US012383639B2

(12) **United States Patent**
Barrios Sierra et al.

(10) **Patent No.: US 12,383,639 B2**
(45) **Date of Patent: Aug. 12, 2025**

(54) **DIRECTIONAL ULTRAVIOLET PROJECTION DEVICES AND RELATED METHODS OF USE**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 918 days.

(21) Appl. No.: **17/319,166**

(22) Filed: **May 13, 2021**

(65) **Prior Publication Data**

US 2022/0152237 A1 May 19, 2022

Related U.S. Application Data

(60) Provisional application No. 63/115,454, filed on Nov. 18, 2020.

(51) **Int. Cl.**
A61L 2/10 (2006.01)

(52) **U.S. Cl.**
CPC ***A61L 2/10*** (2013.01); *A61L 2202/11* (2013.01); *A61L 2202/16* (2013.01)

(58) **Field of Classification Search**
CPC A61L 2/10; A61L 2202/11; A61L 2202/16; A61L 9/20; A61L 2202/14; A61L 2202/25
See application file for complete search history.

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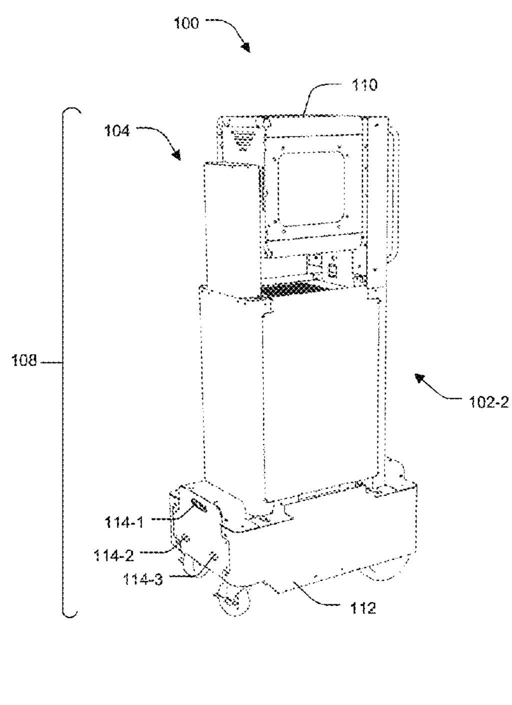
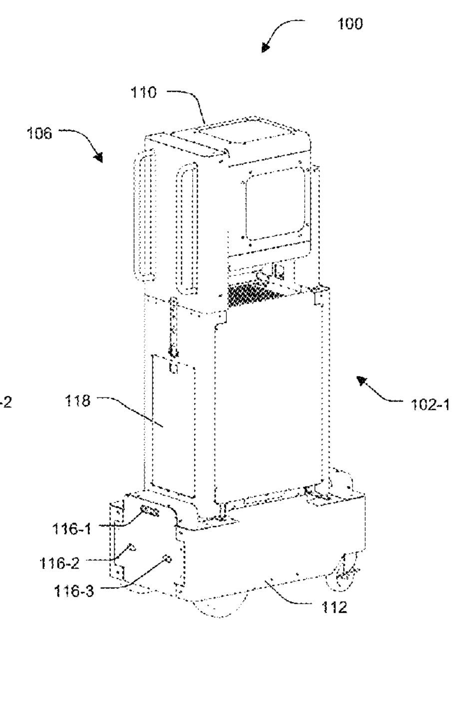
(57) **ABSTRACT**

Embodiments of the present disclosure provide an apparatus and a method for projecting UV light towards surfaces across a path. The apparatus includes a mobile body and including opposing lateral sides and a sagittal plane passing between them. The apparatus also includes a projection head rotatably mounted to the mobile body. The projection head operates to project UV light directionally towards surfaces located above and proximate to the opposing lateral sides, where the projection head is adapted to rotate about a horizontal axis in the sagittal plane while the UV light is being projected towards the surfaces.

19 Claims, 14 Drawing Sheets





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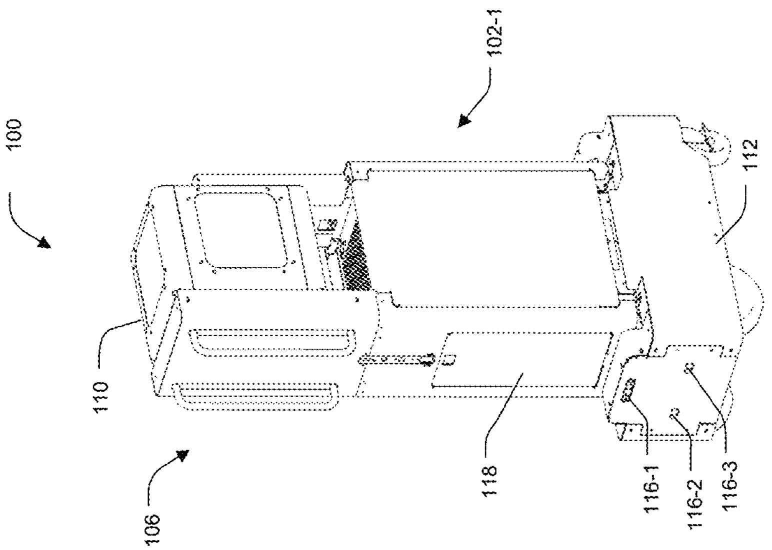
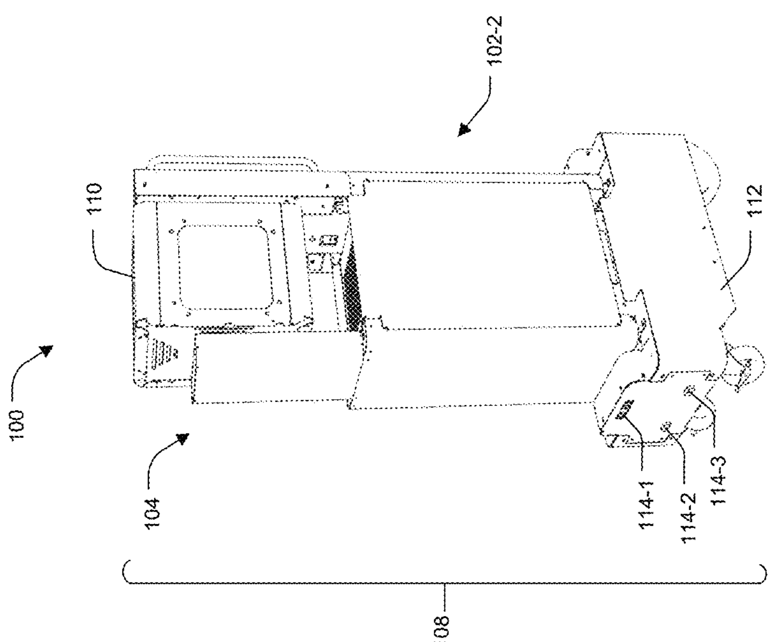

100
102-1
110
106
118
116-1
116-2
116-3
112

FIG. 1B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114-2
114-3
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FIG. 1A

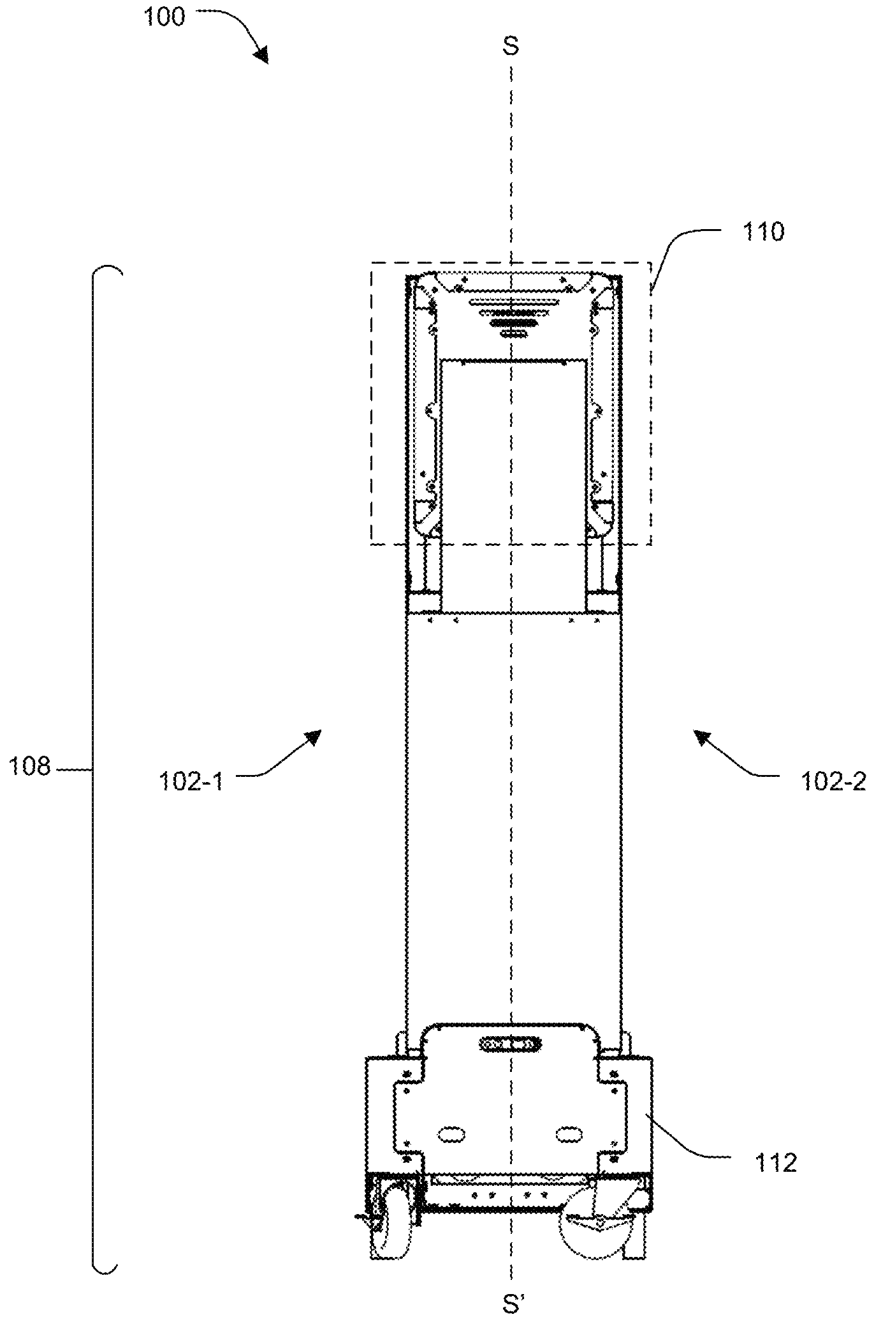
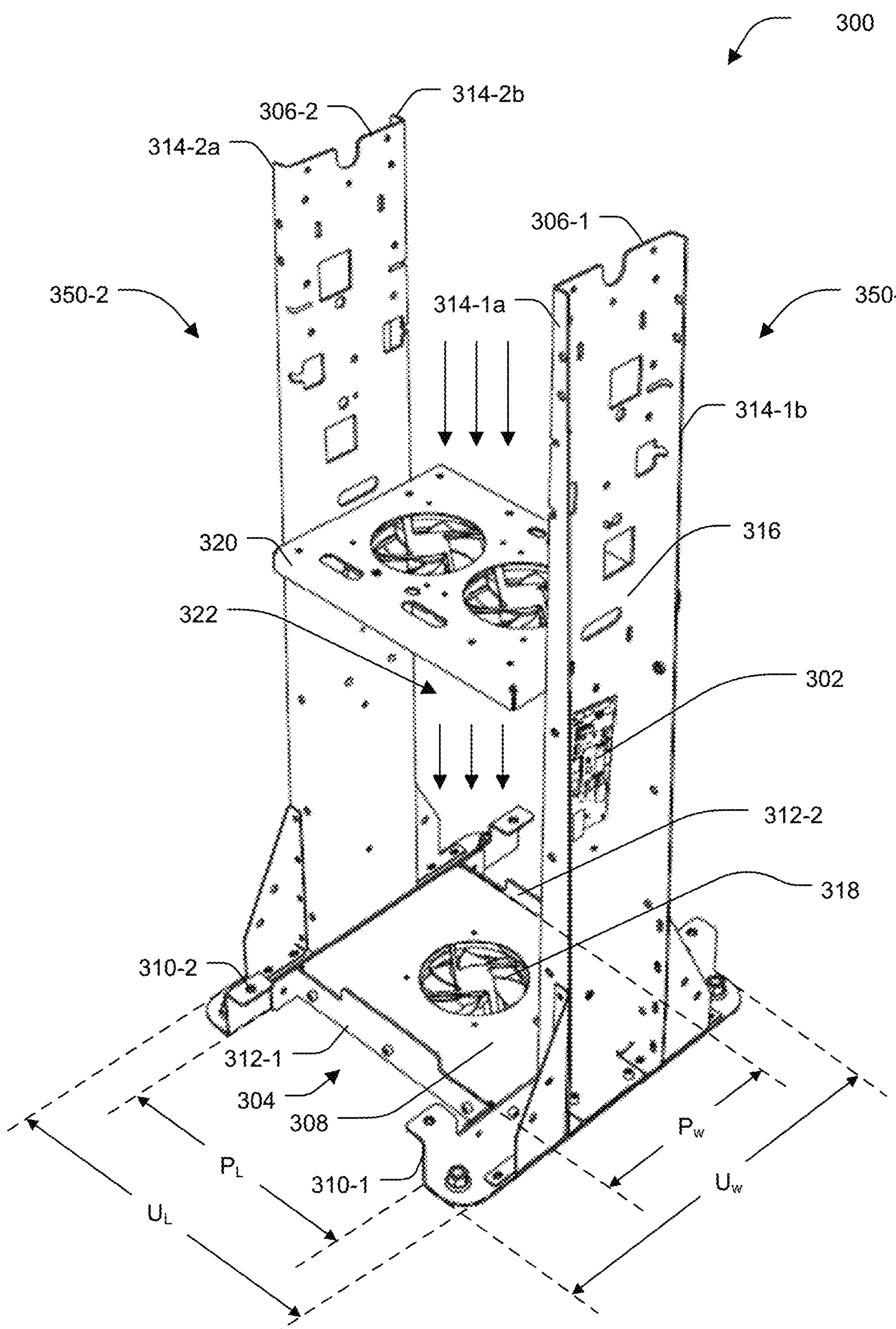


FIG. 2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306-2
314-2b
314-2a
306-1
350-2
314-1a
350-1
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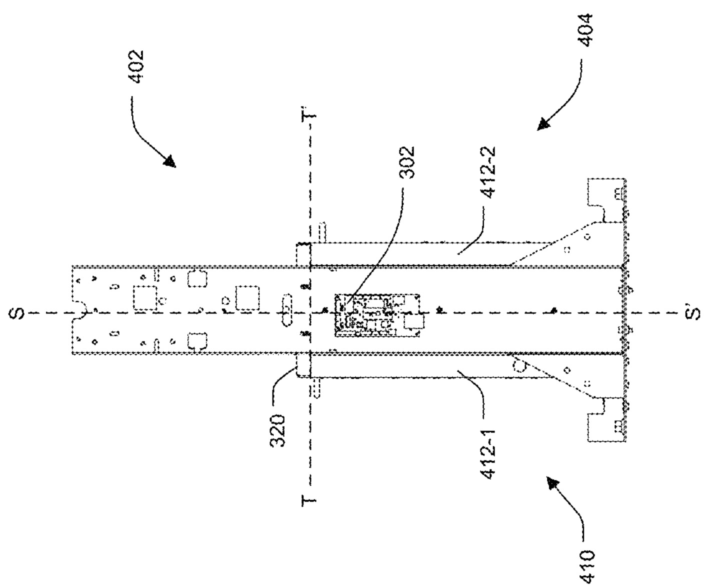
320
316
322
302
312-2
318
310-2
312-1
304
308
P_W
P_L
310-1
U_W
U_L

