signal member as a frame **410** for the UAV **416**, effectively eliminating support arms, which ultimately provides a more compact structure. Furthermore, the inclusion of pivotable extensions **475**, **477**, **479** on the frame **410** is expected to enhance stability of the perimeter device **300** during flight.

[0085] FIGS. **15** and **16** illustrate another example perimeter device **500**. The perimeter device **500** has a storage configuration, illustrated in FIG. **15**, and a transport configuration, illustrated in FIG. **16**.

[0086] In this example, the perimeter device **500** includes a UAV **516** having a triangular frame **510** defined by first **524**, second **526**, and third **528** sides that cooperatively define an opening **530**. The UAV **516** has propellers **578**, **580**, **582** positioned at the vertices formed by the sides **524**, **526**, **528** of the frame **510**. Multiple cameras **511**, **513**, **515** are mounted on the frame **510**, with one camera **511**, **513**, **515** attached to each of the individual sides **524**, **526**, **528** of the frame **510**. The UAV **516** includes a storage bay **595** positioned in the opening **530**, defined by sides **546**, **548** of the frame **510** and covering **597**. A hook **589** is attached to the covering **597** and extends downward, away from the propellers **578**, **580**, **582**. A plurality of signal members **575** is positioned in the storage bay **595**, arranged as a stack with individual signal members positioned in a plane that is parallel to the plane in which the frame **510** is disposed. Each signal member of the plurality of signal members **575** includes a loop **577** through which the hook **589** extends. Individual signal members of the plurality of signal members **575** are adapted to be released from the hook **589** and storage bay **595** for deployment, as best illustrated in FIG. **16**. Individual signal members of the plurality of signal members **575** include support legs **571**, **573** that extend outward upon release of the signal member, such as by spring action or other outwardly biased force.

[0087] FIG. **17** illustrates an example vehicle **600** with an associated plurality of signal members **675** and a UAV **616**. In this example, the vehicle is a commercial delivery van. The plurality of signal members **675** comprises a plurality of individual traffic cones stacked upon each other. The plurality of signal members **675** is disposed on a platform **617** extending from the rear bumper **619** of the vehicle **600**. The UAV **616** includes a hook **689** adapted to extend into an opening in a signal member of the plurality of signal members **675**, allowing the UAV **616** to transport the signal member away from the vehicle **600**. The platform **617** has a depth **621** that extends beyond the rear surface **623** of the vehicle **600** that is greater than a first dimension **625** of the UAV **616** that extends along an axis of the UAV **616** from the outermost surface of the propeller **678** to the furthest surface of the hook **689**. This relative dimensioning of the platform **617** is considered critical as it is the minimum dimension that will allow the UAV to successfully retrieve signal members from the plurality of signal members **675**. It is considered particularly advantageous that the depth **621** of the platform **617** be greater than the first dimension **625** of the UAV **616**. Indeed, it is considered advantageous that the depth **621** of the platform **617** be at least 125% of the first dimension **625** of the UAV **616**. It is also considered advantageous that the depth **621** of the platform **617** be at least 150% of the first dimension **625** of the UAV **616**. It is also considered advantageous that the depth **621** of the platform **617** be at least the same as a second dimension **627** of the UAV **616** that extends along an axis of the UAV **616** from the outermost surface of the first propeller **678** to the outermost surface of the second propeller **680**. It is considered particularly advantageous that the depth **621** of the platform **617** be at least 125% of the second dimension **627** of the UAV **616**. It is considered particularly advantageous that the depth **621** of the platform **617** be at least 150% of the second dimension **627** of the UAV **616**. It is also considered particularly advantageous that the depth **621** of the platform **617** be at least 200% of the second dimension **627** of the UAV **616**.

[0088] FIGS. **18**, **19**, and **20** illustrate another example vehicle **700**. The vehicle **700** has a perimeter device storage configuration, illustrated in FIG. **18**, and a perimeter device deployment configuration, illustrated in FIGS. **19** and **20**.

