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(54) **REMOTE INTERFACE WITH
TYPE-SPECIFIC HANDSHAKE FOR
CONNECTED PERSONAL PROTECTIVE
EQUIPMENT**

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(71) Applicant: **3M INNOVATIVE PROPERTIES
COMPANY**, St Paul, MN (US)

(72) Inventors: **Eric C. Lobner**, Woodbury, MN (US);
Matthew J. Blackford, Hastings, MN
(US); **Daniel E. G. Gullberg**, Gagnef
(SE); **Emil R. Eriksson**, Falun (SE);
Micayla A. Johnson, Farmington, MN
(US)

(57) **ABSTRACT**

In some examples, a system includes a set of personal protection equipment (PPE) controlled by a particular user, wherein an article of PPE in the set of PPE is of a particular type. The computing device may be controlled by the particular user and includes one or more computer processors that: execute, based on receiving a message that is generated by the article of PPE in response to a PPE-handshake input that is unique to the particular type of the article of PPE, a set of PPE-handshake operations to establish a connection with the article of PPE; and output for display, using data received by the second communication device from the first communication device via the connection, a graphical user interface that is based at least in part on the data received from the article of PPE that sent the message.

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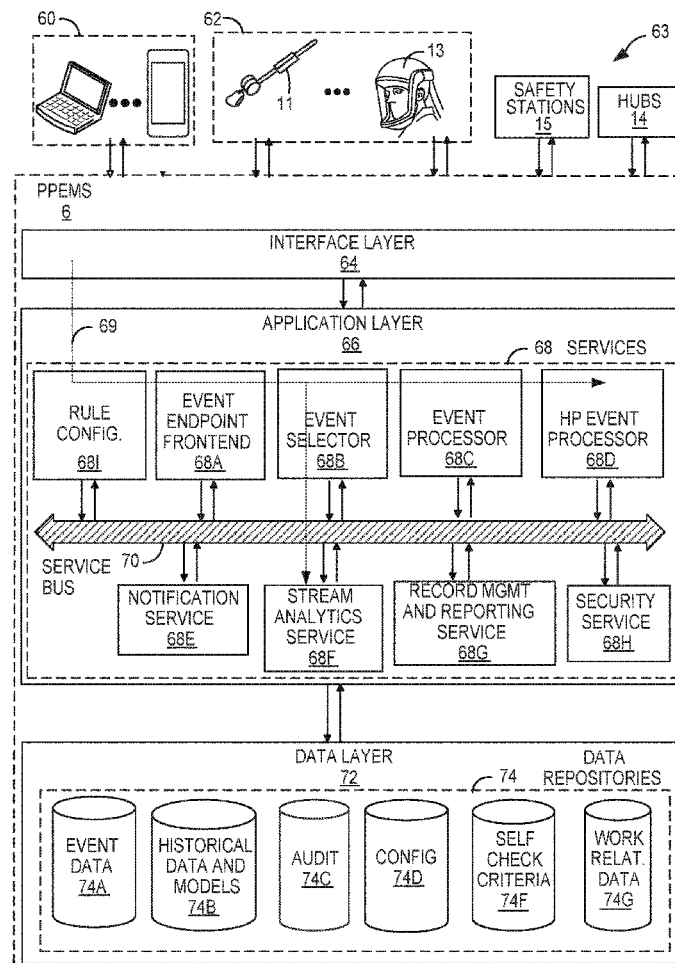
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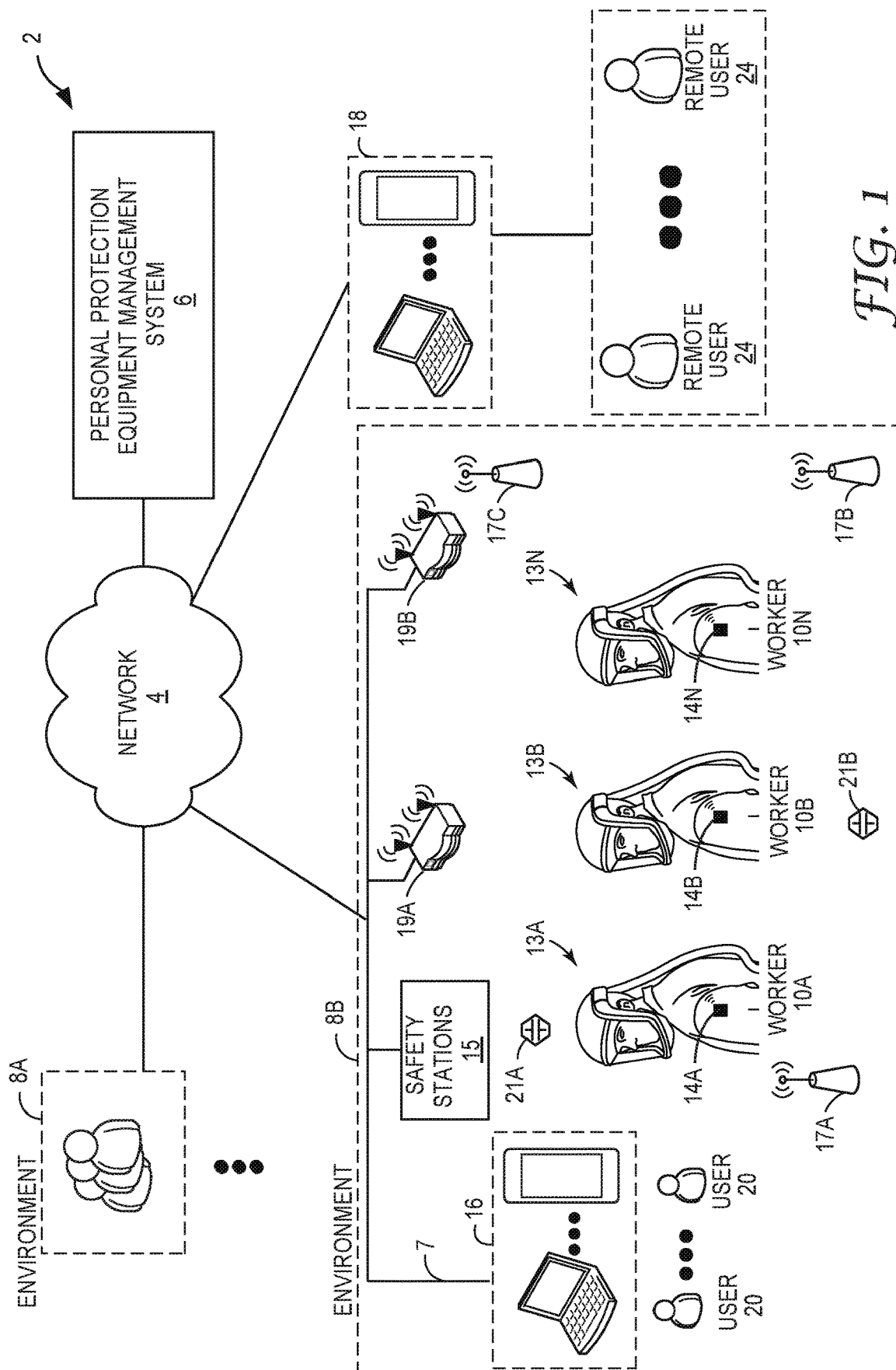
§ 371 (c)(1),

(2) Date: **Mar. 6, 2020**

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(60) Provisional application No. 62/639,958, filed on Mar. 7, 2018, provisional application No. 62/556,771, filed on Sep. 11, 2017.





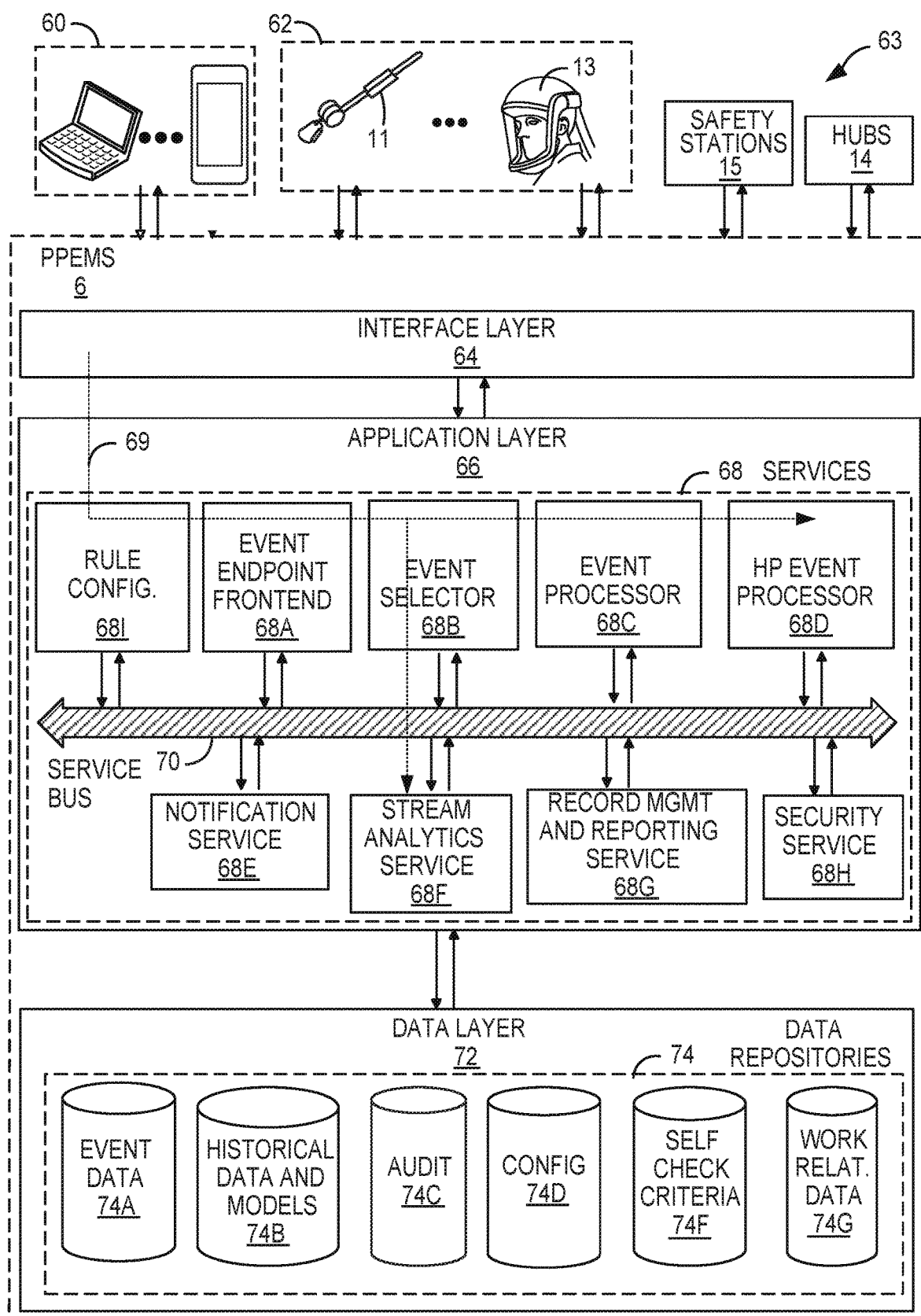
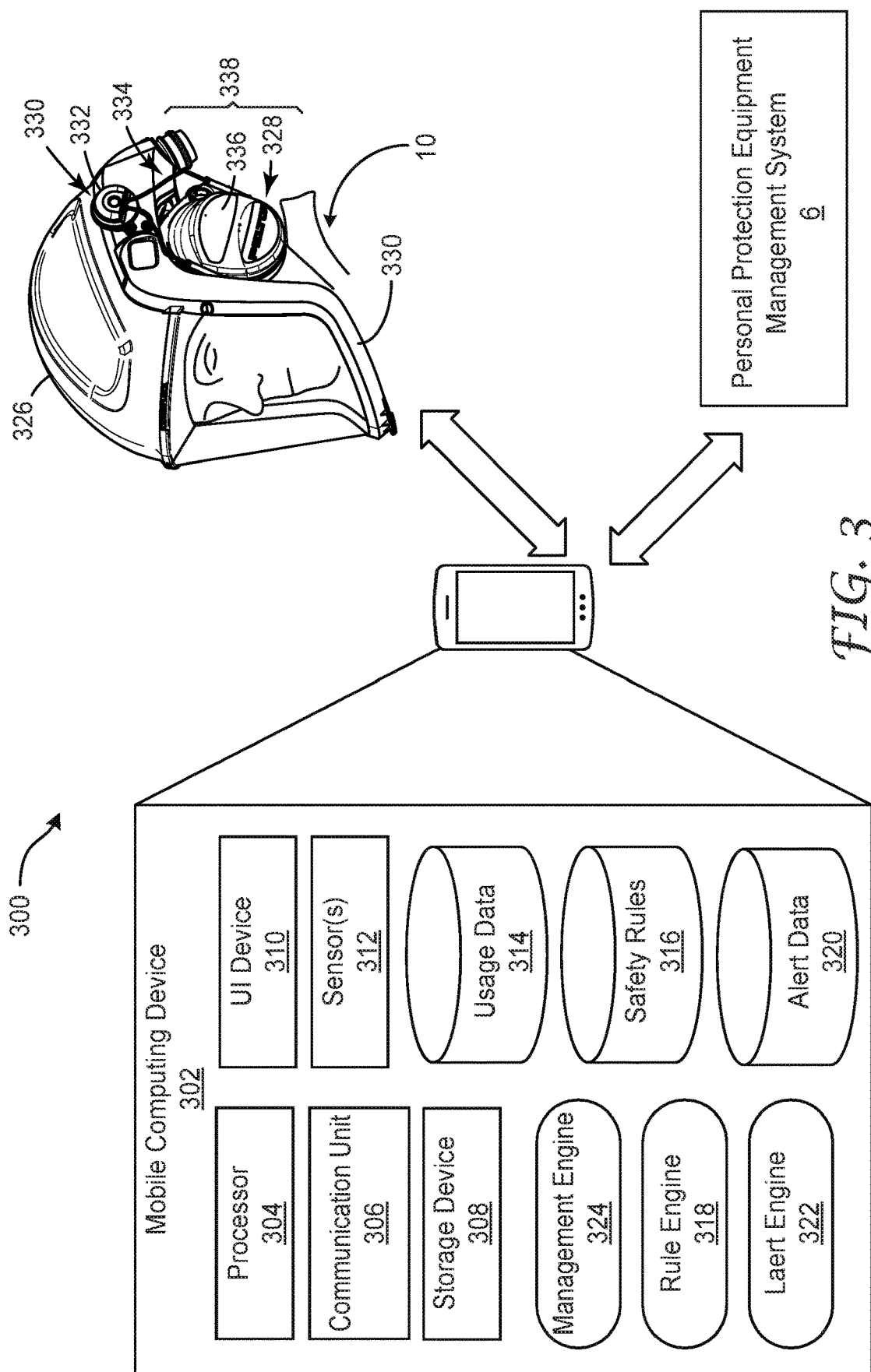


