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Inventor(s)	Muhleman; Daniel Howard

Lighter-than-air vehicle interceptor

Abstract

The present invention provides a lighter-than-air (LTA) vehicle interceptor for neutralizing and/or capturing a non-cooperative LTA vehicle, such as a spy balloon. Embodiments of the interceptor may be equipped with various subsystems useful in missions to intercept, neutralize and ideally capture a threat payload attached to the non-cooperative LTA vehicle, even at stratospheric altitudes. Such subsystems may include an imaging device, severing effector, grasping effector, puncturing effector, weight-bearing apparatus, power subsystem, navigation subsystem, communication subsystem and propulsion.

Inventors: **Muhleman; Daniel Howard (El Cajon, CA)**

Applicant: **The United States of America, as represented by the Secretary of the Navy** (Arlington, VA)

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Primary Examiner: O'Hara; Brian M

Attorney, Agent or Firm: Naval Information Warfare Center Pacific

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Background/Summary

BACKGROUND OF THE INVENTION

Field of the Invention

(1) The present invention relates generally to lighter-than-air vehicles, e.g., balloons. More particularly, the present invention relates to lighter-than-air (LTA) vehicle interceptors.

Description of Related Art

(2) As a type of LTA airship, unmanned balloons generally include a bulbous envelope filled with an LTA gas, e.g., helium or hydrogen, and a payload, generally suspended from below the envelope by cord, rope or cable. The payload may be anything that is useful at its intended altitude or range of flight. Weather balloons and stratospheric balloons are used commonly today to carry sensors to desired altitude with sensors for various measurements, recording and data transmission. The variety and intended use of unmanned balloons is quite diverse.

(3) Balloons were used as an important tool for intelligence gathering in the nineteenth century. Since then, their usefulness for intelligence gathering has declined, especially since they can easily be shot down by a jet fighter plane or missile. Balloons are not ideal as a platform for spying because they tend to be big, hard to hide and they generally go where the winds take them. Nonetheless,

sophisticated nation states continue to use spy balloons.

(4) As first detected on Jan. 28, 2023, China floated a spy balloon over portions of the United States from Alaska to the East Coast, presumably gathering intelligence from several sensitive American military sites. China was able to control motion of the balloon so it could make multiple passes over some of the sites, at times flying figure-eight formations. The possibility that such intelligence data and information might be collected and transmitted back to China, raised serious security concerns for the United States. It is believed that the type of information gathered during the balloon's journey may have included electronic signals picked up from weapons systems or communications from base personnel as well as image and video data.

(5) Regardless of the particular intelligence gathered and the value of that intelligence, the urgency to neutralize the Chinese spy balloon was balanced against capturing its payload safely and as intact as possible to analyze an adversary's intelligence gathering mechanism. During the Chinese balloon's travels over the US, the US military weighed various options to bring down the balloon safely, for analysis, but also to protect US territory from a heavy object (estimated payload weight exceeding 2000 lbs or 910 kg) falling from the sky.

(6) Ultimately, on Feb. 4, 2023, once the balloon was safely over water, a US Air Force F-22 fighter jet flying at 58,000 ft of elevation was used to launch a single AIM-9X Sidewinder air-to-air missile to take down the balloon which was flying at an estimated altitude of 60,000 to 65,000 ft. The balloon's payload was recovered by US Navy divers in an estimated 47 ft depth of water about 6 nautical miles off of the US East Coast.

(7) That particular incident with the Chinese spy balloon, and the possibility of others in the future, highlights the need for better ways of neutralizing or capturing such LTA vehicles that pose a threat to US national security. Additionally, the cost of scrambling an F-22 and expending an AIM-9X Sidewinder air-to-air missile (up to $400,000/unit cost depending on variation) provides an economic incentive to find better methods of neutralizing such threat balloons. Finally, it would be desirable to have a system for safely capturing (if possible) such threat balloons without relying on a 60,000 ft plunge to earth and digging the wreckage out of soil from an impact site, or from the bottom of a body of water. In view of the foregoing and for other reasons that will become evident, there exists a need in the art for improved LTA vehicle interception.

SUMMARY OF THE INVENTION

(8) An embodiment of a lighter-than-air (LTA) vehicle interceptor for intercepting a non-cooperative LTA (NCLTA) vehicle and attached threat payload operating aerially above ground is disclosed. The embodiment of an LTA vehicle interceptor may include an airship vehicle platform capable of maneuvering to within an operable distance of the NCLTA vehicle and the attached threat payload; an interceptor payload attached to the airship vehicle platform, the interceptor payload further including a severing effector for engaging with the NCLTA vehicle and the threat payload and an on-board control subsystem for automated and/or remote control by an operator for controlling the interceptor payload and the severing effector. The embodiment of an LTA vehicle interceptor may further include a power subsystem for powering the interceptor payload and the severing effector; and wherein the airship vehicle platform and the severing effector cooperate to separate the NCLTA vehicle from the threat payload and return the threat payload to the ground for operator retrieval.