[0089] In this example, the vehicle **700** is a passenger automobile, and includes a storage enclosure **717** disposed on the undercarriage of the vehicle **700**. The storage enclosure **717** defines a chamber **719** and a movable door **721**. A perimeter device **701** according to an embodiment is positioned within the chamber **719** when the vehicle **700** is in the perimeter device storage configuration. The perimeter device **701** is secured to the storage enclosure **717**, such as by electromagnets or by a releasable mechanical connection or releasable mechanical connections. As best illustrated in FIG. **19**, the movable door **721** can move to open the chamber **719** to the external environment. Once this has been completed, the perimeter device **701** can be released from its connections to the storage enclosure **717** and flown away from the vehicle **700** by its UAV **716** component, allowing the perimeter device **701** to establish a safety perimeter by the vehicle **700**. While the illustrated example includes only a single perimeter device **701**, multiple perimeter devices can be included in a vehicle according to an embodiment. Indeed, two, more than two, three, a plurality, five, ten, and more perimeter devices can be included in an embodiment. Inclusion of at least three perimeter devices is considered advantageous at least because it represents a balance between space requirements necessary for the storage enclosure **717** and the ability to deploy multiple warning devices in establishing a safety perimeter by the vehicle **700** in accordance with relevant state and federal regulations. The enclosure can include one or more suitable charging units, such as wireless charging pad(s) and/or mechanical connection chargers, for charging the battery of the UAV(s) and/or signal member(s) that are stored in the enclosure.

[0090] FIGS. **21**, **22**, **23**, **24**, and **25** illustrate another example vehicle **800**. The vehicle **800** has a perimeter device storage configuration, illustrated in FIGS. **21** and **22**, and a perimeter device deployment configuration, illustrated in FIGS. **23**, **24**, and **25**.

[0091] In this example, the vehicle **800** is a semi-trailer truck, and includes a tractor unit **802**, sometimes referred to as a “cab” unit, and a trailer **804**. The vehicle **800** also includes and includes a storage enclosure **817** disposed on the uppermost surface of the tractor unit **802**. As best illustrated in FIG. **23**, the storage enclosure **817** defines a chamber **819** and a movable door **821**. A plurality of perimeter devices **801** is positioned within the chamber **819** when the vehicle **800** is in the perimeter device storage configuration. Each safety perimeter device of the plurality of perimeter devices **801** is a perimeter device according to an embodiment of the invention. As best illustrated in FIGS. **24** and **25**, the movable door **821** can move to open the chamber **819** to the external environment. Once this has been completed, each perimeter device of the plurality of perimeter devices **801** can be flown away from the vehicle **800** by its UAV **816** component, allowing the plurality of perimeter devices **801** to establish a safety perimeter by the vehicle **800**.

[0092] FIGS. **26**, **27**, and **28** illustrate another example vehicle **900**. The vehicle **900** has a perimeter device storage configuration, illustrated in FIG. **26**, and a perimeter device deployment configuration, illustrated in FIGS. **27** and **28**.

[0093] The vehicle **900** is similar to the vehicle **800** described above, except as detailed below. Thus, the vehicle **900** is a semi-trailer truck, and includes a tractor unit **902** and a trailer **904**. The vehicle **900** also includes first **909** and second **911** signal members secured to the trailer **904**. A UAV **916** is associated with the vehicle **900** and can be disposed on any suitable portion of the vehicle **900** while the vehicle **900** is in the perimeter device storage configuration. For example, as illustrated in FIG. **28**, the vehicle can include a charging pad **959** disposed on the top surface of the trailer **904** or in another suitable location on the vehicle **900**. The charging pad **959** can mechanically engage with the UAV **916** to establish electrical contact between a power supply operably connected to the charging pad **959**. Alternatively, a wireless charging connection can be established between the charging pad **959** and the UAV to establish electrical charging communication between a power supply operably connected to the charging pad **959** and the UAV **916**. When necessary or desired, as best illustrated in FIG. **27**, the UAV **916** can leave its position on the vehicle **900** and retrieve one or both of the signal members **909**, **911** and position them on a road surface by the vehicle **900** to establish a safety perimeter by the vehicle **900**. Once a safety perimeter is established, the UAV **916** can return to the charging pad **959** to recharge and/or to monitor the safety perimeter through attached cameras and/or sensors.