FIG. 2



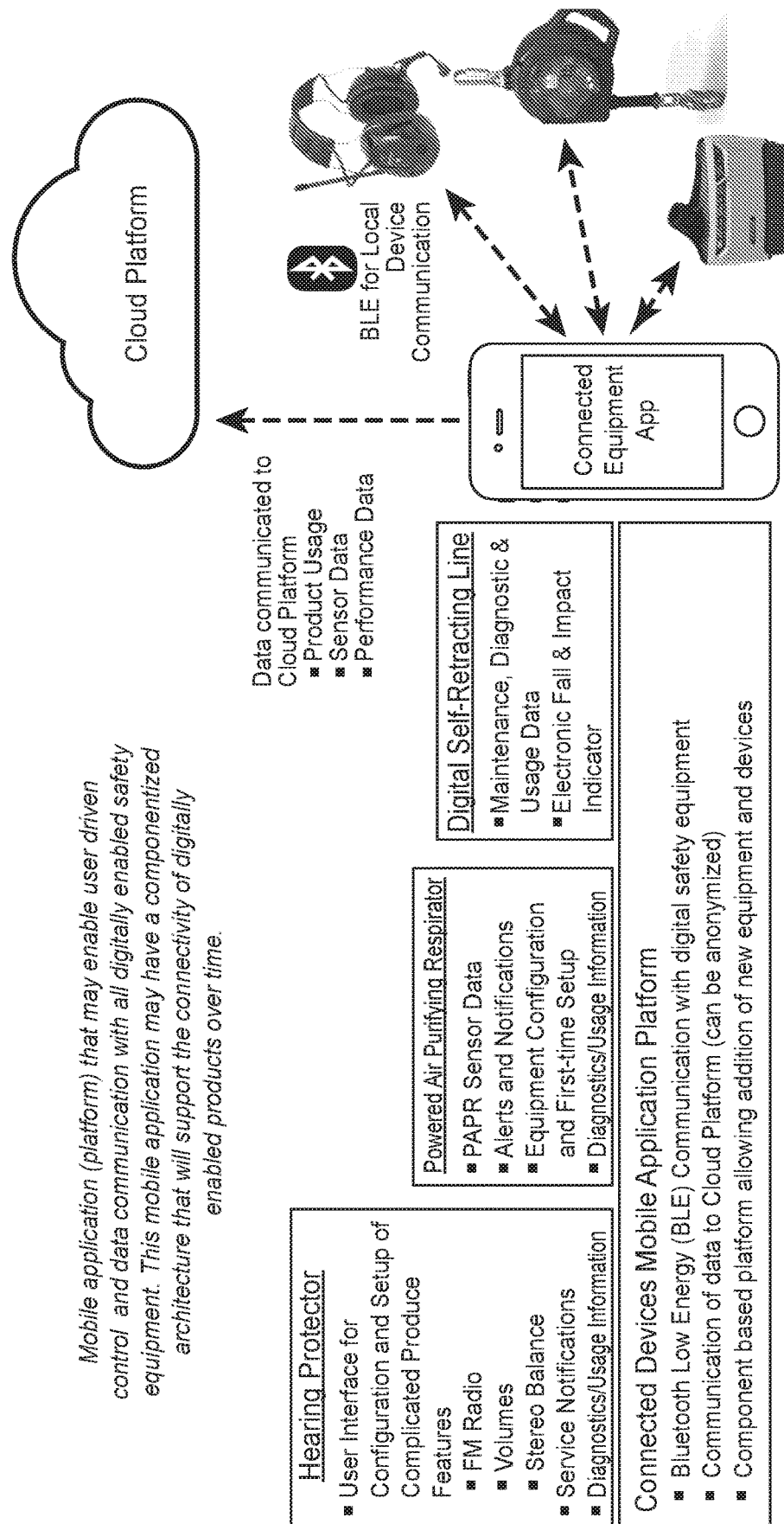


FIG. 4

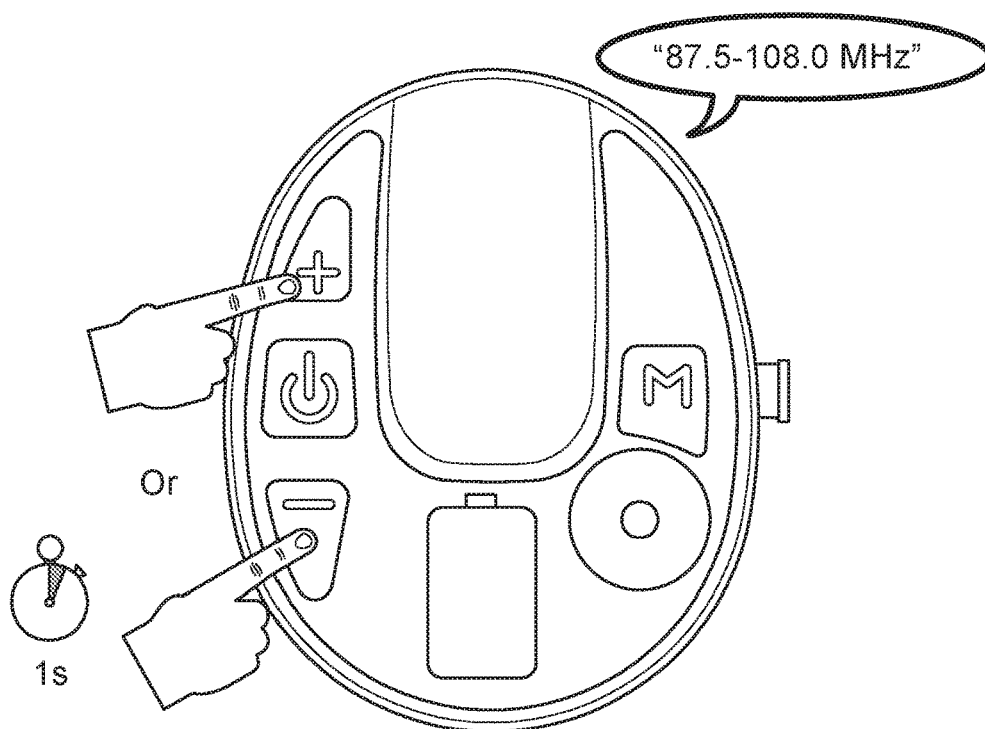


FIG. 5A



FIG. 5B

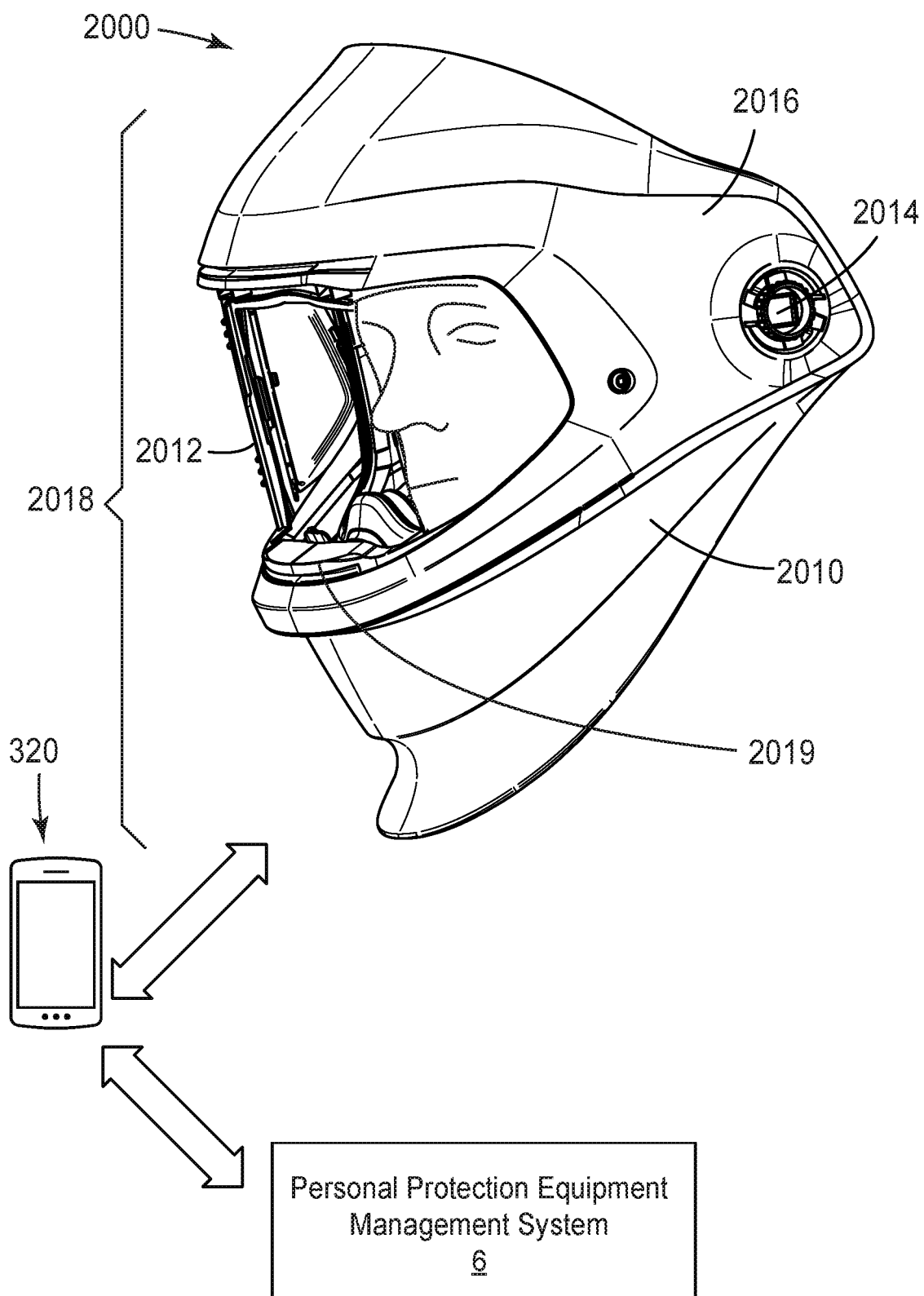


FIG. 6

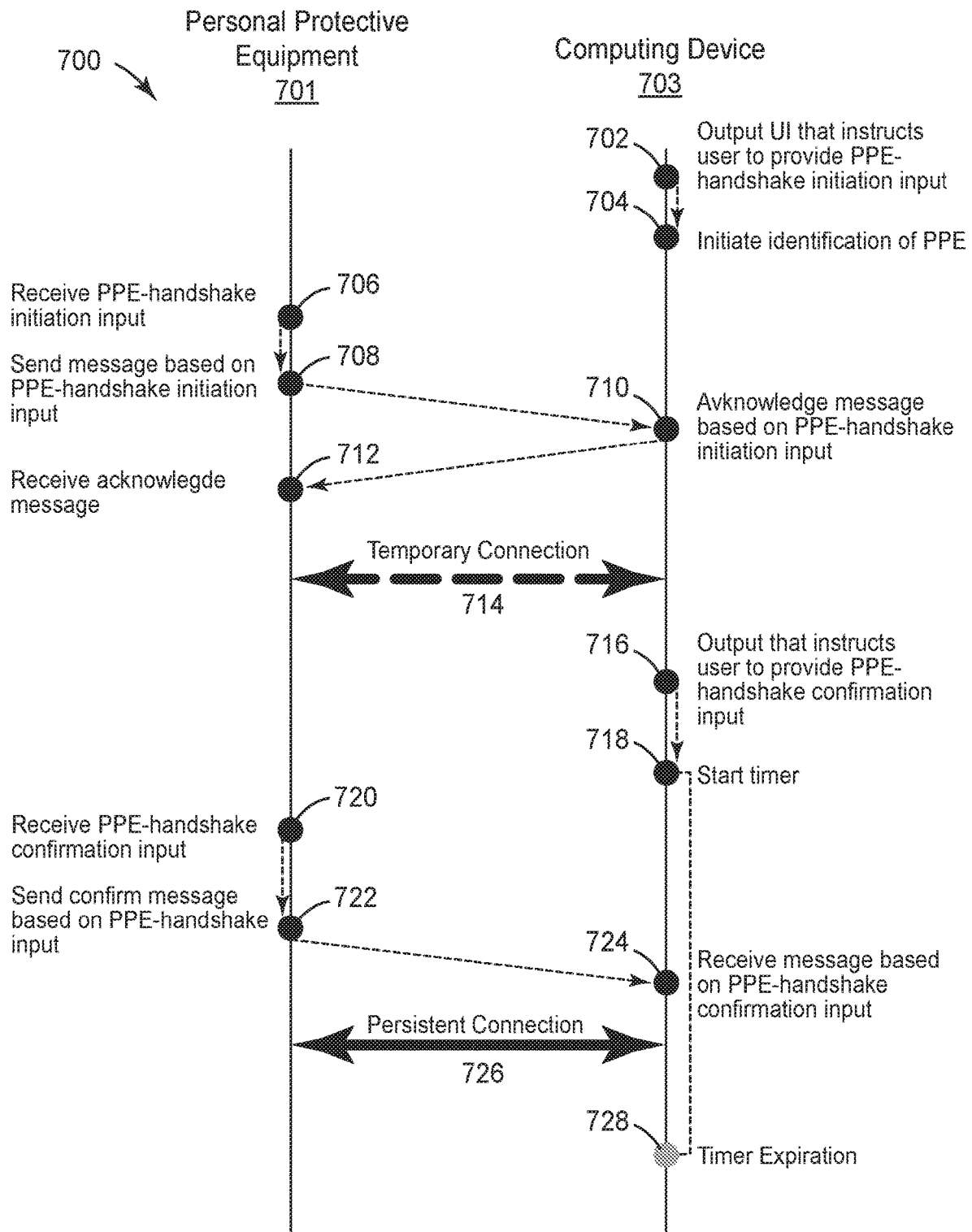


FIG. 7

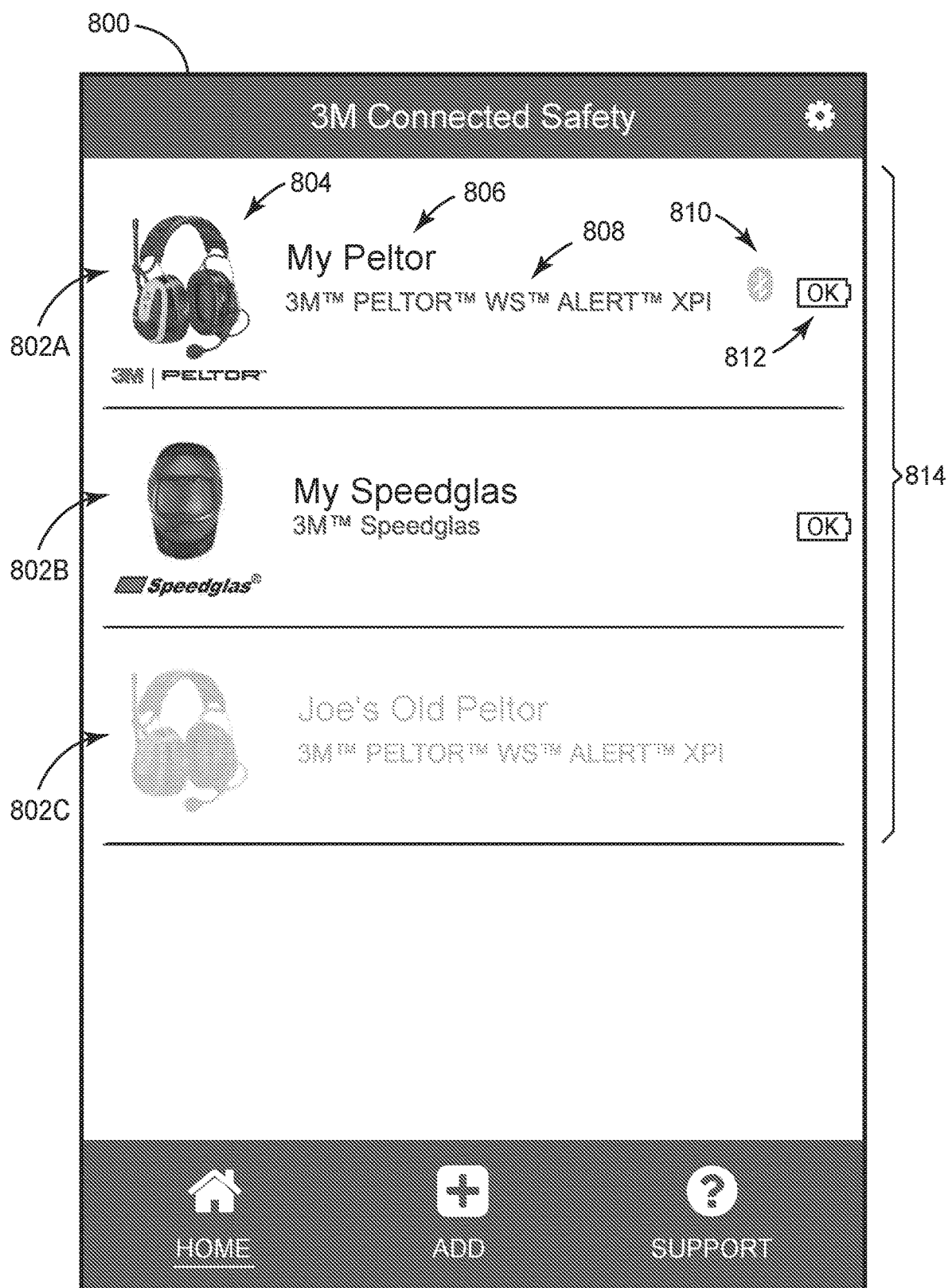


FIG. 8

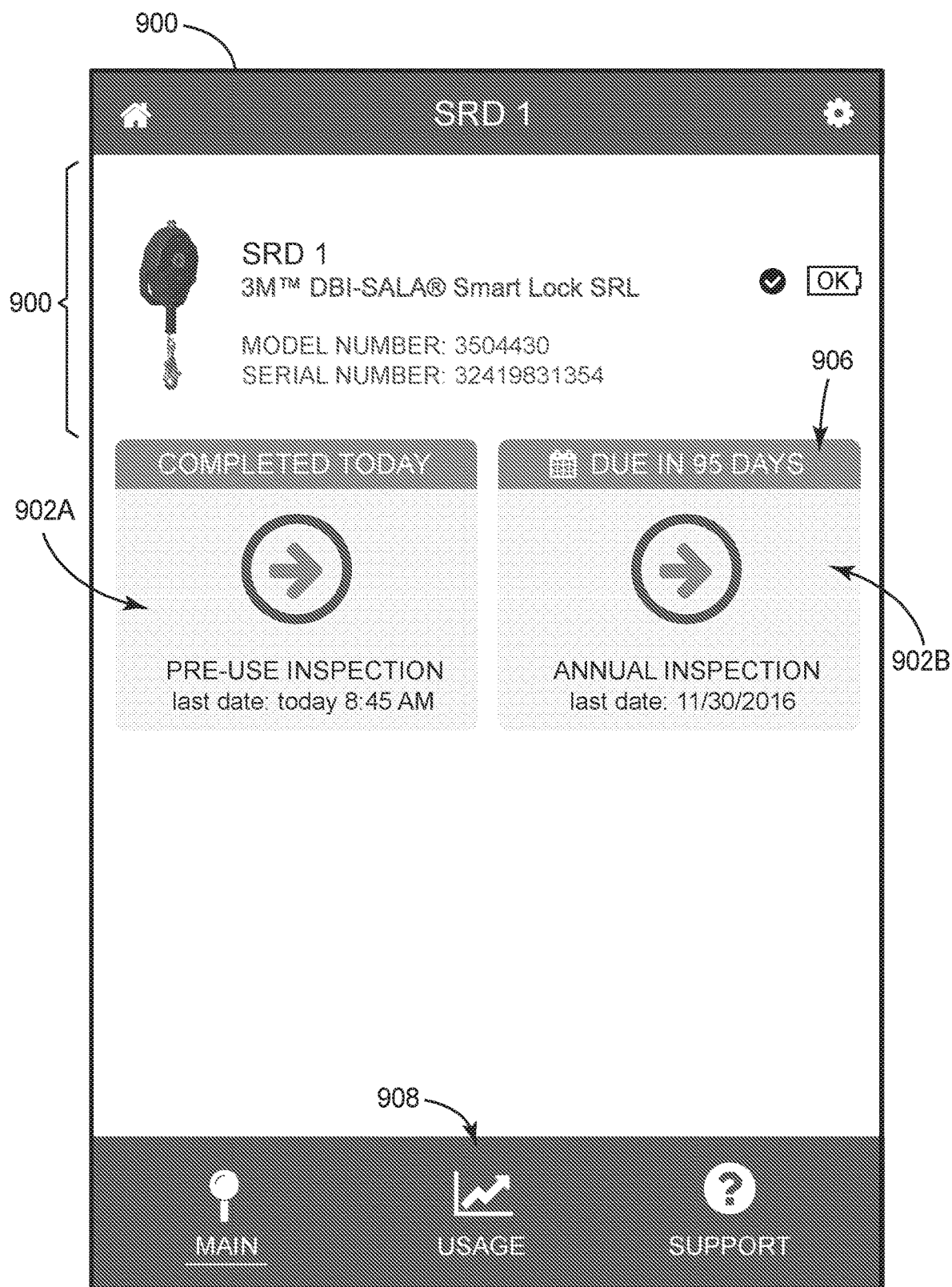


FIG. 9

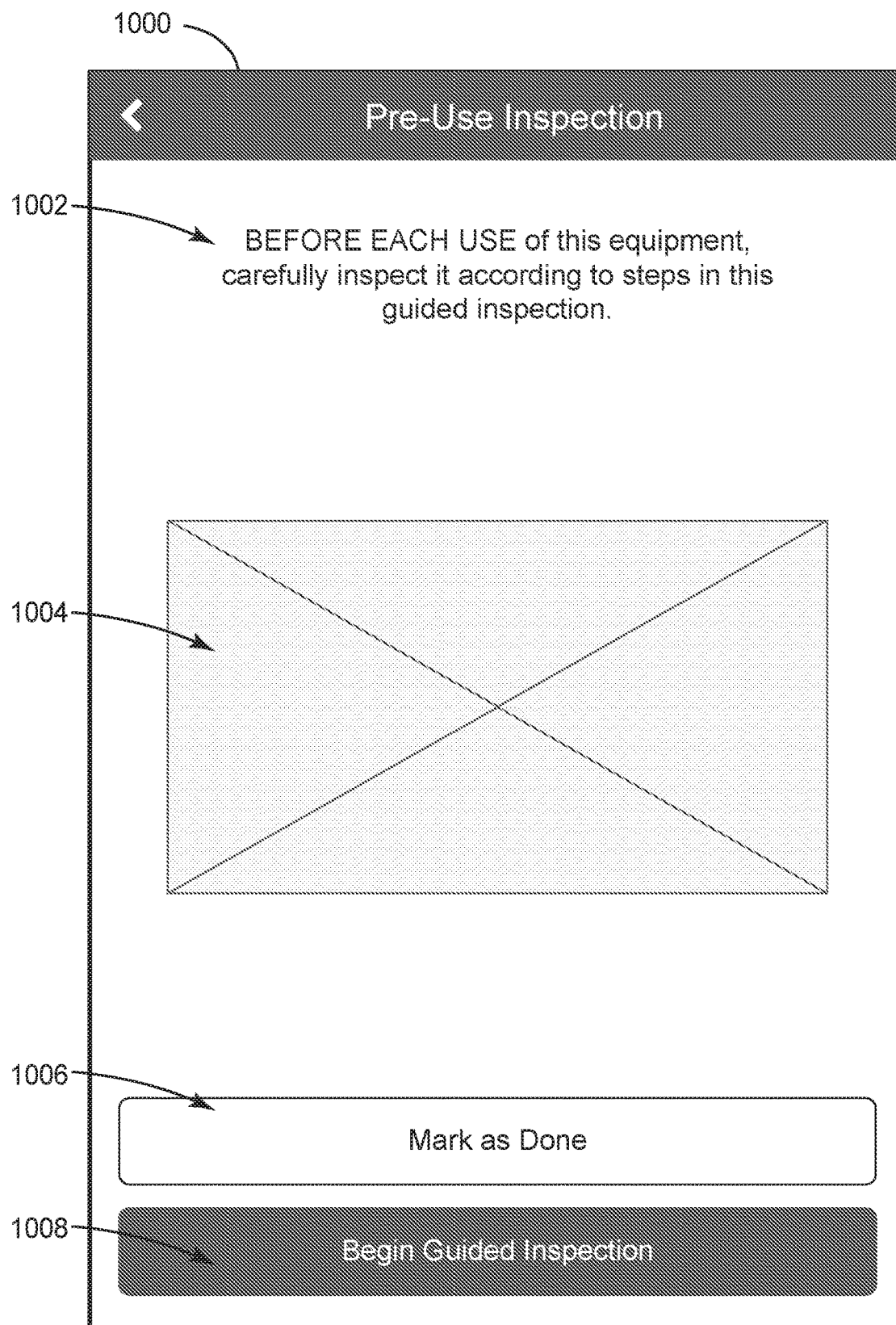


FIG. 10

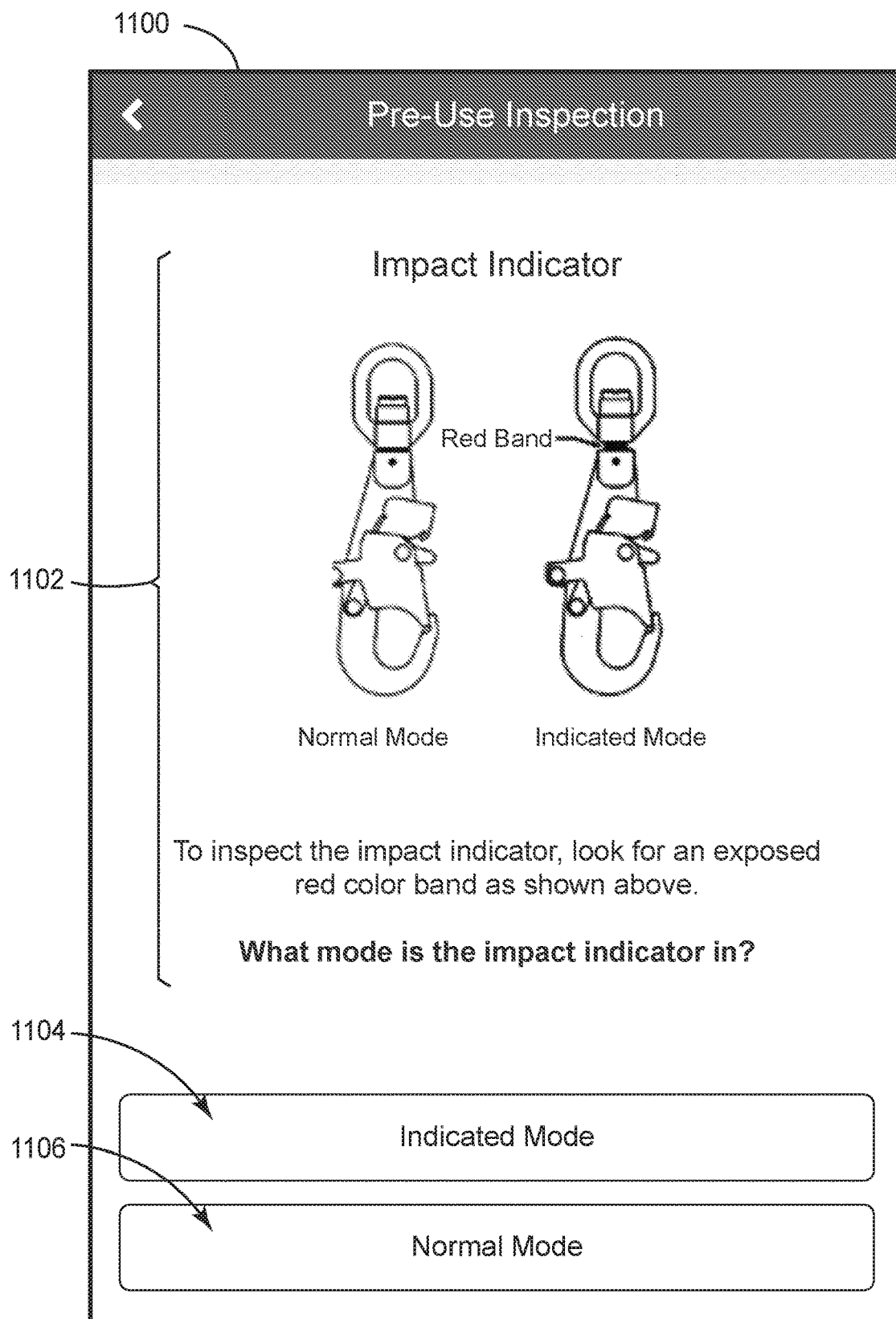


FIG. 11A

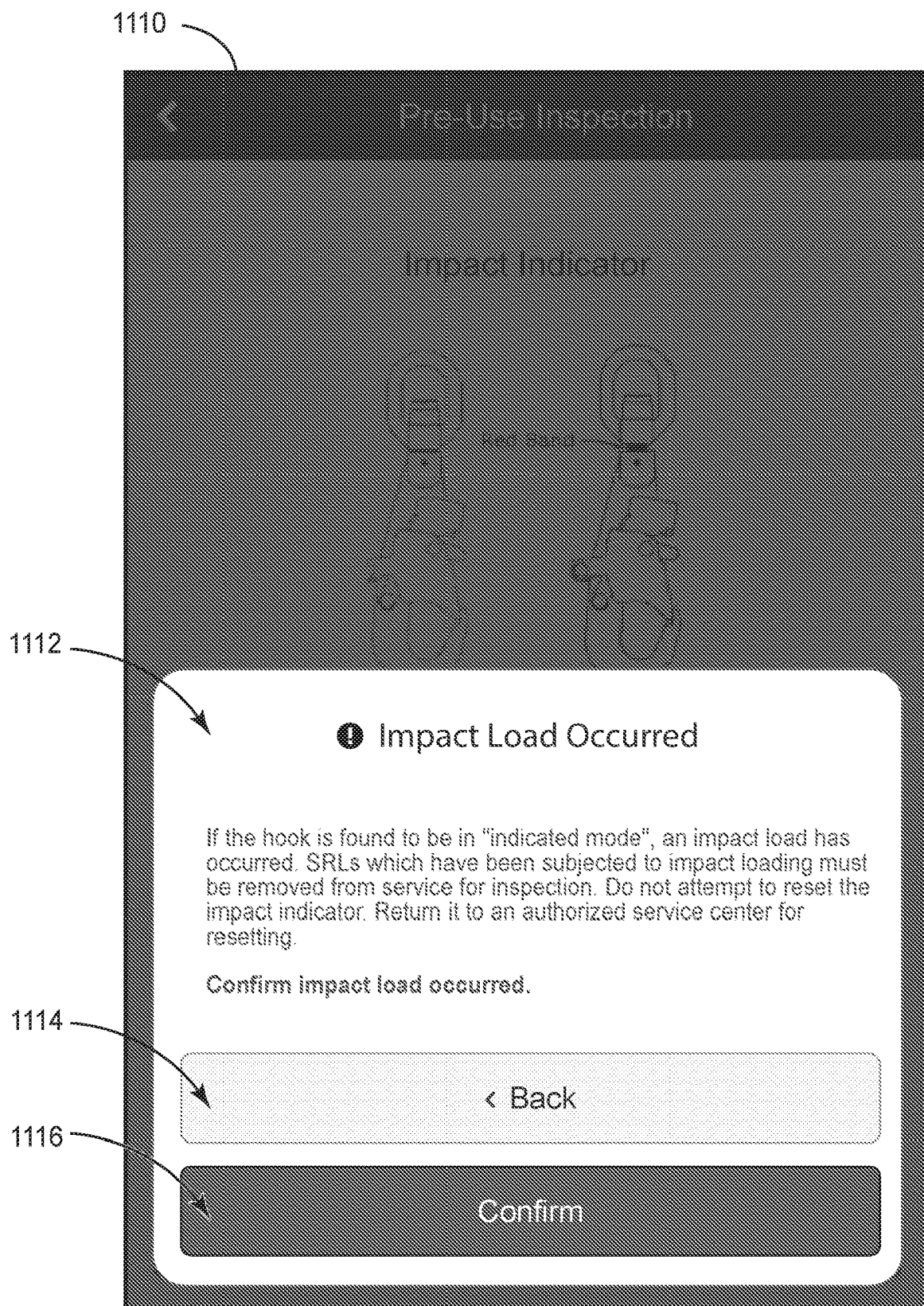


FIG. 11B

1200

Pre-Use Inspection

Inspect Damage

1206

Inspect the equipment for loose screws and bent or damaged parts.

Are any of the above present?