FIG. 3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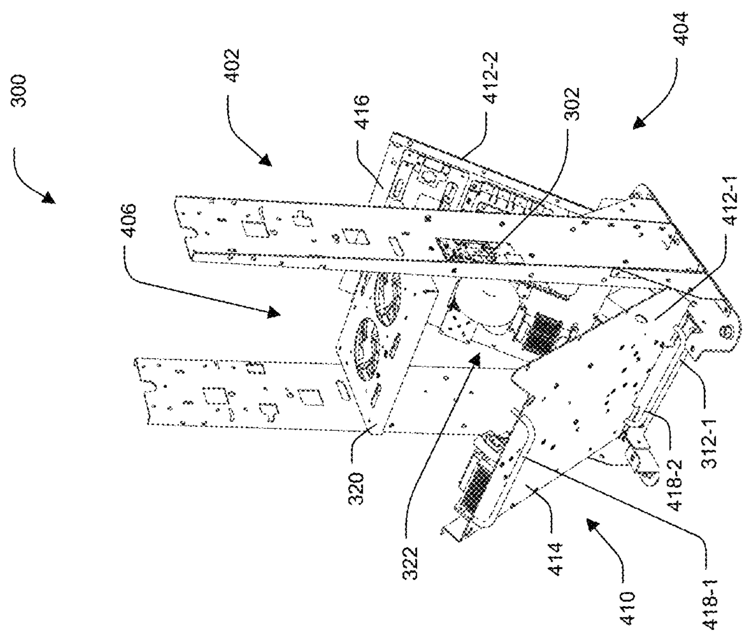
402
404
302
412-2
S
S'
T
T'
320
412-1
410

FIG. 4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402
406
416
412-2
302
404
412-1
320
322
312-1
418-2
414
410
418-1

FIG. 5

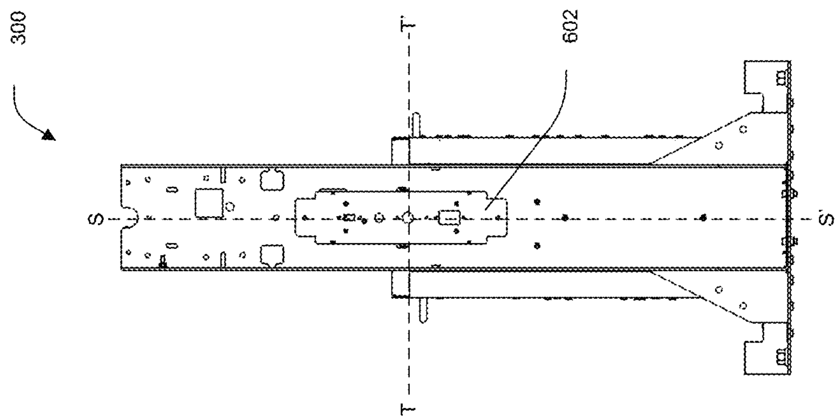


FIG. 7

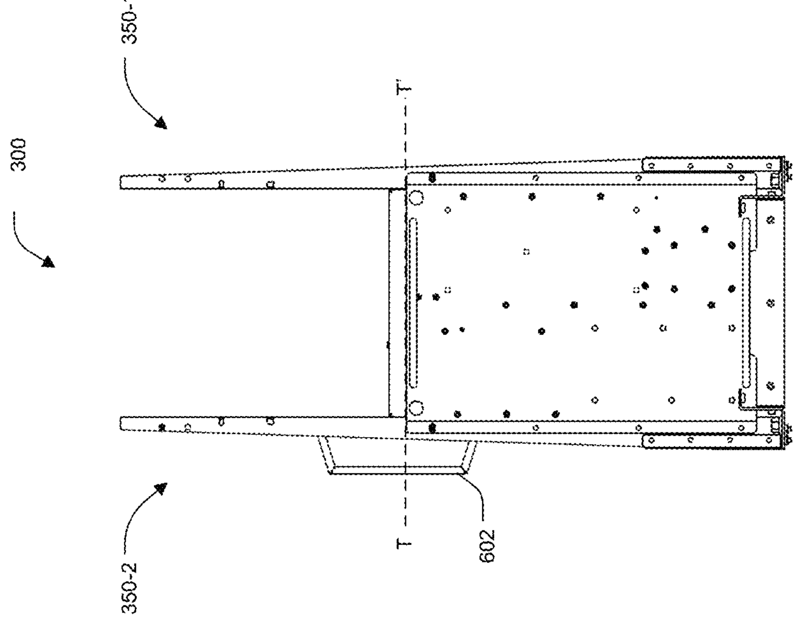
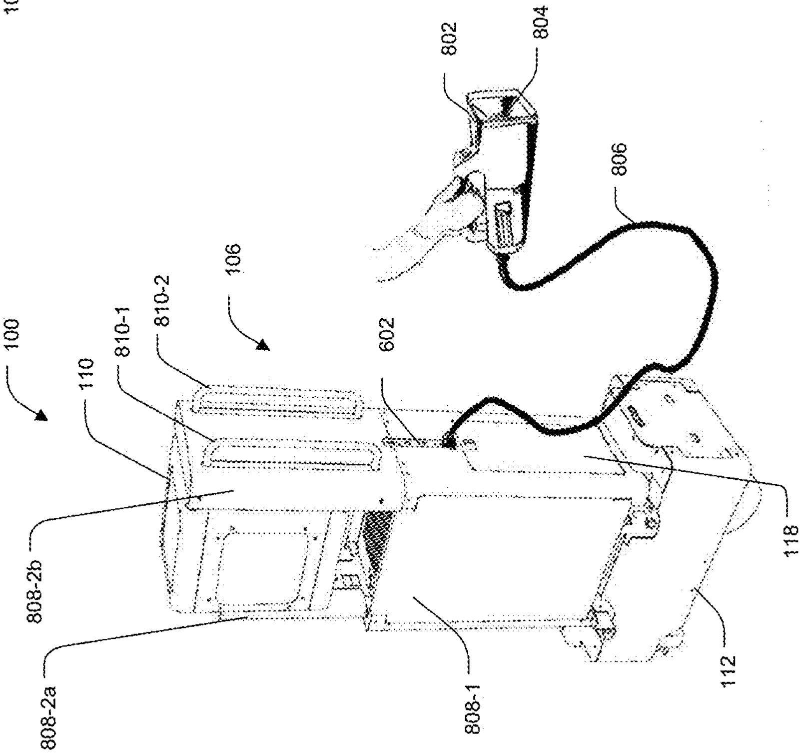


FIG. 6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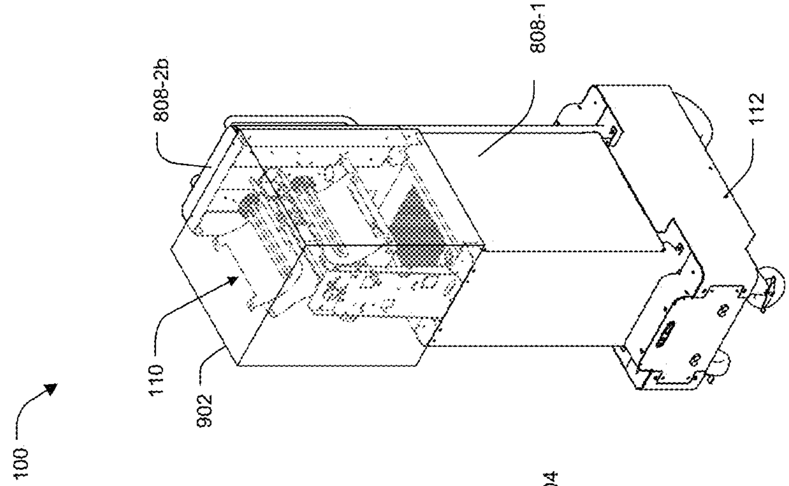
110
810-1
810-2
106
808-2b
808-2a
602
802
804
806
808-1
118
112

FIG. 8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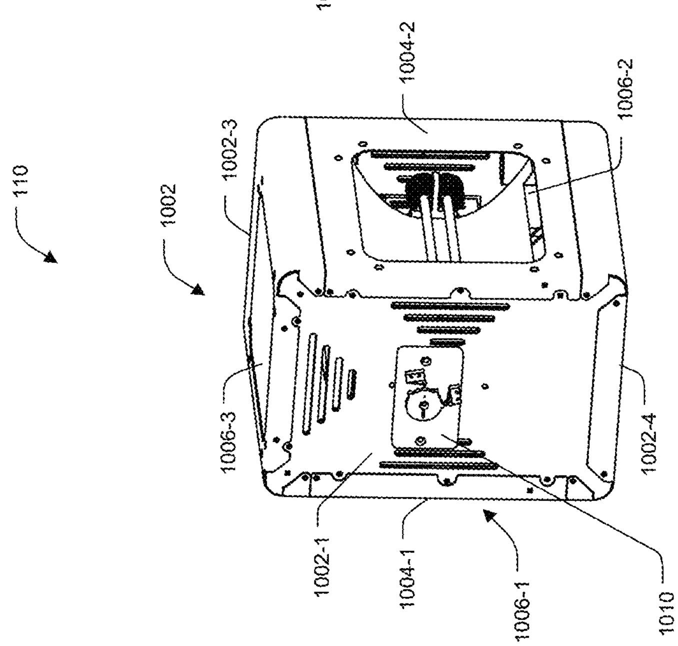
902
110
808-2b
808-1
112

FIG. 9


110
1002
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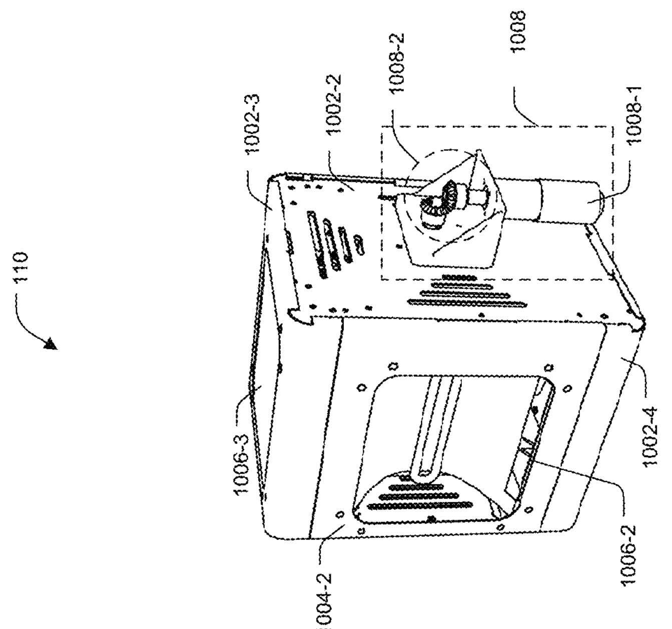
1004-2
1006-2
1006-3
1002-4
1002-1
1004-1
1006-1
1010

FIG. 10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1002-3
1002-2
1008-2
1008
1008-1
1006-3
1002-4
1006-2
1004-2