[0094] FIG. **29** is a schematic illustration of an example vehicle perimeter system **1000**. The vehicle perimeter system **1000** comprises a vehicle **1001** and at least one UAV **1002** adapted to be mounted on and deployed from the vehicle **1001**. The UAV **1002** can be a UAV according to an embodiment of the invention, such as the example UAVs described herein. The UAV **1002** is deployable from the vehicle **1001** when the vehicle **1001**, or a driver or remote operator or monitoring system of the vehicle **1001**, transmits a signal to the UAV **1002** indicating that the vehicle is temporarily immobilized or in response to a triggering event to which the UAV is adapted to respond, as described above. The UAV **1002** is configured to survey the environment immediately surrounding the vehicle **1001** and determine optimal positioning for one or more perimeter devices near the vehicle during its period of immobilization. In some embodiments, the UAV **1002** is configured to fly to the determined position, or one of the determined positions, and to release a perimeter device carried by the UAV **1002**, such as a cone, reflective triangle, flashing light, or the like, at the determined position. In these embodiments, the UAV **1002** can retrieve the perimeter device(s) when the need for the device(s) is removed, as the UAV **1002** returns to the designated mounting area. In other embodiments, the UAV **1002** is a component of a perimeter device, such as the examples described herein and illustrated herein, allowing the UAV **1002** to move itself to a determined position and subsequently serve as a perimeter device itself. In these embodiments, the UAV **1002** is configured to fly to the determined position, or one of the determined positions, and to adopt its perimeter device configuration, and then place itself at the determined position. The UAV **1002** is configured to leave the determined position, and leave its perimeter device configuration if appropriate, when the vehicle **1001**, or a driver or remote operator of the vehicle **1001**, transmits a signal to the UAV **1002** indicating that the vehicle **1001** is no longer temporarily immobilized. Once this signal is received, the UAV **1002** leaves the determined position and flies to the vehicle **1001**, ultimately mounting itself on the designated mounting area on the vehicle **1001**.

[0095] The vehicle **1001** can comprise any suitable vehicle, including a passenger car, a delivery vehicle, and a cargo vehicle. Examples of suitable vehicles include two person cars, four person cars, pickup trucks, minivans, standard vans, contractor vans, dump trucks, box trucks, package delivery trucks, tanker trucks, and semi-trucks. Non-road vehicles can also be used, including agriculture vehicles such as tractors and combines, trains, such as passenger trains and freight trains, planes, boats, and other vehicles. Furthermore, the vehicle can comprise a human-driven vehicle, a partially autonomous vehicle, such as a human-driven vehicle with autonomous functionality that can be activated by a human operator of the vehicle, or a fully autonomous vehicle, such as a vehicle that does not require a human operator to be present in the vehicle during its operation.

[0096] The vehicle **1001** has a designated mounting area **1003** on or in which at least one UAV **1002** is adapted to be mounted. The designated mounting area **1003** can be a portion of a surface of the vehicle, such as a rooftop, exterior sidewall, interior ceiling, interior sidewall, under the vehicle, on a trailer or other component associated with the vehicle, an attached enclosure, or the like. The designated mounting area **1003** can comprise a flat surface on which the UAV(s) are mounted, or can comprise a chamber within which the UAV(s) are disposed or partially disposed. For example, a low profile storage chamber within which the UAV(s) can be disposed can be placed on top of the vehicle, such as a semi-truck. The designated mounting area can include charging functionality for the UAV(s), such as battery charging. Also, the designated mounting area can include mechanical mounting features that facilitate retention of the UAV(s) on the designated mounting area, such as latches, straps, magnetic pads, etc. The vehicle **1001** can include various optional components, including a communications link **1004** for communicating with additional computing resources that are included in the system, as described below. The communications link **1004** can be integrated with an on-board trailer management platform software program **1005**.

[0097] In some embodiments, multiple UAVs are mounted on the vehicle. In these embodiments, one UAV can be designated as the survey UAV. Upon receiving a signal that the vehicle is temporarily immobilized, the survey UAV surveys the seen to determine an optimal number of perimeter devices to secure the scene and the optimal positioning for the one or more perimeter devices to achieve the determined number. Once the survey UAV completes the survey, it transmits one or more signals to other UAVs mounted to the vehicle, instructing each UAV to on a determined position. Each of the UAVs then flies to its respective determined position and either releases a perimeter device it is carrying, such as a cone, reflective triangle, or the like, at the determined position, or adopts its perimeter device configuration and places itself in that configuration at the position.

[0098] In these embodiments, the survey conducted by the survey UAV can include an assessment of the landscape around the vehicle, any traffic near the vehicle, pedestrians near the vehicle, weather, local or other laws, such as laws relating to vehicle perimeter requirements, and other sources. The survey UAV factors information from one, more than one, multiple, or all of these sources when determining the optimum number and position(s) for the safety perimeter UAV(s).