1208

1210

Yes

No

FIG. 12A

1202

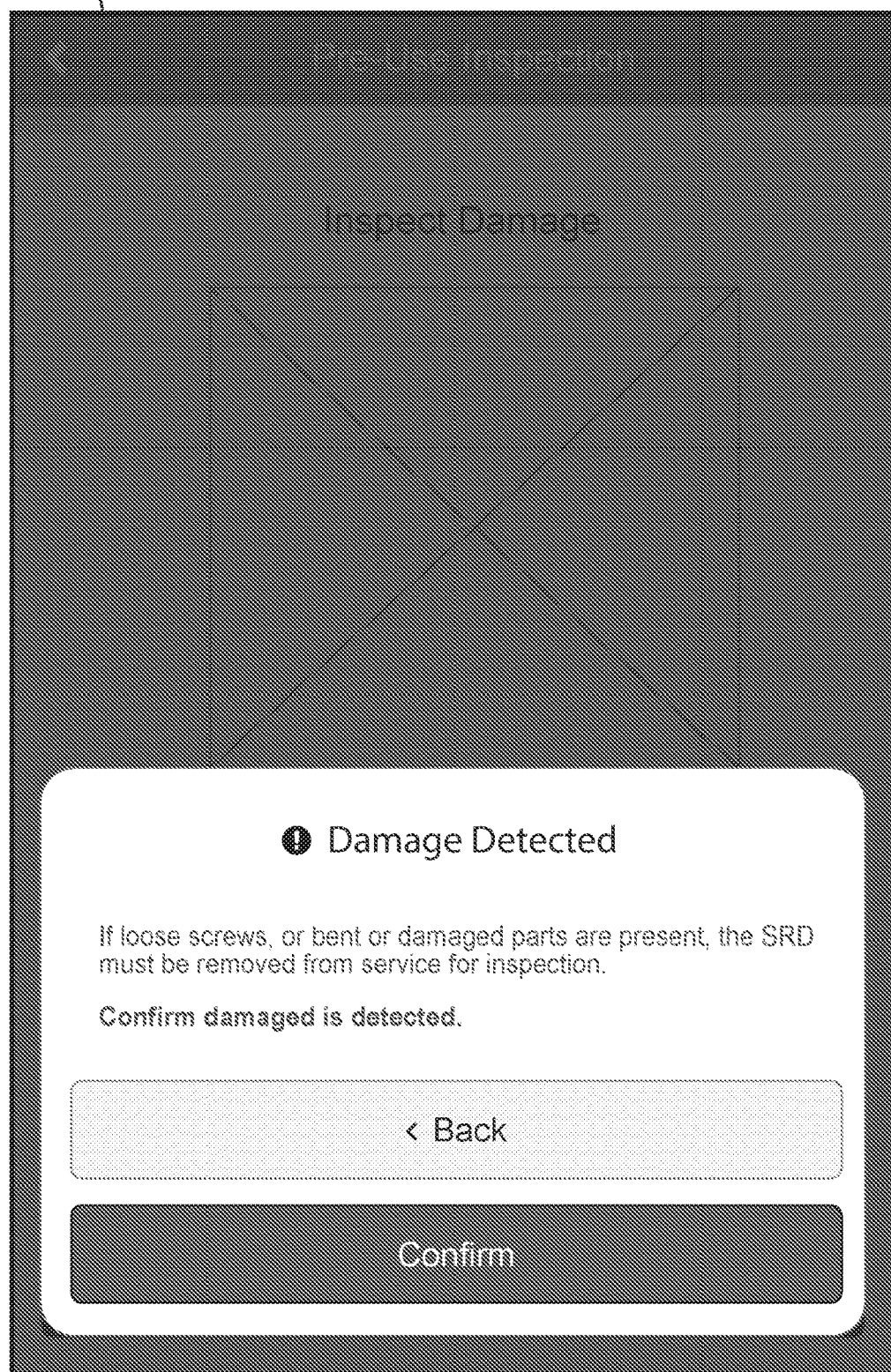


FIG. 12B

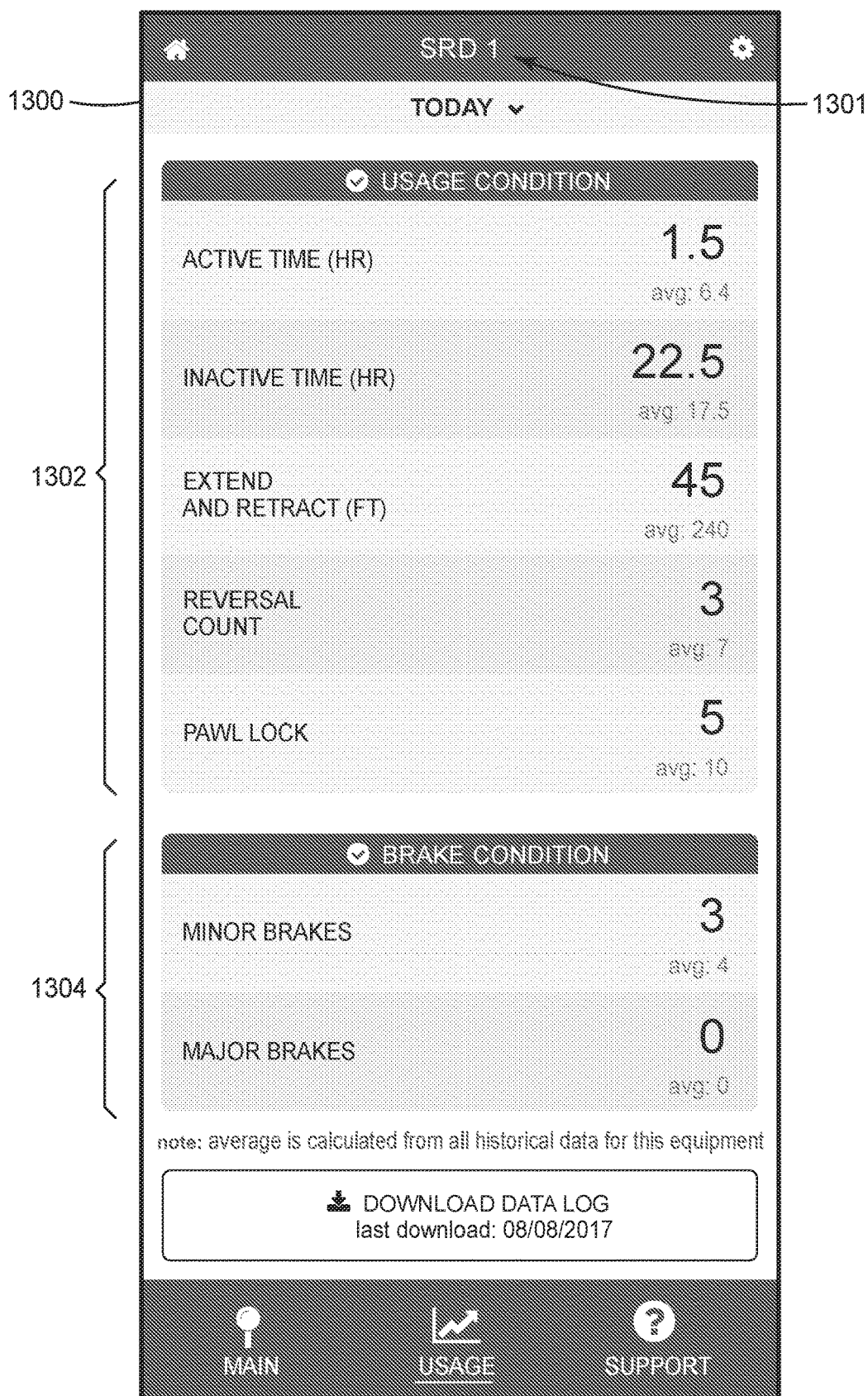


FIG. 13A

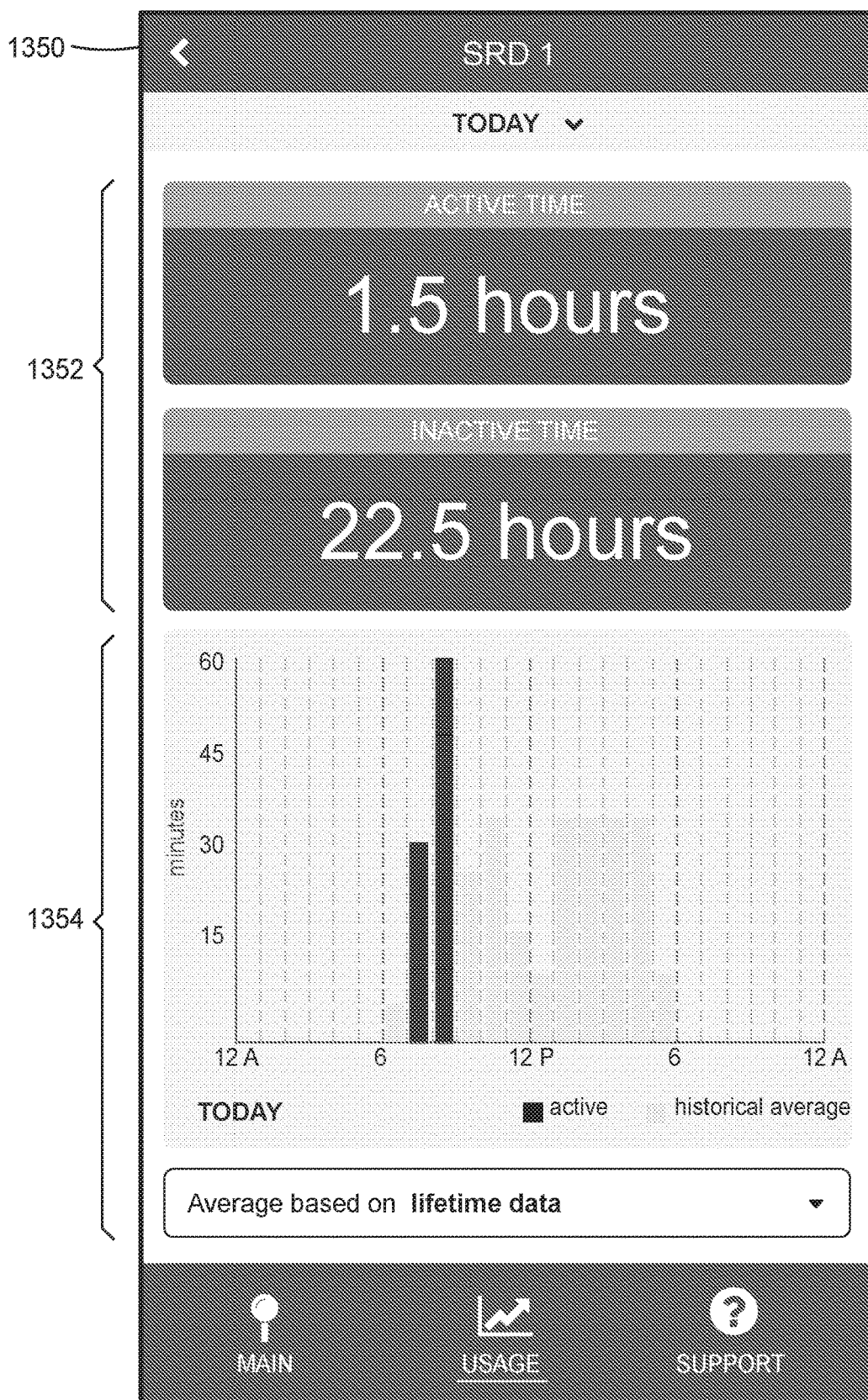


FIG. 13B

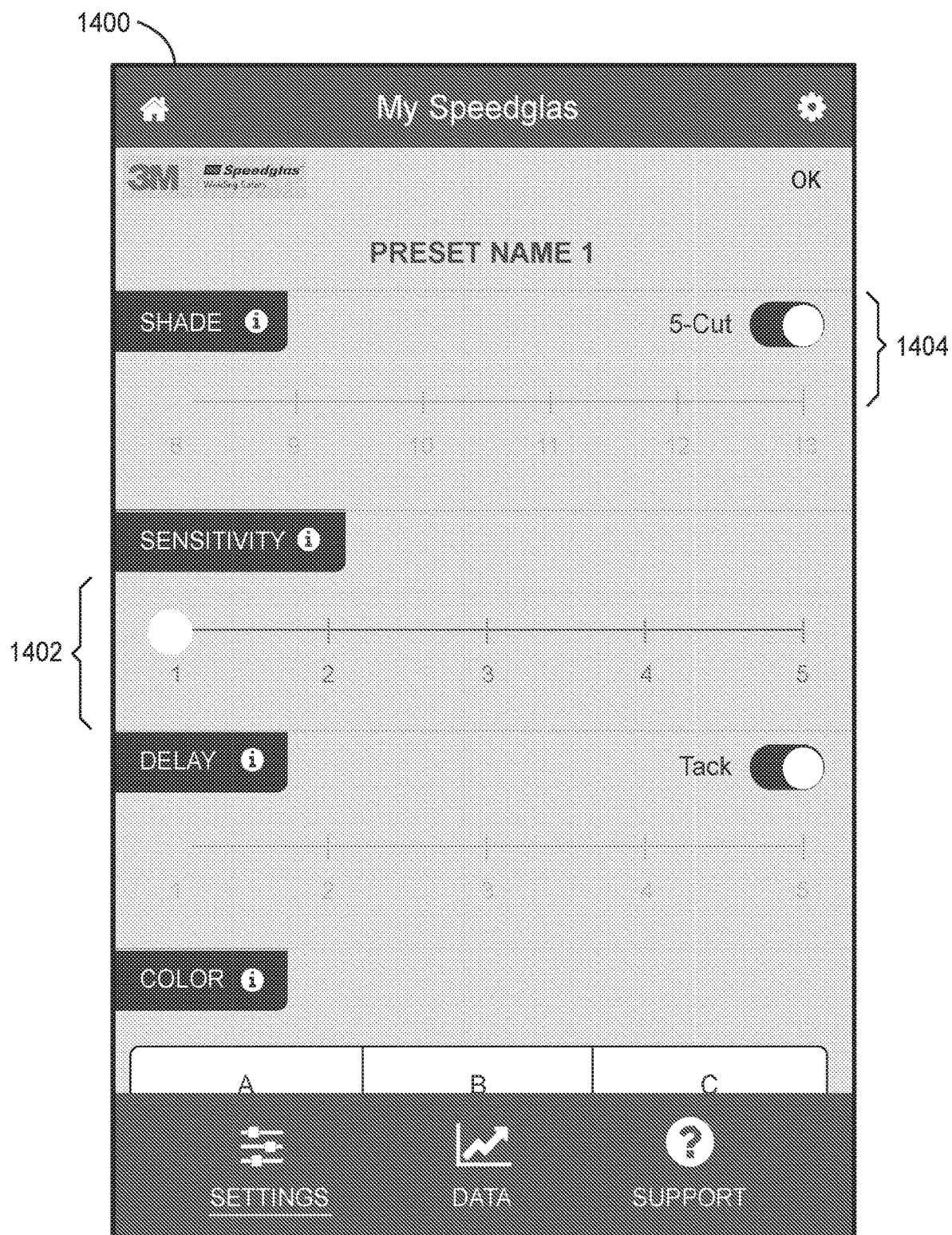


FIG. 14A

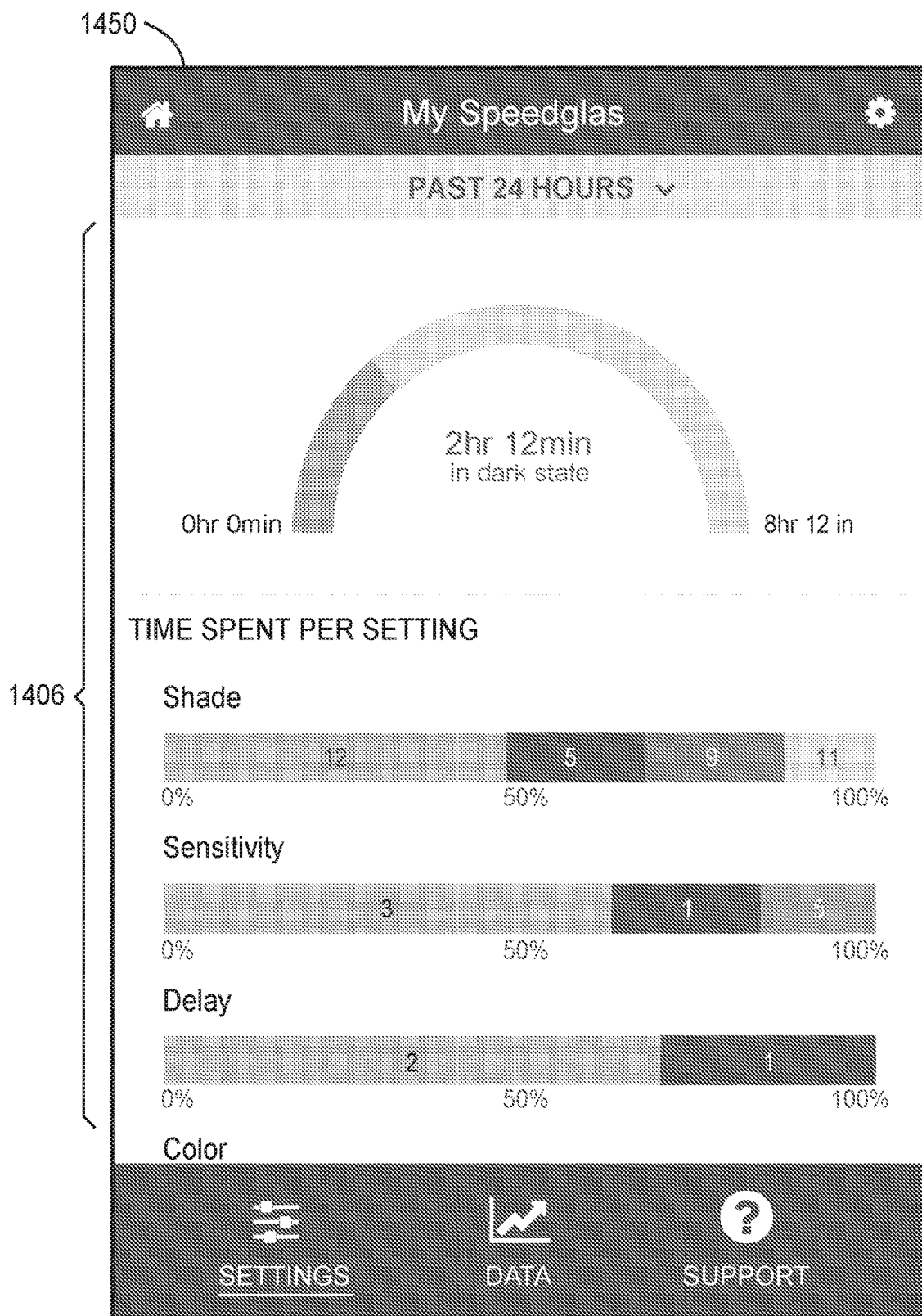


FIG. 14B

REMOTE INTERFACE WITH TYPE-SPECIFIC HANDSHAKE FOR CONNECTED PERSONAL PROTECTIVE EQUIPMENT

RELATED APPLICATIONS

[0001] This application is related to U.S. Application No. 62/556,771 filed Sep. 11, 2017, the entire content of which is incorporated herein by reference.

TECHNICAL FIELD

[0002] The present disclosure relates to the field of personal protective equipment. More specifically, the present disclosure relates to personal protective equipment that generate data.

BACKGROUND

[0003] When working in areas where there is known to be, or there is a potential of there being, dusts, fumes, gases, airborne contaminants, fall hazards, hearing hazards or any other hazards that are potentially hazardous or harmful to health, it is usual for a worker to use personal protective equipment, such as respirator or a clean air supply source. While a large variety of personal protective equipment are available, some commonly used devices include powered air purifying respirators (PAPR), self-contained breathing apparatuses, fall protection harnesses, ear muffs, face shields, and welding masks. For instance, a PAPR typically includes a blower system comprising a fan powered by an electric motor for delivering a forced flow of air through a tube to a head top worn by a user. A PAPR typically includes a device that draws ambient air through a filter, forces the air through a breathing tube and into a helmet or head top to provide filtered air to a user's breathing zone, around their nose or mouth. An SCBA provides clean air from a compressed air tank through a tube or hose to the interior of a head top worn by a user. In some examples, various personal protective equipment may generate various types of data.

SUMMARY

[0004] This disclosure is directed to a system that implements PPE-handshake operations executed between an article of PPE and a computing device. In accordance with techniques of this disclosure, an article of PPE and a computing device (e.g., a mobile device) may execute a set of PPE-handshake operations that include receipt of a PPE-handshake input that is unique to the particular type of the at least one article of PPE. Unlike conventional pairing techniques (e.g., Bluetooth pairing), which can be cumbersome and non-intuitive for a worker (particularly, if wearing other PPE, such as heavy gloves, protective clothing, or protective headwear), the techniques of this disclosure may use a PPE-handshake input that is unique to the particular type of PPE in order to initiate a temporary connection between PPE and computing device that is, in turn, used to establish a persistent connection based on a subsequent confirmation based on the PPE-handshake input.

[0005] By using a PPE-handshake input that is unique to the particular type of the at least one article of PPE, the techniques may eliminate the need to add additional controls, buttons, or other input means to the PPE. In some examples, by using a PPE-handshake input that is unique to the particular type of the at least one article of PPE, the

techniques may enable the worker to interact directly with the PPE to establish the connection, thereby simplifying the connection process with the computing device. In some examples, by using a PPE-handshake, existing physical characteristics of the PPE itself can be used to generate the message that initiates a connection with the PPE, thereby leveraging this existing physical characteristic in an unconventional way that provides the worker with an intuitive technique to initiate the connection. Moreover, in some examples, the PPE-handshake operations provide a process by which an accidentally or unintentionally provided PPE-handshake input does not create a permanent connection with the computing device because, in some examples, the PPE-handshake operations use a subsequent confirmation based on the PPE-handshake input to validate that a permanent connection is intended by the user. In some examples, the PPE-handshake operations provide a process by which security can be applied to establish a permanent connection. In this way, malicious or unauthorized pairing may be prevented by the PPE-handshake operations.

[0006] In some examples, a system includes: a set of personal protection equipment (PPE) controlled by a particular user, wherein at least one article of PPE in the set of PPE is of a particular type and comprises a first communication device; a computing device controlled by the particular user including: a second communication device; one or more computer processors; and a memory comprising instructions that, when executed by the one or more computer processors, cause the one or more computer processors to: execute, based on receiving a message that is generated by the at least one article of PPE in response to a PPE-handshake input that is unique to the particular type of the at least one article of PPE, a set of PPE-handshake operations to establish a connection with the at least one article of PPE; and output for display, using data received by the second communication device from the first communication device via the connection, a graphical user interface that is based at least in part on the data received from the at least one article of PPE that sent the message.

[0007] In some examples, a method includes: executing, by a computing device and based on receiving a message that is generated by at least one article of personal protection equipment (PPE) in response to a PPE-handshake input that is unique to a particular type of the at least one article of PPE, a set of PPE-handshake operations to establish a connection with the at least one article of PPE, wherein a set of PPE controlled by a particular user includes the at least one article of PPE, and the at least one particular of PPE is of a particular type and comprises a first communication device; and outputting for display, by the computing device and using data received by the second communication device from the first communication device via the connection, a graphical user interface that is based at least in part on the data received from the least one article of PPE that sent the message.

[0008] The details of one or more examples of the disclosure are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the disclosure will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1 is a block diagram illustrating an example system in which personal protection equipment (PPEs), such

as filtered air respirator systems, having embedded sensors and communication capabilities are utilized within a number of work environments and are managed by a personal protection equipment management system (PPEMS) in accordance with various techniques of this disclosure.

[0010] FIG. 2 is a block diagram illustrating an operating perspective of the personal protection equipment management system shown in FIG. 1 in accordance with various techniques of this disclosure.

[0011] FIG. 3 illustrates an example system including a mobile computing device, a set of personal protection equipment communicatively coupled to the mobile computing device, and a personal protection equipment management system communicatively coupled to the mobile computing device, in accordance with techniques of this disclosure.

[0012] FIG. 4 illustrates an example architecture and descriptive for systems and techniques of this disclosure.

[0013] FIG. 5A illustrates a hearing protector with buttons for input selection in accordance with techniques of this disclosure.

[0014] FIG. 5B illustrates an example graphical user interface, in accordance with techniques of this disclosure.

[0015] FIG. 6 illustrates a welding helmet with auto-darkening figure, in accordance with techniques of this disclosure.

[0016] FIG. 7 illustrates an example sequence diagram of a PPE-handshake operations executed between an article of PPE and a computing device, in accordance with techniques of this disclosure.

[0017] FIGS. 8-14 illustrate example graphical user interfaces that may be output for display by a computing device in accordance with techniques of this disclosure.

[0018] It is to be understood that the embodiments may be utilized and structural changes may be made without departing from the scope of the invention. The figures are not necessarily to scale. Like numbers used in the figures refer to like components. However, it will be understood that the use of a number to refer to a component in a given figure is not intended to limit the component in another figure labeled with the same number.

DETAILED DESCRIPTION

[0019] According to aspects of this disclosure, an article of PPE may include sensors for capturing data that is indicative of operation, location, or environmental conditions surrounding an article of PPE. Sensors may include any device that generates data or context information. Such data may generally be referred to herein as usage data or, alternatively, operation data or sensor data. In some examples, usage data may take the form of a stream of samples over a period of time. In some instances, the sensors may be configured to measure operating characteristics of components of the article of PPE, characteristics of a worker using or wearing the article of PPE, and/or environmental factors associated with an environment in which the article of PPE is located. Moreover, as described herein, the article of PPE may be configured to include one or more electronic components for outputting communication to the respective worker, such as speakers, vibration devices, LEDs, buzzers or other devices for outputting alerts, audio messages, sounds, indicators and the like.

[0020] According to aspects of this disclosure, articles of PPE may be configured to transmit the acquired usage data to a personal protection equipment management system

(PPEMS), which may be a cloud-based system having an analytics engine configured to process streams of incoming usage data from personal protection equipment deployed and used by a population of workers at various work environments. The analytics engine of the PPEMS may apply the streams of incoming usage data (or at least a subset of the usage data) to one or more models to monitor and predict the likelihood of an occurrence of a safety event for the worker associated with any individual article of PPE. For example, the analytics engine may compare measured parameters (e.g., as measured by the electronic sensors) to known models that characterize activity of a user of an article of PPE, e.g., that represent safe activities, unsafe activities, or activities of concern (which may typically occur prior to unsafe activities) in order to determine the probability of an event occurring.

[0021] The analytics engine may generate an output in response to predicting the likelihood of the occurrence of a safety event. For example, the analytics engine may generate an output that indicates a safety event is likely to occur based on data collected from a user of an article of PPE. The output may be used to alert the user of the article of PPE that the safety event is likely to occur, allowing the user to alter their behavior. In other examples, circuitry embedded within the respirators or processors within intermediate data hubs more local to the workers may be programmed via the PPEMS or other mechanism to apply models or rule sets determined by the PPEMS so as to locally generate and output alerts or other preventative measure designed to avoid or mitigate a predicted safety event. In this way, the techniques provide tools to accurately measure and/or monitor operation of a respirator and determine predictive outcomes based on the operation. Although certain examples of this disclosure are provided with respect to certain types of PPE for illustration purposes, the systems, techniques, and devices of this disclosure are applicable to any type of PPE.

[0022] FIG. 1 is a block diagram illustrating an example computing system 2 that includes a personal protection equipment management system (PPEMS) 6 for managing personal protection equipment. As described herein, PPEMS allows authorized users to perform preventive occupational health and safety actions and manage inspections and maintenance of safety protective equipment. By interacting with PPEMS 6, safety professionals can, for example, manage area inspections, worker inspections, worker health and safety compliance training.

[0023] In general, PPEMS 6 provides data acquisition, monitoring, activity logging, reporting, predictive analytics, PPE control, and alert generation. For example, PPEMS 6 includes an underlying analytics and safety event prediction engine and alerting system in accordance with various examples described herein. In general, a safety event may refer to activities of a user of personal protective equipment (PPE), a condition of the PPE, or an environmental condition (e.g., which may be hazardous). In some examples, a safety event may be an injury or worker condition, workplace harm, or regulatory violation. For example, in the context of fall protection equipment, a safety event may be misuse of the fall protection equipment, a user of the fall equipment experiencing a fall, or a failure of the fall protection equipment. In the context of a respirator, a safety event may be misuse of the respirator, a user of the respirator not receiving an appropriate quality and/or quantity of air, or failure of the respirator. A safety event may also be associ-

ated with a hazard in the environment in which the PPE is located. In some examples, occurrence of a safety event associated with the article of PPE may include a safety event in the environment in which the PPE is used or a safety event associated with a worker using the article of PPE. In some examples, a safety event may be an indication that PPE, a worker, and/or a worker environment are operating, in use, or acting in a way that is normal operation, where normal operation is a predetermined or predefined condition of acceptable or safe operation, use, or activity.