FIG. 11

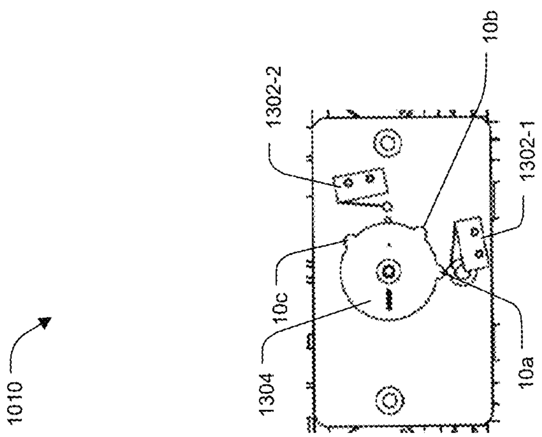

1010
1302-2
10b
1302-1
10c
1304
10a

FIG. 13

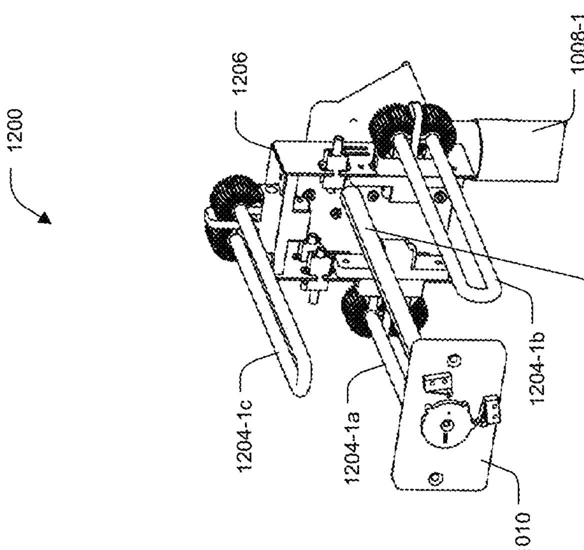

1200
1206
1008-1
1204-1c
1204-1a
1204-1b
1012
1010

FIG. 12

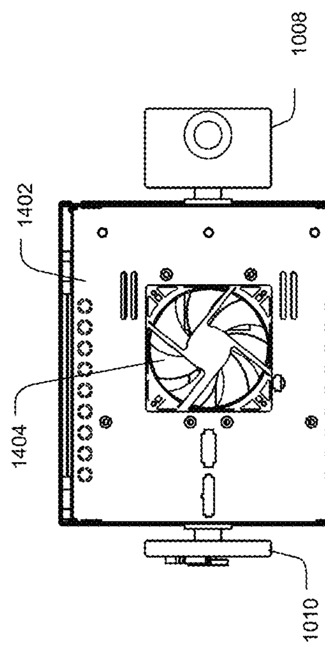

1008
1402
1404
1010

FIG. 15

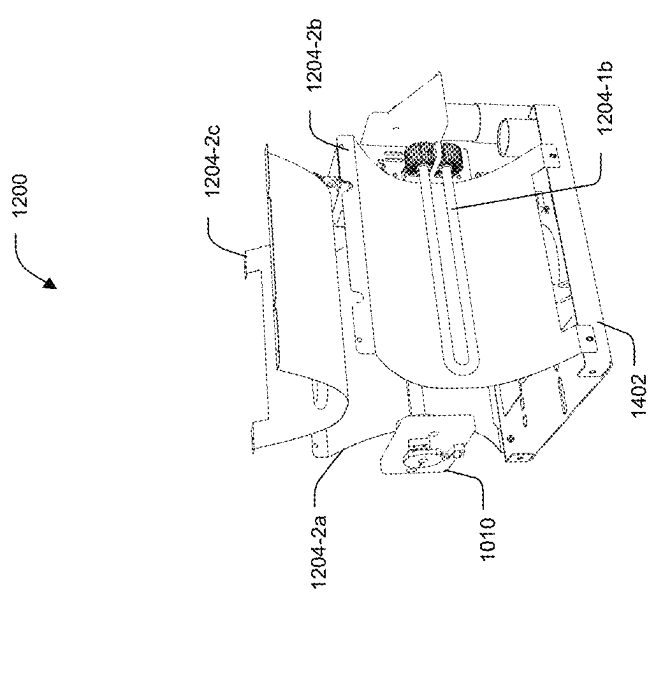

1200
1204-2c
1204-2b
1204-1b
1402
1010
1204-2a

FIG. 14

FIG. 16A

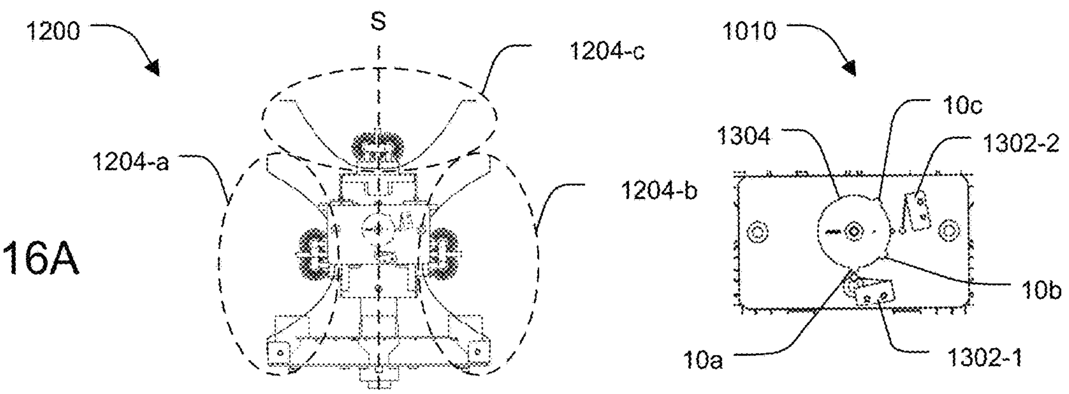


FIG. 16B

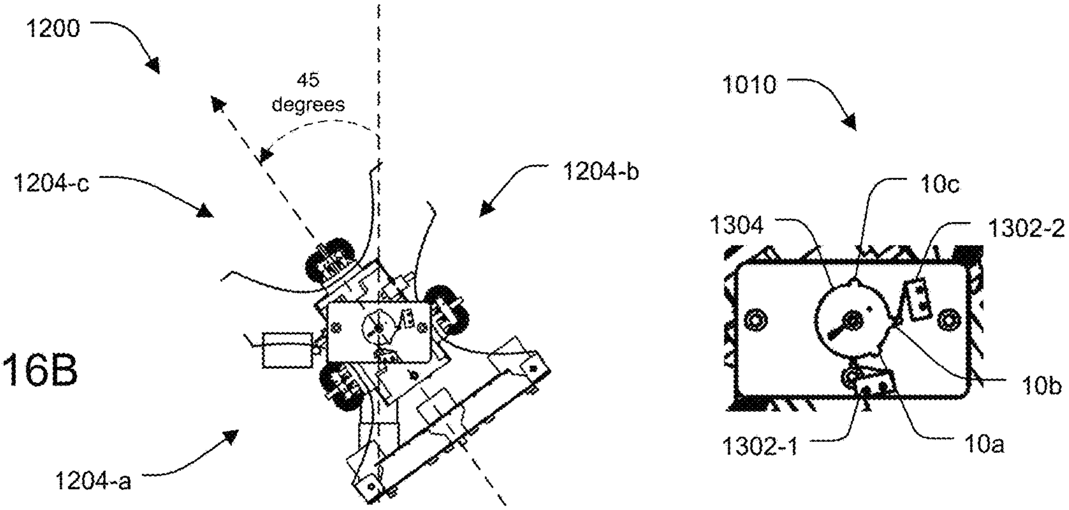
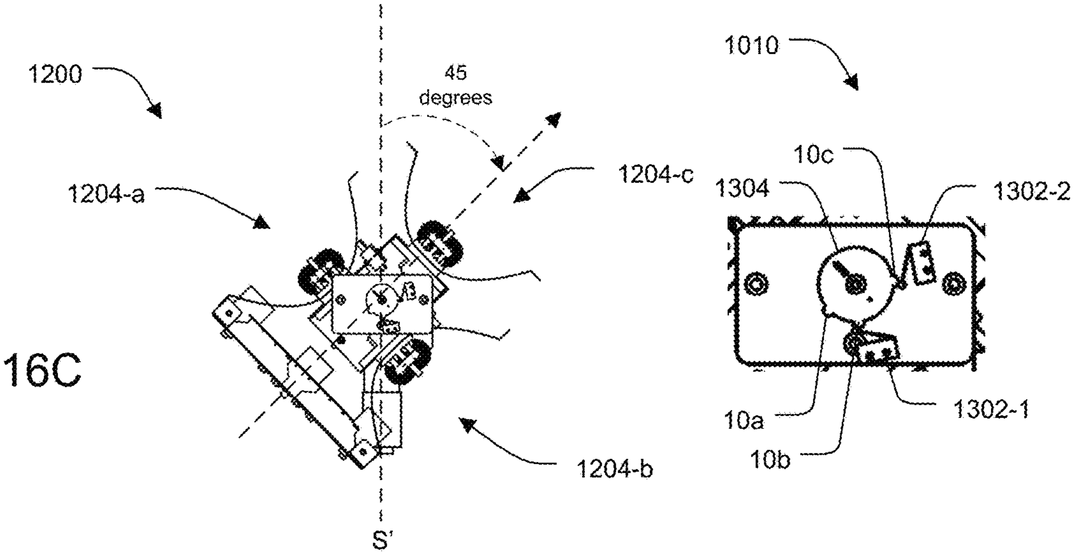


FIG. 16C



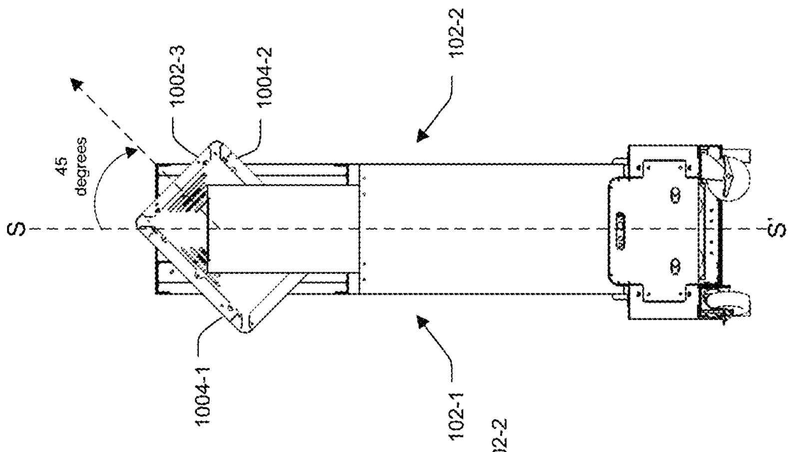


FIG. 17C

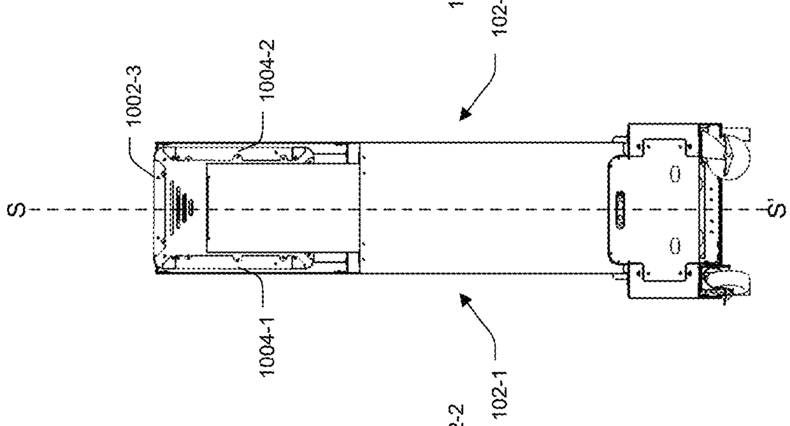


FIG. 17A

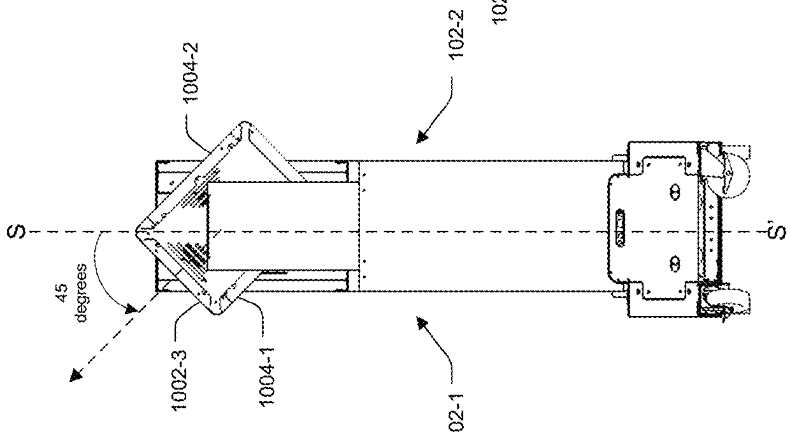


FIG. 17B

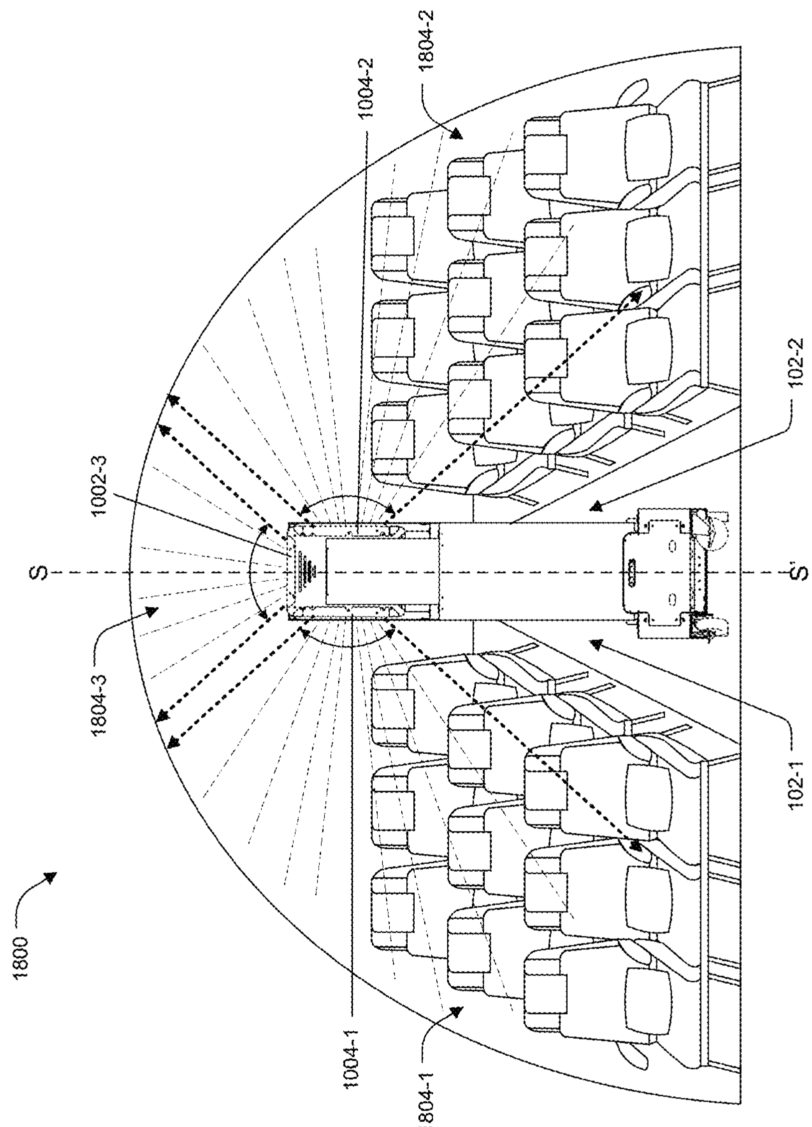


FIG. 18A

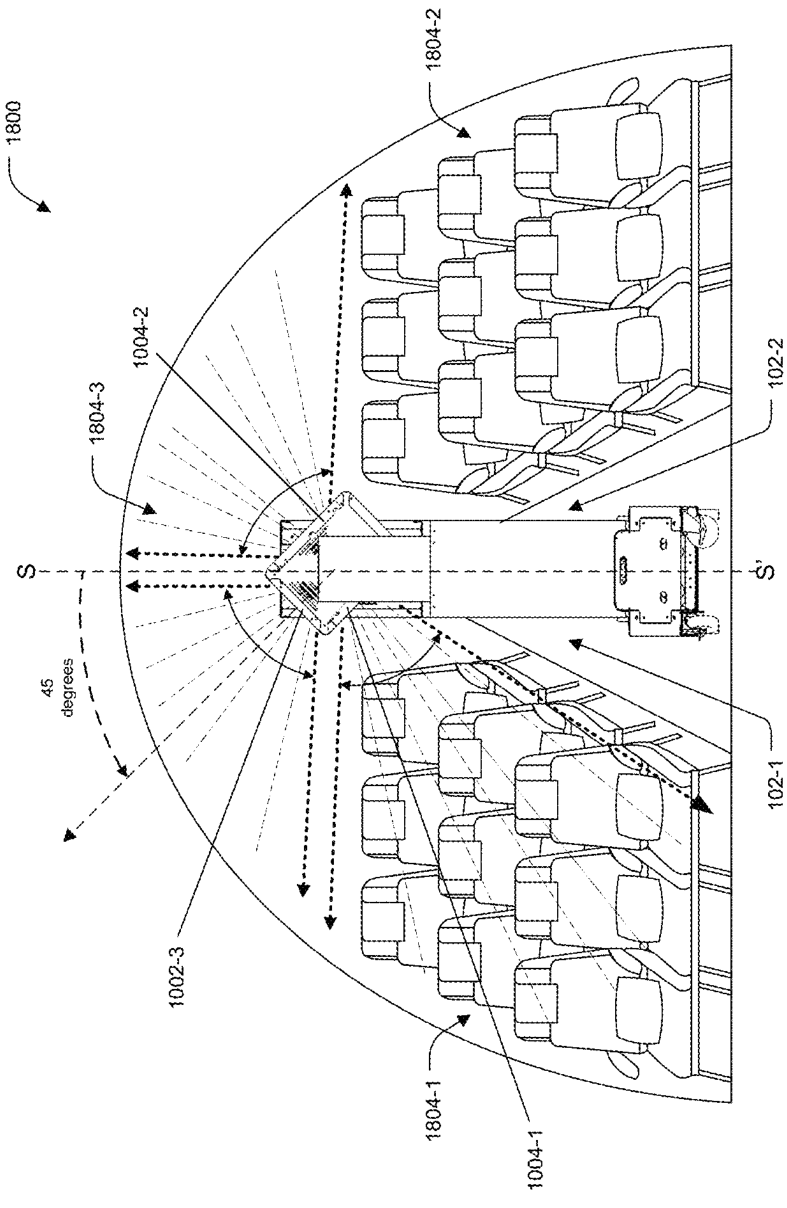
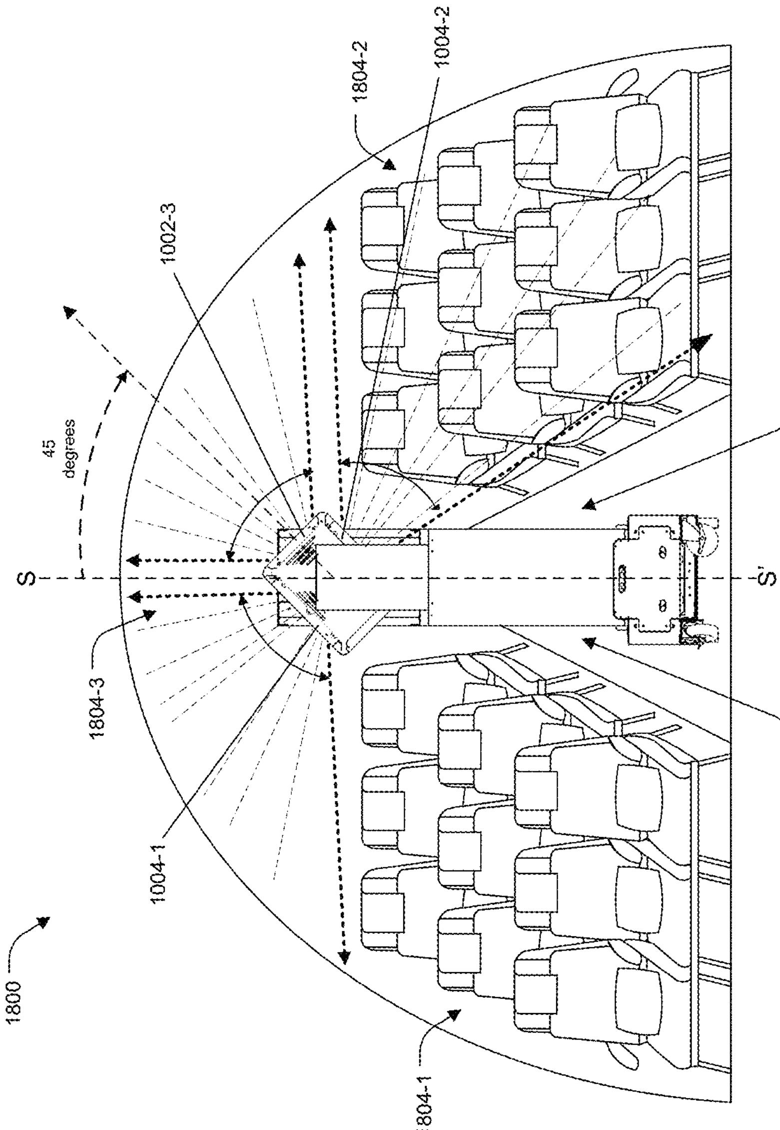

1800
1804-2
1004-2
1804-3
102-2
S
S'
45
degrees
102-1
1002-3
1804-1
1004-1

FIG. 18B



1800
1804-1
1804-2
1804-3
1004-1
1004-2
1002-3
45 degrees
S
S'
102-1
102-2

FIG. 18C

DIRECTIONAL ULTRAVIOLET PROJECTION DEVICES AND RELATED METHODS OF USE

TECHNICAL FIELD

The present disclosure generally relates to disinfection devices and particularly relates to directional ultraviolet projection devices and related methods of use.