(9) Another embodiment of an LTA vehicle interceptor for intercepting a NCLTA vehicle and attached threat payload operating aerially above ground is disclosed. The embodiment of an LTA vehicle interceptor may include an airship vehicle platform capable of maneuvering to within an operable distance of the NCLTA vehicle and the attached threat payload and an interceptor payload attached to the airship vehicle platform. The interceptor payload may further include a grasping effector for engaging the NCLTA vehicle and the threat payload and an on-board control subsystem for automated and/or remote control by an operator for controlling the interceptor payload and the severing effector. The embodiment of an LTA vehicle interceptor may further include a power subsystem for powering the interceptor payload and the severing effector and wherein the airship vehicle platform and the grasping effector cooperate to clamp onto the NCLTA vehicle or the threat

payload and return the threat payload to the ground for operator retrieval.
(10) Still another embodiment of an LTA vehicle interceptor for intercepting a NCLTA vehicle and attached threat payload operating aerially above ground is disclosed. This embodiment of an LTA vehicle interceptor may include an airship vehicle platform capable of maneuvering to within an operable distance of the NCLTA vehicle and the attached threat payload. This embodiment of an LTA vehicle interceptor may further include an interceptor payload attached to the airship vehicle platform, the interceptor payload including a puncturing effector for engaging the NCLTA vehicle and the threat payload and an on-board control subsystem for automated and/or remote control by an operator for controlling the interceptor payload and the severing effector. This embodiment of an LTA vehicle interceptor may further include a power subsystem for powering the interceptor payload and the severing effector. According to this embodiment of an LTA vehicle interceptor, the airship vehicle platform and the puncturing effector may cooperate to reduce buoyancy of the NCLTA vehicle and the threat payload and return the threat payload to the ground for operator retrieval.
(11) An embodiment of a method for intercepting a NCLTA vehicle including an envelope configured for up to stratospheric buoyancy and a threat payload suspended from the envelope by rigging is disclosed. The method embodiment may include providing an LTA vehicle interceptor configured for intercepting the NCLTA vehicle and the threat payload operating aerially above ground, the LTA vehicle interceptor further configured with a plurality of effectors for engaging the NCLTA vehicle and/or the threat payload; deploying the LTA vehicle interceptor from a location below the NCLTA; navigating the LTA vehicle interceptor to within an operational distance away from the NCLTA; engaging the NCLTA vehicle and/or the threat payload with at least one of the plurality of effectors to disable the NCLTA vehicle; securing the threat payload to the LTA vehicle interceptor; and returning the threat payload safely to the ground.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) The following drawings illustrate exemplary embodiments for carrying out the invention. Like reference numerals refer to like parts in different views or embodiments of the present invention in the drawings.
(2) FIG. **1** is a diagram illustrating an embodiment of an LTA vehicle interceptor, according to the present invention.
(3) FIG. **2** is a schematic block diagram illustrating an LTA vehicle interceptor, NCLTA vehicle and operator, according to the present invention.
(4) FIG. **3** is a flowchart of a method for intercepting a NCLTA vehicle including an envelope configured for up to stratospheric buoyancy and a threat payload suspended from the envelope by rigging, according to the present invention.
DETAILED DESCRIPTION
(5) The disclosed methods and systems below may be described generally, as well as in terms of specific examples and/or specific embodiments. For instances where references are made to detailed examples and/or embodiments, it should be appreciated that any of the underlying principles described are not to be limited to a single embodiment but may be expanded for use with any of the other methods, apparatuses and systems described herein as will be understood by one of ordinary skill in the art unless specifically otherwise stated.
(6) LTA vehicles from an adversarial country with military or intelligence, surveillance, and reconnaissance (ISR) payloads may fly over a country as occurred with the Chinese spy balloon that entered the continental United States over Montana, traversed the United States, and was shot down over coastal waters off of South Carolina. The “balloon” and its payload then fell precipitously to the ocean. The uncontrolled nature of this fall was noted as a reason not to shoot down the threat balloon over Montana. There is a need for a better solution to this technical problem. The technical solution

should be: (1) more efficient than sending a fighter jet and using a roughly $400 k missile, (2) ideally, allow for the adversarial system (or portions thereof) to be brought to earth more safely, and (3) ideally, allow the adversarial system to be captured intact for further inspection.
(7) The technical problem addressed by the present invention is a method and system for neutralizing and safely capturing, if possible, a non-cooperative LTA airship, e.g., a spy balloon. While the embodiments of the invention disclosed herein are described with reference to a non-cooperative stratospheric balloon airship with an envelope carrying a threat payload suspended underneath the envelope via cords or other suspension means (rigging), it will be understood that other types of non-cooperative LTA airships, e.g., dirigibles or drones, may also be intercepted according to particular embodiments of the present invention. Particular embodiments of the technical solution (invention) are described below.
(8) FIG. **1** is a diagram illustrating an embodiment of an LTA vehicle interceptor **100** in the air and near a NCLTA vehicle **190**, according to the present invention. It will be understood that FIG. **1** is diagrammatic only, not drawn to scale and is used to illustrate multiple embodiments of the invention in a single diagram for simplicity. The NCLTA vehicle **190** is depicted as a stratospheric balloon with an envelope **192** and a threat payload **194** suspended below the envelope **192** by rigging **196**. It will be understood that rigging **196** may be cord, rope, cable or netting used to secure the threat payload **194** below the envelope **192** that provides buoyancy to NCLTA vehicle **190**. It will be further understood that NCLTA vehicle **190** may be another type of LTA vehicle, such as a dirigible. But, for the exemplary embodiments of the invention shown in FIG. **1**, the NCLTA vehicle **190** is a balloon, as shown. Embodiments of the LTA vehicle interceptor **100** described herein are unmanned and remotely controlled by an operator.
(9) As further illustrated in FIG. **1**, the LTA vehicle interceptor **100** may also include an envelope **102** supporting an interceptor payload **104** via rigging **106**. It will be understood that the particulars of the envelope **102** and rigging **106** are not critical to the inventive concepts of the present invention. The envelope **102** and rigging **106** need only be sufficient to lift and support the interceptor payload **104** to an appropriate altitude to engage with the NCLTA vehicle **190** and safely return the threat payload **194**. It will be understood that any suitable commercial or military grade airship may be used with the interceptor payload **104** of the present invention. For example, and not by way of limitation, the “Thunderhead Balloon Systems”, “Super Pressure Balloons”, and “Zero Pressure Balloons”, available from Aerostar, 3901 W 59th St, Sioux Falls, SD 57108, are all suitable airships from which the inventive interceptor payload **104** might be deployed to engage a NCLTA vehicle **190**, consistent with the teachings of the present invention.
(10) As shown in FIG. **1**, the interceptor payload **104** may be configured with one or more propulsion means, or thrusters **108** for adjusting lateral position of the LTA vehicle interceptor **100** to within a suitable operational distance, depicted as dashed box **198** around the NCLTA vehicle **190**. It will be understood that the maneuverability or station keeping of the LTA vehicle interceptor **100** is context dependent. At moderate altitudes, the use of propellers as the propulsion technology may be sufficient. At stratospheric altitudes, the air gets so thin that propellers have nothing to push and so maneuvering and even station keeping is generally performed by adjusting the buoyancy of the balloon/airship to get to an altitude where the prevailing wind direction will be helpful to get to where you want to go (laterally) and then the altitude adjusted as needed if a different altitude is desired. For some lateral maneuverability one could potentially use thrusters **108** like those used on satellites to get more speed and to orient effectors and other sensors for operational engagement. It will be understood that one of ordinary skill in the art will be familiar with LTA airship propulsion technologies and how to incorporate same in an interceptor payload **104**. Accordingly, no further description of such propulsion technologies that might be included in thrusters **108** is provided herein.
(11) As shown in FIG. **1**, the interceptor payload **104** may also be configured with one or more imaging devices **110** (one shown in FIG. **1**) attached to a pointing apparatus **112**. According to one embodiment, the imaging device **110** may be capable of focusing on the NCLTA vehicle **190** and its