[0024] As further described below, PPEMS 6 provides an integrated suite of personal safety protection equipment management tools and implements various techniques of this disclosure. That is, PPEMS 6 provides an integrated, end-to-end system for managing personal protection equipment, e.g., safety equipment, used by workers 10 within one or more physical environments 8, which may be construction sites, mining or manufacturing sites or any physical environment. The techniques of this disclosure may be realized within various parts of computing environment 2.

[0025] As shown in the example of FIG. 1, system 2 represents a computing environment in which a computing device within a plurality of physical environments 8A, 8B (collectively, environments 8) electronically communicate with PPEMS 6 via one or more computer networks 4. Each of physical environment 8 represents a physical environment, such as a work environment, in which one or more individuals, such as workers 10, utilize personal protection equipment while engaging in tasks or activities within the respective environment.

[0026] In this example, environment 8A is shown as generally as having workers 10, while environment 8B is shown in expanded form to provide a more detailed example. In the example of FIG. 1, a plurality of workers 10A-10N are shown as utilizing respective respirators 13A-13N.

[0027] As further described herein, each of respirators 13 includes embedded sensors or monitoring devices and processing electronics configured to capture data in real-time as a user (e.g., worker) engages in activities while wearing the respirators. For example, as described in greater detail herein, respirators 13 may include a number of components (e.g., a head top, a blower, a filter, and the like) respirators 13 may include a number of sensors for sensing or controlling the operation of such components. A head top may include, as examples, a head top visor position sensor, a head top temperature sensor, a head top motion sensor, a head top impact detection sensor, a head top position sensor, a head top battery level sensor, a head top head detection sensor, an ambient noise sensor, or the like. A blower may include, as examples, a blower state sensor, a blower pressure sensor, a blower run time sensor, a blower temperature sensor, a blower battery sensor, a blower motion sensor, a blower impact detection sensor, a blower position sensor, or the like. A filter may include, as examples, a filter presence sensor, a filter type sensor, or the like. Each of the above-noted sensors may generate usage data, as described herein.

[0028] In addition, each of respirators 13 may include one or more output devices for outputting data that is indicative of operation of respirators 13 and/or generating and outputting communications to the respective worker 10. For example, respirators 13 may include one or more devices to generate audible feedback (e.g., one or more speakers), visual feedback (e.g., one or more displays, light emitting

diodes (LEDs) or the like), or tactile feedback (e.g., a device that vibrates or provides other haptic feedback).

[0029] In general, each of environments 8 include computing facilities (e.g., a local area network) by which respirators 13 are able to communicate with PPEMS 6. For example, environments 8 may be configured with wireless technology, such as 802.11 wireless networks, 802.15 Zig-Bee networks, and the like. In the example of FIG. 1, environment 8B includes a local network 7 that provides a packet-based transport medium for communicating with PPEMS 6 via network 4. In addition, environment 8B includes a plurality of wireless access points 19A, 19B that may be geographically distributed throughout the environment to provide support for wireless communications throughout the work environment.

[0030] Each of respirators 13 is configured to communicate data, such as sensed motions, events and conditions, via wireless communications, such as via 802.11 WiFi protocols, Bluetooth protocol or the like. Respirators 13 may, for example, communicate directly with a wireless access point 19. As another example, each worker 10 may be equipped with a respective one of wearable communication hubs 14A-14M that enable and facilitate communication between respirators 13 and PPEMS 6. For example, respirators 13 as well as other PPEs (such as fall protection equipment, hearing protection, hardhats, or other equipment) for the respective worker 10 may communicate with a respective communication hub 14 via Bluetooth or other short range protocol, and the communication hubs may communicate with PPEMS 6 via wireless communications processed by wireless access points 19. Although shown as wearable devices, hubs 14 may be implemented as stand-alone devices deployed within environment 8B. In some examples, hubs 14 may be articles of PPE. In some examples, communication hubs 14 may be an intrinsically safe computing device, smartphone, wrist- or head-wearable computing device, or any other computing device.

[0031] In general, each of hubs 14 operates as a wireless device for respirators 13 relaying communications to and from respirators 13, and may be capable of buffering usage data in case communication is lost with PPEMS 6. Moreover, each of hubs 14 is programmable via PPEMS 6 so that local alert rules may be installed and executed without requiring a connection to the cloud. As such, each of hubs 14 provides a relay of streams of usage data from respirators 13 and/or other PPEs within the respective environment, and provides a local computing environment for localized alerting based on streams of events in the event communication with PPEMS 6 is lost.

[0032] As shown in the example of FIG. 1, an environment, such as environment 8B, may also include one or more wireless-enabled beacons, such as beacons 17A-17C, that provide accurate location information within the work environment. For example, beacons 17A-17C may be GPS-enabled such that a controller within the respective beacon may be able to precisely determine the position of the respective beacon. Based on wireless communications with one or more of beacons 17, a given respirator 13 or communication hub 14 worn by a worker 10 is configured to determine the location of the worker within work environment 8B. In this way, event data (e.g., usage data) reported to PPEMS 6 may be stamped with positional information to aid analysis, reporting and analytics performed by the PPEMS.

[0033] In addition, an environment, such as environment 8B, may also include one or more wireless-enabled sensing stations, such as sensing stations 21A, 21B. Each sensing station 21 includes one or more sensors and a controller configured to output data indicative of sensed environmental conditions. Moreover, sensing stations 21 may be positioned within respective geographic regions of environment 8B or otherwise interact with beacons 17 to determine respective positions and include such positional information when reporting environmental data to PPEMS 6. As such, PPEMS 6 may be configured to correlate the sense environmental conditions with the particular regions and, therefore, may utilize the captured environmental data when processing event data received from respirators 13. For example, PPEMS 6 may utilize the environmental data to aid generating alerts or other instructions for respirators 13 and for performing predictive analytics, such as determining any correlations between certain environmental conditions (e.g., heat, humidity, visibility) with abnormal worker behavior or increased safety events. As such, PPEMS 6 may utilize current environmental conditions to aid prediction and avoidance of imminent safety events. Example environmental conditions that may be sensed by sensing stations 21 include but are not limited to temperature, humidity, presence of gas, pressure, visibility, wind and the like.

[0034] In example implementations, an environment, such as environment 8B, may also include one or more safety stations 15 distributed throughout the environment to provide viewing stations for accessing respirators 13. Safety stations 15 may allow one of workers 10 to check out respirators 13 and/or other safety equipment, verify that safety equipment is appropriate for a particular one of environments 8, and/or exchange data. For example, safety stations 15 may transmit alert rules, software updates, or firmware updates to respirators 13 or other equipment. Safety stations 15 may also receive data cached on respirators 13, hubs 14, and/or other safety equipment. That is, while respirators 13 (and/or data hubs 14) may typically transmit usage data from sensors of respirators 13 to network 4 in real time or near real time, in some instances, respirators 13 (and/or data hubs 14) may not have connectivity to network 4. In such instances, respirators 13 (and/or data hubs 14) may store usage data locally and transmit the usage data to safety stations 15 upon being in proximity with safety stations 15. Safety stations 15 may then upload the data from respirators 13 and connect to network 4. In some examples, a data hub may be an article of PPE.

[0035] In addition, each of environments 8 include computing facilities that provide an operating environment for end-user computing devices 16 for interacting with PPEMS 6 via network 4. For example, each of environments 8 typically includes one or more safety managers responsible for overseeing safety compliance within the environment. In general, each user 20 interacts with computing devices 16 to access PPEMS 6. Each of environments 8 may include systems. Similarly, remote users may use computing devices 18 to interact with PPEMS via network 4. For purposes of example, the end-user computing devices 16 may be laptops, desktop computers, mobile devices such as tablets or so-called smart phones and the like.

[0036] Users 20, 24 interact with PPEMS 6 to control and actively manage many aspects of safely equipment utilized by workers 10, such as accessing and viewing usage records, analytics and reporting. For example, users 20, 24 may

review usage information acquired and stored by PPEMS 6, where the usage information may include data specifying starting and ending times over a time duration (e.g., a day, a week, or the like), data collected during particular events, such as lifts of a visor of respirators 13, removal of respirators 13 from a head of workers 10, changes to operating parameters of respirators 13, status changes to components of respirators 13 (e.g., a low battery event), motion of workers 10, detected impacts to respirators 13 or hubs 14, sensed data acquired from the user, environment data, and the like. In addition, users 20, 24 may interact with PPEMS 6 to perform asset tracking and to schedule maintenance events for individual pieces of safety equipment, e.g., respirators 13, to ensure compliance with any procedures or regulations. PPEMS 6 may allow users 20, 24 to create and complete digital checklists with respect to the maintenance procedures and to synchronize any results of the procedures from computing devices 16, 18 to PPEMS 6.

[0037] Further, as described herein, PPEMS 6 integrates an event processing platform configured to process thousand or even millions of concurrent streams of events from digitally enabled PPEs, such as respirators 13. An underlying analytics engine of PPEMS 6 applies historical data and models to the inbound streams to compute assertions, such as identified anomalies or predicted occurrences of safety events based on conditions or behavior patterns of workers 10. Further, PPEMS 6 provides real-time alerting and reporting to notify workers 10 and/or users 20, 24 of any predicted events, anomalies, trends, and the like.

[0038] The analytics engine of PPEMS 6 may, in some examples, apply analytics to identify relationships or correlations between sensed worker data, environmental conditions, geographic regions and other factors and analyze the impact on safety events. PPEMS 6 may determine, based on the data acquired across populations of workers 10, which particular activities, possibly within certain geographic region, lead to, or are predicted to lead to, unusually high occurrences of safety events.

[0039] In this way, PPEMS 6 tightly integrates comprehensive tools for managing personal protection equipment with an underlying analytics engine and communication system to provide data acquisition, monitoring, activity logging, reporting, behavior analytics and alert generation. Moreover, PPEMS 6 provides a communication system for operation and utilization by and between the various elements of system 2. Users 20, 24 may access PPEMS 6 to view results on any analytics performed by PPEMS 6 on data acquired from workers 10. In some examples, PPEMS 6 may present a web-based interface via a web server (e.g., an HTTP server) or client-side applications may be deployed for devices of computing devices 16, 18 used by users 20, 24, such as desktop computers, laptop computers, mobile devices such as smartphones and tablets, or the like.

[0040] In some examples, PPEMS 6 may provide a database query engine for directly querying PPEMS 6 to view acquired safety information, compliance information and any results of the analytic engine, e.g., by the way of dashboards, alert notifications, reports and the like. That is, users 24, 26, or software executing on computing devices 16, 18, may submit queries to PPEMS 6 and receive data corresponding to the queries for presentation in the form of one or more reports or dashboards (e.g., as shown in the examples of FIGS. 9-16). Such dashboards may provide various insights regarding system 2, such as baseline ("nor-

mal”) operation across worker populations, identifications of any anomalous workers engaging in abnormal activities that may potentially expose the worker to risks, identifications of any geographic regions within environments 2 for which unusually anomalous (e.g., high) safety events have been or are predicted to occur, identifications of any of environments 2 exhibiting anomalous occurrences of safety events relative to other environments, and the like.

[0041] As illustrated in detail below, PPEMS 6 may simplify workflows for individuals charged with monitoring and ensure safety compliance for an entity or environment. That is, the techniques of this disclosure may enable active safety management and allow an organization to take preventative or correction actions with respect to certain regions within environments 8, particular pieces of safety equipment or individual workers 10, define and may further allow the entity to implement workflow procedures that are data-driven by an underlying analytical engine.

[0042] As one example, the underlying analytical engine of PPEMS 6 may be configured to compute and present customer-defined metrics for worker populations within a given environment 8 or across multiple environments for an organization as a whole. For example, PPEMS 6 may be configured to acquire data and provide aggregated performance metrics and predicted behavior analytics across a worker population (e.g., across workers 10 of either or both of environments 8A, 8B). Furthermore, users 20, 24 may set benchmarks for occurrence of any safety incidences, and PPEMS 6 may track actual performance metrics relative to the benchmarks for individuals or defined worker populations.

[0043] As another example, PPEMS 6 may further trigger an alert if certain combinations of conditions are present, e.g., to accelerate examination or service of a safety equipment, such as one of respirators 13. In this manner, PPEMS 6 may identify individual respirators 13 or workers 10 for which the metrics do not meet the benchmarks and prompt the users to intervene and/or perform procedures to improve the metrics relative to the benchmarks, thereby ensuring compliance and actively managing safety for workers 10.

[0044] As further described in FIG. 7, PPE-handshake operations may be executed between an article of PPE and a computing device, in accordance with techniques of this disclosure. In the example of FIG. 1, respirator 13A may be referred to as PPE 13A and communication hub 14A may be referred to as computing device 14A. In accordance with techniques of this disclosure, PPE 13A and computing device 14A may execute a set of PPE-handshake operations that include receipt of a PPE-handshake input that is unique to the particular type of the at least one article of PPE. Unlike conventional pairing techniques (e.g., Bluetooth pairing), which can be cumbersome and non-intuitive for a worker (particularly, if wearing other PPE, such as heavy gloves, protective clothing, or protective headwear), the techniques of FIG. 1 use a PPE-handshake input that is unique to the particular type of the at least one article of PPE in order to initiate a temporary connection between PPE 13A and computing device 14A that is, in turn, used to establish a persistent connection based on a subsequent confirmation based on the PPE-handshake input.

[0045] By using a PPE-handshake input that is unique to the particular type of the at least one article of PPE, the techniques may eliminate the need to add additional controls, buttons, or other input means to the PPE. In some

examples, by using a PPE-handshake input that is unique to the particular type of the at least one article of PPE, the techniques may enable the worker to interact directly with the PPE to establish the connection, thereby simplifying the connection process with the computing device. In some examples, by using a PPE-handshake, existing physical characteristics of the PPE itself can be used to generate the message that initiates a connection with the PPE, thereby leveraging this existing physical characteristic in an unconventional way that provides the worker with an intuitive technique to initiate the connection. Moreover, in some examples, the PPE-handshake operations provide a process by which an accidentally or unintentionally provided PPE-handshake input does not create a permanent connection with the computing device because, in some examples, the PPE-handshake operations use a subsequent confirmation based on the PPE-handshake input to validate that a permanent connection is intended by the user. In some examples, the PPE-handshake operations provide a process by which security can be applied to establish a permanent connection. In this way, malicious or unauthorized pairing may be prevented by the PPE-handshake operations.

[0046] FIG. 2 is a block diagram providing an operating perspective of PPEMS 6 when hosted as cloud-based platform capable of supporting multiple, distinct work environments 8 having an overall population of workers 10 that have a variety of communication enabled personal protection equipment (PPE), such as safety release lines (SRLs) 11, respirators 13, safety helmets, hearing protection or other safety equipment. In the example of FIG. 2, the components of PPEMS 6 are arranged according to multiple logical layers that implement the techniques of the disclosure. Each layer may be implemented by a one or more modules comprised of hardware, software, or a combination of hardware and software.

[0047] In FIG. 2, personal protection equipment (PPEs) 62, such as SRLs 11, respirators 13 and/or other equipment, either directly or by way of hubs 14, as well as computing devices 60, operate as clients 63 that communicate with PPEMS 6 via interface layer 64. Computing devices 60 typically execute client software applications, such as desktop applications, mobile applications, and web applications. Computing devices 60 may represent any of computing devices 16, 18 of FIG. 1. Examples of computing devices 60 may include, but are not limited to a portable or mobile computing device (e.g., smartphone, wearable computing device, tablet), laptop computers, desktop computers, smart television platforms, and servers, to name only a few examples.

[0048] As further described in this disclosure, PPEs 62 communicate with PPEMS 6 (directly or via hubs 14) to provide streams of data acquired from embedded sensors and other monitoring circuitry and receive from PPEMS 6 alerts, configuration and other communications. Client applications executing on computing devices 60 may communicate with PPEMS 6 to send and receive information that is retrieved, stored, generated, and/or otherwise processed by services 68. For instance, the client applications may request and edit safety event information including analytical data stored at and/or managed by PPEMS 6. In some examples, client applications 61 may request and display aggregate safety event information that summarizes or otherwise aggregates numerous individual instances of safety events and corresponding data acquired from PPEs 62

and or generated by PPEMS 6. The client applications may interact with PPEMS 6 to query for analytics information about past and predicted safety events, behavior trends of workers 10, to name only a few examples. In some examples, the client applications may output for display information received from PPEMS 6 to visualize such information for users of clients 63. As further illustrated and described in below, PPEMS 6 may provide information to the client applications, which the client applications output for display in user interfaces.

[0049] Clients applications executing on computing devices 60 may be implemented for different platforms but include similar or the same functionality. For instance, a client application may be a desktop application compiled to run on a desktop operating system, such as Microsoft Windows, Apple OS X, or Linux, to name only a few examples. As another example, a client application may be a mobile application compiled to run on a mobile operating system, such as Google Android, Apple iOS, Microsoft Windows Mobile, or BlackBerry OS to name only a few examples. As another example, a client application may be a web application such as a web browser that displays web pages received from PPEMS 6. In the example of a web application, PPEMS 6 may receive requests from the web application (e.g., the web browser), process the requests, and send one or more responses back to the web application. In this way, the collection of web pages, the client-side processing web application, and the server-side processing performed by PPEMS 6 collectively provides the functionality to perform techniques of this disclosure. In this way, client applications use various services of PPEMS 6 in accordance with techniques of this disclosure, and the applications may operate within various different computing environment (e.g., embedded circuitry or processor of a PPE, a desktop operating system, mobile operating system, or web browser, to name only a few examples).

[0050] As shown in FIG. 2, PPEMS 6 includes an interface layer 64 that represents a set of application programming interfaces (API) or protocol interface presented and supported by PPEMS 6. Interface layer 64 initially receives messages from any of clients 63 for further processing at PPEMS 6. Interface layer 64 may therefore provide one or more interfaces that are available to client applications executing on clients 63. In some examples, the interfaces may be application programming interfaces (APIs) that are accessible over a network. Interface layer 64 may be implemented with one or more web servers. The one or more web servers may receive incoming requests, process and/or forward information from the requests to services 68, and provide one or more responses, based on information received from services 68, to the client application that initially sent the request. In some examples, the one or more web servers that implement interface layer 64 may include a runtime environment to deploy program logic that provides the one or more interfaces. As further described below, each service may provide a group of one or more interfaces that are accessible via interface layer 64.

[0051] In some examples, interface layer 64 may provide Representational State Transfer (RESTful) interfaces that use HTTP methods to interact with services and manipulate resources of PPEMS 6. In such examples, services 68 may generate JavaScript Object Notation (JSON) messages that interface layer 64 sends back to the client application 61 that submitted the initial request. In some examples, interface

layer 64 provides web services using Simple Object Access Protocol (SOAP) to process requests from client applications 61. In still other examples, interface layer 64 may use Remote Procedure Calls (RPC) to process requests from clients 63. Upon receiving a request from a client application to use one or more services 68, interface layer 64 sends the information to application layer 66, which includes services 68.

[0052] As shown in FIG. 2, PPEMS 6 also includes an application layer 66 that represents a collection of services for implementing much of the underlying operations of PPEMS 6. Application layer 66 receives information included in requests received from client applications 61 and further processes the information according to one or more of services 68 invoked by the requests. Application layer 66 may be implemented as one or more discrete software services executing on one or more application servers, e.g., physical or virtual machines. That is, the application servers provide runtime environments for execution of services 68. In some examples, the functionality interface layer 64 as described above and the functionality of application layer 66 may be implemented at the same server.

[0053] Application layer 66 may include one or more separate software services 68, e.g., processes that communicate, e.g., via a logical service bus 70 as one example. Service bus 70 generally represents a logical interconnections or set of interfaces that allows different services to send messages to other services, such as by a publish/subscription communication model. For instance, each of services 68 may subscribe to specific types of messages based on criteria set for the respective service. When a service publishes a message of a particular type on service bus 70, other services that subscribe to messages of that type will receive the message. In this way, each of services 68 may communicate information to one another. As another example, services 68 may communicate in point-to-point fashion using sockets or other communication mechanism. Before describing the functionality of each of services 68, the layers are briefly described herein.

[0054] Data layer 72 of PPEMS 6 represents a data repository that provides persistence for information in PPEMS 6 using one or more data repositories 74. A data repository, generally, may be any data structure or software that stores and/or manages data. Examples of data repositories include but are not limited to relational databases, multi-dimensional databases, maps, and hash tables, to name only a few examples. Data layer 72 may be implemented using Relational Database Management System (RDBMS) software to manage information in data repositories 74. The RDBMS software may manage one or more data repositories 74, which may be accessed using Structured Query Language (SQL). Information in the one or more databases may be stored, retrieved, and modified using the RDBMS software. In some examples, data layer 72 may be implemented using an Object Database Management System (ODBMS), Online Analytical Processing (OLAP) database or other suitable data management system.

[0055] As shown in FIG. 2, each of services 68A-68I ("services 68") is implemented in a modular form within PPEMS 6. Although shown as separate modules for each service, in some examples the functionality of two or more services may be combined into a single module or component. Each of services 68 may be implemented in software, hardware, or a combination of hardware and software.

Moreover, services **68** may be implemented as standalone devices, separate virtual machines or containers, processes, threads or software instructions generally for execution on one or more physical processors.

[0056] In some examples, one or more of services **68** may each provide one or more interfaces that are exposed through interface layer **64**. Accordingly, client applications of computing devices **60** may call one or more interfaces of one or more of services **68** to perform techniques of this disclosure.

[0057] In accordance with techniques of the disclosure, services **68** may include an event processing platform including an event endpoint frontend **68A**, event selector **68B**, event processor **68C** and high priority (HP) event processor **68D**. Event endpoint frontend **68A** operates as a front end interface for receiving and sending communications to PPEs **62** and hubs **14**. In other words, event endpoint frontend **68A** operates to as a front line interface to safety equipment deployed within environments **8** and utilized by workers **10**. In some instances, event endpoint frontend **68A** may be implemented as a plurality of tasks or jobs spawned to receive individual inbound communications of event streams **69** from the PPEs **62** carrying data sensed and captured by the safety equipment. When receiving event streams **69**, for example, event endpoint frontend **68A** may spawn tasks to quickly enqueue an inbound communication, referred to as an event, and close the communication session, thereby providing high-speed processing and scalability. Each incoming communication may, for example, carry data recently captured data representing sensed conditions, motions, temperatures, actions or other data, generally referred to as events. Communications exchanged between the event endpoint frontend **68A** and the PPEs may be real-time or pseudo real-time depending on communication delays and continuity.

[0058] Event selector **68B** operates on the stream of events **69** received from PPEs **62** and/or hubs **14** via frontend **68A** and determines, based on rules or classifications, priorities associated with the incoming events. Based on the priorities, event selector **68B** enqueues the events for subsequent processing by event processor **68C** or high priority (HP) event processor **68D**. Additional computational resources and objects may be dedicated to HP event processor **68D** so as to ensure responsiveness to critical events, such as incorrect usage of PPEs, use of incorrect filters and/or respirators based on geographic locations and conditions, failure to properly secure SRLs **11** and the like. Responsive to processing high priority events, HP event processor **68D** may immediately invoke notification service **68E** to generate alerts, instructions, warnings or other similar messages to be output to SRLs **11**, respirators **13**, hubs **14** and/or remote users **20**, **24**. Events not classified as high priority are consumed and processed by event processor **68C**.

[0059] In general, event processor **68C** or high priority (HP) event processor **68D** operate on the incoming streams of events to update event data **74A** within data repositories **74**. In general, event data **74A** may include all or a subset of usage data obtained from PPEs **62**. For example, in some instances, event data **74A** may include entire streams of samples of data obtained from electronic sensors of PPEs **62**. In other instances, event data **74A** may include a subset of such data, e.g., associated with a particular time period or activity of PPEs **62**.

[0060] Event processors **68C**, **68D** may create, read, update, and delete event information stored in event data **74A**. Event information may be stored in a respective database record as a structure that includes name/value pairs of information, such as data tables specified in row/column format. For instance, a name (e.g., column) may be “worker ID” and a value may be an employee identification number. An event record may include information such as, but not limited to: worker identification, PPE identification, acquisition timestamp(s) and data indicative of one or more sensed parameters.

[0061] In addition, event selector **68B** directs the incoming stream of events to stream analytics service **68F**, which is configured to perform in depth processing of the incoming stream of events to perform real-time analytics. Stream analytics service **68F** may, for example, be configured to process and compare multiple streams of event data **74A** with historical data and models **74B** in real-time as event data **74A** is received. In this way, stream analytic service **68D** may be configured to detect anomalies, transform incoming event data values, trigger alerts upon detecting safety concerns based on conditions or worker behaviors. Historical data and models **74B** may include, for example, specified safety rules, business rules and the like. In addition, stream analytic service **68D** may generate output for communicating to PPPEs **62** by notification service **68F** or computing devices **60** by way of record management and reporting service **68D**.