BACKGROUND

Rapid surface disinfection is cardinal to a safe and productive work environment. Modern disinfection devices often include a source of ultraviolet (UV) light for surface disinfection. These devices typically project UV light in a single direction at any given instant to limit surface coverage and disinfection per unit time, or randomly project UV light in all directions to heighten energy wastage for disinfecting surfaces in a specific direction or plane.

SUMMARY

A traditional approach for directional disinfection of surfaces, e.g., across a path, includes a device mounted with one or more arms (or wings) fitted with UV lamps. The arms typically extend linearly or rotatably out of the device to deploy the UV lamps near the surfaces during operation. Such increase in arm geometry to set up the device for operation amplifies the total time required for sanitizing an area, operational costs, and area downtime. Moreover, each arm generally couples to a separate moving assembly for extension and orients the UV lamps to project UV light only towards surfaces on a single side of the device. Hence, such a conventional device relies on implementing multiple arms (or otherwise, compromise surface coverage) to increase the device manufacturing time and costs.

One embodiment of the present disclosure includes an apparatus for projecting UV light towards surfaces across a path. The apparatus includes a mobile body including opposing lateral sides and a sagittal plane passing between them. The apparatus also includes a projection head rotatably mounted to the mobile body. The projection head may operate to project UV light directionally towards surfaces located above and proximate to the opposing lateral sides, where the projection head is adapted to rotate about a horizontal axis in the sagittal plane while the UV light is being projected towards the surfaces.

Another embodiment of the present disclosure includes a method of projecting UV light towards surfaces across a path. The method includes providing a projection head including a mobile body having opposing lateral sides and a sagittal plane passing between them; projecting UV light from the projection head directionally towards surfaces located above and proximate to the opposing lateral sides; and rotating the projection head about a horizontal axis in the sagittal plane while the UV light is being projected towards the surfaces.

The above summary of exemplary embodiments is not intended to describe each disclosed embodiment or every implementation of the present disclosure. Other and further aspects and features of the disclosure would be evident from reading the following detailed description of the embodiments, which are intended to illustrate, not limit, the present disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

The illustrated embodiments of the subject matter will be best understood by reference to the drawings, wherein like

parts are designated by like numerals throughout. The following description is intended only by way of example, and simply illustrates certain selected embodiments of devices, systems, and processes that are consistent with the subject matter as claimed herein.

FIG. **1**A is a front perspective view of an exemplary directional UV projection device (or projection device), according to an embodiment of the present disclosure.

FIG. **1**B is a rear perspective view of the projection device of FIG. **1**A, according to an embodiment of the present disclosure.

FIG. **2** is a front elevation view of the projection device of FIG. **1**A, according to an embodiment of the present disclosure.

FIG. **3** is a front perspective view of an exemplary uniframe including a cooling system for the projection device of FIG. **1**A, according to an embodiment of the present disclosure.

FIG. **4** is a front elevation view of the uniframe of FIG. **3** including an exemplary tray assembly in a closed position, according to an embodiment of the present disclosure.

FIG. **5** is a front perspective view of the uniframe of FIG. **3** including the tray assembly of FIG. **4** in an open position, according to an embodiment of the present disclosure.

FIG. **6** is a left elevation view of the uniframe of FIG. **4** including an exemplary auxiliary frame, according to an embodiment of the present disclosure.

FIG. **7** is a rear elevation view of the uniframe of FIG. **4** including the auxiliary frame of FIG. **6**, according to an embodiment of the present disclosure.

FIG. **8** is a rear perspective view of the projection device of FIG. **1**A coupled to an exemplary handheld device, according to an embodiment of the present disclosure.

FIG. **9** is a front perspective view of the projection device of FIG. **1**A including an exemplary optically permeable housing, according to another embodiment of the present disclosure.

FIG. **10** is a front perspective view of an exemplary projection head in a closed configuration coupled to a rotation assembly for the projection device of FIG. **1**A, according to an embodiment of the present disclosure.

FIG. **11** is a rear perspective view of the projection head of FIG. **10**, according to an embodiment of the present disclosure.

FIG. **12** is a front perspective view of an exemplary lamp assembly without reflectors and coupled to the rotation assembly for the projection head of FIG. **10**, according to an embodiment of the present disclosure.

FIG. **13** illustrates an exemplary sensor block for the rotation assembly of FIG. **10** and FIG. **12**, according to an embodiment of the present disclosure.

FIG. **14** is a front perspective view of the projection head of FIG. **10** in an open configuration including the lamp assembly of FIG. **12**, according to an embodiment of the present disclosure.

FIG. **15** is a bottom elevation view of the projection head of FIG. **10** including a cooling unit, according to an embodiment of the present disclosure.

FIGS. **16**A-**16**C illustrate an exemplary operation of the projection head of FIG. **14** for implementing the projection device of FIG. **1**A, according to an embodiment of the present disclosure.

FIGS. **17**A-**17**C illustrate an exemplary operation of the projection head of FIG. **10** for implementing the projection device of FIG. **1**A, according to an embodiment of the present disclosure.

FIGS. **18**A-**18**C illustrate an exemplary scenario to implement the projection device of FIG. **1**A for surface disinfection, according to an embodiment of the present disclosure.

DETAILED DESCRIPTION

The following detailed description is provided with reference to the drawings herein. Exemplary embodiments are provided as illustrative examples so as to enable those skilled in the art to practice the disclosure. It will be appreciated that further variations of the concepts and embodiments disclosed herein can be contemplated. The examples of the present disclosure described herein may be used together in different combinations. In the following description, details are set forth in order to provide an understanding of the present disclosure. It will be readily apparent, however, that the present disclosure may be practiced without limitation to all these details. Also, throughout the present disclosure, the terms "a" and "an" are intended to denote at least one of a particular element. The terms "a" and "an" may also denote more than one of a particular element. As used herein, the term "includes" means includes but not limited to, the term "including" means including but not limited to. The term "based on" means based at least in part on, the term "based upon" means based at least in part upon, and the term "such as" means such as but not limited to. The term "approximately" means a variation of +/−5% in a stated number or a value of a stated parameter. Further, in the present disclosure, an embodiment showing a singular component should not be considered limiting; rather, the present disclosure is intended to encompass other embodiments including a plurality of the same or similar component, and vice-versa, unless explicitly stated otherwise herein. The present disclosure also encompasses present and future known equivalents of the components referred to herein.

Non-Limiting Definitions

Definitions of one or more terms that will be used in this disclosure are described below without limitations. For a person skilled in the art, it is understood that the definitions are provided only for the sake of clarity and are intended to include more examples than just provided below.

A term "software product" is used in the present disclosure in the context of its broadest definition. The software product may refer to a computer code implemented on a computer readable medium and operable to control or influence an intended function or task.

A term "software patch" is used in the present disclosure in the context of its broadest definition. The "software patch" may refer to a computer code designed to operate in combination with the software product. In some examples, the software patch may be an incomplete version of the software product.

A term "path" is used in the present disclosure in the context of its broadest definition. The path may refer to a passage between opposing surfaces. In one example, at least one of the opposing surfaces includes a portion of the ground. In another example, one of the opposing surfaces includes an elevated surface relative to the other. Other examples may include one of the opposing surfaces being positioned or oriented at a non-zero angle relative to a horizontal axis.

A term "sagittal plane" is used in the present disclosure in the context of its broadest definition. The sagittal plane may refer to an imaginary plane extending from a rear to a front of a component or device. The sagittal plane may divide such component or device into left and right parts. The sagittal plane may pass through a center of the component or device to split it into two halves; however, other examples may include the sagittal plane being off centered to split the component or device into unequal left and right parts.

A term "operational cycle" is used in the present disclosure in the context of its broadest definition. The operational cycle may refer to a period during which a device or component may be active for performing an intended task/operation. In some examples, the operational cycle may be predefined or dynamically defined based on clock times, a type of task (e.g., disinfection, communication, navigation, etc.), and a type of location (e.g., aircraft, room, auditorium, etc.) where such device or component may be intended for use.

Exemplary Embodiments

FIGS. **1**A-**1**B are perspective views of an exemplary directional UV projection device, according to an embodiment of the present disclosure. The directional UV projection device **100** (hereinafter referred to as projection device **100**) may be configured for a projection of a germicide directionally towards surfaces in planes above and lateral thereto. The germicide may include UV light alone or in combination with any other suitable types of energies or complementing agents. Examples of such energies may include, but are not limited to, radio, microwave, x-ray, infrared, visible, or any other specific wavelength or group of wavelengths in the electromagnetic spectrum. On the other hand, examples of such complementing agents may include, but are not limited to, chemical agents (e.g., alcohols, aldehydes, oxidizing agents, naturally occurring or modified compounds, etc.), physical agents (e.g., heat, pressure, vibration, sound, radiation, plasma, electricity, etc.), and biological agents (e.g., living organisms, plants or plant products, assistive-pathogens, organic residues, etc.) for catalyzing or effecting disinfection. In some instances, a type of energy or agent for use with the UV light may be selected based on an intended effect or an intended operation linked to a component of the projection device **100**. Further, the projection device **100** may be operable to communicate with a computing device (not shown) over a wired or wireless network. Examples of such computing device may include, but are not limited to, a desktop computer, a personal digital assistant (PDA), a server, a mainframe computer, a mobile computing device (e.g., mobile phones, laptops, tablets, etc.), an internet appliance (e.g., a modem, a wireless access point, a router, a base station, a gateway, etc.), and so on.

The projection device **100** may be implemented as a standalone and/or dedicated mobile or portable device including hardware and installed software, where the hardware is closely matched to the requirements and/or functionality of the software for enabling localized as well as remote operations. In one embodiment, the projection device **100** may be implemented to, at least one of, (1) directionally project the germicide such as UV light towards surfaces above and lateral thereto, (2) limit or prevent dispersion of the germicide towards rear and front sides for better energy management while enabling targeted disinfection of surfaces, (3) have a compact geometry and footprint for traversing a narrow path such as an aircraft aisle and minimizing deployment time, (4) move autonomously while directionally projecting the germicide towards these surfaces, (5) selectively rotate or tilt germicide sources while directionally projecting the germicide towards the surfaces, (6) project the germicide in either pulsed and/or continuous manner for an intended operation such as disinfection and optical communication, (7) enable easy and convenient access to operational components for repair and maintenance, (8) include a mobile body having a center of mass proximate to its geometrical center for stability during movements, (9) move the mobile body autonomously while rotating the germicide sources, (10) enable operationally attaching an external peripheral component such as a handheld device thereto, and (11) provide for better cooling of the operational components during operation.

In some other embodiments, the projection device **100** may operate, or undergo inhibited operation with or without a complete halt, in response to one or more aspects of an external object or surface. Examples of such aspects (or object aspects) may include, but are not limited to, position, orientation, elevation, proximity or distance, size, dimensions, electrical input or output (e.g., voltage, current, resistance, pulse characteristics such as pulse width, duty cycle, amplitude, phase, frequency, shape, etc.), a type of electrical input or output (e.g., cumulative, additive, differential, referential, etc.), a type of non-electrical input or output (e.g., electromagnetic radiation such as UV light, infrared light, and visible light; a chemical agent, a physical agent, a biological agent, etc.), motion, direction, angle, range/proximity, and field of view. Further, the external object may be, wholly or in-part, active, stationary, mobile, wearable, and/or portable. The external object, in some examples, may be operationally coupled to a standalone or networked device in communication with the projection device **100**. The networked device (e.g., via a sensor) may cause to operate, cease to operate, the projection device and/or exchange data therewith. In a further example, the external object may include a component or portion coupled to the projection device **100**. For instance, the external object may include a first part attached to the projection device **100** and a second part operably coupled to the first part, where the second part may be located remote from the first part or the projection device **100**. Other examples may include the external object including another device similar to the projection device **100**.

Embodiments of the projection device **100** may also include a variety of known, related art, or later developed interface(s), including software interfaces (e.g., application programming interfaces, a graphical user interfaces, software ports, network sockets, etc.); hardware interfaces (e.g., cables, cable connectors, plugs, hardware ports and sockets, keyboards, magnetic or barcode readers, biometric scanners, interactive display screens, etc.); or both. The interface(s) may facilitate communication between various devices or components operationally coupled to the projection device **100**. In some embodiments, the interface(s) may facilitate communication with computing devices such as those mentioned above.

The projection device **100** may also, independently or in communication with another device, have video, voice, or data communication capabilities (e.g., unified communication capabilities). For example, the projection device **100**, or a remote device operationally coupled thereto, may include an imaging device (e.g., camera, printer, scanner, medical imaging device/system, etc.), an audio device (e.g., microphone, audio player, audio recorder, telephone, speaker, etc.), a video device (e.g., monitor/display screen, image projector, television, video recorder, etc.), and a sensor, or any other types of hardware commensurate with predefined or dynamically defined functions of the projection device **100**, or a component thereof. Types of such sensor may include, but are not limited to, temperature sensors, proximity sensors (e.g., inductive, capacitive, photoelectric, ultrasonic, light detection and ranging (LIDAR), etc.), pressure sensors, chemical sensors, gas sensors, smoke sensors, level sensors, infrared sensors, image sensors, accelerometers, gyroscopes, optical sensors (e.g., dose sensors, intensity sensors, pulse sensors, etc.), and humidity sensors. The projection device **100** may additionally facilitate data transfer to a computing device or a computer readable medium (CRM).

As illustrated in FIGS. **1A-1B**, in one embodiment, the projection device **100** may include a mobile body **108** and a projection head **110**. The mobile body **108** may include a first lateral side **102-1**, a second lateral side **102-2** (hereinafter collectively referred to as lateral sides **102**), a front side **104**, and a rear side **106**. The lateral sides **102** may extend between the front side **104** and the rear side **106**. The first lateral side **102-1** may be located opposite to the second lateral side **102-2**. The lateral sides **102** may be separated by a sagittal plane SS' (shown in FIG. **2**) passing therebetween. The sagittal plane SS' may pass through a center of the projection device **100**, or components thereof such as the mobile body **108** and the projection head **110**; however, other examples may include the sagittal plane SS' being off-centered. The sagittal plane SS' may extend from the rear side **106** to the front side **104** and divide the projection device **100**, or the components therealong, into left and right parts. The mobile body **108** may include an assembly of parts configured to support, operate, and/or navigate the projection device **100** or any components thereof. The mobile body **108** may be adapted to traverse an intended path.

The mobile body **108** may include at least one mobility device operating to drive the projection device **100** along a path and/or over a surface. The mobility device may be motorized or non-motorized. The mobility device may be automated or configurable for manual operation. Any suitable type of mobility device may be contemplated to spatially move the projection device **100** based on any suitable motion principle known in the art including friction, magnetic or cryogenic levitation, and air-dependent or air-independent propulsion based on the path to be traversed. Examples of the mobility device may include, but are not limited to, a set of one or more wheels (e.g., omnidirectional wheels, caster wheels, etc.), a propeller, and an impeller. In one embodiment, as illustrated in FIGS. **1A-1B**, the mobility device may be adapted as an autonomous vehicle **112** to spatially drive the projection device **100**. The autonomous vehicle **112** may include rear motorized wheels (or drive wheels) and front non-motorized wheels (e.g., caster wheels). In some examples, the autonomous vehicle **112** may also implement turning mechanisms (e.g., an additional turning wheel positioned orthogonal to the drive wheels) to turn or rotate the projection device **100** about a vertical axis (e.g., a central or a lateral axis) of the autonomous vehicle **112** or the device **100**. The autonomous vehicle **112** may include a platform (not shown) to mount or support various components of the projection device **100**. In one example, the platform may be defined by a top surface of the autonomous vehicle **112**; however, some examples may include the platform being defined by a surface lateral to the autonomous vehicle **112**. Other examples may include the platform being a distinct component coupled to the autonomous vehicle **112**.

The autonomous vehicle **112** may further include one or more types of sensors such as those mentioned above. In the illustrated example, the autonomous vehicle **112** includes a set of camera **114-1** and ultrasonic sensors **114-2**, **114-3** (collectively referred to as front sensors **114**), and another set of camera **116-1** and ultrasonic sensors **116-2**, **116-3** (collectively referred to as rear sensors **116**). The front sensors **114** and the rear sensors **116** may be positioned proximate to external surfaces, e.g., along the front side **104** and the rear side **106** respectively, of the projection device **100**. The sensors **114**, **116** may detect various aspects, including those noted above, of any external object proximate to the projection device **100** and assist in navigating the mobile body **108** along an intended path. The autonomous vehicle **112** may be operationally coupled to a control system of the projection device **100**. The control system may operate alone or in combination with a remote computing device to control the autonomous vehicle **112**. For example, the control system may communicate with the front sensors **114** and the rear sensors **116** to manipulate speed, a direction of motion or rotation, or any other operational parameters of the autonomous vehicle **112** based on any detected aspects of the external object or surface. The control system may include or couple to a power supply for powering the autonomous vehicle **112** and other components of the projection device **100**. In one example, the power supply may include a battery (not shown) disposed in a battery compartment **118** (FIG. 1B) of the device **100**. The battery may be positioned proximate to an exterior surface of the projection device **100** to provide easy access for charging, replacement, and/or maintenance.