attached threat payload **194**. The one or more imaging devices **110** may record and transmit video and still image data for use by the operator. According to another embodiment, the imaging device **110** may have a sensor for imaging outside of the visible spectrum, e.g., infra-red, or other wavelengths of radiation that may be of interest for a particular NCLTA vehicle **190**. Embodiments of a pointing apparatus **112** may include an articulating arm, a telescoping arm, or both with rotational capability, holding an imaging device **110** at a distal end that is capable of being oriented in the direction of the NCLTA vehicle **190** and/or its threat payload **194** in order to facilitate focusing of imaging data performed by the one or more imaging devices **110**. It will be understood that any suitable imaging device **110** may be employed with the interceptor payload **104**. According to another embodiment, imaging device(s) **110** may be all or partly off-board from the interceptor payload **104**, e.g., ground-based radar (not shown). It will be further understood that one of ordinary skill in the art will have sufficient knowledge to implement an imaging device **110** and/or pointing apparatus **112** consistent with the teachings of the present invention, and thus will not be further elaborated herein.
(12) Severing Effector
(13) According to a particular embodiment, an LTA vehicle interceptor **100** may include a severing effector, shown at arrow **120**, mounted to, and directly controlled by, the interceptor payload **104**, in turn under operator control. The severing effector **120** may be configured to physically engage and damage vulnerable structure of the NCLTA vehicle **190**, such as the cord on the rigging **196** or the envelope **192**. Thus, the severing effector **120** may be used to decrease buoyancy of the NCLTA vehicle **190** by opening a hole in the envelope **192** in a coordinated effort to bring the NCLTA vehicle **190** to ground. Alternatively, the severing effector **120** may be used to separate the envelope **192** from the threat payload **194**. The severing effector **120** may be configured with one or more cutting elements **124**, e.g., scissors, sheers, bolt cutters, reciprocating or rotating blades, chainsaws, etc., mounted to a distal end **126** of a severing arm **122**, directly controlled by the interceptor payload **104** under operator control. Each type of cutting element **124** may be configured for severing particular structural features of the NCLTA vehicle **190**.
(14) Embodiments of severing arm **122** may be robotic, and capable of telescoping outward from the interceptor payload **104**, using electric motors (not shown) as well as configured to rotate about various axes in order to place the cutting element in position to damage to the NCLTA vehicle **190** once within the operational distance **198** around the NCLTA vehicle **190**. It will be understood that control of the severing effector **120** may be facilitated by visual feedback from an imaging device **110** under operator control, according to one embodiment, or automated to target particular structural elements of the NCLTA vehicle **190** via sensors, according to other embodiments. According to yet another embodiment, the severing effector **120** may be equipped with its own imaging device and targeting mechanism to quickly identify and sever target rigging **196**, envelope **192** or even structural elements of the threat payload **194** itself. It will be understood that suitable types of cutting elements **124** attached to movable severing arms **122** and their control are within the knowledge of one of ordinary skill in the art given this disclosure. Accordingly, further detail regarding same will not be elaborated herein.
(15) Grasping Effector
(16) According to another embodiment, an LTA vehicle interceptor **100** may include a grasping effector, shown at arrow **130**, mounted to, and directly controlled by, the interceptor payload **104**, in turn under operator control. The grasping effector **130** may be configured with one or more grasping elements **134** such as a clamp, grappling hook, collapsible net, harpoon, etc., according to various embodiments of the present invention. It will be understood that one of ordinary skill in the art will be familiar with the workings and how to implement such exemplary grasping elements **134** according to the teachings of the present invention, and thus will not be further elaborated herein. Embodiments of grasping elements may be disposed about the distal end **136** of a grasping arm **132**. The grasping effector **130** may be configured to physically engage and hold onto the structure of the NCLTA vehicle **190**, such as the threat payload **194**, cord on the rigging **196** or a portion of the envelope **192**. In this way, the grasping effector **130** may be capable of grabbing the NCLTA vehicle

190 and reducing buoyancy in combination with LTA vehicle interceptor **100** reducing its buoyancy, i.e., the LTA vehicle interceptor **100** may simply drag the NCLTA vehicle **190** and its threat payload **194** to the ground.