[0062] In this way, analytics service **68F** processes inbound streams of events, potentially hundreds or thousands of streams of events, from enabled safety PPEs **62** utilized by workers **10** within environments **8** to apply historical data and models **74B** to compute assertions, such as identified anomalies or predicted occurrences of imminent safety events based on conditions or behavior patterns of the workers. Analytics service may **68D** publish the assertions to notification service **68F** and/or record management by service bus **70** for output to any of clients **63**.

[0063] In this way, analytics service **68F** may be configured as an active safety management system that predicts imminent safety concerns and provides real-time alerting and reporting. In addition, analytics service **68F** may be a decision support system that provides techniques for processing inbound streams of event data to generate assertions in the form of statistics, conclusions, and/or recommendations on an aggregate or individualized worker and/or PPE basis for enterprises, safety officers and other remote users. For instance, analytics service **68F** may apply historical data and models **74B** to determine, for a particular worker, the likelihood that a safety event is imminent for the worker based on detected behavior or activity patterns, environmental conditions and geographic locations. In some examples, analytics service **68F** may determine whether a worker is currently impaired, e.g., due to exhaustion, sickness or alcohol/drug use, and may require intervention to prevent safety events. As yet another example, analytics service **68F** may provide comparative ratings of workers or type of safety equipment in a particular environment **8**.

[0064] Hence, analytics service **68F** may maintain or otherwise use one or more models that provide risk metrics to predict safety events. Analytics service **68F** may also generate order sets, recommendations, and quality measures. In some examples, analytics service **68F** may generate user interfaces based on processing information stored by

PPEMS 6 to provide actionable information to any of clients 63. For example, analytics service 68F may generate dashboards, alert notifications, reports and the like for output at any of clients 63. Such information may provide various insights regarding baseline (“normal”) operation across worker populations, identifications of any anomalous workers engaging in abnormal activities that may potentially expose the worker to risks, identifications of any geographic regions within environments for which unusually anomalous (e.g., high) safety events have been or are predicted to occur, identifications of any of environments exhibiting anomalous occurrences of safety events relative to other environments, and the like.

[0065] Although other technologies can be used, in one example implementation, analytics service 68F utilizes machine learning when operating on streams of safety events so as to perform real-time analytics. That is, analytics service 68F includes executable code generated by application of machine learning to training data of event streams and known safety events to detect patterns. The executable code may take the form of software instructions or rule sets and is generally referred to as a model that can subsequently be applied to event streams 69 for detecting similar patterns and predicting upcoming events.

[0066] Analytics service 68F may, in some example, generate separate models for a particular worker, a particular population of workers, a particular environment, or combinations thereof. Analytics service 68F may update the models based on usage data received from PPEs 62. For example, analytics service 68F may update the models for a particular worker, a particular population of workers, a particular environment, or combinations thereof based on data received from PPEs 62. In some examples, usage data may include incident reports, air monitoring systems, manufacturing production systems, or any other information that may be used to a train a model.

[0067] Alternatively, or in addition, analytics service 68F may communicate all or portions of the generated code and/or the machine learning models to hubs 16 (or PPEs 62) for execution thereon so as to provide local alerting in near-real time to PPEs. Example machine learning techniques that may be employed to generate models 74B can include various learning styles, such as supervised learning, unsupervised learning, and semi-supervised learning. Example types of algorithms include Bayesian algorithms, Clustering algorithms, decision-tree algorithms, regularization algorithms, regression algorithms, instance-based algorithms, artificial neural network algorithms, deep learning algorithms, dimensionality reduction algorithms and the like. Various examples of specific algorithms include Bayesian Linear Regression, Boosted Decision Tree Regression, and Neural Network Regression, Back Propagation Neural Networks, the Apriori algorithm, K-Means Clustering, k-Nearest Neighbour (kNN), Learning Vector Quantization (LUQ), Self-Organizing Map (SOM), Locally Weighted Learning (LWL), Ridge Regression, Least Absolute Shrinkage and Selection Operator (LASSO), Elastic Net, and Least-Angle Regression (LARS), Principal Component Analysis (PCA) and Principal Component Regression (PCR).

[0068] Record management and reporting service 68G processes and responds to messages and queries received from computing devices 60 via interface layer 64. For example, record management and reporting service 68G

may receive requests from client computing devices for event data related to individual workers, populations or sample sets of workers, geographic regions of environments 8 or environments 8 as a whole, individual or groups/types of PPEs 62. In response, record management and reporting service 68G accesses event information based on the request. Upon retrieving the event data, record management and reporting service 68G constructs an output response to the client application that initially requested the information. In some examples, the data may be included in a document, such as an HTML document, or the data may be encoded in a JSON format or presented by a dashboard application executing on the requesting client computing device. For instance, as further described in this disclosure, example user interfaces that include the event information are depicted in the figures.

[0069] As additional examples, record management and reporting service 68G may receive requests to find, analyze, and correlate PPE event information. For instance, record management and reporting service 68G may receive a query request from a client application for event data 74A over a historical time frame, such as a user can view PPE event information over a period of time and/or a computing device can analyze the PPE event information over the period of time.

[0070] In example implementations, services 68 may also include security service 68H that authenticate and authorize users and requests with PPEMS 6. Specifically, security service 68H may receive authentication requests from client applications and/or other services 68 to access data in data layer 72 and/or perform processing in application layer 66. An authentication request may include credentials, such as a username and password. Security service 68H may query security data 74A to determine whether the username and password combination is valid. Configuration data 74D may include security data in the form of authorization credentials, policies, and any other information for controlling access to PPEMS 6. As described above, security data 74A may include authorization credentials, such as combinations of valid usernames and passwords for authorized users of PPEMS 6. Other credentials may include device identifiers or device profiles that are allowed to access PPEMS 6.

[0071] Security service 68H may provide audit and logging functionality for operations performed at PPEMS 6. For instance, security service 68H may log operations performed by services 68 and/or data accessed by services 68 in data layer 72. Security service 68H may store audit information such as logged operations, accessed data, and rule processing results in audit data 74C. In some examples, security service 68H may generate events in response to one or more rules being satisfied. Security service 68H may store data indicating the events in audit data 74C.

[0072] In the example of FIG. 2, a safety manager may initially configure one or more safety rules. As such, remote user 24 may provide one or more user inputs at computing device 18 that configure a set of safety rules for work environment 8A and 8B. For instance, a computing device 60 of the safety manager may send a message that defines or specifies the safety rules. Such message may include data to select or create conditions and actions of the safety rules. PPEMS 6 may receive the message at interface layer 64 which forwards the message to rule configuration component 681. Rule configuration component 681 may be combination of hardware and/or software that provides for rule

configuration including, but not limited to: providing a user interface to specify conditions and actions of rules, receive, organize, store, and update rules included in safety rules data store **74E**.

[0073] Safety rules data store **75E** may be a data store that includes data representing one or more safety rules. Safety rules data store **74E** may be any suitable data store such as a relational database system, online analytical processing database, object-oriented database, or any other type of data store. When rule configuration component **681** receives data defining safety rules from computing device **60** of the safety manager, rule configuration component **681** may store the safety rules in safety rules data store **75E**.

[0074] In some examples, storing the safety rules may include associating a safety rule with context data, such that

of PPE over a particular time interval; a lifetime of the PPE; a component included within the article of PPE; a usage history across multiple users of the article of PPE; contaminants, hazards, or other physical conditions detected by the PPE, expiration date of the article of PPE; operating metrics of the article of PPE. Context data for a work environment may include, but is not limited to: a location of a work environment, a boundary or perimeter of a work environment, an area of a work environment, hazards within a work environment, physical conditions of a work environment, permits for a work environment, equipment within a work environment, owner of a work environment, responsible supervisor and/or safety manager for a work environment.

[0075] Table 4, shown below, includes a non-limiting set of rules that may be stored to safety rules data store **74E**:

TABLE 4

SAFETY RULES

Hub shall immediately assert an "Attention Initial" Alert if Visor Position Status is OPEN in current location requiring Visor Open Allow = NO
 Hub shall immediately assert a "Critical Initial" Alert if Filter Type Status is not equal to Filter Type or no filter found required by current location
 Hub shall store all alerts in a queue.
 Critical Alerts shall be highest priority in alert queue
 Attention Alerts shall have secondary priority in alert queue
 Hub shall immediately remove an alert from the queue if its conditions causing the alert have been corrected
 A newly added alert to the alert queue shall be flagged as "Active", if it is higher priority than any other alarms in the queue.
 A newly added alert to the alert queue shall be flagged as "Active", if all other alarms in the queue are Acknowledged or Notify
 A newly added alert to the alert queue shall be flagged as "Pending" if an Active alert already exists in the queue and the newly added alert is lower in priority than the currently Active alert
 If an Active alert in the queue is replaced by a new Active alert because of priority, the replaced alert shall be flagged as "Pending"
 An active alert shall enable its respective haptic feedback and LED pattern
 Hub shall assert an Acknowledge event when user presses and releases button within <3 seconds. (Button_Tap)
 Upon an Acknowledge event the Hub shall immediately flag the currently Active alert as Acknowledged, if any Active alerts are in the queue.
 An Acknowledged alert shall disable its respective haptic feedback and LED pattern
 Upon an Acknowledge event the Hub shall immediately flag the highest priority Pending alert as Active, if any Pending alerts exist in the queue.
 Upon an Acknowledge event the Hub shall immediately flag the highest priority Acknowledged alert as Notify, if no Active alerts or Pending exist in the queue.
 A Notify alert shall disable its respective haptic feedback and enable its LED pattern
 Immediate Cloud Updates - Hub shall send safety violation asserted message via Wi-Fi to cloud service immediately upon assertion of alert
 Immediate Worker Interface Updates - Hub shall send safety rule violation alerts asserted message via BLE to Worker Interface immediately upon assertion of alert
 Immediate Cloud Updates - Hub shall send safety violation deasserted message via Wi-Fi to cloud service immediately upon deassertion of alert
 Immediate Worker Interface Updates - Hub shall send safety violation deasserted message via BLE to Worker Interface immediately upon deassertion of alert

rule configuration component **681** may perform a lookup to select safety rules associated with matching context data. Context data may include any data describing or characterizing the properties or operation of a worker, worker environment, article of PPE, or any other entity. Context data of a worker may include, but is not limited to: a unique identifier of a worker, type of worker, role of worker, physiological or biometric properties of a worker, experience of a worker, training of a worker, time worked by a worker over a particular time interval, location of the worker, or any other data that describes or characterizes a worker. Context data of an article of PPE may include, but is not limited to: a unique identifier of the article of PPE; a type of PPE of the article of PPE; a usage time of the article

It should be understood that the examples of Table 4 are provided for purposes of illustration only, and that other rules may be developed.

[0076] According to aspects of this disclosure, the rules may be used for purposes of reporting, to generate alerts, or the like. In an example for purposes of illustration, worker **10A** may be equipped with respirator **13A** and data hub **14A**. Respirator **13A** may include a filter to remove particulates but not organic vapors. Data hub **14A** may be initially configured with and store a unique identifier of worker **10A**. When initially assigning the respirator **13A** and data hub to worker **10A**, a computing device operated by worker **10A** and/or a safety manager may cause RMRS **68G** to store a

mapping in work relation data 74F. Work relation data 74F may include mappings between data that corresponds to PPE, workers, and work environments. Work relation data 74F may be any suitable datastore for storing, retrieving, updating and deleting data. RMRS 69G may store a mapping between the unique identifier of worker 10A and a unique device identifier of data hub 14A. Work relation data store 74F may also map a worker to an environment. In the example of FIG. 4, self-check component 681 may receive or otherwise determine data from work relation data 74F for data hub 14A, worker 10A, and/or PPE associated with or assigned to worker 10A.

[0077] Worker 10A may initially put on respirator 13A and data hub 14A prior to entering environment 8A. As worker 10A approaches environment 8A and/or has entered environment 8A, data hub 14A may determine that worker 10A is within a threshold distance of entering environment 8A or has entered environment 8A. Data hub 14A may determine that it is within a threshold distance of entering environment 8A or has entered environment 8A and send a message that includes context data to PPEMS 6 that indicates data hub 14A is within a threshold distance of entering environment 8A.

[0078] According to aspects of this disclosure, as noted above, PPEMS 6 may additionally or alternatively apply analytics to predict the likelihood of a safety event. As noted above, a safety event may refer to activities of a worker 10 using PPE 62, a condition of PPE 62, or a hazardous environmental condition (e.g., that the likelihood of a safety event is relatively high, that the environment is dangerous, that SRL 11 is malfunctioning, that one or more components of SRL 11 need to be repaired or replaced, or the like). For example, PPEMS 6 may determine the likelihood of a safety event based on application of usage data from PPE 62 to historical data and models 74B. That is, PEMS 6 may apply historical data and models 74B to usage data from respirators 13 in order to compute assertions, such as anomalies or predicted occurrences of imminent safety events based on environmental conditions or behavior patterns of a worker using a respirator 13.

[0079] PPEMS 6 may apply analytics to identify relationships or correlations between sensed data from respirators 13, environmental conditions of environment in which respirators 13 are located, a geographic region in which respirators 13 are located, and/or other factors. PPEMS 6 may determine, based on the data acquired across populations of workers 10, which particular activities, possibly within certain environment or geographic region, lead to, or are predicted to lead to, unusually high occurrences of safety events. PPEMS 6 may generate alert data based on the analysis of the usage data and transmit the alert data to PPEs 62 and/or hubs 14. Hence, according to aspects of this disclosure, PPEMS 6 may determine usage data of respirator 13, generate status indications, determine performance analytics, and/or perform prospective/preemptive actions based on a likelihood of a safety event.

[0080] For example, according to aspects of this disclosure, usage data from respirators 13 may be used to determine usage statistics. For example, PPEMS 6 may determine, based on usage data from respirators 13, a length of time that one or more components of respirator 13 (e.g., head top, blower, and/or filter) have been in use, an instantaneous velocity or acceleration of worker 10 (e.g., based on an accelerometer included in respirators 13 or hubs 14), a

temperature of one or more components of respirator 13 and/or worker 10, a location of worker 10, a number of times or frequency with which a worker 10 has performed a self-check of respirator 13 or other PPE, a number of times or frequency with which a visor of respirator 13 has been opened or closed, a filter/cartridge consumption rate, fan/blower usage (e.g., time in use, speed, or the like), battery usage (e.g., charge cycles), or the like.

[0081] According to aspects of this disclosure, PPEMS 6 may use the usage data to characterize activity of worker 10. For example, PPEMS 6 may establish patterns of productive and nonproductive time (e.g., based on operation of respirator 13 and/or movement of worker 10), categorize worker movements, identify key motions, and/or infer occurrence of key events. That is, PPEMS 6 may obtain the usage data, analyze the usage data using services 68 (e.g., by comparing the usage data to data from known activities/events), and generate an output based on the analysis.

[0082] In some examples, the usage statistics may be used to determine when respirator 13 is in need of maintenance or replacement. For example, PPEMS 6 may compare the usage data to data indicative of normally operating respirators 13 in order to identify defects or anomalies. In other examples, PPEMS 6 may also compare the usage data to data indicative of a known service life statistics of respirators 13. The usage statistics may also be used to provide an understanding how respirators 13 are used by workers 10 to product developers in order to improve product designs and performance. In still other examples, the usage statistics may be used to gathering human performance metadata to develop product specifications. In still other examples, the usage statistics may be used as a competitive benchmarking tool. For example, usage data may be compared between customers of respirators 13 to evaluate metrics (e.g. productivity, compliance, or the like) between entire populations of workers outfitted with respirators 13.

[0083] Additionally or alternatively, according to aspects of this disclosure, usage data from respirators 13 may be used to determine status indications. For example, PPEMS 6 may determine that a visor of a respirator 13 is up in hazardous work area. PPEMS 6 may also determine that a worker 10 is fitted with improper equipment (e.g., an improper filter for a specified area), or that a worker 10 is present in a restricted/closed area. PPEMS 6 may also determine whether worker temperature exceeds a threshold, e.g., in order to prevent heat stress. PPEMS 6 may also determine when a worker 10 has experienced an impact, such as a fall.

[0084] Additionally or alternatively, according to aspects of this disclosure, usage data from respirators 13 may be used to assess performance of worker 10 wearing respirator 13. For example, PPEMS 6 may, based on usage data from respirators 13, recognize motion that may indicate a pending fall by worker 10 (e.g., via one or more accelerometers included in respirators 13 and/or hubs 14). In some instances, PPEMS 6 may, based on usage data from respirators 13, infer that a fall has occurred or that worker 10 is incapacitated. PPEMS 6 may also perform fall data analysis after a fall has occurred and/or determine temperature, humidity and other environmental conditions as they relate to the likelihood of safety events.

[0085] As another example, PPEMS 6 may, based on usage data from respirators 13, recognize motion that may indicate fatigue or impairment of worker 10. For example,

PPEMS 6 may apply usage data from respirators 13 to a safety learning model that characterizes a motion of a user of at least one respirator. In this example, PPEMS 6 may determine that the motion of a worker 10 over a time period is anomalous for the worker 10 or a population of workers 10 using respirators 13.

[0086] Additionally or alternatively, according to aspects of this disclosure, usage data from respirators 13 may be used to determine alerts and/or actively control operation of respirators 13. For example, PPEMS 6 may determine that a safety event such as equipment failure, a fall, or the like is imminent. PPEMS 6 may send data to respirators 13 to change an operating condition of respirators 13. In an example for purposes of illustration, PPEMS 6 may apply usage data to a safety learning model that characterizes an expenditure of a filter of one of respirators 13. In this example, PPEMS 6 may determine that the expenditure is higher than an expected expenditure for an environment, e.g., based on conditions sensed in the environment, usage data gathered from other workers 10 in the environment, or the like. PPEMS 6 may generate and transmit an alert to worker 10 that indicates that worker 10 should leave the environment and/or active control of respirator 13. For example, PPEMS 6 may cause respirator to reduce a blower speed of a blower of respirator 13 in order to provide worker 10 with substantial time to exit the environment.

[0087] PPEMS 6 may generate, in some examples, a warning when worker 10 is near a hazard in one of environments 8 (e.g., based on location data gathered from a location sensor (GPS or the like) of respirators 13). PPEMS 6 may also applying usage data to a safety learning model that characterizes a temperature of worker 10. In this example, PPEMS 6 may determine that the temperature exceeds a temperature associated with safe activity over the time period and alert worker 10 to the potential for a safety event due to the temperature.

[0088] In another example, PPEMS 6 may schedule preventative maintenance or automatically purchase components for respirators 13 based on usage data. For example, PPEMS 6 may determine a number of hours a blower of a respirator 13 has been in operation, and schedule preventative maintenance of the blower based on such data. PPEMS 6 may automatically order a filter for respirator 13 based on historical and/or current usage data from the filter.

[0089] Again, PPEMS 6 may determine the above-described performance characteristics and/or generate the alert data based on application of the usage data to one or more safety learning models that characterizes activity of a user of one of respirators 13. The safety learning models may be trained based on historical data or known safety events. However, while the determinations are described with respect to PPEMS 6, as described in greater detail herein, one or more other computing devices, such as hubs 14 or respirators 13 may be configured to perform all or a subset of such functionality.

[0090] In some examples, a safety learning model is trained using supervised and/or reinforcement learning techniques. The safety learning model may be implemented using any number of models for supervised and/or reinforcement learning, such as but not limited to, an artificial neural networks, a decision tree, naïve Bayes network, support vector machine, or k-nearest neighbor model, to name only a few examples. In some examples, PPEMS 6 initially trains the safety learning model based on a training set of metrics

and corresponding to safety events. The training set may include a set of feature vectors, where each feature in the feature vector represents a value for a particular metric. As further example description, PPEMS 6 may select a training set comprising a set of training instances, each training instance comprising an association between usage data and a safety event. The usage data may comprise one or more metrics that characterize at least one of a user, a work environment, or one or more articles of PPE. PPEMS 6 may, for each training instance in the training set, modify, based on particular usage data and a particular safety event of the training instance, the safety learning model to change a likelihood predicted by the safety learning model for the particular safety event in response to subsequent usage data applied to the safety learning model. In some examples, the training instances may be based on real-time or periodic data generated while PPEMS 6 managing data for one or more articles of PPE, workers, and/or work environments. As such, one or more training instances of the set of training instances may be generated from use of one or more articles of PPE after PPEMS 6 performs operations relating to the detection or prediction of a safety event for PPE, workers, and/or work environments that are currently in use, active, or in operation.

[0091] Some example metrics may include any characteristics or data described in this disclosure that relate to PPE, a worker, or a work environment, to name only a few examples. For instance, example metrics may include but are not limited to: worker identity, worker motion, worker location, worker age, worker experience, worker physiological parameters (e.g., heart rate, temperature, blood oxygen level, chemical compositions in blood, or any other measureable physiological parameter), or any other data descriptive of a worker or worker behavior. Example metrics may include but are not limited to: PPE type, PPE usage, PPE age, PPE operations, or any other data descriptive of PPE or PPE use. Example metrics may include but are not limited to: work environment type, work environment location, work environment temperature, work environment hazards, work environment size, or any other data descriptive of a work environment.

[0092] Each feature vector may also have a corresponding safety event. As described in this disclosure, a safety event may include but is not limited to: activities of a user of personal protective equipment (PPE), a condition of the PPE, or a hazardous environmental condition to name only a few examples. By training a safety learning model based on the training set, a safety learning model may be configured by PPEMS 6 to, when applying a particular feature vector to the safety learning model, generate higher probabilities or scores for safety events that correspond to training feature vectors that are more similar to the particular feature set. In the same way, the safety learning model may be configured by PPEMS 6 to, when applying a particular feature vector to the safety learning model, generate lower probabilities or scores for safety events that correspond to training feature vectors that are less similar to the particular feature set. Accordingly, the safety learning model may be trained, such that upon receiving a feature vector of metrics, the safety learning model may output one or more probabilities or scores that indicate likelihoods of safety events based on the feature vector. As such, PPEMS 6 may select

likelihood of the occurrence as a highest likelihood of occurrence of a safety event in the set of likelihoods of safety events.

[0093] In some instances, PPEMS 6 may apply analytics for combinations of PPE. For example, PPEMS 6 may draw correlations between users of respirators 13 and/or the other PPE (such as fall protection equipment, head protection equipment, hearing protection equipment, or the like) that is used with respirators 13. That is, in some instances, PPEMS 6 may determine the likelihood of a safety event based not only on usage data from respirators 13, but also from usage data from other PPE being used with respirators 13. In such instances, PPEMS 6 may include one or more safety learning models that are constructed from data of known safety events from one or more devices other than respirators 13 that are in use with respirators 13.

[0094] In some examples, a safety learning model is based on safety events from one or more of a worker, article of PPE, and/or work environment having similar characteristics (e.g., of a same type). In some examples the “same type” may refer to identical but separate instances of PPE. In other examples the “same type” may not refer to identical instances of PPE. For instance, although not identical, a same type may refer to PPE in a same class or category of PPE, same model of PPE, or same set of one or more shared functional or physical characteristics, to name only a few examples. Similarly, a same type of work environment or worker may refer to identical but separate instances of work environment types or worker types. In other examples, although not identical, a same type may refer to a worker or work environment in a same class or category of worker or work environment or same set of one or more shared behavioral, physiological, environmental characteristics, to name only a few examples.

[0095] In some examples, to apply the usage data to a model, PPEMS 6 may generate a structure, such as a feature vector, in which the usage data is stored. The feature vector may include a set of values that correspond to metrics (e.g., characterizing PPE, worker, work environment, to name a few examples), where the set of values are included in the usage data. The model may receive the feature vector as input, and based on one or more relations defined by the model (e.g., probabilistic, deterministic or other functions within the knowledge of one of ordinary skill in the art) that has been trained, the model may output one or more probabilities or scores that indicate likelihoods of safety events based on the feature vector.

[0096] In general, while certain techniques or functions are described herein as being performed by certain components, e.g., PPEMS 6, respirators 13, or hubs 14, it should be understood that the techniques of this disclosure are not limited in this way. That is, certain techniques described herein may be performed by one or more of the components of the described systems. For example, in some instances, respirators 13 may have a relatively limited sensor set and/or processing power. In such instances, one of hubs 14 and/or PPEMS 6 may be responsible for most or all of the processing of usage data, determining the likelihood of a safety event, and the like. In other examples, respirators 13 and/or hubs 14 may have additional sensors, additional processing power, and/or additional memory, allowing for respirators 13 and/or hubs 14 to perform additional techniques. Determinations regarding which components are responsible for

performing techniques may be based, for example, on processing costs, financial costs, power consumption, or the like.

[0097] FIG. 3 illustrates an example system including a mobile computing device, a set of personal protection equipment communicatively coupled to the mobile computing device, and a personal protection equipment management system communicatively coupled to the mobile computing device, in accordance with techniques of this disclosure. For purposes of illustration only, system 300 includes mobile computing device 302, which may be an example of hub 14A in FIG. 1.

[0098] FIG. 3 illustrates components of mobile computing device 302 including processor 304, communication unit 306, storage device 308, user-interface (UI) device 310, sensors 312, usage data 314, safety rules 316, rule engine 318, alert data 320, alert engine 322, and management engine 324. As noted above, mobile computing device 302 represents one example of hubs 14 shown in FIG. 1. Many other examples of mobile computing device 302 may be used in other instances and may include a subset of the components included in example mobile computing device 302 or may include additional components not shown example mobile computing device 302 in FIG. 3.