[0099] In some embodiments, the survey is conducted remotely from the vehicle and UAV(s), such as by computer servers or other computer resources that are adapted to communicate with the UAV(s) via computer network communications, such as over the internet. For example, one or more cloud-based servers **1010** can receive information and/or content from one or more of the UAVs **1002** relating to the scene at which the vehicle **1001** is temporarily disabled, including geolocation coordinates, photographs, video, sound, and other information and/or content. The cloud-based servers **1010** or other remote computing resources can factor this information and/or media into a survey determination, and then transmit information relating an optimum number and positions for perimeter devices to a designated survey UAV **1002** or to individual UAVs, as described above. In addition to, or as an alternative to, position-related information, other information can be transmitted back to the designated survey UAV **1002**, such as next actions, event-related information (e.g., aircraft entering air space above the vehicle, official declaration of a no-fly zone that includes the vehicle, etc.). Remote computer resources in all embodiments can include computing resources connected by satellite network(s), computing network(s), local network(s), personal network(s), or vehicle network(s). Also, remote computer resources can include computing resources that are components of a remote trailer management platform. Also, cloud computing resources can include an application programming interface layer, a serverless computing layer, such as Lambda from Amazon Web Services, messaging layers, and other computing layers typically associated with cloud-based computing platforms.

[0100] In some embodiments, the survey UAV and/or the remote computing resources use one or more artificial intelligence **1020** and/or machine learning algorithms **1022** in the determination of optimum number and/or position of perimeter devices. Human in the loop training **1024**, can be implemented to improve the AI/ML components, such as Amazon Mechanical Turk projects. Various support operational computing resources **1030**, **1032** can also be integrated into the system **1000**, such as customer support communications, remote video monitoring, and the like. Also in some embodiments, the survey UAV and/or the remote computing resources use machine vision and/or sensors in the determination of optimum number and/or position of perimeter devices. Additional system components can include various accessories **1040**, such as a storage enclosure, one or more charging devices, associated controllers, batteries, and the like, and a software development kit **1050** operably associated with the UAV **1002**. One or more perimeter devices **1070**, **1072** are also associated with the vehicle **1001**. The vehicle **1001** can be a fully autonomous vehicle, or a human controlled vehicle controlled by vehicle operator **1080**.

[0101] Thus, some embodiments are assisted by a human operator, which can be a driver or human serving another operational role for the vehicle **1001**, such as to initiate scene survey, etc., while others are fully autonomous in which the vehicle **1001** detects its temporary immobilization or other condition for which a perimeter is desired and sends one or more instruction signals to the associated UAV(s) based on the occurrence of one or more triggering events, such as those described above. Also, in some embodiments, the computing effort to survey the scene is done completely locally, such as by a designated survey drone. In other embodiments, the computing effort is completely centralized, such as in a dedicated server or servers located in a cloud computing environment that are in configured to communicate with the UAV(s). In still other embodiments, the computing effort is shared, with some of the effort completed by one or more UAVs as edge devices and some of the effort completed by a dedicated server or servers located in a cloud computing environment that are in configured to communicate with the UAV(s).

[0102] In some embodiments, one or more of the UAV(s) continually monitor the environment immediately around the vehicle to determine, either locally or by or with assistance of remote computing resources, if a situational change has occurred that warrants deployment of a safety perimeter. In these embodiments, the UAV(s) can use various inputs to continuously monitor the environment around the vehicle, such as audio input, time interval photographs, video, etc. For example, the UAV(s) can conduct surveillance of the perimeter of the scene, monitor for warning devices, and vehicles and/or people approaching or moving into or out of the perimeter. In some embodiments, the UAV(s) are configured to issue to vehicles and/or people approaching or moving into or out of the perimeter, such as an audible warning, a visual warning, or both.

[0103] In some embodiments, the UAV(s) are configured to autonomously avoid fixed and moving obstacles while performing various functions described herein, such as trees, overpasses, oncoming vehicles, and people.

[0104] Embodiments of the invention can be used to satisfy requirements issued by the Department of Transportation, including requirements for Stopped Commercial Motor Vehicles-Emergency signals, stopper commercial motor vehicles. For example, embodiments of the invention can be used to satisfy US Government CFR Title **49**: Transportation, Subpart C-Stopped Commercial Motor Vehicles, § 392.22 Emergency signals; stopped commercial motor vehicles.

[0105] The systems, methods, and devices described herein can be used to provide warning systems and also to designate and/or demarcate other types of areas, too, such as hazardous areas, zones, lanes, and fields.

[0106] In some embodiments, the one or more of the UAV(s) are configured to detect a rollover in progress by the vehicle and/or pre-rollover indicators and initiate deployment in response to these detection activities. This would allow the UAV(s) to deploy before any accident associated with the rollover or anticipated rollover is over, which could avoid destruction of the UAV(s) and/or interruption and/or destruction of reporting by the UAV(s). This also allows the UAV(s) to survey and report the accident scene and report geo location to service providers.

[0107] In some embodiments, the UAV(s) are configured to generate and submit automated permission requests, such as flight plans, emergency flight zones/areas compliant with FAA **107**, an/or requests for institution of a temporary no-flight zone.