(17) Embodiments of grasping arm **132** may be robotic, and capable of telescoping outward from the interceptor payload **104**, using electric motors (not shown), as well as configured to rotate about various axes in order to place the grasping element **134** in position to grasp some structural feature of the NCLTA vehicle **190** once within the operational distance **198** around the NCLTA vehicle **190**. It will be understood that control of the grasping effector **130** may be facilitated by visual feedback from an imaging device **110** under operator control, according to one embodiment, or automated to target particular structural elements of the NCLTA vehicle **190** via sensors, according to other embodiments. According to another embodiment, the grasping effector **130** may be equipped with its own imaging device and targeting mechanism (neither shown) to quickly identify target rigging **196**, envelope **192** or even structural elements of the threat payload **194** itself for grasping. It will be understood that suitable types of grasping elements **134** attached to movable grasping arms **132** and their control are within the knowledge of one of ordinary skill in the art given this disclosure. Accordingly, further detail regarding same will not be elaborated herein.

(18) According to a particular embodiment of LTA vehicle interceptor **100**, a severing effector **120** may be used in combination with a grasping effector **130**. For example, safely securing the threat payload **194** may be achieved by first grabbing onto threat payload **194** structure with the grasping effector **130**, then severing cords from rigging **196**, or puncturing the envelope **192** using the severing effector **120**, followed by gently descending to ground with the threat payload **194** under LTA vehicle interceptor **100** control, with or without envelope **192**. In this way, the NCLTA vehicle **190** is neutralized and the threat payload **194** secured for further analysis.

(19) Puncturing Effector

(20) According to yet another embodiment, an LTA vehicle interceptor **100** may include a puncturing effector **140** mounted to, and directly controlled by, the interceptor payload **104**, in turn under operator control. The puncturing effector **140** may be configured with one or more puncturing elements **144**, for example and not by way of limitation, a blade or knife, a needle, a spear, an arrow, a bolt, a ballistic projectile from a gun, etc. Puncturing effector **140** may be configured to reduce buoyancy of the NCLTA vehicle **190** reducing the integrity of envelope **192** by puncturing or tearing one or more holes in envelope **192**. Depending on the particular embodiment, puncturing element **144**, may be a single use, or reloadable, expendable item, such as an arrow, a bolt or a cartridge from a gun that is aimed at the envelope **192** for the purpose of creating a hole in the envelope **192**. Other embodiments of the puncturing element **144** may remain connected to payload **104** and be mounted to a robotic puncturing arm (not shown, but see **122** and **132**) capable of telescoping outward from the interceptor payload **104**, using electric motors (not shown), as well as configured to rotate about various axes in order to place the puncturing element **144** in position to puncture the envelope **192** of the NCLTA vehicle **190** once within the operational distance **198** around the NCLTA vehicle **190**. For simplicity of illustration in FIG. **1**, puncturing effector **140** is simply illustrated as a needle extending from the interceptor payload **104**. One of ordinary skill in the art will be familiar with how to employ puncturing elements whether directly mounted to the interceptor payload **104** or at the distal end of a robotic puncturing arm given the disclosure herein. Accordingly, further detail regarding same will not be elaborated herein.

(21) According to a particular embodiment of LTA vehicle interceptor **100**, a puncturing effector **140** may be used in combination with a grasping effector **130**. For example, and not by way of limitation, safely securing the threat payload **194** may be achieved by first grabbing onto threat payload **194** structure with the grasping effector **130**. Once the threat payload is secured by the grasping effector **130**, the puncturing effector **140** may then be used to open a hole in the envelope **192**. This will reduce the buoyancy of the NCLTA vehicle **190**, allowing the LTA vehicle interceptor **100** to gently descend to ground with the threat payload **194** under LTA vehicle interceptor **100** buoyancy and control. In this way, the NCLTA vehicle **190** is neutralized and the threat payload **194** secured for

further analysis.

(22) FIG. **1** further illustrates a weight-bearing apparatus **160** for use with one or more of the effectors **120**, **130**, **140** described herein. More particularly, FIG. **1** illustrates a particular weight-bearing apparatus **160**, namely a cable **162** and winch **164** that may be configured with one end of the cable attached to a particular effector, in this instance a grasping element **134** such as a clamp. Once the grasping element **134** is secured to the threat payload **194** it could be detached from grasping arm **132** and fully supported from the interceptor payload **104** chassis via winch **164**. By using the weight-bearing apparatus **160**, the grasping arm **132** need not support the entire tethered weight of the threat payload **194** and/or the entire NCLTA vehicle **190**. Additionally, the winch **164** may be used to selectively raise or lower the NCLTA vehicle **190** and/or threat payload **194** relative to the LTA vehicle interceptor **100**.

(23) While the weight-bearing apparatus **160** is shown in cooperation with the grasping effector **130**, it will be understood that it could also be configured for cooperation with other effector elements described herein, such as a harpoon, grappling hook, net, arrow, bolt, etc., that could secure one end of the cable **162** to the NCLTA vehicle **190** or threat payload **194** and then be tethered to the LTA vehicle interceptor **100** via winch **164** wrapped with the cable **162**.

(24) As shown in FIG. **1**, the interceptor payload **104** may also be configured with a power subsystem, shown generally at arrow **150**, for powering interceptor payload **104** and each of its effectors **120**, **130**, **140** described herein. The power subsystem **150** may include one or more batteries (not shown in FIG. **1**), one or more solar panels **152** for passive charging of the batteries and a power controller (not shown) for managing batteries and solar panels.