[0099] In some examples, mobile computing device 302 may be an intrinsically safe computing device, smartphone, wrist- or head-wearable computing device, or any other computing device that may include a set, subset, or superset of functionality or components as shown in mobile computing device 302. Communication channels may interconnect each of the components in mobile computing device 302 for inter-component communications (physically, communicatively, and/or operatively). In some examples, communication channels may include a hardware bus, a network connection, one or more inter-process communication data structures, or any other components for communicating data between hardware and/or software.

[0100] Mobile computing device 302 may also include a power source, such as a battery, to provide power to components shown in mobile computing device 302. A rechargeable battery, such as a Lithium Ion battery, can provide a compact and long-life source of power. Mobile computing device 302 may be adapted to have electrical contacts exposed or accessible from the exterior of the hub to allow recharging the mobile computing device 302. As noted above, mobile computing device 302 may be portable such that it can be carried or worn by a user. Mobile computing device 302 can also be personal, such that it is used by an individual and communicates with personal protective equipment (PPE) assigned to that individual. In FIG. 3, mobile computing device 302 may be secured to a user by a strap. However, communication hub may be carried by a user or secured to a user in other ways, such as being secured to PPE being worn by the user, to other garments being worn to a user, being attached to a belt, band, buckle, clip or other attachment mechanism as will be apparent to one of skill in the art upon reading the present disclosure. As described throughout this disclosure, in examples, functionality of mobile computing device 302 may be integrated into one or more articles of PPE, such that a separate mobile computing device 302 is not required to perform the techniques of this disclosure.

[0101] One or more processors 304 may implement functionality and/or execute instructions within mobile comput-

ing device **302**. For example, processor **304** may receive and execute instructions stored by storage device **308**. These instructions executed by processor **304** may cause mobile computing device **302** to store and/or modify information, within storage devices **308** during program execution. Processors **304** may execute instructions of components, such as rule engine **318** and alert engine **322** to perform one or more operations in accordance with techniques of this disclosure. That is, rule engine **318** and alert engine **322** may be operable by processor **304** to perform various functions described herein.

[0102] One or more communication units **306** of mobile computing device **302** may communicate with external devices by transmitting and/or receiving data. For example, mobile computing device **302** may use communication units **306** to transmit and/or receive radio signals on a radio network such as a cellular radio network. In some examples, communication units **306** may transmit and/or receive satellite signals on a satellite network such as a Global Positioning System (GPS) network. Examples of communication units **306** include a network interface card (e.g. such as an Ethernet card), an optical transceiver, a radio frequency transceiver, a GPS receiver, or any other type of device that can send and/or receive information. Other examples of communication units **306** may include Bluetooth®, GPS, 3G, 4G, and Wi-Fi® radios found in mobile devices as well as Universal Serial Bus (USB) controllers and the like.

[0103] One or more storage devices **308** within mobile computing device **302** may store information for processing during operation of mobile computing device **302**. In some examples, storage device **308** is a temporary memory, meaning that a primary purpose of storage device **308** is not long-term storage. Storage device **308** may be configured for short-term storage of information as volatile memory and therefore not retain stored contents if deactivated. Examples of volatile memories include random access memories (RAM), dynamic random access memories (DRAM), static random access memories (SRAM), and other forms of volatile memories known in the art.

[0104] Storage device **308** may, in some examples, also include one or more computer-readable storage media. Storage device **308** may be configured to store larger amounts of information than volatile memory. Storage device **308** may further be configured for long-term storage of information as non-volatile memory space and retain information after activate/off cycles. Examples of non-volatile memories include magnetic hard discs, optical discs, floppy discs, flash memories, or forms of electrically programmable memories (EPROM) or electrically erasable and programmable (EEPROM) memories. Storage device **308** may store program instructions and/or data associated with components such as rule engine **318** and alert engine **322**.

[0105] UI device **310** may be configured to receive user input and/or output information to a user. One or more input components of UI device **310** may receive input. Examples of input are tactile, audio, kinetic, and optical input, to name only a few examples. UI device **310** of mobile computing device **302**, in one example, include a mouse, keyboard, voice responsive system, video camera, buttons, control pad, microphone or any other type of device for detecting input from a human or machine. In some examples, UI device **310** may be a presence-sensitive input component, which may include a presence-sensitive screen, touch-sensitive screen, etc.

[0106] One or more output components of UI device **310** may generate output. Examples of output are data, tactile, audio, and video output. Output components of UI device **310**, in some examples, include a presence-sensitive screen, sound card, video graphics adapter card, speaker, cathode ray tube (CRT) monitor, liquid crystal display (LCD), or any other type of device for generating output to a human or machine. Output components may include display components such as cathode ray tube (CRT) monitor, liquid crystal display (LCD), Light-Emitting Diode (LED) or any other type of device for generating tactile, audio, and/or visual output. Output components may be integrated with mobile computing device **302** in some examples.

[0107] UI device **310** may include a display, lights, buttons, keys (such as arrow or other indicator keys), and may be able to provide alerts to the user in a variety of ways, such as by sounding an alarm or vibrating. The user interface can be used for a variety of functions. For example, a user may be able to acknowledge or snooze an alert through the user interface. The user interface may also be used to control settings for the head top and/or turbo peripherals that are not immediately within the reach of the user. For example, the turbo may be worn on the lower back where the wearer cannot access the controls without significant difficulty.

[0108] Sensors **312** may include one or more sensors that generate data indicative of an activity of a worker **10** associated with mobile computing device **302** and/or data indicative of an environment in which mobile computing device **302** is located. Sensors **312** may include, as examples, one or more accelerometers, one or more sensors to detect conditions present in a particular environment (e.g., sensors for measuring temperature, humidity, particulate content, noise levels, air quality, or any variety of other characteristics of environments in which respirator **13** may be used), or a variety of other sensors.

[0109] Mobile computing device **302** may store usage data **314** from components of air respirator system **100**. For example, as described herein, components of air respirator system **100** (or any other examples of respirators **13**) may generate data regarding operation of system **100** that is indicative of activities of worker **10** and transmit the data in real-time or near real-time to mobile computing device **302**.

[0110] In some examples, mobile computing device **302** may immediately relay usage data **314** to another computing device, such as PPEMS **6**, via communication unit **306**. In other examples, storage device **308** may store usage data **314** for some time prior to uploading the data to another device. For example, in some instances, communication unit **306** may be able to communicate with system **100** but may not have network connectivity, e.g., due to an environment in which system **100** is located and/or network outages. In such instances, mobile computing device **302** may store usage data **314** to storage device **308**, which may allow the usage data to be uploaded to another device upon a network connection becoming available. Mobile computing device **302** may store safety rules **316** as described in this disclosure. Safety rules **316** may be stored in any suitable data store as described in this disclosure.

[0111] System **300** may include head top **326** and hearing protector **328**, in accordance with this disclosure. As shown in FIG. 3, head top **326** may include structure and functionality that is similar to or the same as respirator **13A** as described in FIG. 1 and other embodiments of this disclosure. Head top **326** (or other headworn device, such as a

head band) may include hearing protector **328** that includes, ear muff attachment assembly **330**. Ear muff attachment assembly **330** may include housing **332**, an arm set **334**, and ear muffs **336**. Hearing protector **328** may include two separate ear muff cups **336**, one of which is visible in FIG. 3 and the other on the opposite side of the user's head and similarly configured to the visible ear muff cup in FIG. 3. Arm set **334** is rotatable between one or more different positions, such that hearing protector **328** may be adjusted and/or toggled, for example, between "active" and "standby" positions (or one or more additional intermediate positions). In an active position, hearing protector **328** is configured to at least partially cover a user's ear. In a standby mode, hearing protector **328** is in a raised position away from and/or out of contact with a user's head. A user is able to switch between active and standby positions when entering or leaving an area necessitating hearing protection, for example, or as may be desired by the user. Adjustment to a standby position allows hearing protector **328** to be readily available for the user to move hearing protector **328** into an active position in which hearing protection is provided without the need to carry or store ear muffs.

[0112] Ear muff attachment assembly **330** may be attached directly or indirectly to a helmet, hard hat, strap, head band, or other head support, such as a head top **326**. Head top **326** may be worn simultaneously with, and provide a support for, ear muff attachment assembly **330**. Ear muff attachment assembly **330** is attached to an outer surface of head top **326**, and arm set **334** extends generally downwardly around an edge of head top **326** such that ear muffs of hearing protector **328** may be desirably positioned to cover a user's ear.

[0113] In various examples, head top **326** and ear muff attachment assembly **330** may be joined using various suitable attachment components, such as snap-fit components, rivets, mechanical fasteners, adhesive, or other suitable attachment components as known in the art. Ear muffs of hearing protector **328** are configured to cover at least a portion of a user's ear and/or head. In FIG. 3, ear muffs exhibit a cup shape and include a cushion and a sound absorber (not shown). Cushions are configured to contact a user's head and/or ear when ear muffs are in an active position forming an appropriate seal to prevent sound waves from entering. Arm set **334** extends outwardly from head top **326** and is configured to carry ear muffs of hearing protector **328**.

[0114] In the example of FIG. 3, ear muff attachment assembly **330** may have positional or motion sensors to detect whether the ear muffs are in the standby or active position. The positional or motion sensor may generate one or more signals that indicate a particular position from a set of one or more positions. The signals may indicate one or more position values (e.g., discrete "active"/"standby" values, numeric position representations, or any other suitable encoding or measurement values). If, for example, the standby condition is detected by the one or more positional or motion sensors and if an environmental sound detector detects unsafe sound levels, then a computing device may generate an indication of output, such as a notification, log entry, or other type of output. In some examples, the indication of output may be audible, visual, haptic, or any other physical sensory output.

[0115] In high noise environment workers may be required to use hearing protection in the form of ear plugs or ear muffs. Ear muffs typically comprise cup shaped shell with a

sound absorbing liner that seals against the ear of the user. Many workers also use head and/or face protection while wearing ear muffs. Therefore, many ear muff models are designed to attach to a helmet, hard hat or other headgear, such as shown in FIG. 3. The ear muffs may be affixed to the headgear via an arm that attaches to the headgear and is adjustable between various positions over or away from the worker's ear.

[0116] As described above, headgear mounted ear muffs rotate between two positions: the active position where the ear muffs cover the worker's ears providing hearing protection, and the standby position where the ear muffs are rotated up and away from the ears. While in the standby position the ear muff does not provide hearing protection to the worker. In some types of headgear attached ear muffs, the muffs can be pivoted outward away from the ear of the user in the standby position. In this case, the ear muffs rest at a small distance away from the head of the user. In the active position, the muffs are pivoted toward the head where it is sealed around the ears of the user providing hearing protection.

[0117] Returning to mobile computing device **302**, safety rules **316** may include threshold information both for a length of time visor **340** is allowed to be in an open position before an alert is generated, and the level or type of contaminants that will trigger an alert. For example, when mobile computing device **302** receives information from an environmental beacon that there are no hazards present in the environment, the threshold for the visor **340** being in the open position may be infinite. If a hazard is present in the environment, then the threshold may be determined based upon the concern of the threat to the user. Radiation, dangerous gases, or toxic fumes would all require assignment of the threshold to be on the order of one second or less.

[0118] Thresholds for head top temperature can be used to predict, e.g., by PPEMS **6**, heat related illness and more frequent hydration and/or rest periods can be recommended to the user. Thresholds can be used for predicted battery run time. As the battery nears selectable remaining run time, the user can be notified/warned to complete their current task and seek a fresh battery. When a threshold is exceeded for a specific environmental hazard, an urgent alert can be given to the user to evacuate the immediate area. Thresholds can be customized to various levels of openness for the visor. In other words, a threshold for the amount of a time the visor may be open without triggering an alarm may be longer if the visor is in the partially open position as compared to the open position.

[0119] Reaching different thresholds set forth in safety rules **316** may result in triggering different types of alerts or alarms. For example, alarms may be informational (not requiring a user response), urgent (repeated and requiring a response or acknowledgement from a user), or emergency (requiring immediate action from a user.) The type of alert or alarm can be tailored to the environment. Different types of alerts and alarms can be coupled together to get user attention. In some instances, a user may be able to "snooze" an alert or alarm.

[0120] Rule engine **318** may be a combination of hardware and software that executes one or more safety rules, such as safety rules **316**. For instance, rule engine **318** may determine which safety rules to execute based on context data, information included in the safety rule set, other information

received from PPEMS 6 or other computing devices, user input from the worker, or any other source of data that indicates which safety rules to execute. In some examples, safety rules 316 may be installed prior to a worker entering a work environment, while in other examples, safety rules 316 be dynamically retrieved by mobile computing device 302 based on context data generated at first particular point in time.

[0121] Rule engine 318 may execute safety rules periodically, continuously, or asynchronously. For instance, rule engine 318 may execute safety rules periodically by evaluating the conditions of such rules each time a particular time interval passes or expires (e.g., every second, every minute, etc.). In some examples, rule engine 318 may execute safety rules continuously by checking such conditions using one or more scheduling techniques that continuously evaluate the conditions of such rules. In some examples, rule engine 318 may execute safety rules asynchronously, such as in response to detecting an event. An event may be any detectable occurrence, such as moving to a new location, detecting a worker, coming within a threshold distance of another object, or any other detectable occurrence.

[0122] Rule engine 318, upon determining that a condition of a safety rule has or has not been satisfied may perform one or more actions associated with the safety rule by executing one or more operations that define the actions. For instance, rule engine 318 may execute a condition that determines if a worker is approaching or has entered a work environment, (a) whether a PAPR is being worn by the worker and (b) whether the filter in the PAPR of a particular type of filter, e.g., a filter that removes contaminants of a particular type. This safety rule may specify actions if the condition is not satisfied which cause rule engine 318 to generate an alert at mobile computing device 302 using UI device 310 and send a message using communication unit 306 to PPEMS 6, which may cause PPEMS 6 to send a notification to a remote user (e.g., the safety manager).

[0123] Alert data 320 may be used for generating alerts for output by UI device 310. For example, mobile computing device 302 may receive alert data from PPEMS 6, end-user computing devices 16, remote users using computing devices 18, safety stations 15, or other computing devices as illustrated in FIG. 1. In some examples, alert data 320 may be based on operation of system 300. For example, mobile computing device 302 may receive alert data 320 that indicates a status of system 300, that system 300 is appropriate for the environment in which system 300 is located, that the environment in which system 300 is located is unsafe, or the like.

[0124] In some examples, additionally or alternatively, mobile computing device 302 may receive alert data 320 associated with a likelihood of a safety event. For example, as noted above, PPEMS 6 may, in some examples, apply historical data and models to usage data from system 300 in order to compute assertions, such as anomalies or predicted occurrences of imminent safety events based on environmental conditions or behavior patterns of a worker using system 300. That is, PPEMS 6 may apply analytics to identify relationships or correlations between sensed data from system 300, environmental conditions of environment in which system 300 is located, a geographic region in which system 300 is located, and/or other factors. PPEMS 6 may determine, based on the data acquired across populations of workers 10, which particular activities, possibly within

certain environment or geographic region, lead to, or are predicted to lead to, unusually high occurrences of safety events. Mobile computing device 302 may receive alert data 320 from PPEMS 6 that indicates a relatively high likelihood of a safety event.

[0125] Alert engine 322 may be a combination of hardware and software that interprets alert data 320 and generate an output at UI device 310 (e.g., an audible, visual, or tactile output) to notify worker 10 of the alert condition (e.g., that the likelihood of a safety event is relatively high, that the environment is dangerous, that system 300 is malfunctioning, that one or more components of system 300 need to be repaired or replaced, or the like). In some instances, alert engine 322 may also interpret alert data 320 and issue one or more commands to system 300 to modify operation or enforce rules of system 300 in order to bring operation of system 300 into compliance with desired/less risky behavior. For example, alert engine 322 may issue commands that control the operation of head top 326 or a clean air supply source.

[0126] Various techniques described in this disclosure may be implemented by mobile computing device 320. In some examples, management engine 324 may execute one or more anti-theft techniques in conjunction with articles of PPE, such as a respirator, welding mask, hearing protector, digital SRL or any other type of PPE. In particular, the article of PPE and mobile computing device 320 are linked together by an authentication credential and/or challenge process by which the article of PPE may not operate or be locked to prevent unauthorized use. For instance, if a welding helmet includes an auto-darkening filter, then the filter may remain permanently on to protect the worker's eyes, but without a passcode, proximity threshold between PPE and mobile device being satisfied, or other authentication challenge or technique being satisfied, the auto-darkening filter may not turn off to provide the visibility convenience to the user when a welding arc is not present. Management engine 324 may enforce the change in functionality to the article of PPE based on whether the authentication or proximity requirement is satisfied, by sending an indication to the PPE that changes its operation when the requirement is satisfied.

[0127] Such anti-theft techniques may, for example, disable light sensors on the welding mask, such that the user takes the welding helmet a distance away from the mobile computing device and/or work environment, the auto-darkening filter is locked in dark mode. Management engine 324 may only permit the welding mask to exit the dark-mode if an authentication challenge and/or proximity require is satisfied, in which case management engine 324 sends an authentication credential or other indication of data to the welding helmet that enables the auto-darkening filter to operate normally (e.g., between dark and light mode based on presence of welding arc). In some examples, the authentication challenge could be implemented with a public key encryption infrastructure in the management engine 324 and a computing device in the article of PPE (e.g., welding helmet). In other examples, a cryptochip may be included in the article of PPE. In some examples, if management engine 324 can communicate with the article of PPE using a short-range wireless communication (e.g., Bluetooth or same WiFi SSID), management engine 324 can assume that the article of PPE and mobile computing device have similar GPS and therefore no theft of the article of PPE has occurred. In some examples, a helmet may be stolen at a

work site but as the auto-darkening filter is “locked” in dark mode, and the ADF needs a password before the ADF can be used as intended.

[0128] In some examples, management engine 324 may store and/or use a user identifier to unique identify a specific article of PPE for a user. For instance, mobile computing device 320, may detect multiple respirators in proximity to the mobile computing device. Management engine 324 may be configured with a unique identifier of the article of PPE (e.g., respirator) such that management engine 324 automatically connects to configures communication for the specific article of PPE configured with management engine 324, thereby avoiding inadvertent communication with other articles of PPE not assigned to the user of mobile computing device 320. If an equipment locker has ten different helmets, management engine 324 may pre-configure a personalized helmet for a user of mobile computing device 320 to automatically connect to personalized helmet.

[0129] In some examples, management engine 324 may be used to locate an article of PPE that is misplaced or otherwise located away from a worker. For instance, management engine 324 may provide a location on a map user interface of where the article of PPE (e.g., a welding mask) is presently located based on location information detected or provided by the article of PPE. In some examples, management engine 324 may determine through a day, locations where the welder is spending her time either welding or not welding. Management engine 324 may determine locations where the welder was welding and advise a worker to re-investigate those locations to locate the welding mask. In some examples, management engine 324 may determine whether the welding arc is enabled and output for display or otherwise provide those locations in a user interface. As such, the user may retrace her location to identify the article of PPE.

[0130] In some examples, management engine 324 may cause the alert engine to output alerts to the auto-darkening filter or other face-positioned surface of an article of PPE. The alert may notify the user of an urgent matter. LED's or the actual ADF could be blinking. As an example, if info about e.g. a gas leak (or her/his children trying to reach her/him on the phone) is communicated to the mobile computing device, management engine 324 may cause the alert engine to notify the user as the ADF starts blinking. The user/welder then can remove his protective equipment and to find a solution. As welders often are wearing a lot of protective equipment this could delay the perception of an urgent message, the critical seconds that may make the difference. By alerting the user via the ADF he/she can get needed information faster. The ADF could also be equipped with various sensors and work as a detection device itself. In some examples, the alerting process could affect the function the PPE. For instance, the alert may start as LED on bottom of welding mask and as priority/urgency of message increases, then management engine 324 could turn off ADF on a welding mask. A priority spectrum could be established by management engine 324, based on the article of PPE, age of message or any other contextual information. As the priority increases the alert to the article of PPE may increase, such as disabling a welding art, permanently enabling dark mode on the welding mask and the like.

[0131] In some examples, management engine 324 may initiate or execute a self-diagnostic check on an article of PPE such as a welding helmet with an auto-darkening filter.

If one or more parameters indicate that the article of PPE is not operating correctly, management engine 324 may perform one or more operations, such as outputting information for display, alerting the user, and/or communicating with PPEMS 6. In some examples, the ADF may run a self check at every start. The users may receive confirmation via management engine 324 which may output information for display. This may provide the user a quick confirmation that the equipment will keep him safe or if there is a replacement part that should be changed.

[0132] In some examples, management engine 324 may generate, store, send, and/or use statistics about articles of PPE communicatively coupled to mobile computing device 324. For instance, management engine 324 may use such statistics to estimate if battery needs to be replaced. In some examples, management engine 324 may determine that a user has have N number of days of welding based on estimate battery life. Other statistics such as number of arcs initiated, length of arc time, number of ADF mode changes, or any other information about articles of PPE may be determined from the statistics. In some examples, based on historically recorded usage data, management engine 324 may indicate remaining battery capacity to the user. Battery running time may be presented in a user interface generated by management engine 324.

[0133] In some examples, management engine 324 may use the statistics or data to estimate worker productivity. An example of measuring worker productivity may include a number of hours that an article of PPE is in use. For instance, measuring may include determining a number of minutes or hours that an arc of a welding device is present. The number of minutes or hours that an arc is present within a given span of time may indicate the productivity of the worker. In some examples, the statistics may be used to predict maintenance schedules, recommend a replacement of an article of PPE or component within the article, and/or make recommendations for future equipment purchases or replenishment.

[0134] In some examples, management engine 324 may maintain a maintenance schedule for articles of PPE associated with mobile computing device 324. For instance, the maintenance schedule may support the user and keep a log of when spare parts was last changed. A user interface, automated scheduler, or other logic may assist the user to keep track and remind her of service and maintenance intervals. As an example, the welding arc may be measured by the sensor (arc, and heat), then and management engine 324 may measure how much exposure welding shield has and when to replace to ADF.

[0135] In some examples, management engine 324 may receive a set of data or “data dump” from one or more articles of PPE. For instance, an ADF “dumps” recorded data to mobile computing device 324. Management engine 324 may present the data/statistics in a comprehensive and/or integrated way in a user interface. Statistics might also be pushed forward to e.g. technical service or to a factory supervisor. E.g. data of “hours in use”/“time in dark state” and other sensors could be used to indicate productivity or safety level. In some examples, such data or the aforementioned statistics may be used for productivity measurements and/or analysis. For instance, management engine 324 may measure hours per shift of arc being in action, compare what is needed for an arc versus what is actually used to weld, identify target arc times that are compared with actual arc time (e.g., using camera vision or motion during

art to identify number of seams or time of seams), or perform any other measurement of productivity related to the article of PPE's operation or use. In some examples, management engine 324 may receive user input that indicates the job info for the target arc time, welding site information, welding speeds for certain types of welds, or any other information, which may be synchronized, pre-populated, or otherwise distributed on mobile computing device 320, articles of PPE, and/or PPMS 6. In some examples, management engine 324 may measure how often the ADF has been used to judge % usage time, meters/time welded/shift/part. In some examples management engine may output for display information in a GUI that indicates measured productivity and/or quality. In some examples, the "productivity data" collected from PPE are presented in a macro view or homepage.

[0136] In some examples, different PPE statuses may be output for display by management engine 324 in graphical user interfaces. For instance, a PAPR-status, ADF status, or any other status may be output for display using one or more visual characteristics, such as color, size, shape, image content, animation content and any other visual characteristic. In some examples, mobile computing device 302 may be a wearable computing device (e.g., smartwatch, smart headband, etc) that is wearable on the exterior of a workers PPE garments. In some examples, this wearable computing device may receive gesture inputs that can control the operation of PPE by management engine 324 detecting a gesture and sending messages or data that control the operation of different articles of PPE. In some examples, a single gesture may change the operation of multiple different articles of PPE. For example, a "quiet" gesture may turn off a blower on a PAPR, turn off noise cancellation on a headset, and turn the volume off a headset. More generally, a single gesture may be mapped to multiple different operations for multiple different articles of PPE, such that the execution of the single gesture causes the multiple different options to be performed.

[0137] In some examples, mobile computing device 302 may provide for a connected system where a PAPR and a welding head-top can communicate. Management engine and/or the PPE may cause, for example, output at an ADF when PAPR requires a filter replacement. In some examples, other sensors (smoke, gas, pressure, moisture . . .) may be able to detect hazards/environment, which may if, for example, a respiratory hazard is detected, cause an ADF to display an alert. In this way, management engine 324 may enable an event at one article of PPE to influence the operation or configuration of another article of PPE.

[0138] In some examples, management engine 324 may enable the registration of an identifier or serial number of an article of PPE with a manufacturer. In some examples, management engine 324 may identify which product/version that is connected and output for display the relevant spare parts. In some examples, management engine 324 may indicate which suppliers in a geographical region carry these spare parts. In some examples, management engine 324 may generate push-notifications about relevant upgrades/replacements and/or enable the placement of orders of such upgrades/replacements/purchases/replenishments.

[0139] In some examples, management engine 324 may store, management and output for display user instructions, training videos, and the like that are based at least in part on articles of PPE configured with management engine 324. As an example, a worker may query "how to disassemble the

head band?", management engine 324 may provide information such as service information with a picture or diagram of a welding helmet and the auto-darkening filter. The user may provide input such as tapping on the head top, the user interface may zoom in, then the user may provide user input to tap on the headband, and the user interface may present drawings, instructions and videos links to the user to perform an inspection of the headband.