[0108] In some embodiments, the UAV(s) are configured to issue perimeter violation or change warnings to on site entities, such as people, cars, etc., near a site, and/or to remote services, such as local police or emergency services, when a person or object violates an established safety perimeter, and/or when an established safety perimeter changes. A perimeter violation or change warning can be an audible signal, such as a siren pre-recorded message, or computer-generated message, a visual signal, such as a flashing light, a data signal, or any combination of these.

[0109] In some embodiments, the designated mounting area is configured to recharge batteries in the UAV(s) and/or the signal members. Also, the designated mounting area can include spare batteries for the UAV(s) and/or the signal members with their own chargers. The UAV(s) can be adapted to engage spare batteries when needed, which can include removing spent or partially spent batteries. In these embodiments, the UAV(s) are configured to self-swap batteries, and the designated mounting area is configured to support this functionality.

[0110] The designated mounting area can include suitable structure for charging and/or recharging any associated batteries, such as solar panels, wind turbine, connections to on-vehicle electrical system(s), and trailer power sources. These charging and/or recharging structures can be redundant over primary charging and/or recharging systems for the UAV(s) and advantageously are configurable.

[0111] In some embodiments, the designated mounting area is adapted to support battery charging for both the UAV(s) and the perimeter devices.

[0112] In some embodiments, the perimeter safety devices are adapted to self-swap batteries when needed. Also, in some embodiments, the UAV(s) are adapted to swap batteries out of the perimeter safety devices when needed.

[0113] In some embodiments, the perimeter safety devices are adapted to self-charge or redundant charge via solar panel(s) and/or mini-wind turbine(s) located on the vehicle. For example, the vehicle can include one or more mini wind turbines adapted to charge the batteries of the perimeter safety devices and/or the UAV(s) using the wind exposed to the mini wind turbines while the vehicle is at rest and/or while the vehicle is in motion.

[0114] FIGS. **30**, **31**, and **32** illustrate an example vehicle **1100** and a deployed vehicle perimeter **1150**. First **1160**, second **1162**, and third **1164** perimeter devices have been deployed from the vehicle **1100** and positioned at first **1180**, second **1182**, and third **1184** determined locations by the vehicle **1100**. Each of the first **1160**, second **1162**, and third **1164** perimeter devices comprise a perimeter device according to an embodiment in which the perimeter device includes a UAV component. First **1166** and second **1168** UAVs, which may include perimeter devices, are positioned above the vehicle **1100** and monitoring the safety perimeter **1150**.

[0115] As best illustrated in FIG. **31**, a UAV **1166** designated for monitoring the safety perimeter **1150** can monitor for penetration of the safety perimeter by humans **1170** or other animals. If a human **1170** enters a pre-defined area surrounding the safety perimeter **1150**, the UAV **1166** can transmit a visible and/or audible signal to the human **1170** to notify them of the presence of the safety perimeter **1150** their intrusion into the pre-defined area.

[0116] As best illustrated in FIG. **32**, a UAV **1168** designated for monitoring the safety perimeter **1150** can survey the safety perimeter **1150** after its deployment, flying along the length of the safety perimeter **1150** and vehicle **1100** and measuring distances between the vehicle **1100** and the perimeter devices **1160**, **1162**, **1164** and verifying compliance with applicable rules, regulations, and/or laws. Furthermore, the UAV **1168** can adjust the position one or more of the perimeter devices **1160**, **1162**, **1164** if any measurements indicate non-compliance with applicable rules, regulations, and/or laws. Furthermore, the UAV **1168** can record and store still and video images of the safety perimeter **1150** for later retrieval and/or viewing by others to verify compliance with applicable rules, regulations, and/or laws. Monitoring performed by UAV **1168** can include use of one or more appropriate sensors on the UAV **1168**, including cameras and other sensors, and can include collection of images and/or other data for forensics (e.g. scene reconstruction), verification of visibility of the perimeter, monitoring to disturbance of perimeter, and jurisdictional compliance, such as compliance with local rules and regulations for perimeters, UAV operation, environmental rules and regulations, and the like.