(25) While the interceptor payload **104** illustrated in FIG. **1** is shown hanging from envelope **102** via rigging **106**, another configuration has also been contemplated and illustrated. FIG. **1** further illustrates a top-mounted interceptor payload **170**. It will be understood that structural rigging (not shown) would be required for an embodiment of a top-mounted payload **170**. Top-mounted interceptor payload **170** may include any of the features described herein with respect to interceptor payload **104**, but rather located above envelope **102**. Top-mounted interceptor payload **170** may be particularly advantageous for engaging the threat payload **194** from underneath the NCLTA vehicle **190** and without necessarily first engaging envelope **192**. Additionally, accessing the threat payload **194** from underneath may be advantageous if the size of the envelope **192** of the NCLTA vehicle **190** makes it difficult to approach because of its size and how it might impede access to the threat payload **194**. According to one embodiment of top-mounted interceptor payload **170**, a grasping effector **130** may be used to secure attachment to the threat payload **194** from underneath the threat payload **194** and in coordination with a weight-bearing apparatus **160**, LTA vehicle interceptor may simply drag the entire NCLTA vehicle **190** safely to ground. Thus, rather than puncturing or deflating the envelope **192** of NCLTA vehicle **190**, the LTA vehicle interceptor **100** could attach to the NCLTA vehicle **190** and then decrease its own (interceptor's) buoyancy so as to bring them both down to earth. Depending on the relative buoyancies and payload weights involved, this may require added weight/ballast for the LTA vehicle interceptor **100** (i.e., its own deflated weight has to be enough when added to the NCLTA vehicle **190** to exceed the lift of the threat envelope **192**).

(26) FIG. **2** is a schematic block diagram illustrating an LTA vehicle interceptor **100**, NCLTA vehicle **190** and operator **210**, according to the present invention. More particularly, FIG. **2** illustrates an operator **210** wirelessly in communication with the LTA vehicle interceptor **100** from the ground **220**. Both the NCLTA vehicle **190** and the LTA vehicle interceptor **100** may be located anywhere above ground **220**, perhaps at stratospheric elevations. The LTA vehicle interceptor **100** may include an LTA vehicle **200** such as the balloons or dirigibles described herein. The LTA vehicle interceptor **100** may further include rigging **106** for attaching interceptor payload **104** to the LTA vehicle **200** below or above (see interceptor payload **174**, FIG. **1**), as described herein.

(27) As shown in FIG. **2**, the interceptor payload **104** may include a number of subsystems, for example, imaging device(s) **110**, a power subsystem **150**, a severing effector **120**, a navigation subsystem **230**, a grasping effector **130**, a weight-bearing apparatus **160**, a puncturing effector **140**, a

communications subsystem **240** with associated antenna **242**, one or more thrusters **108** and an on-board control subsystem **250**. Again, it will be understood that "thrusters **108**" as used herein could be any suitable propulsion technology and one of ordinary skill in the art will be equipped with sufficient knowledge to implement such propulsion technology for use as described in this disclosure. The on-board control subsystem **250** may be configured to provide operator **210**, remote control, or automated control of the interceptor payload **104** and its interactions with the NCLTA vehicle **190**.

(28) Embodiments of the navigation subsystem **230** may include one or more global positioning system (GPS) units, one or more inertial navigation units (INUs), compasses or other suitable means for establishing the location of the LTA vehicle interceptor **100** which may be used in combination with the on-board control subsystem **250** to navigate to the NCLTA vehicle **190** for operational engagement and away from such engagement to return the threat payload **194** (FIG. **1**) to ground **220**. The use and implementation of such navigational features will be within the knowledge of one of ordinary skill in the art given this disclosure. Accordingly, further detail regarding same will not be elaborated herein.

(29) Embodiments of the communication subsystem **240** with its associated antenna **242** may include any suitable wireless communications suitable for an operator **210** to use and control the interceptor payload **104**, **170** (see FIG. **1**) remotely away from LTA vehicle interceptor **100**, e.g., from the ground **220** or any suitable location. Depending on the particular embodiment, an operator **210** may have remote control of the interceptor payload **104** including video data from the imaging device(s) **110** or other pointing/aiming mechanisms used to guide effectors **120**, **130**, **140** for their intended purposes in engaging the NCLTA vehicle **190**. FIG. **2** illustrates a single operator **210** controlling the interceptor payload **104**. However, it will be understood that a team of operators **210** may be employed to operate various aspects of the interceptor payload **104** and/or the LTA vehicle **200** to the extent it also has remote controls.

(30) Embodiments of the on-board control subsystem **250** may include one or more processors in communication with one or more memory subsystems for storing data and executable computer program instructions for implementing control of the interceptor payload **104**. Embodiments of the on-board control subsystem **250** may be in communication with, and in control of, all of the other interceptor payload **104** subsystems, including imaging devices **110**, severing effectors **120**, grasping effectors **130**, puncturing effectors **140**, power subsystem **150**, navigation subsystem **230**, weight-bearing apparatus **160**, communication subsystem **240**, and thrusters **108**. However, it will be understood that according to other embodiments, some subsystems within the interceptor payload **104** may operate autonomously. For example, and not by way of limitation, the power subsystem **150** may automatically generate and deliver power to other electrically powered subsystems on the interceptor payload **104** without intervention from the on-board control subsystem **250**.

(31) Though not illustrated in FIGS. **1** and **2**, another embodiment of the LTA vehicle interceptor **100** may be configured with intelligence, surveillance and reconnaissance (ISR) payloads configured to characterize NCLTA vehicle **190** before intercepting it (which could drive the decision whether or not to intercept). According to another embodiment, also not illustrated in FIGS. **1** and **2**, yet another embodiment of the LTA vehicle interceptor **100** may also be configured with electronic warfare payloads to interfere with NCLTA vehicle **190** functionalities, e.g., data transmission, navigation jamming, etc.