[0140] In some examples, management engine 324 may manage welding modes and pre-settings. For instance, via management engine 324, different settings of an ADF or other PPE may be changed based on user input including but not limited to voice control or quick buttons provided in different user interfaces generated by management engine 324. As an example, certain settings may be preferable if the user is a TIG welder and others if a different user is a MAG-welder or welding with stick. Recommended settings for different welding situations may be pre-configured in the management engine 324. Management engine 324 may enable a user to save personalized settings e.g. "welding of part #332". Management engine 324 may enable settings that are otherwise not possible using the ADF-located dashboard and could be made available in user interfaces provided by management engine 324 (e.g., stepless adjustments, special welding modes . . .) since the ADF dashboard on the ADF itself may be limited or restricted to a finite number of LED's and buttons. In some examples, management engine 324 may store a workers "favorite" settings within a "welding community" by forwarding the user's settings to another user management engine 324.

[0141] In some examples, management engine 324 may provide access and connectivity to a customer service line via VOIP, cellular, or any other type of communication. In this way, the user and customer service representative may resolve any issue the user may be having efficiently. Quick/extended trouble shooting as data and status of the ADF, for example, may be forwarded to customer service and/or the manufacturer of the PPE. As an example, pictures of the PPE or otherwise can be transferred between manufacturer/customer service and the user for help solving problems.

[0142] In some examples, management engine 324 may provide remote control, status and usage statistics. For instance, management engine 324 may access app settings and history of PPE. In some examples, settings made via the ADF or other PPE are reflected on mobile computing device 320 and/or the articles of PPE. Management engine 324 may enable more settings via the volume buttons on the phone, voice control via the phone, adjust shade level whilst welding, whereas such functionality may not have been possible without a more expandable user interface. Status of battery and specific errors/warnings may be provided in one or more user interfaces.

[0143] In some examples, as described herein, management engine 324 may collect usage statistics and perform operations or processing based on the statistics. For instance, management engine 324 may collect "hidden data" form e.g. accelerometer sensor and send to manufacturer or customer service to provide info how and where the product has been used. For example, an accelerometer data event may indicate proof of mechanical shock. In some examples, a user may be required to opt in before such hidden data is sent to manufacturer and/or customer service.

[0144] In some examples, management engine 324 may impose access controls such as denying or granting access at

a safety checkpoint based on connected PPE and/or operating state of the PPE. In some examples, because various functionality may be included in the user interface provided by mobile computing device 320, a user interface of PAPR visor or ADF dashboard may include fewer functions or information that are easier to see and/or operate. In some examples, firmware updates may be downloaded, scheduled, and/or provided to the ADF or other PPE by management engine 324. In some examples, management engine 324 may communicate with welding equipment (e.g., TIG welder, MIG welder or any other welding device). Communication may occur via Bluetooth or any suitable communication channel and be used to configure communication with a welding machine to achieve secure triggering or control of auto-shade. In some examples, management engine 324 may provide for streaming (e.g., audio or video) content to an article of PPE, such as an ADF or visor of a PAPR. In some examples, management engine 324 may enable communication between multiple workers via voice, image, video, and/or textual communication. Via management engine 324, a worker may connect with welding partner and via the app/phone allow communication whilst working. Two workers working together in a noisy environment may be connected in a seamless manner.

[0145] In some examples, management engine 324 may detect a change in a setting, configuration or operation of one article of PPE and, in response to the change, automatically change a setting, configuration or operation. For example, if a change in blower speed of a PAPR is detected, management engine 324 may change a noise-cancellation and/or volume level in a hearing protector that is assigned to the worker having the PAPR. Such changes and/or statuses in settings, configurations, or operations that change the settings, configurations, or operations in other articles of PPE may be configured by pre-set rules and/or rules that are learned over time using learning techniques described in this disclosure.

[0146] In some examples, different articles of PPE may refer to different sub-components of an article of PPE. For instance an article of PPE may be a filter, blower unit, head top, or visor of a PAPR. An article of PPE may be the PAPR with all the sub-component articles of PPE.

[0147] As further described in FIG. 7, PPE-handshake operations may be executed between an article of PPE and a computing device, in accordance with techniques of this disclosure. In the example of FIG. 3, headtop 326 may be referred to as PPE 326 and mobile computing device 302 may be referred to as computing device 302. In accordance with techniques of this disclosure, PPE 326 and computing device 302 may execute a set of PPE-handshake operations that include receipt of a PPE-handshake input that is unique to the particular type of the at least one article of PPE. Unlike conventional pairing techniques (e.g., Bluetooth pairing), which can be cumbersome and non-intuitive for a worker (particularly, if wearing other PPE, such as heavy gloves, protective clothing, or protective headwear), the techniques of FIG. 3 use a PPE-handshake input that is unique to the particular type of the at least one article of PPE in order to initiate a temporary connection between PPE 326 and computing device 302 that is, in turn, used to establish a persistent connection based on a subsequent confirmation based on the PPE-handshake input.

[0148] By using a PPE-handshake input that is unique to the particular type of the at least one article of PPE, the

techniques may eliminate the need to add additional controls, buttons, or other input means to the PPE. In some examples, by using a PPE-handshake input that is unique to the particular type of the at least one article of PPE, the techniques may enable the worker to interact directly with the PPE to establish the connection, thereby simplifying the connection process with the computing device. In some examples, by using a PPE-handshake, existing physical characteristics of the PPE itself can be used to generate the message that initiates a connection with the PPE, thereby leveraging this existing physical characteristic in an unconventional way that provides the worker with an intuitive technique to initiate the connection. Moreover, in some examples, the PPE-handshake operations provide a process by which an accidentally or unintentionally provided PPE-handshake input does not create a permanent connection with the computing device because, in some examples, the PPE-handshake operations use a subsequent confirmation based on the PPE-handshake input to validate that a permanent connection is intended by the user. In some examples, the PPE-handshake operations provide a process by which security can be applied to establish a permanent connection. In this way, malicious or unauthorized pairing may be prevented by the PPE-handshake operations.

[0149] FIG. 4 illustrates an example architecture and descriptive for systems and techniques of this disclosure. Techniques of this disclosure relate to a remote interface to digitally enabled safety equipment. A remote interface for safety equipment may enable a new mode of user interaction with the safety equipment and may add new functionality or improve usability of complex or challenging tasks. One such task is changing multiple or complex configuration settings within the safety equipment. Other functionality enabled by a remote interface includes retrieving and viewing equipment data and receiving notifications and alerts on equipment performance. Additionally, usage and performance data can be collected communicated back to the equipment manufacturer for warranty, support and future product development purposes.

[0150] In the proposed invention, three components may exist including but not limited to: a Remote Interface, Digitally Enabled Safety Equipment, and a Digital Communication Interface. In the case of the Remote Interface, the proposed remote interface may exist within a software mobile application. This mobile application may have a modular architecture that allows adding new equipment types (Communication headset, Digital SRL, PAPR, etc. . .) quickly and efficiently while sharing core application functionality. In the case of Digitally Enabled Safety Equipment, smart, digital safety equipment may have wireless communication and event processing logic to accept and process commands and data requests from the Remote Interface. In the case of the Digital Communication Interface, a local, short range wireless communication protocol may enable communication of data between the Remote Interface and the Safety Equipment. Examples of such an interface include Bluetooth Low Energy (BLE) and Near Field Communication (NFC).

[0151] In some examples, techniques of this disclosure may provide for Modification of Safety Equipment Configuration. For instance, conventional safety equipment (or personal protection equipment) may have a limited capability or functionality to provide a convenient and easy to use user interface. Due to restrictions related to durability and

cost, a small number of buttons and indicators may often be all that is available for users to change configuration and settings of their conventional safety equipment. Leveraging a remote interface within a smartphone application opens up additional options available within a Graphical User Interface. One example of this functionality is proposed for changing the radio station within a hearing protector such as a Peltor WS ALERT XPI communication headset. The hardware interface on the XPI headset may contain a single up and down button for changing the radio station, the user guide instructions are shown in FIG. 5A.

[0152] FIG. 5A illustrates a hearing protector with buttons for input selection in accordance with techniques of this disclosure. This interface in FIG. 5A can pose a challenge to a user when changing from a low frequency (e.g. 87.5) to a high frequency (e.g. 108.0) as many button presses would be required to increment the frequency. A graphical user interface within the remote interface app to make this task more convenient for the user, as illustrated by a proposed graphical user interface in FIG. 5B.

[0153] FIG. 5B illustrates an example graphical user interface, in accordance with techniques of this disclosure. In FIG. 5B, the GUI proposed may enable a user to directly enter a radio station frequency using the numeric keyboard rather than sequentially incrementing through adjacent station frequencies. In some examples, a software user interface may also enable new functionality for a targeted piece of safety equipment. An example of adding new functionality can be seen in the same product scenario presented FIG. 5B. This example shows a Radio Preset functionality exposed within the remote interface GUI that allows saving and storing preset radio stations. This functionality is enabled solely through the remote interface and requires no modification to the existing safety equipment. Additionally, groupings of settings could be configured into a single package and sent to the safety equipment in bulk, saving time when a user wishes to change multiple configuration settings

[0154] In the case of Maintenance and Usage Data, digital communication between a remote interface and safety equipment can be used as previous concepts have demonstrated to change configuration and settings of the target safety equipment, but it can also be used to communicate data from the safety equipment to the remote interface, or even a cloud backend, for analysis and processing. In this scenario, the safety equipment would log usage information and upon periodic connection, transfer that data to the remote interface. Once the data is within the remote interface it could be viewed by the user through reports or other GUI elements, or transmitted to PPEMS 6 for further analysis and processing. This usage and performance data could be of particular value for warranty claims, repair centers or for guiding future product development efforts.

[0155] In the case of New Modes of Interaction, some existing safety equipment provides a single mode of interaction, via the tactile or button interfaces provided on the exterior of the equipment. Leveraging new capabilities available in smartphones and computing analysis, voice or motion commands could also be issued to the safety equipment via the remote interface. This may be useful for industrial environments where the user is typically performing a manual task oftentimes involving both hands. In this scenario, a voice interface to control operation of the safety equipment could improve productivity and improve safety. A wide range of digitally enabled safety equipment may be

designated for integration into the proposed remote interface, including but not limited to: Hearing Communication Equipment (Peltor WS ALERT XPI), Digital Self Retracting Line, Intrinsically Safe PAPR, Powered Air Purifying Respirator Connected System, Connected Welding Headtop, or any other connected PPE.

[0156] In some examples, techniques may include controlling and retrieving data from safety equipment. The proposed techniques may be directed to domain specific safety configurations for safety equipment as well as provide for advanced functionality (modes of interaction, usage data, component of a large safety data analysis system) that may not be addressed by conventional safety equipment.

[0157] FIG. 6 illustrates a welding helmet 2018 with auto-darkening figure, in accordance with techniques of this disclosure. FIG. 6 illustrates a system 2000 comprising head-mounted device 2010, visor attachment assembly 2014 that includes at least one position sensor coupled to the head-mounted device 2010, at least one visor 2016 that includes light-filtering shield coupled to the at least one position sensor; at least one light detector 2019; and at least one computing device 320 communicatively coupled to the at least one position sensor and at least one light detector 2019. Light detector 2019 is capable of detecting at least: “high” input that indicates the presence of high light intensity, “low” input that indicates the absence of high light intensity, a change from high to low input, and a change from low to high input. In some examples, light detector 2019 may also detect intermediate levels of light intensity. Light detector 2019 is also capable of communicating the detection of such high and low input and changes there between to the other components of system 2000. As such, when expressions are used in this disclosure such as detects high input, detects low input, detects a change from high input to low input, etc., it will be understood that such detection is by way of light detector 2019.

[0158] In some examples, light detector 2019 may detect different types of light where different types refer to different wavelengths. An example of a type of light may be laser light. In some examples, light detector 2019 may determine a type of light rather than an intensity of light. In other examples light detector 2019 may determine a type and an intensity of light.

[0159] In various embodiments, light detector 2019 may be located physically close to some or all of the other components (hardware, etc.) of system 2000 or may be located physically remote from some or all of the other components. Regardless, light detector 2019 may be in communication with other components of system 2000 via one or more wired or wireless communication channels as needed for functioning of system 2000. In one embodiment, light detector 2019 is capable of directly detecting incident light of high intensity (e.g., light detector 2019 comprises a photosensitive device, including but not limited to a photodiode, phototransistor, and so on). In this instance, “high input” means that light detector 2019 is directly sensing incident light of high intensity. (In such an embodiment, it may be preferential to locate light detector 2019 in close proximity to system 2000, so that the light incident on light detector 2019 is closely representative of the light incident on system 2000).

[0160] In an alternative embodiment, light detector 2019 is capable of detecting the high light intensity indirectly. In such a case a high input can comprise an input that is

indicative of the presence of a high light intensity. In a particular embodiment, light detector **2019** is in communication with a (potentially) light-emitting device and is capable of receiving a high input from the light-emitting device that indicates that the light-emitting device is in a condition (e.g., powered up and operating) that is likely to emit high light intensity. In this context, a high input can comprise any signal sent via a connection (whether a dedicated wire, an optical fiber, a wireless connection, an IR signal, a radiofrequency broadcast, and the like) that can be received by light detector **2019** and that indicates that light-emitting device is in a condition that is likely to emit high light intensity. In such an arrangement, the light-emitting device may include a communication unit that is capable of performing such communication with light detector **2019** via a connection. If desired, such an arrangement can include a provision for two-way communication such that the light-emitting device can receive an acknowledgement from system **2000** or other computing device, prior to the light-emitting device emitting light.

[0161] FIG. 6 also illustrates computing device **320** comprising one or more computer processors and a memory comprising instructions that may be executed by the one or more computer processors. Computing device **320** may include the same, a subset, or a superset of functionality and components illustrated and described in other figures of this disclosure. Computing device **320** may be included in or attached to an article of personal protective equipment (e.g., system **2000**), may be positioned on or attached to the worker in a separate device external to headtop **2010** and visor **2016**, or may be in a remote computing device separate from the worker altogether (e.g., a remote server). Computing device **320** may perform any of the techniques with respect to an ADF or welding helmet or welding mask as described in this disclosure. Computing device **320** may communicate with PPEMS **6** in accordance with techniques of this disclosure.

[0162] In accordance with this disclosure, computing device **320** may receive, from light detector **2019**, an indication that an intensity of light detected by the light detector exceeds an exposure threshold and/or that a type of light detected by the light detector matches a particular type of light. In some examples, the exposure threshold may be user-defined, hard-coded, or machine-generated. Computing device **320** may determine, from the position sensor included in visor attachment assembly **2014**, that the light-filtering shield is or is not positioned at the face of a worker to filter light with the intensity that exceeds the exposure threshold and/or the type of light matches a particular type. In some examples, computing device **320** may determine that the light-filtering shield is or is not positioned at the face of a worker to filter light with the intensity that exceeds the exposure threshold within a threshold time at which the user was in a location during which the light exposure was present. As shown in FIG. 6, visor **2016** is positioned at the face of a worker to filter light with the intensity that exceeds the exposure threshold (e.g., active position). Visor **2016** may not be positioned at the face of a worker to filter light with the intensity that exceeds the exposure threshold (e.g., standby position).

[0163] Computing device **320** may generate, in response to the determination that the light-filtering shield is not positioned at the face of a worker to filter light with the intensity that exceeds the threshold and/or the type of light

matches a particular type, an indication for output. In some examples, the indication of output may be haptic or audible and output at one or more computing devices as described in this disclosure. Computing device **320** may generate any type of indication of output. In some examples, the indication of output may be a message that includes various notification data. Notification data may include but is not limited to: an alert, warning, or information message; a type of personal protective equipment; a worker identifier; a timestamp of when the message was generated; a position of the personal protective equipment; one or more light intensities, or any other descriptive information. In some examples, the message may be sent to one or more computing devices as described in this disclosure and output for display at one or more user interfaces of output devices communicatively coupled to the respective computing devices. In some examples computing device **320** may receive an indication whether welding activity was occurring (e.g., welding arc was present) and generate the indication of output further based on whether the welding activity was occurring.

[0164] FIG. 7 illustrates a diagram of PPE-handshake operations that are executed between an article of PPE and a computing device, in accordance with techniques of this disclosure. In the example of FIG. 7, PPE **701** may be welding helmet **2018** and computing device **703** may be computing device **320**, as respectively illustrated in FIG. 6. In accordance with techniques of this disclosure, PPE **701** and computing device **703** may execute a set of PPE-handshake operations that include receipt of a PPE-handshake input that is unique to the particular type of the at least one article of PPE. Unlike conventional pairing techniques (e.g., Bluetooth pairing), which can be cumbersome and non-intuitive for a worker (particularly, if wearing other PPE, such as heavy gloves, protective clothing, or protective headwear), the techniques of FIG. 7 use a PPE-handshake input that is unique to the particular type of the at least one article of PPE in order to initiate a temporary connection between PPE **701** and computing device **703** that is, in turn, used to establish a persistent connection based on a subsequent confirmation based on the PPE-handshake input.

[0165] By using a PPE-handshake input that is unique to the particular type of the at least one article of PPE, the techniques may eliminate the need to add additional controls, buttons, or other input means to the PPE. In some examples, by using a PPE-handshake input that is unique to the particular type of the at least one article of PPE, the techniques may enable the worker to interact directly with the PPE to establish the connection, thereby simplifying the connection process with the computing device. In some examples, by using a PPE-handshake, existing physical characteristics of the PPE itself can be used to generate the message that initiates a connection with the PPE, thereby leveraging this existing physical characteristic in an unconventional way that provides the worker with an intuitive technique to initiate the connection. Moreover, in some examples, the PPE-handshake operations provide a process by which an accidentally or unintentionally provided PPE-handshake input does not create a permanent connection with the computing device because, in some examples, the PPE-handshake operations use a subsequent confirmation based on the PPE-handshake input to validate that a permanent connection is intended by the user. In some examples, the PPE-handshake operations provide a process by which

security can be applied to establish a permanent connection. In this way, malicious or unauthorized pairing may be prevented by the PPE-handshake operations.

[0166] In the example of FIG. 7, system 700 includes a set of personal protection equipment (PPE), e.g., PPE 701, controlled by a particular user. PPE 701 may be a welding helmet, such as welding helmet 2018. Computing device 703 may be computing device 320 as shown in FIG. 6. Accordingly, system 700 may represent system 2000 in FIG. 6. PPE 701 may be of a particular type and may include a communication device. Particular types of PPE may include but are not limited to: a powered-air purifying respirator, reusable respirator, disposable respirator, fall protection harness, self-retracting line, welding helmet or welding mask, protective ear muffs or protective ear plugs, protective eyewear, protective hard hat, protective gloves, protective clothing, a data hub, protective footwear. In some examples, a particular type of PPE may refer to a particular category of PPE (e.g., powered-air purifying respirator). In some examples a particular type of PPE may refer to a particular model of PPE (e.g., TR-600). A particular type of PPE may have one or more features or characteristics that are distinguishable from other types of PPE. Features or characteristics may include, but are not limited to: mechanical operation, physical shape, visual appearance, digital, composition, purpose, feature set, capability, regulatory classification or certification, or any other determinable property that distinguishes one article of PPE from another.

[0167] System 700 may include computing device 703 that is also controlled by the particular user that controls PPE 701. Computing device 703 may include a communication device; one or more computer processors; and a memory comprising instructions that, when executed by the one or more computer processors, cause the one or more computer processors to perform one or more operations. For instance, computing device 703 may execute, based on receiving a message that is generated by the at least one article of PPE in response to a PPE-handshake input that is unique to the particular type of the at least one article of PPE, a set of PPE-handshake operations to establish a connection with the at least one article of PPE.

[0168] A PPE-handshake input that is unique to the particular type of PPE may, in some examples, only be performed at that particular type of PPE because of one or more features that are distinguishable from other types of PPE. As an example, a self-retracting line that provides fall protection safety may include a microcontroller or a processor coupled to a memory, which can detect one or more properties of an extension or retraction of the self-retracting line. A user may provide user input by extracting the self-retracting line in a particular way or otherwise performing a pre-determined action, such that the particular way of extracting the self-retracting line corresponds to or generates a particular value of input. Examples of such a self-retracting line with are described in PCT Application Number PCT/IB2018/050763, entitled SAFETY APPARATUS COMPRISING MECHANICAL COMMAND INTERFACE, filed on Feb. 7, 2018, which is incorporated herein by reference in its entirety. Unlike a powered-air purifying respirator, which has no self-retracting line, the use of the self-retracting line may use extensions or retractions or other actions to establish the connection between the computing device and PPE.

[0169] As another example of a PPE-handshake input that is unique to the particular type of PPE, a welding helmet with a mask may include a particular button placed at a particular location relative to the welding mask. A user may provide user input by accessing and selecting the button in a particular way before a welding operation, such that the particular way of selecting the button in a particular location relative to the welding mask corresponds to or generates a particular value of input. Unlike a powered-air purifying respirator or self-retracting line, which has no welding mask, welding mask and computing device may use the selection of the button in the particular way and location before a welding operation to establish the connection between the computing device and PPE.

[0170] In some examples, computing device 703 may output for display, using data received via a connection between computing device 703 and PPE 701, a graphical user interface that is based at least in part on the data received from the least one article of PPE that sent the message. Further examples of such graphical user interfaces are illustrates in this disclosure.

[0171] FIG. 7 illustrates a set of PPE-handshake operations to establish a connection with the at least one article of PPE. In some examples, computing device 703 may output a user interface for display that includes content to instruct the user to provide a PPE-handshake initiation input (702). A PPE-handshake initiation input may be a PPE-handshake input that is initially provided at PPE 701 to cause computing device 703 to detect PPE 701. Computing device 703 may initiate identification of PPE 704, for example, in response to a user input at computing device 703 or in response to outputting the user interface for display. To initiate identification of PPE 704, computing device 703 may cause its communication device to listen for a message that is generated in response to a PPE-handshake initiation input at PPE 701.

[0172] The user (e.g., a worker) in control of computing device 703 and PPE 701 may view the user interface output by computing device 703 and provide a PPE-handshake initiation input at PPE 701 (706). As described above, in some examples, the PPE-handshake input is unique to the particular type of the at least one article of PPE. For instance, the user interface output may instruct the user to pull or tug a self-retracting line twice in a period of time that is less than a pre-defined threshold time period. In response to detecting, the PPE-handshake initiation input, PPE 701 may generate a message based on the PPE-handshake initiation input. PPE 701 may send the message to computing device 703 using the communication device of PPE 701 (708). In some examples, the message may include a unique identifier of the PPE 701. In some examples, the message may include any other metadata including but not limited to: model type, timestamp, timeout value, or any other data.

[0173] Computing device 703 may receive the message generated based on the PPE-handshake initiation input (710). In response to receiving the message, computing device 703 may send an acknowledgement message, which is received by PPE 701 (712). The acknowledgement message may include a unique identifier of computing device 703. In some examples, the message may include any other metadata including but not limited to: model type, timestamp, timeout value, or any other data. Based on the message sent by PPE 701 to computing device 703, and the

acknowledgement message sent by computing device 703 to PPE 701, a temporary connection 714 is established between PPE 701 and 703.

[0174] Techniques of the disclosure may create temporary connection 714 initially in response to the PPE-handshake initiation input, rather than immediately creating persistent connection 726, because a user may accidentally or unintentionally provide the PPE-handshake initiation input (e.g., due to accidental or unintentional input by the user due to use of the existing physical characteristic of the PPE itself that is used to generate the message). As further described with respect to FIG. 7, temporary connection 714 may expire if a confirmation input is not received within a threshold period of time (e.g., expiration of a timer). In this way, temporary connection 714 may be established in response to a PPE-handshake initiation input to temporarily receive a confirmation input that establishes a persistent connection 726. However, if no confirmation input is received, temporary connection 714 may be terminated. In this way, PPE-handshake inputs specific to a particular type of PPE may be used to establish a temporary connection, while avoiding accidental or inadvertent persistent connections from being established, and in some cases, saving power by terminating temporary connections if no confirmation is received within the threshold period of time.

[0175] As shown in FIG. 7, computing device 703 may output a user interface for display that instructs the user to provide a PPE-handshake confirmation input (716). In some examples, computing device 703 may output a user interface for display that instructs the user to provide a PPE-handshake confirmation input, in response to temporary connection 714 being established between PPE 701 and computing device 703. In some examples, computing device 703 may initiate a timer that expires after a threshold period of time (718). Computing device 703 may initiate the timer in response to outputting the user interface for display that instructs the user to provide a PPE-handshake confirmation input. In some examples, computing device 703 may initiate the timer in response to sending a message (not shown) to PPE 701. In any case, in response to computing device 703 starting the timer, computing device 703 may listen or otherwise wait to receive a message generated based on a PPE-handshake confirmation input. In some examples, computing device 703 may listen or otherwise wait to receive a message generated based on a PPE-handshake confirmation input using temporary connection 714.

[0176] The user in control of PPE 701 and computing device 703 may provide a PPE-handshake confirmation input at PPE 701. In some examples, a PPE-handshake confirmation input may be the same as the PPE-handshake initiation input, but received subsequent to the PPE-handshake initiation input. In other examples, PPE-handshake confirmation input is different than the PPE-handshake initiation input. In still other examples, PPE-handshake confirmation input is not a PPE-handshake input, as described in this disclosure. In any case, in response to the PPE-handshake confirmation input, PPE 701 may send a message to computing device 703 (722). In some examples, the message may include a unique identifier of the PPE 701. In some examples, the message may include any other metadata including but not limited to: model type, timestamp, timeout value, or any other data.