[0117] FIGS. **33** and **34** illustrate another example vehicle **1200** a plurality of UAVs **1260** positioned above the vehicle **1200**. In FIG. **33**, the plurality of UAVs **1260** is inspecting the scene surrounding the vehicle prior to deployment of a perimeter using cameras and/or sensors (as signified by inspection zones **1220**, **1222**, **1224**). In this example, the UAVs record images, video, and/or sensor data relating to the situation presented in the scene, such as weather conditions, traffic conditions, visibility levels, topographic information, and the like. Once sufficient data is acquired, the UAVs, acting individually or collectively, process the data, either locally or via connection to remote computing resources, to develop a perimeter device deployment plan, which includes recommended deployment locations for individual perimeter devices. Once the perimeter device deployment plan is developed, the UAVs can deploy themselves into individual deployment locations or initiate deployment of additional UAVs according to embodiments described herein, either as perimeter devices themselves or to retrieve and position perimeter devices associated with the vehicle **1200**. Following deployment, as best illustrated in FIG. **34**, the perimeter **1250** is established. First **1260**, second **1262**, and third **1264** perimeter devices have been deployed from the vehicle **1200** and positioned at first **1280**, second **1282**, and third **1284** determined locations by the vehicle **1200**. Each of the first **1260**, second **1262**, and third **1264** perimeter devices comprise a perimeter device according to an embodiment in which the perimeter device includes a UAV component.

[0118] As noted above, vehicle perimeters established using the inventive devices, systems, and methods are defined relative to the position of a vehicle for which the perimeter is demarcating an area adjacent the vehicle. The vehicle can be stationary or moving. Similarly, the perimeter can be stationary or moving. In examples in which the vehicle is stationary, such as an immobilized vehicle, the perimeter is also stationary once deployed, although adjustments to positions of perimeter device(s) and/or the overall relative location and/or size of the perimeter can be made as needed. In examples in which the vehicle is moving, the perimeter is dynamic and moves along with the vehicle to maintain the established perimeter. In examples where the perimeter is moving, the perimeter devices may dynamically vary their location or height or mode of operation to maximize the effectiveness of the perimeter for applications like security, data collection, and/or environment control.

[0119] FIG. **35** is a flowchart representation of an example method **1500** of establishing a vehicle safety perimeter. A first step **1510** comprises operating a vehicle having at least one perimeter device associated with the vehicle according to an embodiment of the invention, such as one of the example perimeter devices described and illustrated herein. A second step **1520** comprises deploying the perimeter device from the vehicle by operating the UAV component of the perimeter device. A third step **1530** comprises positioning the perimeter device at a predetermined location relative to the vehicle to establish the safety perimeter. An optional step **1540** comprises returning the perimeter device to the vehicle such that the perimeter device is again associated with the vehicle.

[0120] In this method, and all methods, the predetermined location can comprise a location defined by a specific distance and angle from a particular portion of the vehicle (e.g., 100 ft. from the left corner of the front bumper of the vehicle), a location defined by specific GPS coordinates, or other suitable location-defining information. Also, the predetermined location can be determined prior to operating the vehicle **1510** and, indeed, prior to initiation of the method. For example, a distance and angle position relative to the vehicle can be predefined and stored in a perimeter device prior to association of the perimeter device with the vehicle. Alternatively, the predetermined location can be determined after operating the vehicle **1510** and prior to deploying the perimeter device **1520**. For example, in the event of a vehicle incapacitating event, such as an accident or mechanical and/or electrical failure, the perimeter device or a remote computing resource, such as cloud connected servers or other components, can determine an appropriate predetermined position based solely on physical attributes of the vehicle (e.g., rollover status, presence of a jack-knife, etc.), solely on situational attributes (e.g., weather, visibility, traffic levels, etc.), or a combination of both of these approaches. Event triggers can be transmitted to remote computing resources for decision-making, with instructions transmitted back to the local perimeter devices for implementation of designated actions, such as placement at a particular location relative to the vehicle. Alternatively, decision-making can be performed locally by computing resources located on the perimeter device and/or the vehicle. Also alternatively, decision-making in response to event triggers can be performed by a combination of local and remote computing resources.

[0121] Operating the vehicle **1510** can comprise driving the vehicle by a human positioned in the vehicle, autonomous operation of the vehicle initiated by a human positioned in the vehicle, autonomous operation of the vehicle initiated by a human not positioned within the vehicle (e.g., a human located outside of the vehicle, including located at a remote location), and non-human initiated autonomous operation of the vehicle, such as operation of the vehicle initiated by a computer, such as scheduled operation and/or sensor triggered operation.

[0122] Deploying the perimeter device **1520** is accomplished by operating the UAV component of the perimeter device in accordance with the structure and function of the perimeter device. For example, if the perimeter device comprises one of the example perimeter devices described and illustrated herein, operating the UAV component of the perimeter device will be in accordance with the structure and function of that particular example perimeter device. At a minimum, deploying the perimeter device **1520** is accomplished by powering on the UAV component of the perimeter device and flying the UAV component of the perimeter device away from the vehicle and toward the predefined location.