In one embodiment, the mobile body **108** also includes a uniframe **300** serving as an integral frame to mount or support various operational components of the projection device **100**. Examples of the operational components may include, but are not limited to, the projection head **110**, a cooling system, and the control system including a controller **302**. The uniframe **300** may be mounted on to the platform of the autonomous vehicle **112**. The uniframe **300** may be positioned within a set of vertical planes including lateral exterior surfaces (hereinafter collectively referred to as exterior planes) of the autonomous vehicle **112** to ensure that a footprint of the projection device **100** is commensurate with dimensions of an intended path or surface to be traversed. In the illustrated embodiment of FIGS. **3-7**, the uniframe **300** includes a base **304**, a first column **306-1** and a second column **306-2** (hereinafter collectively referred to as columns **306**), and a tray assembly **410** (shown in FIG. **4**). The base **304** may have an H-shape defined by a central plate **308** attached between a first side plate **310-1** and a second side plate **310-2** (hereinafter collectively referred to as side plates **310**). The side plates **310** may have approximately the same lengths (hereinafter referred to as side lengths); however, some examples may include the side plates **310** of different lengths. The side lengths may define a width of the uniframe **300** (or uniframe width U_W), and an extent between outer surfaces of the side plates **310** may define a length of the uniframe **300** (or uniframe length U_L). The uniframe width U_W and the uniframe length U_L may be set based on a supporting platform of a mobility device such as the autonomous vehicle **112** and a path to be traversed by the projection device **100**. The central plate **308** may have a width (hereinafter referred to as plate width P_W) extending along a longitudinal axis of the side plates **310**. The plate width P_W may be relatively smaller than the uniframe width U_W. The plate width P_W may depend on a number and type(s) of components and/or compartments to be arranged with or proximate to the central plate **308**.

In the illustrated example, the central plate **308** has a first lateral surface and a second lateral surface (hereinafter collectively referred to as lateral surfaces). The lateral surfaces (not shown) may extend longitudinally between the side plates **310**. The lateral surfaces may have lengths (hereinafter referred to as plate length P_L) depending on a supporting platform of a mobility device such as the autonomous vehicle **112**. Each of the lateral surfaces along with proximate inner surfaces of the side plates **310** may define a cutout region formed due to the plate width P_W being relatively smaller than the uniframe width U_W. The cutout region may allow the uniframe **300** to accommodate additional components without exceeding the uniframe width U_W and hence, assist to keep the device footprint within the exterior planes. The lateral surfaces may include ridge plates **312** located within the respective proximate cutout regions. For example, the first lateral surface may be attached to a left ridge plate **312-1** and the second lateral surface may be attached to a right ridge plate **312-2**. Each of the right ridge plate **312-2** and the left ridge plate **312-1** (collectively referred to as ridge plates **312**) may have a similar geometry and/or dimensions for ease of construction. The ridge plates **312** may assist to support or restrict movement of an intended component (e.g., trays **412**) of the projection device **100**, discussed below in greater detail. The ridge plates **312** and the side plates **310** may be permanently attached, detachably secured, or formed integral to the base **304** using any suitable connection mechanisms known in the art including, but are not limited to, welding, nut and bolt, and gluing.

Further, the base **304** supports the columns **306** attached thereto. The columns **306** may be arranged perpendicular to the base **304**; however, some examples may include one or more of the columns **306** being tilted relative to the base **304** depending on an intended separation between them. The first column **306-1** may be attached to the first side plate **310-1** and may define a front section **350-1** of the uniframe **300**. The front section **350-1** may be disposed proximate to the front side **104** of the mobile body **108**. The second column **306-2** may be attached to the second side plate **310-2** and may define a rear section **350-2** of the uniframe **300**. The rear section **350-2** may be disposed proximate to the rear side **106** of the mobile body **108**. The columns **306** may be positioned opposite to each other in the same vertical plane; however, some examples may include the columns **306** being located at least partially in different vertical planes. The columns **306** may have similar geometries and dimensions for ease of construction and intended stability of the uniframe **300**. For the sake of brevity, constructional aspects of the first columns **306-1** are discussed here in detail; however, one having ordinary skill in the art would understand that the remaining column **306-2** may be made to have relatively similar constructional aspects including any required variations within the scope and spirit of the present disclosure.

In one embodiment, the columns **306** may include flanges arranged laterally thereto. In one example, as illustrated in FIG. **3**, the first column **306-1** includes a first left flange **314-1*a*** and a first right flange **314-1*b*** (hereinafter collectively referred to as first flanges **314-1**). Similarly, the second column **306-2** may have a second left flange **314-2*a*** and a second right flange **314-2*b*** (hereinafter collectively referred to as second flanges **314-2**). Both the first flanges **314-1** and the second flanges **314-2** (hereinafter collectively referred to as column flanges **314**) may extend outwardly and away from the base **304**. The first flanges **314-1** may form a first U-channel **316** with an outer surface of the first column **306-1**. Similarly, the second flanges **314-2** may form a second U-channel (not shown) with an outer surface of the second column **306-2**. The first U-channel **316** and the second U-channel may accommodate additional components and assist in maintaining a footprint of the mobile body **108** within the exterior planes of the autonomous vehicle **112**. In one example, the first U-channel **316** may removably secure the controller **302** in the front section **350-1** of the uniframe **300** and the second U-channel may removably secure the battery (not shown) in the rear section **350-2** of the uniframe **300**. Moreover, the column flanges **314**, or the columns **306**, may be tapered to have a lower portion being relatively broader than a corresponding upper portion. The tapering provides a relatively larger surface area in the lower portion and assists, along with the H-shaped base **304**, in establishing a center of mass of the mobile body **108** towards a geometrical center thereof to improve stability and prevent tipping during movements. The column flanges **314** may be permanently attached, detachably secured, or formed integral to the respective columns **306** using any suitable connection mechanisms known in the art.

Further, the uniframe **300** may include or support additional components of the projection device **100**. For example, the uniframe **300** may support the cooling system between the columns **306**. The cooling system may include a heat sink **318** and a cooling panel **320**. In one instance, the heat sink **318** (e.g., an active heat sink including a fan or a passive heat sink, or a combination thereof) may be embedded into an opening in the central plate **308** of the base **304**. The heat sink **318** may be arranged in fluidic communication with the cooling panel **320** to expel heat from the projection device **100** during operation. The cooling panel **320** may be removably attached to the columns **306** at a preset minimum elevation point from the base **304** or the ground. The minimum elevation point may depend on a number and types of components and/or compartments under the cooling panel **320**. In one example, the minimum elevation point may be located at a height of approximately 30 inches (or 76 centimeters) from the ground; however, other examples may include such height being greater or lesser than 30 inches. Further, the cooling panel **320** of some embodiments may be made to slide between the columns **306** for moving above the minimum elevation point. Other embodiments may include the cooling panel **320** being rotatable about a set axis extending along a transverse plane TT'. In some examples, the set axis may be perpendicular to the sagittal plane SS' of the device **100**.

As shown in FIG. **4**, the transverse plane TT' may intersect with the sagittal plane SS' and divide the uniframe **300**, and the mobile body **108**, into an upper section **402** and a lower section **404**. The transverse plane TT' may extend horizontally through the minimum elevation point and across the lateral sides **102** of the mobile body **108**. The upper section **402** may include the cooling panel **320**; however, some examples may include the cooling panel **320** being positioned in the lower section **404**. Above the cooling panel **320**, the uniframe **300** may define a utility space **406** (FIG. **5**) between the columns **306**, e.g., in the upper section **402**, to accommodate one or more components (such as the projection head **110**) of the projection device **100**, discussed below in further detail. Further, the cooling panel **320** may be disposed over the heat sink **318** to facilitate an airflow through an interior portion **322** therebetween within the uniframe **300**. In one example, the cooling panel **320** may create a positive airstream into the interior portion **322** and the heat sink **318** may create a negative airstream moving away from the interior portion **322** for a substantially downward airflow (shown by downward arrows in FIG. **3**) to remove heat from projection device **100** during operation. Other examples may include such positive and negative airstreams being created by any of the cooling panel **320** and the heat sink **318** for creating an airflow into or out of the interior portion **322** in the lower section **404** of the uniframe **300**.

In one embodiment, as illustrated in FIGS. **4-7**, the lower section **404** of the uniframe **300** may include the tray assembly **410** for carrying one or more operational components of the projection device **100**. The tray assembly **410** may be positioned under the cooling panel **320**. In one example, the tray assembly **410** includes a first tray **412-1** and a second tray **412-2** (collectively referred to as trays **412**) and a hinge assembly (not shown). The trays **412** may be disposed between the columns **306** and lateral to the front section **350-1**, or the rear section **350-2**, of the uniframe **300**. The trays **412** may be positioned on opposite sides of the columns **306** across the sagittal plane SS'. For example, the first tray **412-1** may be positioned proximate to the first lateral side **102-1** and the second tray **412-2** may be positioned proximate to the second lateral side **102-2** of the mobile body **108**, or the projection device **100**.

The trays **412** may have a similar geometry and/or dimensions for ease of construction and stability of the uniframe **300**. For the sake of brevity, constructional aspects of only one of the trays **412** are discussed here in detail; however, one having ordinary skill in the art would understand that the remaining tray may also have relatively similar constructional aspects including any required variations within the scope and spirit of the present disclosure. In the illustrated example of FIG. **5**, the first tray **412-1** may have an interior tray surface (not shown) and an opposing exterior tray surface **414**. The interior tray surface of the first tray **412-1**, similar to an interior tray surface **416** of the second tray **412-2**, may provide a space to mount or support various operational components of the projection device **100**. For instance, the first tray **412-1** may carry low voltage components and the second tray **412-2** may carry high voltage components, or vice versa in other examples, on the respective interior surfaces. On the other hand, the exterior tray surface **414** may include an upper tray handle **418-1** and a lower tray handle **418-2** (hereinafter collectively referred to as tray handles **418**). The tray handles **418** may assist to manipulate and support the trays **412** in different positions, discussed below in further detail. The second tray **412-2** may also include tray handles (not shown) similar to the tray handles **418**.

The trays **412** may be pivotably attached to the lower section **404** using the hinge assembly (not shown) to transition between a closed position and an open position. The hinge assembly may be arranged with the base **304** and/or the columns **306** along a bottom portion of the trays **412**. In one embodiment, the hinge assembly may include a rod (not shown) extending parallel to a horizontal axis in the sagittal plane SS'. The rod may be movably connected to the corresponding tray, such as the first tray **412-1**, via movable or non-movable brackets (not shown). Other suitable types of hinge assembly known in the art can also be contemplated including a roller pin assembly. In some embodiments, the hinge assembly may also include aspects (e.g., gears, rollers, ribs, levers, magnets, etc.) to lock the trays **412** in one or more positions between the closed position and the open position. The hinge assembly may include portions permanently attached, detachably secured, or formed integral to the uniframe **300** and/or the tray assembly **410**. In the closed position (FIG. **4**), the trays **412** may be arranged parallel to a vertical axis of the projection device **100** such that the respective interior tray surfaces carrying the operational components may be perpendicular to the base **304** and orient towards each other. Such vertically-arranged trays **412** may have a predefined separation therebetween in the closed position. This separation may include the interior portion **322** of the uniframe **300** under the cooling panel **320**. Hence, unlike traditional support frames providing for horizontal stacking of operational components on top of each other, such vertical arrangement of operational components with the trays **412** in the closed position enables an unobstructed airflow through the interior portion **322** for efficient cooling of the operational components during operation.

As illustrated in FIG. **5**, the trays **412** may be manipulated to transition from the closed position to the open position, and vice versa. For example, the tray handles **418**, such as the upper tray handle **418-1**, may be used to pull the trays **412** outward from the uniframe **300**. Upon being manipulated, the trays **412** may pivot about a pivoting axis defined by a longitudinal axis of a component (e.g., such as the rod) of the hinge assembly connected to the respective trays **412**. The trays **412** may pivot to at least partially extend out from one of the lateral sides **102** of the mobile body **108**, or the projection device **100**, for opening up. In the open position, the trays **412** may extend up to a maximum pivot angle relative to the pivoting axis or a horizontal axis in the sagittal plane SS'. The maximum pivot angle of the trays **412** may be controlled by the corresponding lower tray handle **418-2**. For example, as shown in FIG. **5**, the lower tray handle **418-2** may engage with a ridge plate, such as the left ridge plate **312-1**, of the base **304** to limit the maximum pivot angle of the first tray **412-1** in the open position. Similarly, the second tray **412-2** may also include a lower tray handle (not shown), similar to the lower tray handle **418-2**, engaging with the right ridge plate **312-2** to limit the maximum pivot angle of second first tray **412-2** in the open position. Hence, the lower tray handle, such as the lower tray handle **418-2**, may assist in controlling an outward (or lateral) extension of the corresponding tray, such as the first tray **412-1**, to prevent such tray from inadvertently falling out and/or hit any adjacent surfaces to jeopardize operational safety, e.g., when the mobile body **108**, or the projection device **100**, may be traversing a narrow path such as an aircraft aisle. In one example, the maximum pivot angle may be 45 degrees relative to the vertical axis; however, other examples may include the maximum pivot angle being increased (e.g., up to approximately 90 degrees) or decreased (e.g., up to approximately 35 degrees) based on dimensions of the ridge plates **312** and heights of the proximate lower tray handles. Some embodiments may also include the height of the lower tray handles, such as the lower tray handle **418-2**, being adjustable for on-demand change in the maximum pivot angle of the corresponding trays **412**.

Each of the trays **412** may have a predefined tray length, tray width, and tray depth. The tray length may refer to a tray extension between the base **304** and the minimum elevation point. The tray width may refer to a tray extension between the columns **306** (or the side plates **310**) of the base **304**. The tray depth may refer to a tray extension between the columns **306** and a ridge plate of the base **304** proximate thereto. Both the trays **412** may have approximately the same tray dimensions (e.g., tray length, tray breadth, and tray depth); however, some examples may include the trays **412** having different tray dimensions. In some other examples, the tray dimensions may be proportionate to each other. For instance, the tray length may be at least approximately 1.2 times the tray breadth and/or at least approximately 8 times the tray depth depending on the minimum elevation point. In further examples, at least one of the trays **412** may be removable, partitioned/partitionable, and/or formed out of multiple trays **412** being integrally or removably joined together. Moreover, in some examples, the trays **412** may be removably attached to respective support plates pivotably attached to the uniframe **300**. Other examples may include the trays **412** being coupled to a linear or rotary actuator (not shown) in the hinge assembly, where such actuator may be driven by the control system to automate transitioning of the trays **412** between the closed and open positions.

The lower section **404** of the uniframe **300** may also include or support the control system including the power supply and the controller **302** for controlling various components of the projection device **100**. The controller **302** may be positioned in the lower section **404**; however, some examples may include one or more components (e.g., a driver circuit or trigger circuit for one or more germicide sources, etc.) of the control system being located in the upper section **402**. In one embodiment, the power supply such as the battery may be disposed proximate to the rear side **106** of the projection device **100** and the controller **302** may be arranged proximate to the front side **104** of the projection device **100** to provide easy of access for maintenance and replacement. However, in some examples, the controller **302** may be positioned proximate to the battery on the same side, such as the front side **104** or the rear side **106**, of the mobile body **108**.

The controller **302** may correspond to an electrical or electronic component operating to control predefined or dynamically defined functions and movements of various components including, but not limited to, the tray assembly **410**, the mobile body **108**, the projection head **110**, and any peripheral components operationally coupled to the projection device **100**. Aspects of the controller **302**, in some examples, may also include or couple to mechanical components, such as the actuator, of the projection device **100**. In some embodiments, the controller **302** may include or be implemented by way of a single device (e.g., a computing device, a processor or an electronic storage device) or a combination of multiple devices. The controller **302** may be implemented in hardware or a suitable combination of hardware and software. The controller **302** may include, for example, microprocessors, microcomputers, microcontrollers, digital signal processors, central processing units, state machines, logic circuits, and/or any devices that may manipulate signals based on operational instructions. Among other capabilities, the controller **302** may be configured to fetch and execute computer readable instructions in communication with a storage device (not shown). The storage device may be configured to store, manage, or process data in a database related to operations of the projection device **100** and a log of profiles of various devices coupled to the controller **302** and associated communications including instructions, queries, data, and related metadata. The storage device may include any computer-readable medium known in the art, related art, or developed later including, but not limited to, a processor or multiple processors operatively connected, a volatile memory, a non-volatile memory, and a disk drive. Further, the controller **302** may include or operate in communication with one or more interfaces, such as those mentioned above.