(32) FIG. **3** is a flowchart of a method **300** for intercepting a NCLTA vehicle including an envelope configured for up to stratospheric buoyancy and a threat payload suspended from the envelope by rigging, according to the present invention. The embodiment of method **300** may include providing **302** an LTA vehicle interceptor configured for intercepting the NCLTA vehicle and the threat payload operating aerially above ground, the LTA vehicle interceptor further configured with a plurality of effectors for engaging the NCLTA vehicle and/or the threat payload. The embodiment of method **300** may further include deploying **304** the LTA vehicle interceptor from a location below the NCLTA vehicle. The embodiment of method **300** may further include navigating **306** the LTA vehicle interceptor to within an operational distance away from the NCLTA vehicle. The embodiment of

method **300** may further include engaging **308** the NCLTA vehicle and/or the threat payload with at least one of the plurality of effectors to disable the NCLTA vehicle. The embodiment of method **300** may further include securing **310** the threat payload to the LTA vehicle interceptor. The embodiment of method **300** may further include returning **312** the threat payload safely to the ground. According to another embodiment of method **300**, the plurality of effectors includes at least one each of the following effectors: a severing effector, a grasping effector and a puncturing effector.

(33) Having described specific embodiments of an LTA vehicle interceptor **100** and method **300** for intercepting a NCLTA vehicle **190** using an LTA vehicle interceptor **100** with reference to the drawing FIGS. **1**, **2** and **3**, additional general embodiments of an LTA vehicle interceptor according to the present invention are described, below.

(34) An embodiment of an LTA vehicle interceptor for intercepting a NCLTA vehicle and attached threat payload operating aerially above ground is disclosed. The embodiment of an LTA vehicle interceptor may include an airship vehicle platform capable of maneuvering to within an operable distance of the NCLTA vehicle and the attached threat payload. The embodiment of an LTA vehicle interceptor may further include an interceptor payload attached to the airship vehicle platform. According to this embodiment of an LTA vehicle interceptor, the interceptor payload may further include a severing effector for engaging with the NCLTA vehicle and the threat payload. According to this embodiment of an LTA vehicle interceptor, the interceptor payload may further include an on-board control subsystem for automated and/or remote control by an operator for controlling the interceptor payload and the severing effector. According to this embodiment of an LTA vehicle interceptor, the interceptor payload may further include a power subsystem for powering the interceptor payload and the severing effector. According to this embodiment of an LTA vehicle interceptor, the airship vehicle platform and the severing effector may be configured to cooperate to separate the NCLTA vehicle from the threat payload and return the threat payload to the ground for operator retrieval.

(35) According to another embodiment of an LTA vehicle interceptor, the airship vehicle platform may be a balloon, a dirigible, or a drone. According to yet another embodiment of an LTA vehicle interceptor, the airship vehicle platform may also be controlled by the operator.

(36) According to one embodiment of the LTA vehicle interceptor, the interceptor payload may further include a navigation subsystem for sensing and providing location data for the LTA vehicle interceptor. According to this embodiment of the LTA vehicle interceptor, the interceptor payload may further include at least one imaging device for gathering and providing imaging data of the NCLTA vehicle. According to this embodiment of the LTA vehicle interceptor, the interceptor payload may further include a communications subsystem for transmitting the location data and the imaging data to the operator. According to this embodiment of the LTA vehicle interceptor, the interceptor payload may further include an on-board control subsystem in communication with, and for controlling, the navigation system, the at least one imaging device and the communications subsystem under operator control.

(37) According to another embodiment of the LTA vehicle interceptor, the power subsystem may include at least one battery and optionally a solar panel operably coupled to the at least one battery. According to other embodiments of the LTA vehicle interceptor, the severing effector may be scissors, sheers, or bolt cutter. According to a particular embodiment of the LTA vehicle interceptor, the severing effector may be connected to a distal end of a movable arm secured to the interceptor payload by a proximal end of the movable arm. According to this embodiment, the severing effector may be movable in any direction under operator control.

(38) An embodiment of an LTA vehicle interceptor for intercepting a NCLTA vehicle and attached threat payload operating aerially above ground is disclosed. The embodiment of an LTA vehicle interceptor may include an airship vehicle platform capable of maneuvering to within an operable distance of the NCLTA vehicle and the attached threat payload. The embodiment of an LTA vehicle interceptor may further include an interceptor payload attached to the airship vehicle platform. Embodiments of the interceptor payload may further include a grasping effector for engaging the

NCLTA vehicle and/or the threat payload. Embodiments of the interceptor payload may further include an on-board control subsystem for automated and/or remote control by an operator for controlling the interceptor payload and the severing effector. Embodiments of the interceptor payload may further include a power subsystem for powering the interceptor payload and the severing effector. According to this embodiment of an LTA vehicle interceptor, the airship vehicle platform and grasping effector may cooperate to clamp onto the NCLTA vehicle or the threat payload and return the threat payload to the ground for operator retrieval.

(39) According to another embodiment of the LTA vehicle interceptor, the airship vehicle platform may be a balloon, a dirigible, or a drone. According to yet another embodiment of the LTA vehicle interceptor, the airship vehicle platform may also be remotely controlled by the operator. According to still another embodiment of the LTA vehicle interceptor, the interceptor payload may further include a navigation subsystem for sensing and providing location data for the LTA vehicle interceptor. According to this embodiment of the LTA vehicle interceptor, the interceptor payload may further include at least one imaging device for gathering and providing imaging data of the NCLTA vehicle. According to this embodiment of the LTA vehicle interceptor, the interceptor payload may further include a communications subsystem for transmitting the location data and the imaging data to the operator. According to this embodiment of the LTA vehicle interceptor, the interceptor payload may further include an on-board control subsystem in communication with, and for controlling, the navigation subsystem, the at least one imaging device and the communications subsystem under operator control.

(40) According to one embodiment of an LTA vehicle interceptor, the power subsystem may further include at least one battery and optionally a solar panel operably coupled to the at least one battery. According to other embodiments of an LTA vehicle interceptor, the grasping effector may be a clamp, a grappling hook or a net. According to yet another embodiment of an LTA vehicle interceptor, the grasping effector may be connected to a distal end of a movable arm secured to the interceptor payload by a proximal end of the movable arm and the grasping effector may be movable in any direction under operator control. According to still another embodiment of an LTA vehicle interceptor, the interceptor payload and the grasping effector may be located at the top of the airship vehicle platform to facilitate grasping the NCLTA vehicle or the threat payload from underneath the NCLTA vehicle or the threat payload.