[0123] Positioning the perimeter device **1530** at the predetermined location relative to the vehicle is accomplished in accordance with the structure and function of the perimeter device. For example, if the perimeter device comprises one of the example perimeter devices described and illustrated herein, positioning the perimeter device will be in accordance with the structure and function of that particular example perimeter device. If the perimeter device is in accordance with an embodiment in which the perimeter device is carries one or more releasable signal members, positioning the perimeter device **1530** at the predetermined location will comprise releasing one of the releasable signal members from the perimeter device to position the released signal member at the predetermined location. If the perimeter device is in accordance with an embodiment in which the perimeter device includes a non-releasable signal member, such as the embodiment illustrated in FIGS. **1-4** and the embodiment illustrated in FIGS. **5-8**, positioning the perimeter device **1530** at the predetermined location will comprise operating the UAV component of the perimeter device to position the perimeter device at the predetermined location and to position the signal member in the desired orientation relative to the predetermined location and any associated base member of the perimeter device.

[0124] The steps of deploying the perimeter device **1520** and positioning the perimeter device **1520** at the predetermined location can be repeated any suitable number of times, each using a new and different predetermined location, based on the number of perimeter devices associated with the vehicle. A safety perimeter is established once a first perimeter device is positioned at a first predetermined location. Positioning additional perimeter devices and further predetermined locations modifies the initial safety perimeter to effectively create a new, or updated, safety perimeter that reflects the inclusion of the additional perimeter device.

[0125] If included, the optional step **1540** of returning the perimeter device to the vehicle can be accomplished in any suitable manner, including human transport of the perimeter device to the vehicle to reestablish the association between the perimeter device and the vehicle. Alternatively, returning the perimeter device to the vehicle can be accomplished by operating the UAV component of the perimeter device in a manner that moves the perimeter device, including the signal member component of the perimeter device, from the predetermined location to a location on the vehicle, such as a storage enclosure, charging pad, or other location on the vehicle. In these methods, operating the UAV component of the perimeter device to accomplish this step will be performed in accordance with the structural and functional characteristics of the perimeter device and, accordingly, may include folding the signal member and base member components or retrieving a previously-released signal member component.

[0126] FIG. **36** is a flowchart representation of another example method **1600** of establishing a vehicle safety perimeter. The method **1600** is similar to the method **1500** described above, except as detailed below. Thus, a first step **1610** comprises operating a vehicle having at least one perimeter device associated with the vehicle according to an embodiment of the invention, such as one of the example perimeter devices described and illustrated herein. A second step **1620** comprises deploying the perimeter device from the vehicle by operating the UAV component of the perimeter device. Another step **1625** comprises acquiring information relating to one or more situational parameters by the UAV component of the perimeter device. Another step **1630** comprises positioning the perimeter device at a predetermined location to establish the safety perimeter. An optional step **1635** comprises acquiring information relating to one more safety perimeter parameters by the UAV component of the perimeter device. An optional step **1640** comprises returning the perimeter device to the vehicle such that the perimeter device is again associated with the vehicle. The steps of deploying the perimeter device **1620** and positioning the perimeter device **1620** at the predetermined location can be repeated any suitable number of times, each using a new and different predetermined location, based on the number of perimeter devices associated with the vehicle.

[0127] Performance of the step **1625** of acquiring information relating to one or more situational parameters by the UAV component of the perimeter device is accomplished in accordance with the structure and function of the perimeter device. For example, if the perimeter device includes one or more cameras, acquiring information relating to one or more situational parameters can comprise recording still and/or video imagery of the scene near the vehicle, including the location(s) at which placement of the perimeter device(s) is/are probable or likely to be placed, a wider view of the scene, and/or views of the scene as others may view it, such as vehicles in oncoming traffic. Additional information can be acquired based on the capabilities of the perimeter device. For example, if the perimeter device includes one or more sensors, such as a temperature sensor, a humidity sensor, or other sensor, acquiring information can comprise acquiring readings from the sensor(s). Furthermore, acquiring information can comprise acquiring map-based information about the scene, including road locations, topography, traffic forecasts, historical traffic information, and the like. Any and all information, if desired, can be included in a step of defining a predetermined location for one or more perimeter devices. An optional step of adjusting the position of one or more perimeter device based on the one or more situational parameters can be included.