The controller **302** may be configured to control various components, such as the autonomous vehicle **112**, the projection head **110**, and the tray assembly **410**, of the projection device **100** based one or more predefined or dynamically defined operational modes, discussed in detail below. The controller **302**, in some examples, may operate in communication with a software product configured to control one or more aspects of the projection device **100**. The software product may include one of an operating system, a computer application, and a device driver loaded on a computer readable medium including those mentioned above. In some examples, the software product may include or communicate with a software patch operating to modify or assist in implementing an aspect (e.g., installation, uninstallation, synchronization, general or specialized operation, etc.) of the software product or that of the projection device **100**. The software product, alone or in combination with the software patch, may assist to adjust a value of an operating parameter of a component or a device associated with the projection device **100** for modulating a corresponding output. For instance, the software product may provide an interface between the controller **302** and a trigger circuit (not shown) of the projection head **110**. The trigger circuit may include a trigger sensor (e.g., variable resistor or potentiometer) to assist in manipulating an input voltage being applied to the projection head **110** based on a control signal from the controller **302**. The software product may interpret a sensor signal from the trigger sensor to cause the controller **302** into providing the control signal that drives the trigger circuit to adjust the applied input voltage. Hence, in one example, the software product may assist in increasing an input voltage for increasing a first value (e.g., 2 KV) thereof to a second value (e.g., 3 KV) for improving an intensity or dose of the projected germicide. Other examples of the operating parameters may include, but are not limited to, operational duration or cycle, pulse frequency, toggling rate, output voltage, input or output (I/O) currents, I/O resistances, polarity, direction of rotation or motion, and operational modes. In some instances, the software patch may inhibit an operation of a component of the projection device **100** and/or the software product. Both the software patch and the software product may be installed on the same computing device operationally coupled to the projection device **100**; however, other examples may include the software product and the software patch being installed on different computing devices, e.g., including a remote device.

In a further embodiment, the lower section **404** may include or support an auxiliary frame **602**. As illustrated in FIGS. **6-7**, the auxiliary frame **602** may be attached to the second column **306-2** in the rear section **350-2** of the uniframe **300**. The auxiliary frame **602** may be aligned vertically (or horizontally in some examples) relative to the transverse plane TT' and/or the cooling panel **320** and extend outwardly away from the uniframe **300**. The auxiliary frame **602** may have a fixed geometry; however, some examples may include the auxiliary frame **602** having portions made to selectively collapse or retract relative to the uniframe **300**. The auxiliary frame **602** may be disposed within (i) vertical planes including the lateral sides **102** of the mobile body **108**, or (ii) the exterior planes of the autonomous vehicle **112**, to avoid exceeding a width of a path to be traversed by the projection device **100**. The auxiliary frame **602** may include ports (not shown) coupled to the control system. The ports may assist to operationally couple one or more peripheral components or devices to the projection device **100**. For instance, the auxiliary frame **602** may assist in connecting a handheld device with the control system.

As illustrated in FIG. **8**, in one example, a handheld projection device **802** may be coupled to the control system via the auxiliary frame **602**. The handheld projection device **802** may include a UV source **804** to project UV light and a power cable **806** having a suitable length based on surfaces to be accessed for disinfection. The cable **806** may be removably attached to the auxiliary frame **602**. Upon being attached, the handheld projection device **802** may be powered by the battery and controlled via the controller **302** of the control system. In some examples, the handheld projection device **802** may be cableless to operationally connect with the controller **302** via a transceiver (not shown) attached to the auxiliary frame **602**. The controller **302** may drive the handheld projection device **802** to project the UV light for surface disinfection based on selection or deselection of one or more operational modes of the projection device **100**, discussed below in further detail. The controller **302** along with the uniframe **300** and the auxiliary frame **602** may be covered by a casing of the mobile body **108**.

In one embodiment, the mobile body **108** may include one or more cover panels defining one or more casings to protect one or more components of the projection device **100** from dust and damage. Such casings may also assist to improve aesthetics of the projection device **100**. In one example, as shown in FIG. **8**, the mobile body **108** may include a lower casing **808-1** formed out of a single panel or a set of panels to surround one or more components (e.g., the tray assembly **410**, the controller **302**, a portion of the auxiliary frame **602**, etc.) in the lower section **404** of the uniframe **300**. For instance, the lower casing **808-1** may extend along the rear section **350-2** of the uniframe **300** to define the battery compartment **118** therewith along the rear side **106** of the mobile body **108**. The lower casing **808-1** may be removably secured to the columns **306** in the lower section **404**; however, some portions of the lower casing **808-2** may be additionally, or alternatively, secured to the autonomous vehicle **112**. In addition to the lower casing **808-1**, the mobile body **108** may include cover panels **808-2*a*** and **808-2*b*** collectively defining an upper casing **808-2** of the uniframe **300**. The cover panels **808-2*a***, **808-2*b*** may be secured to the first column **306-1** and the second column **306-2** respectively in the upper section **402** of the uniframe **300**. The cover panels **808-2*a***, **808-2*b*** may be separated from each other to substantially maintain the utility space **406** between the columns **306** in the upper section **402**. The upper casing **808-2** and the lower casing **808-1** (hereinafter collectively referred to as casings **808**) may be made up of any rigid, durable, fire-retardant, or fire-resistant materials known in the art, related art, or developed later including, but not limited to, metals, polymers, alloys, and glass, or any combinations thereof.

The upper casing **808-2** may further include or support one or more components of the mobile body **108**. In one embodiment (FIG. **8**), the upper casing **808-2** may include or support a first drive handle **810-1** and a second drive handle **810-2** (hereinafter collectively referred to as drive handles **810**). The drive handles **810** may assist a user to manually maneuver the projection device **100** or the mobile body **108** from one position, or orientation, to another. In another embodiment, the upper casing **808-2** may additionally include a display unit (not shown) positioned along the rear side **106** of the mobile body **108**; however, some embodiments may include the display unit being located remote from the upper casing **808-2** or the projection device **100**. The display unit may independently or in communication with a user interface (not shown) may indicate information pertaining to an operation of the projection device **100**. In one example, the display unit may represent or include an interactive display screen operating as an input device for enabling an operator to access, control, or dynamically define different functions of the projection device **100**. In another example, the display unit may display a dashboard providing a list of functions, modes, parameters, avatars, operational aspects, etc. that the operator may select or modify for a desired operation of the projection device **100**. The operational aspects may relate to any predefined or dynamically defined tasks related to a functionality and/or administration of the projection device **100**, or a corresponding component(s) thereof. Examples of these aspects may include, but are not limited to, (i) values of operational parameters such as frequency, wavelength, duration, energy, and dose, (ii) a selected mode in operation, (iii) operational states of different components, (iv) statuses of various operational tasks such as disinfection and navigation, and so on.

In a further embodiment (FIG. **9**), the upper casing **808-2** may include or couple to a transparent housing **902** that may surround (or envelop) the upper section **402** including the utility space **406** therein. The housing **902** may be made up of any suitable material (e.g., quartz glass) or include an arrangement (e.g., wire mesh, holes, etc.) that may be substantially rigid. The housing **902** may be made transparent or include portions that are optically permeable to UV light. These portions may extend along surfaces intended for being irradiated with the UV light. In some examples, the housing **902** may include, or operate as, an optical filter to pass, or block, an intended wavelength of light (e.g., a specific UV wavelength such as UVC, visible light, etc.) therethrough. The housing **902** may be removably secured with portions of the casings **808** and/or the columns **306** in the upper section **402**; however, some examples may include portions of the housing **902** being formed integral to the upper casing **808-2**. The housing **902** may be supported by the opposing lateral sides **102** of the mobile body **108**, or the projection device **100**. Proximate to the upper casing **808-2**, the projection device **100** may further include the projection head **110** positioned within the utility space **406** in the upper section **402** of the uniframe **300**.

In one embodiment, the projection head **110** may be operated by the controller **302** to, at least one of, (1) directionally project the germicide towards surfaces above and proximate to the opposing lateral sides **102** of the projection device **100**, (2) alternately tilt (or rotate) about a horizontal axis in the sagittal plane SS' to project the germicide towards the surfaces, and (3) alternately tilt (or rotate) in opposite directions across the sagittal plane SS'. The projection head **110** may be implemented in a closed configuration or an open configuration (hereinafter collectively referred to as head configurations). In some embodiments, the projection head **110** in the closed configuration may be implemented on the handheld projection device **802**.

In the closed configuration, as illustrated in FIGS. **10-11**, the projection head **110** may include a lamp housing **1002** configured to carry components operating to project the germicide. The lamp housing **1002** may include a front plate **1002-1**, a rear plate **1002-2**, a top plate **1002-3**, and a bottom plate **1002-4**. The lamp housing **1002** may also include a first lateral plate **1004-1** and a second lateral plate **1004-2** (hereinafter collectively referred to as lateral plates **1004**) extending between the front plate **1002-1** and the rear plate **1002-2**. In the illustrated example, the first lateral plate **1004-1**, the second lateral plate **1004-2**, and the top plate **1002-3** includes a first window **1006-1**, a second window **1006-2**, and a third window **1006-3** (hereinafter collectively referred to as windows **1006**) respectively. The windows **1006** may be made optically permeable to at least UV light using openings and/or any suitable materials known in the art including glass, quartz, and polymers. The front plate **1002-1**, the rear plate **1002-2**, and the bottom plate **1002-4** of the lamp housing **1002** may be made opaque to block UV the germicide such as UV light and support operational components of the projection head **110**. The lamp housing **1002** may be made of any suitable materials known in the art including, but not limited to, metals, polymers, glass, quartz, alloys, or a combination thereof that may be sufficiently rigid and sturdy to support the operational components.

As illustrated in FIGS. **10-11**, the lamp housing **1002** may be attached to a rotation assembly including a driver assembly **1008**, a sensor block **1010**, and a shaft **1012** (shown in FIG. **12**) connected therebetween. The driver assembly **1008** may include a motor **1008-1** and a bevel-gear arrangement **1008-2** for rotating the shaft **1012**; however, any other suitable mechanisms known in the art may be implemented. The shaft **1012** may pass through the lamp housing **1002** and have one end attached to the bevel-gear arrangement **1008-2**. The other end of the shaft **1012** may be attached to the sensor block **1010** operating in communication with the controller **302**. The sensor block **1010** may be attached to an exterior of the front plate **1002-1** and the driver assembly **1008** may be attached to an exterior of the rear plate **1002-2** of the lamp housing **1002**. Further, the shaft **1012** may operate to support and rotate the projection head **110** with the lamp housing **1002** in the closed configuration. However, in the open configuration (shown in FIG. **9** and FIG. **14**), the projection head **110** may be implemented without a dedicated housing such as the lamp housing **1002**. For example, the upper casing **808-2** may include, or be implemented as, a stationary housing such as the housing **902**, which may be disconnected or distanced from the projection head **110** and the rotation assembly. The upper casing **808-2** or the housing **902** may remain stationary relative to the projection head **110** during rotations of the shaft **1012**. Each of the head configurations may include the projection head **110** having a lamp assembly **1200** to project the germicide such as UV light.

As illustrated in FIG. **12**, the lamp assembly **1200** may include a first radiation source **1204-1***a*, a second radiation source **1204-1***b*, and a third radiation source **1204-1***c* (hereinafter collectively referred to as radiation sources **1204-1**) operating to emit UV light. However, some examples may include the lamp assembly **1200** having additional components operating to emit other types of germicides such as those mentioned above. The radiation sources **1204-1** may be secured to a bracket **1206** for connecting to the rotation assembly. For example, the bracket **1206** may be attached to the shaft **1012** passing therethrough. One end of the shaft **1012** may be attached to the driver assembly **1008** (e.g., rear to the bracket **1206**) and an opposing end of the shaft **1012** may be attached to the sensor block **1010** (e.g., towards a front of the lamp assembly **1200** opposing the bracket **1206**). As illustrated in FIG. **13**, the sensor block **1010** may include a first contact sensor **1302-1**, a second contact sensor **1302-2** (hereinafter referred to as contact sensors **1302**) and a rotatable contact ring **1304** proximate thereto. The contact ring **1304** may include a first contact pin **10***a*, a second contact pin **10***b*, and a third contact pin **10***c* (hereinafter collectively referred to as contact pins **10**). The contact ring **1304** may be rotated by the shaft **1012** to engage the contact pins **10** with the contact sensors **1302** for indicating a position or a direction of rotation of the projection head **110**.

Further, the bracket **1206** may be attached directly to the driver assembly **1008** in the open configuration of the projection head **110**; however, the closed configuration may include the bracket **1206** being coupled to the driver assembly **1008** via the lamp housing **1002**, as discussed above. On the bracket **1206**, the radiation sources **1204-1** may be arranged around the shaft **1012** with the first radiation source **1204-1***a* and the second radiation source **1204-1***b* located in a common plane, and the third radiation source **1204-1***c* positioned therebetween in a different plane. The radiation sources **1204-1** may include, or be implemented as, a bulb, a light emitting diode (LED), a Xenon UV lamp, or any other types of radiation sources known in the art. The radiation sources **1204-1** may be pulsed radiation sources, continuous radiation sources, or a combination thereof, driven by the control system or the controller **302**. For example, the pulsed radiation sources may be configured by the controller **302** to emit pulses of UV light of a predetermined energy or intensity at a predefined or dynamically defined pulse frequency and within a predetermined wavelength range. On the other hand, the continuous radiation sources may be configured by the controller **302** to emit a continuous stream of UV light. In some examples, the continuous radiation sources may be turned on and off at a predetermined frequency (or pulse frequency) by the controller **302** to emit pulses of UV light. Further, the controller **302** may configure the radiation sources **1204-1** to irradiate timed pulses of the UV light with each pulse having predefined characteristics such as energy, power, wavelength, and/or frequency. For example, the controller **302** may simultaneously drive each of the radiation sources **1204-1** at a predefined or dynamically defined pulse frequency to emit an intended amount of energy per pulse. In another example, the controller **302** may drive the radiation sources **1204-1** at a combined pulse frequency of at least 20 Hz to emit a predefined amount of energy. In yet another example, the controller **302** may drive at least two of the radiation sources **1204-1** at different frequencies. For instance, the energy per pulse may range from 30 to 150 Joules and the pulse frequency may range from 10 Hz to 60 Hz.

In one embodiment, the controller **302** may drive the radiation sources **1204-1** alternately to emit the UV light for same or different durations during the operational cycle. For example, the controller **302** may sequentially drive the third radiation source **1204-1***c*, followed by the first radiation source **1204-1***a*, and the second radiation source **1204-1***b* to emit the UV light within the operational cycle. In another example, the controller **302** may constantly drive the third radiation source **1204-1***c* to emit the UV light while alternately triggering the first radiation source **1204-1***a* and the second radiation source **1204-1***b* to emit the UV light. In yet another example, the controller **302** may constantly drive the first radiation source **1204-1***a* to emit the UV light while alternately triggering the second radiation source **1204-1***b* and the third radiation source **1204-1***c* to emit the UV light. In still another example, the controller **302** may constantly drive the second radiation source **1204-1***b* to emit the UV light while alternately triggering the first radiation source **1204-1***a* and the third radiation source **1204-1***c* to emit the UV light. In a further example, the controller **302** may switch-off at least one of the radiation sources **1204-1**, for example, the third radiation source **1204-1***c*, while alternately triggering the remaining radiation sources **1204-1** to emit the UV light. The controller **302** may toggle or switch from driving one radiation source to another at a predefined or dynamically defined toggling rate to emit UV light within the operational cycle. In some embodiments, the toggling rate may be defined based on the pulse frequency and/or the energy per pulse associated with one or more of the radiation sources **1204-1**.