(41) Still another embodiment of an LTA vehicle interceptor for intercepting a NCLTA vehicle and attached threat payload operating aerially above ground is disclosed. The embodiment of an LTA vehicle interceptor may include an airship vehicle platform capable of maneuvering to within an operable distance of the NCLTA vehicle and the attached threat payload. The embodiment of an LTA vehicle interceptor may further include an interceptor payload attached to the airship vehicle platform. According to this embodiment of an LTA vehicle interceptor, the interceptor payload may further include a puncturing effector for engaging the NCLTA vehicle and the threat payload. According to this embodiment of an LTA vehicle interceptor, the interceptor payload may further include an on-board control subsystem for automated and/or remote control by an operator for controlling the interceptor payload and the severing effector. According to this embodiment of an LTA vehicle interceptor, the interceptor payload may further include a power subsystem for powering the interceptor payload and the severing effector. According to this embodiment of an LTA vehicle interceptor, the airship vehicle platform and the puncturing effector cooperate to reduce buoyancy of the NCLTA vehicle and the threat payload and return the threat payload to the ground for operator retrieval.

(42) According to particular embodiments of the LTA vehicle interceptor, the airship vehicle platform may be a balloon, a dirigible, or a drone. According to one embodiment of the LTA vehicle interceptor, the airship vehicle platform may also be controlled by the operator. According yet another embodiment of an LTA vehicle interceptor, the interceptor payload may further include a navigation subsystem for sensing and providing location data for the LTA vehicle interceptor. According to this embodiment of an LTA vehicle interceptor, the interceptor payload may further

include at least one imaging device for gathering and providing imaging data of the NCLTA vehicle. According to this embodiment of an LTA vehicle interceptor, the interceptor payload may further include a communications subsystem for transmitting the location data and the imaging data to the operator. According to this embodiment of an LTA vehicle interceptor, the interceptor payload may further include an on-board control subsystem in communication with, and for controlling, the navigation subsystem, the at least one imaging device and the communications subsystem under operator control.

(43) According to another embodiment of this LTA vehicle interceptor, the power subsystem may further include at least one battery and optionally a solar panel operably coupled to the at least one battery. According to yet another embodiment of this LTA vehicle interceptor, the puncturing effector may be any one of the following: a knife, a needle, a spear, an arrow, or a bolt. According to still another embodiment of this LTA vehicle interceptor, the puncturing effector may be connected to a distal end of a movable arm secured to the interceptor payload by a proximal end of the movable arm and the puncturing effector may be movable in any direction under operator control.

(44) In understanding the scope of the present invention, the term “configured” as used herein to describe a component, section or part of a device includes hardware and/or software that is constructed and/or programmed to carry out the desired function. In understanding the scope of the present invention, the term “comprising” and its derivatives, as used herein, are intended to be open ended terms that specify the presence of the stated features, elements, components, groups, integers, and/or steps, but do not exclude the presence of other unstated features, elements, components, groups, integers and/or steps. The foregoing also applies to words having similar meanings such as the terms, “including”, “having” and their derivatives. Finally, terms of degree such as “substantially”, “about” and “approximately” as used herein mean a reasonable amount of deviation of the modified term such that the end result is not significantly changed.

(45) From the above description of the embodiments of an LTA vehicle interceptor **100** and method **300**, it is manifest that various alternative structures may be used for implementing features of the present invention without departing from the scope of the claims. The described embodiments are to be considered in all respects as illustrative and not restrictive. It will further be understood that the present invention may suitably comprise, consist of, or consist essentially of the component parts, method steps and limitations disclosed herein. The method and/or apparatus disclosed herein may be practiced in the absence of any element that is not specifically claimed and/or disclosed herein.

(46) While the foregoing advantages of the present invention are manifested in the detailed description and illustrated embodiments of the invention, a variety of changes can be made to the configuration, design and construction of the invention to achieve those advantages. Hence, reference herein to specific details of the structure and function of the present invention is by way of example only and not by way of limitation.

Claims

1. A lighter-than-air (LTA) vehicle interceptor for intercepting a non-cooperative LTA (NCLTA) vehicle having attached threat payload configured to operate aerially above ground, the LTA vehicle interceptor comprising: an airship vehicle platform capable of maneuvering to within an operable distance of the NCLTA vehicle having the attached threat payload; an interceptor payload attached to the airship vehicle platform, the interceptor payload further comprising: a severing effector for engaging with the NCLTA vehicle and the threat payload; and an on-board control subsystem for automated and/or remote control by an operator for controlling the interceptor payload and the severing effector; a power subsystem for powering the interceptor payload and the severing effector; and wherein the onboard control subsystem and the severing effector are configured to cooperate to separate the NCLTA vehicle from the threat payload and return the threat payload to the ground for operator retrieval.