[0128] Performance of optional step **1635** of acquiring information relating to one or safety perimeter parameters by the UAV component of the perimeter device, if included, is accomplished in accordance with the structure and function of the perimeter device. For example, if the perimeter device includes one or more cameras, acquiring information relating to the safety perimeter parameters can comprise recording still and/or video imagery of the safety perimeter, views of the safety perimeter as others may view it, such as vehicles in oncoming traffic, and the like. Additional information can be acquired based on the capabilities of the perimeter device. For example, if the perimeter device includes one or more sensors, such as a motion sensor, a noise sensor, or other sensor, acquiring information can comprise acquiring readings from the sensor(s).

[0129] Those with ordinary skill in the art will appreciate that various modifications and alternatives for the described and illustrated examples can be developed in light of the overall teachings of the disclosure, and that the various elements and features of one example described and illustrated herein can be combined with various elements and features of another example without departing from the scope of the invention. Accordingly, the particular examples disclosed herein have been selected by the inventor simply to describe and illustrate examples of the invention and are not intended to limit the scope of the invention or its protection, which is to be given the full breadth of the appended claims and any and all equivalents thereof.

Claims

1. A method of establishing a vehicle safety perimeter, comprising: operating a vehicle having at least one perimeter device associated with the vehicle, the perimeter device comprising a UAV, having a non-deployed configuration and a deployed configuration and adapted to transition from the non-deployed configuration to the deployed configuration in response to a triggering event relating to a status of the vehicle or its environment; deploying the perimeter device from the vehicle; and positioning the perimeter device at a deployment location away from the vehicle.

2. The method of claim 1, wherein the perimeter device further comprises a signal member.

3. The method of claim 2, wherein the UAV is in a first position relative to the signal member when the perimeter device is in the non-deployed configuration and the UAV is in a second position relative to the signal member when the perimeter device is in the deployed configuration.

4. The method of claim 3, wherein the vehicle has an external surface; and wherein the perimeter device disposed on the external surface in the non-deployed configuration.

5. The method of claim 1, wherein the triggering event comprises a vehicle immobilizing event.

6. The method of claim 1, wherein the triggering event comprises one or more of image recognition by artificial intelligence, a GPS-based event, and an environment-based event.

7. The method of claim 1, further comprising acquiring information relating to one or more situational parameters relating to an environment around the vehicle.

8. The method of claim 7, wherein the perimeter device further comprises a sensor.
9. The method of claim 8, wherein the sensor comprises a camera, an infrared sensor, a radar sensor, or a LIDAR sensor.
10. The method of claim 8, wherein the sensor comprises a camera; and wherein the acquiring information comprises recording an image using the camera.
11. The method of claim 1, wherein the deploying is performed while the vehicle is in motion.
12. The method of claim 1, wherein the deploying is performed while the vehicle is stationary.
13. The method of claim 7, wherein the perimeter device further comprises a sensor; and wherein the acquiring information comprises acquiring readings from the sensor.
14. The method of claim 13, wherein the acquiring information comprises acquiring map-based information about the environment near the vehicle.
15. The method of claim 1, further comprising: acquiring information relating to one or more situational parameters relating to an environment around the vehicle; and defining a predetermined location away from the vehicle based on the information; wherein the deployment location is based on the predetermined location.
16. The method of claim 15, further comprising adjusting the deployment location based on the information.
17. The method of claim 11, wherein the deployment location is a roadside position adjacent the vehicle.
18. A method of establishing a vehicle safety perimeter, comprising: operating a vehicle having a perimeter device associated with the vehicle, the perimeter device comprising a UAV and a camera and having a non-deployed configuration and a deployed configuration; deploying the perimeter device from the vehicle by operating the UAV of the perimeter device to transition the perimeter device from the non-deployed configuration to the deployed configuration and to move the perimeter device to a deployment location away from the vehicle to establish the vehicle safety perimeter; recording imagery of the scene near the vehicle using the camera; and issuing a signal to a recipient when the vehicle safety perimeter is violated.
19. The method of claim 14, wherein the signal comprises one or more of an audible signal, a visual signal, and a data signal.
20. A method of establishing a vehicle safety perimeter, comprising: operating a vehicle having a perimeter device associated with the vehicle, the perimeter device comprising a UAV and a camera and having a non-deployed configuration and a deployed configuration; deploying the perimeter device from the vehicle by operating the UAV of the perimeter device to transition the perimeter device from the non-deployed configuration to the deployed configuration and to move the perimeter device to a deployment location away from the vehicle to establish the vehicle safety perimeter; recording imagery of the scene near the vehicle using the camera; and issuing a signal to a recipient located within the environment of the vehicle when the vehicle safety perimeter is violated, the signal comprising one or more of an audible signal, a visual signal, and a data signal.