The lamp assembly **1200**, as illustrated in FIG. **14**, additionally includes a first reflector **1204-2***a*, a second reflector **1204-2***b*, and a third reflector **1204-2***c* (hereinafter collectively referred to as reflectors **1204-2**). The first reflector **1204-2***a* may be positioned behind the first radiation source **1204-1***a* to collectively define a first radiation unit **1204-***a*. The second reflector **1204-2***b* may be positioned behind the second radiation source **1204-1***b* to collectively define a second radiation unit **1204-***b*. The third reflector **1204-2***c* may be positioned behind the third radiation source **1204-1***c* to collectively define a third radiation unit **1204-***c*. The first radiation unit **1204-***a*, the second radiation unit **1204-***b*, and the third radiation unit **1204-***c* (hereinafter collectively referred to as radiation units **1204**) may include respective reflectors **1204-2** being oriented to project the UV light in different directions or planes. For example, the first reflector **1204-2***a*, the second reflector **1204-2***b*, and the third reflector **1204-2***c* may be oriented to direct the UV light towards a first plane, a second plane, and a third plane (collectively referred to as projection planes) respectively. The first plane may be opposite (and parallel in some examples) to the second plane. In another example, the third plane may be orthogonal to at least one of the first plane and the second plane. Each of the reflectors **1204-2** may have a curved profile to provide a predefined field of view of projection (or projection angle) of approximately 45 degrees with respect to a longitudinal axis of the respective radiation sources **1204-1**. The projection angle of approximately 45 degrees for the reflectors **1204-2** may assist to balance a trade-off between the surface coverage and the UV intensity at a set distance (e.g., approximately 1 meter) from the radiation units **1204**; however, other examples may include the projection angle being greater or lesser than approximately 45 degrees.

Further, the lamp assembly **1200** may also include a supporting plate **1402** to support the reflectors **1204-2** with the bracket **1206**. For example, the first reflector **1204-2***a* and the second reflector **1204-2***b* may be attached to the supporting plate **1402** and the bracket **1206**. The third reflector **1204-2***c* may be attached to the bracket **1206** and located above the supporting plate **1402**, the first reflector **1204-2***a*, and the second reflector **1204-2***b*. The lamp assembly **1200** including the supporting plate **1402**, the radiation units **1204**, and the bracket **1206** may collectively define the projection head **110** in the open configuration. Other examples may include the supporting plate **1402** including the bottom plate **1002-4** of the lamp housing **1002** in the closed configuration of the projection head **110**. As illustrated in FIG. **15**, the supporting plate **1402** (or the bottom plate **1002-4**) may include a cooling unit **1404** (e.g., a fan, a vacuum pump, etc.) creating an airflow for cooling the radiation units **1204**. In one embodiment, the cooling unit **1404** may create a suction airstream in the lamp assembly **1200** or the lamp housing **1002**; however, other examples may include the cooling unit **1404** operating as a blower to create a positive airstream into the lamp assembly **1200** or the lamp housing **1002** for cooling the radiation units **1204** therein. The radiation units **1204** may be positioned proximate to the windows **1006** of the lamp housing **1002** to project the UV light therethrough in the closed configuration of the projection head **110**. For example, the first radiation unit **1204-***a* may be positioned proximate to the first lateral plate **1004-1** with the first reflector **1204-2***a* oriented towards the first window **1006-1**. Similarly, the second radiation unit **1204-***b* may be positioned proximate to the second lateral plate **1004-2** with the second reflector **1204-2***b* oriented towards the second window **1006-2**. On the other hand, the third radiation unit **1204**-*c* may be positioned proximate to the top plate **1002-3** with the third reflector **1204-2***c* oriented towards the third window **1006-3** of the lamp housing **1002**. The radiation units **1204** may project the UV light through the respective windows **1006** towards target surfaces located exterior to the projection device **100**. Such orientations and positioning of the radiation units **1204** may limit or prevent UV dispersion towards the front side **104** and the rear side **106**, and assists to directionally project UV light towards the surfaces above and lateral to the projection head **110**, or the projection device **100**, for better energy management per surface to be disinfected.

In one embodiment, the projection head **110** including the lamp assembly **1200** may be rotatably mounted to the mobile body **108** via the rotation assembly. For example, the shaft **1012** may be rotatably mounted to the columns **306** such that the projection head **110** may be positioned within the utility space **406** above the cooling panel **320** in the uniframe **300**. The mounted shaft **1012** may have a longitudinal axis extending along the horizontal axis in the sagittal plane SS' with the sensor block **1010** mounted to the first column **306-1** and the bracket **1206** mounted to the second column **306-2**. The projection head **110** may be coupled to the shaft **1012** via the bracket **1206** and positioned on the uniframe **300** in the open configuration or the closed configuration, as discussed above.

In a first embodiment, as illustrated in FIGS. **16**A-**16**C, the projection head **110** may be implemented in the open configuration for operation. In the open configuration, the lamp assembly **1200** may be coupled to the rotation assembly without the lamp housing **1002** for operation. The rotation assembly may be operated to transition the lamp assembly **1200** between a stationary position and one or more rotary positions. In the stationary position (FIG. **16**A), the lamp assembly **1200** may include the radiation units **1204** oriented away from each other and operating to project the UV light towards surfaces in different planes or directions relative to the mobile body **108** or the projection device **100**. For example, in the stationary position, the first radiation unit **1204**-*a* and the second radiation unit **1204**-*b* may be oriented to project the UV light across the sagittal plane SS' in a first direction and a second direction respectively. The second direction may be opposite to the first direction. In some examples, the second direction may be parallel to the first direction. The first radiation unit **1204**-*a* and the second radiation unit **1204**-*b* may be located in the same plane with the third radiation unit **1204**-*c* located therebetween. In the illustrated example, the third radiation unit **1204**-*c* is positioned above the first radiation unit **1204**-*a* and the second radiation unit **1204**-*b*; however, other examples may include the third radiation unit **1204**-*c* being positioned with one of the first radiation unit **1204**-*a* and the second radiation unit **1204**-*b*. The third radiation unit **1204**-*c* may be oriented to project the UV light along a vertical axis in the sagittal plane SS' in a third plane in the stationary position. In some examples, the third direction may be orthogonal to at least one of the first direction and the second direction. Each of the radiation units **1204** may be arranged around the shaft **1012** defining an axis of rotation of the lamp assembly **1200**, and the projection head **110**. The axis of rotation may extend along the horizontal axis in the sagittal plane SS'.

The stationary position of the shaft **1012** and the lamp assembly **1200** may be sensed by the controller **302** based on a first engagement of a set of contact pins **10** with the contact sensors **1302** in the sensor block **1010**. For instance, the sensor block **1010** may provide a first position signal based on pin **10***a* engaging with the first contact sensor **1302-1** while pin **10***b* and pin **10***c* being disengaged from the contact sensors **1302**. The first position signal may indicate the stationary position of the lamp assembly **1200** to the controller **302**. The lamp assembly **1200** may be rotated from the stationary position based on a rotation of the shaft **1012** in the rotation assembly. The shaft **1012** may be rotated in a preset or dynamically set direction by the controller **302** during the operational cycle. For example, the controller **302** may trigger the motor **1008-1** to rotate the shaft **1012** (via the bevel-gear arrangement **1008-2**) either clockwise or anticlockwise. In one instance, the shaft **1012** may be rotated anticlockwise to transition the lamp assembly **1200** from the stationary position to a first rotary position.

As illustrated in FIG. **16**B, in the first rotary position, the lamp assembly **1200** may rotate anticlockwise up to a first rotation angle across the sagittal plane SS'. In one example, the first rotation angle may be approximately 45 degrees relative to the sagittal plane SS'; however, other examples may include the first rotation angle up to approximately 90 degrees. Such anticlockwise rotation may orient the first radiation unit **1204**-*a* and the second radiation unit **1204**-*b* downwards and upwards respectively relative to the axis of rotation. In the downward orientation, the first radiation unit **1204**-*a* may project the UV light towards surfaces located below the axis of rotation and along a first side of the sagittal plane SS'. In some instances, the surfaces below the axis of rotation may include the ground or a portion of path being traversed by the projection device **100**. In the upward orientation, the second radiation unit **1204**-*b* may project the UV light towards surfaces located above the axis of rotation and along a second side of the sagittal plane SS'. Simultaneously, the third radiation unit **1204**-*c* may be oriented to project the UV light towards surfaces located above the axis of rotation and along the first side of the sagittal plane SS'.

The first rotary position of the lamp assembly **1200** may be sensed by the controller **302** based on a second engagement of a set of contact pins **10** with the contact sensors **1302** in the sensor block **1010**. For instance, the sensor block **1010** may provide a second position signal based on pin **10***b* engaging with the second contact sensor **1302-2** while pin **10***a* and pin **10***c* being disengaged from the contact sensors **1302** due to the anticlockwise rotation of the shaft **1012**. The second position signal may indicate the first rotary position of the lamp assembly **1200** to the controller **302**. Similarly, in another instance, the shaft **1012** may be rotated clockwise to transition the lamp assembly **1200** to a second rotary position.

As illustrated in FIG. **16**C, in the second rotary position, the lamp assembly **1200** may rotate clockwise up to a second rotation angle across the sagittal plane SS'. In one example, the second rotation angle may be approximately 45 degrees relative to the sagittal plane SS'; however, other examples may include the second rotation angle up to approximately 90 degrees. Such clockwise rotation may orient the first radiation unit **1204**-*a* and the second radiation unit **1204**-*b* upwards and downwards respectively relative to the axis of rotation. In the upward orientation, the first radiation unit **1204**-*a* may project the UV light towards surfaces located above the axis of rotation and along the first side of the sagittal plane SS'. Simultaneously, the third radiation unit **1204**-*c* may be oriented to project the UV light towards surfaces located above the axis of rotation and along the second side of the sagittal plane SS'. On the other hand, in the downward orientation, the second radiation unit **1204**-*b* may project the UV light towards surfaces located below the axis of rotation and along the second side of the sagittal plane SS'. The second rotary position of the lamp assembly

1200 may be sensed by the controller **302** based on a third engagement of a set of contact pins **10** with the contact sensors **1302** in the sensor block **1010**. For instance, the sensor block **1010** may provide a third position signal based on pin **10***b* engaging with the first contact sensor **1302-1** and pin **10***c* engaging with the second contact sensor **1302-2** while pin **10***a* being disengaged from the contact sensors **1302** due to the clockwise rotation of the shaft **1012**. The third position signal may indicate the second rotary position of the lamp assembly **1200** to the controller **302**.

In a second embodiment, as illustrated in FIGS. **17A-17C**, the projection head **110** may be implemented in the closed configuration. In the closed configuration, the lamp assembly **1200** may be located within the lamp housing **1002** coupled to the rotation assembly for operation. The rotation assembly may be operated to transition the lamp housing **1002** (or the projection head **110**) between the stationary position and one or more tilt positions, which may be synchronized with the first and second rotary positions, discussed above. Each of the tilt positions may be determined by the controller **302** in communication with the sensor block **1010** as discussed above.

In the stationary position (FIG. **17A**), the lamp housing **1002** (or the projection head **110**) may be located within the exterior planes of the autonomous vehicle **112**. The lamp housing **1002** (or the projection head **110**) may include the first lateral plate **1004-1** positioned proximate to the first radiation unit **1204-***a* oriented towards the first lateral side **102-1** of the mobile body **108**. Opposite to the first lateral plate **1004-1**, the lamp housing **1002** (or the projection head **110**) may include the second lateral plate **1004-2** positioned proximate to the second radiation unit **1204-***b* oriented towards the second lateral side **102-2** of the mobile body **108**. The first lateral plate **1004-1** may include the first window **1006-1** arranged parallel to the second window **1006-2** of the second lateral plate **1004-1**. Each of the first window **1006-1** and the second window **1006-2** may be parallel to the sagittal plane SS' passing therebetween. The first window **1006-1** and the second window **1006-2** may be located in the same horizontal plane with the top plate **1002-3** of the lamp housing **1002** located therebetween. The top plate **1002-3** may be positioned above the lateral plates **1004** of the lamp housing **1002**. The top plate **1002-3** may include the third window **1006-3** proximate to the third radiation unit **1204-***c*. The third window **1006-3** may be arranged perpendicular to a vertical axis in the sagittal plane SS'. The windows **1006** may enable the radiation units **1204** to emit the UV light exterior to the lamp housing **1002** (or the projection head **110**). For example, the first radiation unit **1204-***a* may project the UV light through the first window **1006-1** towards surfaces proximate to the first lateral side **102-1** of the mobile body **108**. The second radiation unit **1204-***b* may project the UV light through the second window **1006-2** towards surfaces proximate to the second lateral side **102-2** of the mobile body **108**. The third radiation unit **1204-***c* may project the UV light through the third window **1006-3** towards surfaces above the lamp housing **1002** (or the projection head **110**), and the mobile body **108**. The windows **1006** may be arranged around the shaft **1012** passing through the lamp housing **1002**. The stationary position of the shaft **1012** and the lamp housing **1002** (or the projection head **110**) may be sensed by the controller **302** based on the first position signal from the sensor block **1010** as discussed above. The shaft **1012** may be rotated by the controller **302** to tilt the lamp housing **1002** (or the projection head **110**) across the sagittal plane SS'. The lamp housing **1002** (or the projection head **110**) may tilt with the lamp assembly **1200** based on a rotation of the shaft **1012**. In one example, the shaft **1012** may be rotated anticlockwise to transition the lamp housing **1002** (or the projection head **110**) from the stationary position to a first tilt position.

As illustrated in FIG. **17B**, in the first tilt position, the lamp housing **1002** (or the projection head **110**) may tilt up to a predefined tilt angle towards the first lateral side **102-1** of the mobile body **108**. In one example, the tilt angle may be approximately 45 degrees relative to the sagittal plane SS'; however, other examples may include the tilt angle up to approximately 90 degrees. Such tilt may orient the first lateral plate **1004-1** (and the first window **1006-1**) downwards as well as the second lateral plate **1004-2** (and the second window **1006-2**) upwards relative to the axis of rotation defined by the shaft **1012**. In the downward orientation, the first radiation unit **1204-***a* may project the UV light through the first window **1006-1** towards surfaces located below the axis of rotation and proximate to the first lateral side **102-1** of the mobile body **108**. In some instances, the surfaces below the axis of rotation may include the ground or a portion of path being traversed by the projection device **100**. In the upward orientation, the second radiation unit **1204-***b* may project the UV light through the second window **1006-2** towards surfaces located above the axis of rotation and proximate to the second lateral side **102-2** of the mobile body **108**. Simultaneously, the third radiation unit **1204-***c* may be oriented to project the UV light through the third window **1006-3** in the top plate **1002-3** towards surfaces located above the axis of rotation and proximate the first lateral side **102-1** of the mobile body **108**. Since the lamp housing **1002** tilts with the lamp assembly **1200**, the first tilt position of the lamp housing **1002** (or the projection head **110**) may be sensed by the controller **302** based on the second position signal from the sensor block **1010** as discussed above.

Similarly, in another example, the shaft **1012** may be rotated clockwise to transition the lamp housing **1002** (or the projection head **110**) to a second tilt position. As illustrated in FIG. **17C**, in the second tilt position, the lamp housing **1002** (or the projection head **110**) may tilt up to a predefined tilt angle towards the second lateral side **102-2** of the mobile body **108**. In one example, the tilt angle may be approximately 45 degrees relative to the sagittal plane SS'; however, other examples may include the tilt angle up to approximately 90 degrees. Such tilt may orient the first lateral plate **1004-1** (and the first window **1006-1**) upwards and the second lateral plate **1004-2** (and the second window **1006-2**) downwards relative to the axis of rotation defined by the shaft **1012**. In the upward orientation, the first radiation unit **1204-***a* may project the UV light through the first window **1006-1** towards surfaces located above the axis of rotation and proximate to the first lateral side **102-1** of the mobile body **108**. In the downward orientation, the second radiation unit **1204-***b* may project the UV light through the second window **1006-2** towards surfaces located below the axis of rotation and proximate to the second lateral side **102-2** of the mobile body **108**. In some instances, the surfaces below the axis of rotation may include the ground or a portion of path being traversed by the projection device **100**. Simultaneously, the third radiation unit **1204-***c* may be oriented to project the UV light through the third window **1006-3** in the top plate **1002-3** towards surfaces located above the axis of rotation and proximate the second lateral side **102-2** of the mobile body **108**. Since the lamp housing **1002** tilts with the lamp assembly **1200**, the second tilt position of the lamp housing **1002** (or the projection head **110**) may be sensed by the controller **302** based on the third position signal from the sensor block **1010** as discussed above.