2. The LTA vehicle interceptor of claim 1, wherein the airship vehicle platform is selected from the

group consisting of: a balloon, a dirigible, and an uncrewed aerial vehicle.
3. The LTA vehicle interceptor of claim 1, wherein the airship vehicle platform is also configured to be controlled by the operator.
4. The LTA vehicle interceptor of claim 1, wherein the interceptor payload further comprises: a navigation subsystem configured for sensing and providing location data for the LTA vehicle interceptor; at least one imaging device configured for gathering and providing imaging data of the NCLTA vehicle; a communications subsystem configured for transmitting the location data and the imaging data to the operator; and an on-board control subsystem in communication with, and configured for controlling, the navigation subsystem, the at least one imaging device and the communications subsystem under operator control.
5. The LTA vehicle interceptor of claim 1, wherein the power subsystem further comprises at least one battery and optionally a solar panel operably coupled to the at least one battery.
6. The LTA vehicle interceptor of claim 1, wherein the severing effector is selected from the group consisting of: scissors, sheers and bolt cutter.
7. The LTA vehicle interceptor of claim 1, wherein the severing effector is connected to a distal end of a movable arm secured to the interceptor payload by a proximal end of the movable arm, the severing effector movable in any direction under operator control.
8. A lighter-than-air (LTA) vehicle interceptor for intercepting a non-cooperative LTA (NCLTA) vehicle having attached threat payload configured to operate aerially above ground, the LTA vehicle interceptor comprising: an airship vehicle platform capable of maneuvering to within an operable distance of the NCLTA vehicle and the attached threat payload; an interceptor payload attached to the airship vehicle platform, the interceptor payload further comprising: a grasping effector configured for engaging the NCLTA vehicle and the threat payload; and an on-board control subsystem configured for automated and/or remote control by an operator for controlling the interceptor payload and the grasping effector; a power subsystem for powering the interceptor payload and the grasping effector; and wherein the onboard control subsystem and the grasping effector cooperate to clamp onto the NCLTA vehicle or the threat payload and return the threat payload to the ground for operator retrieval.
9. The LTA vehicle interceptor of claim 8, wherein the airship vehicle platform is selected from the group consisting of: a balloon, a dirigible, and an uncrewed aerial vehicle.
10. The LTA vehicle interceptor of claim 8, wherein the airship vehicle platform is also configured to be controlled by the operator.
11. The LTA vehicle interceptor of claim 8, wherein the interceptor payload further comprises: a navigation subsystem configured for sensing and providing location data for the LTA vehicle interceptor; at least one imaging device configured for gathering and providing imaging data of the NCLTA vehicle; a communications subsystem configured for transmitting the location data and the imaging data to the operator; and an on-board control subsystem in communication with, and configured for controlling, the navigation subsystem, the at least one imaging device and the communications subsystem under operator control.
12. The LTA vehicle interceptor of claim 8, wherein the power subsystem further comprises at least one battery and optionally a solar panel operably coupled to the at least one battery.
13. The LTA vehicle interceptor of claim 8, wherein the grasping effector is selected from the group consisting of: clamp, grappling hook and net.
14. The LTA vehicle interceptor of claim 8, wherein the grasping effector is connected to a distal end of a movable arm secured to the interceptor payload by a proximal end of the movable arm, the grasping effector movable in any direction under operator control.
15. The LTA vehicle interceptor of claim 8, wherein the interceptor payload and the grasping effector is located at the top of the airship vehicle platform to facilitate grasping the NCLTA vehicle or the threat payload from underneath the NCLTA vehicle or the threat payload.
16. A lighter-than-air (LTA) vehicle interceptor for intercepting a non-cooperative LTA (NCLTA) vehicle having attached threat payload configured to operate aerially above ground, the LTA vehicle

interceptor comprising: an airship vehicle platform capable of maneuvering to within an operable distance of the NCLTA vehicle and the attached threat payload; an interceptor payload attached to the airship vehicle platform, the interceptor payload further comprising: a puncturing effector configured for engaging the NCLTA vehicle and the threat payload; and an on-board control subsystem configured for automated and/or remote control by an operator for controlling the interceptor payload and the puncturing effector; a power subsystem configured for powering the interceptor payload and the puncturing effector; and wherein the on-board control subsystem and the puncturing effector are configured to cooperate to reduce buoyancy of the NCLTA vehicle and the threat payload and return the threat payload to the ground for operator retrieval.
17. The LTA vehicle interceptor of claim 16, wherein the airship vehicle platform is selected from the group consisting of: a balloon, a dirigible, and an uncrewed aerial vehicle.
18. The LTA vehicle interceptor of claim 16, wherein the airship vehicle platform is also configured to be controlled by the operator.
19. The LTA vehicle interceptor of claim 16, wherein the interceptor payload further comprises: a navigation subsystem configured for sensing and providing location data for the LTA vehicle interceptor; at least one imaging device configured for gathering and providing imaging data of the NCLTA vehicle; a communications subsystem configured for transmitting the location data and the imaging data to the operator; and an on-board control subsystem in communication with, and configured for controlling, the navigation subsystem, the at least one imaging device and the communications subsystem under operator control.
20. The LTA vehicle interceptor of claim 16, wherein the power subsystem further comprises at least one battery and optionally a solar panel operably coupled to the at least one battery.
21. The LTA vehicle interceptor of claim 16, wherein the puncturing effector is selected from the group consisting of: knife, needle, spear, arrow and bolt.
22. The LTA vehicle interceptor of claim 16, wherein the puncturing effector is connected to a distal end of a movable arm secured to the interceptor payload by a proximal end of the movable arm, the puncturing effector movable in any direction under operator control.
23. A method for intercepting a non-cooperative lighter-than-air (NCLTA) vehicle including an envelope configured for up to stratospheric buoyancy and a threat payload suspended from the envelope by rigging, the method comprising: providing a lighter-than-air (LTA) vehicle interceptor configured for intercepting the NCLTA vehicle and the threat payload operating aerially above ground, the LTA vehicle interceptor further configured with a plurality of effectors for engaging the NCLTA vehicle and/or the threat payload; deploying the LTA vehicle interceptor from a location below the NCLTA vehicle; navigating the LTA vehicle interceptor to within an operational distance away from the NCLTA vehicle; engaging the NCLTA vehicle and/or the threat payload with at least one of the plurality of effectors to disable the NCLTA vehicle; securing the threat payload to the LTA vehicle interceptor; and returning the threat payload safely to the ground.
24. The method of claim 23, wherein the plurality of effectors comprises at least one each of: a severing effector, a grasping effector and a puncturing effector.