Hence, the clockwise and anticlockwise rotations of the shaft **1012** may tilt (or rotate) the projection head **110** up to the predefined tilt (or rotation) angle in opposite directions across the sagittal plane SS'. The tilt/rotation angle may be set based on a minimum distance up to which the projection head **110** may be intended to project the UV light downwardly without casting a shadow of the projection device **100** on a target surface. Such minimum distance may depend on a height of the projection head **110** from the ground. In one instance, the projection head **110** may be positioned at a height of at least 38 inches (or 96 centimeters) from the ground for the tilt/rotation angle of 45 degrees; however, other instances may include such tilt angle being increased to an angle greater than 45 degrees relative to a vertical axis of the sagittal plane SS' based on the height of the projection head **110** being greater than 38 inches, and vice versa.

In one embodiment, the projection device **100** including the projection head **110** may be employed for targeted disinfection of surfaces, e.g., within an aircraft **1800** (FIGS. **18**A-**18**C); however, other embodiments may include the projection device **100** or the projection head **110** being employed for any other task or operation including those mentioned above.

During operation, the controller **302** may operate the projection device **100** in a manual mode or an automated mode (hereinafter collectively referred to as device modes). In the automated mode, the controller **302** may drive (i) the mobility device, such as the autonomous vehicle **112**, autonomously or via a remote device for moving or orienting the projection device **100** proximate to a target surface and/or along a path such as an aircraft aisle. The automated mode, in some examples, may also include the controller **302** driving the projection head **110** to automatically project the germicide such as UV light based on, at least one of, (a) a speed or direction of movement of the autonomous vehicle **112**, (b) number of rotations of the projection head **110** per unit time (e.g., second, minute, etc.) or per operational cycle such as the disinfection cycle, (c) speed or direction of rotations of the projection head **110**, (d) object aspects such as those mentioned above including proximity to a target surface or an intended path, and/or (e) a preset duration, the pulse frequency, or the toggling rate associated with the projection head **110** within an operational cycle such as a disinfection cycle. In the manual mode, the controller **302** may enable an operator to manually (a) move or steer the mobility device (e.g., autonomous vehicle **112**) or the projection device **100** and (b) remotely control a projection of the germicide such as UV light from the projection head **110**.

In another example, the controller **302** may additionally operate the projection head **110** in one of a rotary mode and a stationary mode (hereinafter collectively referred to as projection modes). In the stationary mode, the projection head **110** may be kept stationary within the exterior planes. In the rotary mode, the controller **302** may drive the projection head **110** to tilt (or rotate) for changing the planes or directions in which the germicide such as UV light may be projected therefrom. In a further example, the controller **302** may also operate in a peripheral mode to enable operation of a peripheral component such as the handheld projection device **802** upon being operationally connected to the projection device **100**. Each of the device modes, the projection modes, and the peripheral mode (collectively referred to as the operational modes) may be implementable to operate independently, or in tandem with each other, in any suitable combination or order. However, some examples may include a particular operational mode being operable mutually exclusive to one or more of the remaining operational modes. For instance, the controller **302** may implement the peripheral mode based on the projection modes and the automated mode being deactivated. In some instances, the controller **302** may automatically deactivate the automated mode and the projection modes based on the peripheral mode being selected. These operational modes may be selected by a user using any of the suitable input devices known in the art. For example, the user may login on an input device such as an interactive display screen of a mobile computing device operating in communication with the controller **302** of the projection device **100** to select one or more of these modes for operation.

As illustrated in FIGS. **18**A-**18**C, the projection device **100** may be driven along a path such as an aircraft aisle to disinfect surfaces (e.g., seats, overhead luggage compartments, etc.) located above and proximate to the lateral sides **102**. The projection device **100** may be operated by the controller **302** to traverse the path autonomously based on the automated mode being selected, or driven manually based upon the manual mode being selected. While traversing the path, the projection device **100** may be operated to project UV light from the projection head **110** towards the surfaces. As illustrated, the aircraft **1800** may include a first set of surfaces **1804-1** proximate to the first lateral side **102-1**, a second set of surfaces **1804-2** proximate to the second lateral side **102-2**, and a third set of surfaces **1804-3** above the projection head **110**, or the projection device **100**. Each of the first set of surfaces **1804-1**, the second set of surfaces **1804-2**, and the third set of surfaces **1804-3** (hereinafter collectively referred to as proximate surfaces **1804**) may be located in an arch extending across from the sagittal plane SS' of the projection device **100**. The projection device **100** may be set to operate in one of the stationary mode, the rotary mode, and the peripheral mode for disinfecting the proximate surfaces **1804**.

Stationary Mode

When the stationary mode is selected, the controller **302** may deactivate the rotary mode and the peripheral mode for the projection device **100**. The controller **302** may implement the stationary mode with any of the selected device modes including the automated mode and the manual mode. During the stationary mode, in one embodiment (FIG. **18**A), the controller **302** may set up the projection head **110** (including the lamp assembly **1200**) in the stationary position while projecting the germicide such as UV light therefrom towards the proximate surfaces **1804**. The projection head **110** may include the lamp housing **1002** located within the exterior planes and the sagittal plane SS' passing therethrough in the stationary position. The lamp housing **1002** may be operable to rotate about a horizontal axis in the sagittal plane SS' and surround the lamp assembly **1200** of the projection head **110**. Further in the stationary position, the lamp housing **1002** may include the lateral plates **1004** and the top plate **1002-3** positioned orthogonal thereto. The lateral plates **1004** may be arranged parallel to the sagittal plane SS' and the top plate **1002-3** may be arranged perpendicular to the sagittal plane SS'. In the stationary mode, the controller **302** may trigger the projection head **110** (or the lamp assembly **1200**) to project the UV light through respective windows **1006** in the lateral plates **1004** and the top plate **1002-3** towards the ambient proximate surfaces **1804** (e.g., seats, walls, ceiling, etc.) located exterior to the projection device **100**. In some instances, the controller **302** may trigger the projection head **110** (or the lamp assembly **1200**) to project the UV light towards the proximate surfaces

1804 alternately in any predefined order during the disinfection cycle. Other instances may include the controller 302 triggering the projection head 110 (or the lamp assembly 1200) to project the UV light towards only one or a set of any two of the proximate surfaces 1804 for disinfection. The controller 302 may sense the stationary position of the projection head 110 (or the lamp housing 1002) based on the first position signal from the sensor block 1010, as discussed above.

Rotary Mode

When the rotary mode is selected, the controller 302 may deactivate the stationary mode and the peripheral mode for the projection device 100. The controller 302 may implement the rotary mode with any of the device modes including the automated mode and the manual mode. During the rotary mode, the controller 302 may drive the rotation assembly to rotate the projection head 110 (including the lamp assembly 1200) in at least one direction across the sagittal plane SS'. The projection head 110 may include the lamp housing 1002 rotating with the lamp assembly 1200 based on the shaft 1012 in the rotation assembly being driven by the controller 302, as discussed above. In one example, the controller 302 may alternately rotate the shaft 1012 clockwise and anticlockwise within the disinfection cycle. The shaft 1012 may be rotated about a horizontal axis in the sagittal plane SS' to rotate the projection head 110. During the anticlockwise rotation (FIG. 18B), the projection head 110 may be rotated to tilt the lamp housing 1002 across the sagittal plane SS' up to a predefined tilt angle (e.g., 45 degrees) relative to the sagittal plane SS'. Such anticlockwise tilt may drive the projection head 110 to the first rotary/tilt position from the stationary position.

In the first rotary/tilt position, the projection head 110 including the lamp assembly 1200 may rotate (or tilt) with the lamp housing 1002 towards the first lateral side 102-1 of the mobile body 108, or the projection device 100, across the sagittal plane SS'. The lamp housing 1002 may include the first lateral plate 1004-1 orienting downwards and the second lateral plate 1004-2 orienting upwards in this position. In the downward orientation, the projection head 110 (including the lamp assembly 1200) may project the UV light through the window 1006-1 in the first lateral plate 1004-1 for disinfecting portions of the first set of surfaces 1804-1, where these portions may be located below the axis of rotation defined by the longitudinal axis of the shaft 1012. In some instances, these portions below the axis of rotation may include the ground such as a part of the aircraft aisle being traversed by the projection device 100. The downward orientation may assist to disinfect adjacent surfaces (e.g., seat handles) that may be outside a trajectory of UV light projected in the stationary position of the projection head 110 due to the adjacent surface being relatively closer (e.g., less than one meter) to the first lateral side 102-1 of the mobile body 108.

In the upward orientation, the projection head 110 (including the lamp assembly 1200) may project the UV light through the window 1006-2 in the second lateral plate 1004-2 for disinfecting portions of the second set of surfaces 1804-2 and the third set of surfaces 1804-3, where these portions may be located above the axis of rotation of the projection head 110. In some instances, simultaneously, the projection head 110 (including the lamp assembly 1200) may be operated by the controller 302 to project the UV light through the window 1006-3 in the top plate 1002-3 for disinfecting portions of the first set of surfaces 1804-1 and the third set of surfaces 1804-3, where these portions may be located above the axis of rotation of the projection head 110.

The controller 302 may determine the first rotary/tilt position of the projection head 110 (or the lamp housing 1002) based on the second position signal from the sensor block 1010, as discussed above. In response to determining the first rotary/tilt position, the controller 302 may rotate the shaft 1012 in the reverse direction (such as clockwise direction) and return the projection head 110 (or the lamp housing 1002) to the stationary position. However, some instances may include the controller 302 operating the shaft 1012 to selectively maintain the projection head 110 (or the lamp housing 1002) at the first rotary/tilt position for a predefined duration within the disinfection cycle. Upon returning to the stationary position, the sensor block 1010 may assist to detect such position of the projection head 110 (or the lamp housing 1002) and trigger the controller 302 to rotate the shaft 1012 in the clockwise direction within the same disinfection cycle or a predefined period thereafter.

During the clockwise rotation (FIG. 18C), the projection head 110 may be rotated to tilt the lamp housing 1002 across the sagittal plane SS' up to a predefined tilt angle (e.g., 45 degrees) relative to the sagittal plane SS'. Such clockwise tilt may drive the projection head 110 to the second rotary/tilt position from the stationary position. In the second rotary/tilt position, the projection head 110 including the lamp assembly 1200 may rotate (or tilt) with the lamp housing 1002 towards the second lateral side 102-2 of the mobile body 108, or the projection device 100, across the sagittal plane SS'. The lamp housing 1002 may include the second lateral plate 1004-2 orienting downwards and the first lateral plate 1004-1 orienting upwards in this position. In the downward orientation, the projection head 110 (including the lamp assembly 1200) may project the UV light through the window 1006-2 in the second lateral plate 1004-2 for disinfecting portions of the second set of surfaces 1804-2, where these portions may be located below the axis of rotation of the projection head 110. In some instances, these portions below the axis of rotation may include the ground such as a part of the aircraft aisle being traversed by the projection device 100. The downward orientation may assist to disinfect adjacent surfaces (e.g., seat handles) that may be outside a trajectory of UV light projected in the stationary position of the projection head 110 due to the adjacent surface being relatively closer (e.g., less than one meter) to the second lateral side 102-2 of the mobile body 108.

In the upward orientation, the projection head 110 (including the lamp assembly 1200) may project the UV light through the window 1006-1 in the first lateral plate 1004-2 for disinfecting portions of the first set of surfaces 1804-1 and the third set of surfaces 1804-3, where these portions may be located above the axis of rotation of the projection head 110. In some instances, simultaneously, the projection head 110 (including the lamp assembly 1200) may be operated by the controller 302 to project the UV light through the window 1006-3 in the top plate 1002-3 for disinfecting portions of the first set of surfaces 1804-1 and the third set of surfaces 1804-3, where these portions may be located above the axis of rotation of the projection head 110.

The controller 302 may determine the second rotary/tilt position of the projection head 110 (or the lamp housing 1002) based on the third position signal from the sensor block 1010, as discussed above. In response to determining the second rotary/tilt position, the controller 302 may rotate the shaft 1012 in the reverse direction (such as anticlockwise direction) and return the projection head 110 (or the lamp housing 1002) to the stationary position. However, some instances may include the controller 302 operating the shaft 1012 to selectively maintain the projection head 110 (or the lamp housing **1002**) at the second rotary/tilt position for a predefined duration within the disinfection cycle. Upon returning to the stationary position, the controller **302** may determine such position of the projection head **110** (or the lamp housing **1002**) and continue rotating the shaft **1012** between the anticlockwise direction and the clockwise direction within the disinfection cycle. Hence, the projection head **110** operates in the stationary and the rotary/tilt positions to project the UV light for disinfecting surfaces, such as the proximate surfaces **1804**, located above and lateral to the device **100** while limiting UV dispersion towards the front side **104** and the rear side **106** of the mobile body **108**, or the projection device **100**. Other examples may include the controller **302** alternately rotating the shaft **1012** for rotating/tilting the projection head **110** between the stationary position and one of the rotary/tilt positions in the rotary mode.

Peripheral Mode

In a further embodiment, the operator may select the peripheral mode to operate a peripheral component such as the handheld projection device **802** (e.g., handheld UV device) attached to the auxiliary frame **602** of the projection device **100**. Some examples may include the controller **302** deactivating the projection modes and the automated mode of the projection device **100** upon selection of the peripheral mode. In the peripheral mode, the auxiliary frame **602** may couple the attached handheld projection device **802** to the control system. The handheld projection device **802** may be powered (via the battery) and/or controlled by the controller **302** for manually disinfecting surfaces that may be outside the trajectories of UV light projected by the projection head **110** in the stationary position and the rotary/tilt positions.

While the foregoing written description of the invention enables one of ordinary skill to make and use what is considered presently to be the best mode thereof, those of ordinary skill will understand and appreciate the existence of variations, combinations, and equivalents of the specific embodiment, method, and examples herein. The invention should therefore not be limited by the above-described embodiments, methods, and examples, but by all embodiments and methods within the scope and spirit of the invention(s).

We claim:

1. An apparatus for projecting UV light towards surfaces across a path, the apparatus comprising:

a mobile body including opposing lateral sides and a sagittal plane passing therebetween; and

a projection head rotatably mounted to the mobile body, the projection head operating to project UV light directionally towards surfaces located above and proximate to the opposing lateral sides, wherein the projection head is adapted to rotate about a horizontal axis in the sagittal plane while the UV light is being projected towards the surfaces, wherein the projection head includes a set of radiation units for projecting the UV light, wherein the set includes a first radiation unit and a second radiation unit respectively oriented towards each of the opposing lateral sides and wherein each of the radiation units in the set of radiation units is fixed relative to the other radiation units in the set of radiation units.

2. The apparatus of claim **1**, wherein the projection head is further adapted to tilt up to a predefined tilt angle towards at least one of the opposing lateral sides across the sagittal plane.

3. The apparatus of claim **2**, wherein the tilt angle is 45 degrees relative to the sagittal plane.

4. The apparatus of claim **1**, further comprising a housing proximate to the projection head, wherein the housing includes a portion at least in-part permeable to the UV light.

5. The apparatus of claim **4**, wherein the housing is supported by the opposing lateral sides.

6. The apparatus of claim **1**, wherein the set further includes a third radiation unit located between the first radiation unit and the second radiation unit, wherein the third radiation unit is oriented to project the UV light towards a surface above the horizontal axis.

7. The apparatus of claim **6**, wherein the third radiation unit is oriented to project the UV light in a first direction orthogonal to a second direction of projection associated with at least one of the first radiation unit and the second orientation unit.

8. The apparatus of claim **1**, wherein the radiation units are oriented away from each other.

9. The apparatus of claim **1**, wherein the projection head is located at a height of at least 38 inches (or 96 centimeters) from the ground.

10. The apparatus of claim **1**, wherein the mobile body further includes a tray pivotably attached thereto, the tray being pivotable to transition between a closed position and an open position, wherein the tray is parallel to a vertical axis in the closed position and non-parallel to the vertical axis in the open position.

11. The apparatus of claim **10**, wherein the tray is pivotable to at least partially extend outward from one of the opposing lateral sides in the open position.

12. The apparatus of claim **10**, wherein the tray includes a support surface for carrying operational components of the apparatus, wherein the support surface is parallel to the vertical axis in the closed position.

13. The apparatus of claim **1**, wherein the mobile body is adapted to move the apparatus autonomously while the projection head rotates about the horizontal axis.

14. The apparatus of claim **1**, wherein the projection head operates to project the UV light towards the surfaces alternately within an operational cycle.

15. The apparatus of claim **1**, further comprising a plurality of windows providing for the projection head to directionally project the UV light.

16. The apparatus of claim **1**, wherein the mobile body includes a camera.

17. The apparatus of claim **1**, wherein at least one of the mobile body and the projection head are operable via a remote device.

18. The apparatus of claim **1**, further comprising a handheld device operably connected to the apparatus.

19. The apparatus of claim **1**, wherein the projection head is implementable on a handheld device.

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