[0177] Computing device 703 may receive the message generated based on the PPE-handshake confirmation input

(724). In some examples, computing device 703 may determine whether the message generated based on the PPE-handshake confirmation input was generated prior to expiration of the timer. In response to determining that the message generated based on the PPE-handshake confirmation input was received after the timer expired, computing device 703 may terminate temporary connection 714. For instance, computing device 703 may delete or modify state data for temporary connection 714, such that communication is not possible between PPE 701 and computing device 703. In some examples, computing device 703 may turn off or otherwise disable the communication device of computing device 703, such that communication is not possible between PPE 701 and computing device 703.

[0178] In some examples, in response to determining that the message generated based on the PPE-handshake confirmation input was received prior to expiration of the timer, computing device 703 may establish persistent connection 726. In some examples, computing device 703 may establish persistent connection 726 by modifying state data that defines temporary connection 714, such that communication remains possible between PPE 701 and computing device 703. In some examples, computing device 703 may establish persistent connection 726, by refraining from modifying state data that defines temporary connection 714, such that communication remains possible between PPE 701 and computing device 703. In still other examples, computing device 703 may establish persistent connection 726 as a connection separate from temporary 714. In any case, if the timer expires after the message generated based on the PPE-handshake confirmation input is received by computing device 703 (728), a persistent connection 726 is present between PPE 701 and computing device 703. In this way, either of PPE 701 and computing device 703 may exchange information by sending or receiving data from one device to the other. Examples of such data are further described in this disclosure, and include but are not limited to: usage data, settings and configuration data, alert or notification data, data to control the operation of PPE, or any other suitable data for the PPE and/or computing device.

[0179] FIG. 8 illustrates a graphical user interface that indicates a set of PPE controlled by a particular user, in accordance with techniques of this disclosure. Although FIG. 8 illustrates an example arrangement of graphical elements, other arrangements of graphical elements are possible and within the spirit and scope of this disclosure. Although FIG. 8 illustrates example appearances of graphical elements, other appearances of graphical elements are possible and within the spirit and scope of this disclosure.

[0180] In some examples a computing device, such as computing device 320 (as shown in FIG. 6) may output graphical user interface 800 for display. As shown in FIG. 8, graphical user interface 800 may include a set 814 of PPE graphical elements 802A-802C (“PPE graphical elements 802”). As such, computing device 320 may output for display, based at least in part on the data received from the at least one article of PPE, graphical user interface 800 that contemporaneously includes a set 814 of one or more graphical elements 800, wherein each respective graphical element corresponds to a respective article of PPE in the set of PPE. In some examples, at least one graphical element, e.g., 802A, in the set of one or more graphical elements indicates the particular type of the at least one article of PPE.

[0181] Each graphical element in graphical elements 802 may correspond to an article of PPE, which is connected, connectable, or was previously connected to computing device 320. In some examples, an appearance of a graphical element may indicate whether the PPE that corresponds to the graphical element is currently connected to computing device 320. For instance, the opacity level of graphical element 802C may indicate that the PPE that corresponds to graphical element 802C is not currently connected to computing device 320 and/or was previously connected to computing device 320.

[0182] Graphical element 802A, as an example, may include graphical content. For instance, graphical element 802A may include an image 804 of the PPE that corresponds to graphical element 802A. Graphical element 802A may include a user-defined label for the PPE that corresponds to graphical element 802A. Graphical element 802A may include pre-defined descriptive information for the PPE that corresponds to graphical element 802A. In some examples, pre-defined descriptive information may include a model, type, unique identifier, or any other suitable information. In some examples, the pre-defined descriptive information may be received from the PPE using a connection with computing device 320. In some examples, graphical element 802A may include one or more state indicators, such as connection status or connection type indicator, as illustrated by connection state indicator 810. In some examples, graphical element 802A may include battery state indicator 812. In still other examples, graphical element 802A may include a state indicator for expiration, use time, or remaining life of the PPE or a component of the PPE.

[0183] In some examples, the visual appearance of the state indicator may be varied based on one or more possible states for the state indicator. For instance, one or more states may be whether a connection exists between the PPE and computing device, whether the battery state is above or below a threshold battery life, whether the PPE or component of PPE is above or below a usage, expiration, or remaining life threshold, whether a fault at the PPE has occurred. The visual appearance may be varied based on color, size, shape, pattern, animation, or any other visual characteristic that may be modified.

[0184] In some examples, a graphical element, such as graphical element 802A may be selectable in response to a user input. For instance, if graphical element 802A is output for display at a touchscreen and a user touches the touchscreen at a location of the touchscreen that includes a portion of graphical element 802A, the computing device may perform one or more operations. For instance, a user may provide an input to select graphical element 802A, which causes computing device 320 to transition from display of the graphical user interface 800 to display of a graphical user interface 900 in FIG. 9 that contemporaneously includes at least one identifier of the at least one article of PPE and a graphical element that indicates at least one time-based event. In other examples, a user may provide an input to select graphical element 802A, which causes computing device 320 to transition from display of the graphical user interface 800 to display of a graphical user interface that is different than graphical user interface 900. In some examples, the transition from graphical user interface 800 to graphical user interface 900 may be a direct transition in which no other graphical user interface is output for display between the transition from graphical user interface 800 to

graphical user interface 900. In other examples, the transition from graphical user interface 800 to graphical user interface 900 may be an indirect transition in which at least one other graphical user interface is output for display between the transition from graphical user interface 800 to graphical user interface 900.

[0185] FIG. 9 illustrates a graphical user interface that indicates at least one time-based event for an article of PPE, in accordance with techniques of this disclosure. Although FIG. 9 illustrates an example arrangement of graphical elements, other arrangements of graphical elements are possible and within the spirit and scope of this disclosure. Although FIG. 9 illustrates example appearances of graphical elements, other appearances of graphical elements are possible and within the spirit and scope of this disclosure.

[0186] In some examples, graphical user interface 900 may include one or more graphical elements, such as graphical element 904, that include descriptive information of an article of PPE. Examples of such descriptive information include information described with respect to graphical element 804A of FIG. 8. In some examples graphical element 904 may include a subset or superset of information described with respect to graphical element 804A, such as illustrated in FIG. 8 (e.g., model number and serial number).

[0187] Graphical user interface 900 may include one or more graphical elements 902A, 902B that correspond respectively to time-based events. A time-based event may be an event that includes, occurs, depends on, is established with respect to, or is otherwise associated with time. In some examples, a time-based event corresponds to a particular type or article of PPE. In some examples, a time-based event corresponds to an action, result, occurrence, effect, or condition that corresponds to a particular type or article of PPE.

[0188] In FIG. 9, graphical element 902A corresponds to a time-based event that indicates the occurrence of an inspection of the PPE described in graphical element 904. In some examples, graphical element 902A indicates a type of inspection (“pre-use”) and a timestamp when the inspection occurred (“today 8:45 AM”). In some examples, a graphical element 906 that corresponds to a time-based event may indicate a due date, expiration, duration to a due date, or other indication of a future event that corresponds to the time-based event.

[0189] In some examples, a graphical element, such as graphical element 902A may be selectable in response to a user input. For instance, if graphical element 902A is output for display at a touchscreen and a user touches the touchscreen at a location of the touchscreen that includes a portion of graphical element 902A, the computing device may perform one or more operations. For instance, a user may provide an input to select graphical element 902A, which causes computing device 320 to transition from display of the graphical user interface 900 to display of a graphical user interface 1000 in FIG. 10 that is output for display initially in a pre-defined set of graphical user interfaces that are individually displayed in sequence, in response to successive indications of user inputs, to complete an inspection of an article of PPE.

[0190] In other examples, a user may provide an input to select graphical element 802A, which causes computing device 320 to transition from display of the graphical user interface 900 to display of a graphical user interface that is different than graphical user interface 1000. In some examples, the transition from graphical user interface 900 to

graphical user interface **1000** may be a direct transition in which no other graphical user interface is output for display between the transition from graphical user interface **900** to graphical user interface **1000**. In other examples, the transition from graphical user interface **900** to graphical user interface **1000** may be an indirect transition in which at least one other graphical user interface is output for display between the transition from graphical user interface **900** to graphical user interface **1000**.

[0191] FIG. **10** illustrates a graphical user interface that is output for display initially in a pre-defined set of graphical user interfaces that are individually displayed in sequence, in response to successive indications of user inputs, to complete an inspection of the at least one article of PPE, in accordance with techniques of this disclosure. In some examples, the inspection may be based at least in part on manufacturer-recommended inspection operations, steps, or actions. Although FIG. **10** illustrates an example arrangement of graphical elements, other arrangements of graphical elements are possible and within the spirit and scope of this disclosure. Although FIG. **10** illustrates example appearances of graphical elements, other appearances of graphical elements are possible and within the spirit and scope of this disclosure.

[0192] In some examples, graphical user interface **1000** includes one or more graphical elements, such as graphical element **1002**, which includes an instruction to a user. The instruction in FIG. **10** indicates one or more actions that the user is instructed to perform with respect to an article of PPE. In some examples, graphical user interface **1000** graphical element **1004**, which may one or more images of defects, visual features, or other indicia that are to be checked by a user. In some examples, graphical user interface **1000** includes graphical element **1006**, which may be a button, selector or other control that may be selected in response to user input. A user may provide a user input to select graphical element **1006** if the user has completed the actions for the instructions provided in graphical user interface **1000**.

[0193] In some examples, graphical user interface **1000** may be displayed initially in a pre-defined set of graphical user interfaces that are individually displayed in sequence, in response to successive indications of user inputs, to complete an inspection of the at least one article of PPE. In some examples, graphical user interface **1000** may be included in the pre-defined set of graphical user interfaces. The pre-defined set of graphical user interfaces may represent a set of actions to be performed by a user in order to use an article of PPE. The actions may be based on a statute, regulation, safety rule, safety procedure, inspection requirement, training information, or any other information. In any case, each graphical user interface, in the pre-defined set of graphical user interfaces, may represent an action which a user may perform or which may be automatically performed without user intervention based on communication between an article of PPE and computing device **320** that outputs the graphical user interfaces for display. In some examples, a user may provide a user input to select graphical element **1008**, which causes the computing device **320** to initiate output of a graphical user interface in the pre-defined set of graphical user interfaces.

[0194] In some examples, a graphical element, such as graphical element **1008** may be selectable in response to a user input. For instance, if graphical element **1008** is output

for display at a touchscreen and a user touches the touchscreen at a location of the touchscreen that includes a portion of graphical element **1008**, the computing device may perform one or more operations. For instance, a user may provide an input to select graphical element **1008**, which causes computing device **320** to transition from display of the graphical user interface **1000** to display of a graphical user interface **1100** in FIG. **11A** that is output for display to complete an inspection of an article of PPE.

[0195] In other examples, a user may provide an input to select graphical element **1000**, which causes computing device **320** to transition from display of the graphical user interface **1000** to display of a graphical user interface that is different than graphical user interface **1100**. In some examples, the transition from graphical user interface **1000** to graphical user interface **1100** may be a direct transition in which no other graphical user interface is output for display between the transition from graphical user interface **1000** to graphical user interface **1100**. In other examples, the transition from graphical user interface **1000** to graphical user interface **1100** may be an indirect transition in which at least one other graphical user interface is output for display between the transition from graphical user interface **1000** to graphical user interface **1100**.

[0196] FIGS. **11A** and **11B** illustrate a graphical user interface that is output for display to complete an inspection of an article of PPE, in accordance with techniques of this disclosure. Although FIG. **11** illustrate an example arrangement of graphical elements, other arrangements of graphical elements are possible and within the spirit and scope of this disclosure. Although FIG. **11** illustrate example appearances of graphical elements, other appearances of graphical elements are possible and within the spirit and scope of this disclosure.

[0197] In some examples, graphical user interface **1100** includes one or more graphical elements that define a specific action to be performed by a user or automatically without user intervention in a set of graphical user interfaces. For instance, graphical user interface **1100** includes graphical element **1102**, which may be a set of graphical content that corresponds to a specific action to be performed by a user or automatically without user intervention or a combination of the user performing an action and one or more operations being performed by computing device **320** and/or PPE without user intervention. In an example of an action performed without user intervention, computing device **320** may automatically perform an operation with respect to the PPE. The PPE may perform one or more operations or actions. The PPE may send one or more messages to computing device **320**. The messages may be based at least in part on the operations or actions, and/or results of operations or actions. Computing device **320** may perform one or more operations based on the messages. For instance, if the action or operation corresponding to a failed step in an inspection process, then computing device **320** may output for display a particular graphical user interface or store/send particular data. If the action or operation corresponding to a successful or validated step in an inspection process, then computing device **320** may output for display a different graphical user interface or store/send different data.

[0198] In some examples, graphical content may include images, videos, text or any other visual indication. In some

examples, audio content may be provided with graphical user interface **1100**, wherein the audio content corresponds to the specific action.

[0199] FIG. **11A** may include graphical elements **1104** and/or **1106**. Graphical elements **1104** and/or **1106** may be a button, selector or other control that may be selected in response to user input. A user may provide a user input to select graphical element **1104** to provide a confirmation or selection in response to a query in graphical element **1102**. A user may provide a user input to select graphical element **1106** to provide a confirmation or selection in response to a query in graphical element **1102**. For instance, in response to an indication of user input, computing device **320** may transition from display of graphical user interface **1200** to graphical user interface **1202** that includes an indication of an inspection irregularity. Graphical user interface **1202** may include a graphical element (e.g., “Confirm” button) selectable by an indication of user input to indicate the inspection irregularity. In response to the determination that no inspection irregularities exist for an article of PPE, computing device **320** may output a graphical user interface that indicates information that is based at least in part on the determination that no inspection irregularities exist for the PPE.

[0200] In the example of FIG. **11A**, if a user inspects the PPE and identifies a particular feature of the PPE (e.g., “indicated mode” in the image of graphical user interface **1100**), this may indicate that further inspection, repair, or decommissioning of the PPE is required. Accordingly, if graphical element **1104** is output for display at a touchscreen and a user touches the touchscreen at a location of the touchscreen that includes a portion of graphical element **1104**, the computing device may perform one or more operations. For instance, a user may provide an input to select graphical element **1104**, which causes computing device **320** to transition from display of the graphical user interface **1100** to display of a graphical user interface **1110** in FIG. **11B** that is output for display to notify the user that further inspection, repair, or decommissioning of the PPE may be required.

[0201] In other examples, a user may provide an input to select graphical element **1104**, which causes computing device **320** to transition from display of the graphical user interface **1100** to display of a graphical user interface that is different than graphical user interface **1110**. In some examples, the transition from graphical user interface **1100** to graphical user interface **1110** may be a direct transition in which no other graphical user interface is output for display between the transition from graphical user interface **1100** to graphical user interface **1110**. In other examples, the transition from graphical user interface **1100** to graphical user interface **1110** may be an indirect transition in which at least one other graphical user interface is output for display between the transition from graphical user interface **1100** to graphical user interface **1110**.

[0202] FIG. **11B** illustrates a graphical element that is output for display to notify the user that further inspection, repair, or decommissioning of the PPE may be required, in accordance with techniques of this disclosure. FIG. **11B** illustrates graphical user interface **1110**, which includes graphical element **1112**. Graphical element **1112** may indicate a warning, alert, informational statement, or any other graphical content that indicates further inspection, repair, or decommissioning of the PPE may be required. In some

examples, graphical user interface **1110** may include one or more graphical elements such as graphical elements **1114** and/or **1116**. In some examples, graphical user interface **1000** may include graphical elements **1114** and/or **1116**, which may be a button, selector or other control that may be selected in response to user input. A user may provide a user input to select graphical element **1114** to return to graphical user interface **1100**, or provide user input to select graphical element **1116** confirm that further inspection, repair, or decommissioning of the PPE may be required based on graphical content **1112**. In some examples, a user input to select graphical element **1116** may cause computing device **320** to store data for an inspection irregularity that indicates further inspection, repair, or decommissioning of the PPE may be required. In some examples, computing device **320** may send one or more messages for the inspection irregularity to one or more other computing devices that indicates further inspection, repair, or decommissioning of the PPE may be required.

[0203] FIGS. **12A** and **12B** illustrate a graphical user interface that is output for display to complete an inspection of an article of PPE, in accordance with techniques of this disclosure. Although FIG. **12** illustrate an example arrangement of graphical elements, other arrangements of graphical elements are possible and within the spirit and scope of this disclosure. Although FIG. **12** illustrate example appearances of graphical elements, other appearances of graphical elements are possible and within the spirit and scope of this disclosure.

[0204] FIGS. **12A** and **12B** illustrate graphical user interfaces **1200** and **1202**. Graphical user interface **1200** may include one or more graphical elements as shown in FIG. **12A**. Graphical user interface **1202** may include one or more graphical elements as shown in FIG. **12B**. Like FIG. **11A**, graphical user interface **1200** in FIG. **12A** may be included in a set of graphical user interfaces. In some examples, FIG. **12A** may be one of multiple different graphical user interfaces included in the set of graphical user interfaces. In some examples, the user may navigate sequentially through the graphical user interfaces.

[0205] In some examples, graphical user interface **1200** includes one or more graphical elements that define a specific action to be performed by a user or automatically without user intervention in a set of graphical user interfaces. For instance, graphical user interface **1200** includes graphical element **1206**, which may be a set of graphical content that corresponds to a specific action to be performed by a user or automatically without user intervention. For instance, the graphical content may include images, videos, text or any other visual indication. In some examples, audio content may be provided with graphical user interface **1200**, wherein the audio content corresponds to the specific action.

[0206] Graphical user interface **1200** may include graphical elements **1208**, **1210**, which may be a button, selector or other control that may be selected in response to user input. A user may provide a user input to select graphical element **1208** to provide a confirmation or selection in response to a query or other content. A user may provide a user input to select graphical element **1208** to provide a confirmation or selection in response to a query or other content.

[0207] In the example of FIG. **12A**, if a user inspects the PPE and identifies a particular feature of the PPE (e.g., “YES” in the image of graphical user interface **1200**), this may indicate that further inspection, repair, or decommis-

sioning of the PPE is required. Accordingly, if graphical element **1208** is output for display at a touchscreen and a user touches the touchscreen at a location of the touchscreen that includes a portion of graphical element **1208**, the computing device may perform one or more operations. For instance, a user may provide an input to select graphical element **1208**, which causes computing device **320** to transition from display of the graphical user interface **1200** to display of a graphical user interface **1202** in FIG. **12B** that is output for display to notify the user that further inspection, repair, or decommissioning of the PPE may be required.

[0208] In other examples, a user may provide an input to select graphical element **1210**, which causes computing device **320** to transition from display of the graphical user interface **1200** to display of a graphical user interface that is different than graphical user interface **1202**. In some examples, the transition from graphical user interface **1200** to graphical user interface **1202** may be a direct transition in which no other graphical user interface is output for display between the transition from graphical user interface **1200** to graphical user interface **1202**. In other examples, the transition from graphical user interface **1200** to graphical user interface **1202** may be an indirect transition in which at least one other graphical user interface is output for display between the transition from graphical user interface **1200** to graphical user interface **1202**.

[0209] FIGS. **13A** and **13B** illustrate graphical user interfaces that indicate usage of an article of PPE, in accordance with techniques of this disclosure. Although FIG. **13** illustrate an example arrangement of graphical elements, other arrangements of graphical elements are possible and within the spirit and scope of this disclosure. Although FIG. **13** illustrate example appearances of graphical elements, other appearances of graphical elements are possible and within the spirit and scope of this disclosure.

[0210] In some examples, a user may provide a user input to select, for example, graphical element **908** of graphical user interface **900** in FIG. **9**. Graphical element **908** may be a button, selector or other control that may be selected in response to user input. A user may provide a user input to select graphical element **908** that causes computing device **320** to transition from display of graphical user interface **900** to graphical user interface **1300** or **1350** as illustrated in FIGS. **13A-13B**.

[0211] Graphical user interface **1300** contemporaneously includes at least one identifier of the at least one article of PPE **1301** and a graphical element **1302** and/or **1304** that indicates usage of the article of PPE. In some examples, such as graphical user interface **1300**, graphical element **1302** that indicates usage of the article of PPE may indicate one or more instances of quantitative data that correspond to usage of the article of PPE. Examples of quantitative data may include one or more of numerical statistics or graphical representations of the numerical statistics. In some examples, graphical elements may include one or more instances of qualitative or descriptive data.

[0212] FIG. **13B** illustrates graphical user interface **1350**, which may include graphical elements **1352** and/or **1353**. Computing device **320** may transition from graphical user interface **900** to graphical user interface that indicates one or more instances of quantitative data that correspond to usage of the article of PPE. The one or more instances of quantitative data may include one or more of numerical statistics or graphical representations of the numerical statistics. For

instances, graphical element **1354** may include a graphical representation of numerical statistics or raw data. A graphical representation may be a graph, chart, list, or any other visual representation of numerical statistics or raw data.

[0213] FIGS. **14A-14B** illustrate graphical user interfaces in accordance with techniques of this disclosure for different types of PPE. Although some examples of this disclosure illustrated various systems and techniques for an article of PPE that is a self-retracting line, such techniques and systems may be adapted to any type of PPE. For instance, FIGS. **14A-14B** illustrate graphical user interfaces **1400** and **1450**, which include graphical elements **1402**, **1404**, and **1406**. Graphical elements **1402** and **1404**, in the example of FIG. **14A** are a switch control and slide control respectively, although graphical elements **1402** and **1404** may be any selectable control in other examples. In response to a user selecting or adjusting one or more of graphical elements **1402** and **1404**, computing device **320** may store data, perform one or more operations, and/or send one or more messages to an article of PPE that corresponds to graphical user interface **1400**. In some examples, the one or more messages include data that indicates at least one change to at least one configuration setting of the article of PPE.

[0214] Graphical user interface **1450** illustrates, in graphical element **1406**, quantitative data for the article of PPE that corresponds to graphical user interface **1450**. Any suitable information may be included as or within graphical element **1406**. In some examples, computing device **320**, in response to receiving a user input that selects a graphical element (e.g., **1302**, **1304**, **1352**, or **1354**) may output for display one or more other graphical elements and/or transition to another graphical user interface.

[0215] In some examples, the transition from or from graphical user interfaces **1300**, **1350** may be a direct transition in which no other graphical user interface is output for display between the transition from graphical user interfaces **1300**, **1350** to another graphical user interface. In other examples, the transition from or to graphical user interfaces **1300**, **1350** may be an indirect transition in which at least one other graphical user interface is output for display between the transition from or graphical user interfaces **1300**, **1350**.

[0216] In the present detailed description of the preferred embodiments, reference is made to the accompanying drawings, which illustrate specific embodiments in which the invention may be practiced. The illustrated embodiments are not intended to be exhaustive of all embodiments according to the invention. It is to be understood that other embodiments may be utilized and structural or logical changes may be made without departing from the scope of the present invention. The following detailed description, therefore, is not to be taken in a limiting sense, and the scope of the present invention is defined by the appended claims.

[0217] Unless otherwise indicated, all numbers expressing feature sizes, amounts, and physical properties used in the specification and claims are to be understood as being modified in all instances by the term “about.” Accordingly, unless indicated to the contrary, the numerical parameters set forth in the foregoing specification and attached claims are approximations that can vary depending upon the desired properties sought to be obtained by those skilled in the art utilizing the teachings disclosed herein.

[0218] As used in this specification and the appended claims, the singular forms “a,” “an,” and “the” encompass

embodiments having plural referents, unless the content clearly dictates otherwise. As used in this specification and the appended claims, the term “or” is generally employed in its sense including “and/or” unless the content clearly dictates otherwise.

[0219] Spatially related terms, including but not limited to, “proximate,” “distal,” “lower,” “upper,” “beneath,” “below,” “above,” and “on top,” if used herein, are utilized for ease of description to describe spatial relationships of an element(s) to another. Such spatially related terms encompass different orientations of the device in use or operation in addition to the particular orientations depicted in the figures and described herein. For example, if an object depicted in the figures is turned over or flipped over, portions previously described as below or beneath other elements would then be above or on top of those other elements.

[0220] As used herein, when an element, component, or layer for example is described as forming a “coincident interface” with, or being “on,” “connected to,” “coupled with,” “stacked on” or “in contact with” another element, component, or layer, it can be directly on, directly connected to, directly coupled with, directly stacked on, in direct contact with, or intervening elements, components or layers may be on, connected, coupled or in contact with the particular element, component, or layer, for example. When an element, component, or layer for example is referred to as being “directly on,” “directly connected to,” “directly coupled with,” or “directly in contact with” another element, there are no intervening elements, components or layers for example. The techniques of this disclosure may be implemented in a wide variety of computer devices, such as servers, laptop computers, desktop computers, notebook computers, tablet computers, hand-held computers, smart phones, and the like. Any components, modules or units have been described to emphasize functional aspects and do not necessarily require realization by different hardware units. The techniques described herein may also be implemented in hardware, software, firmware, or any combination thereof. Any features described as modules, units or components may be implemented together in an integrated logic device or separately as discrete but interoperable logic devices. In some cases, various features may be implemented as an integrated circuit device, such as an integrated circuit chip or chipset. Additionally, although a number of distinct modules have been described throughout this description, many of which perform unique functions, all the functions of all of the modules may be combined into a single module, or even split into further additional modules. The modules described herein are only exemplary and have been described as such for better ease of understanding.

[0221] If implemented in software, the techniques may be realized at least in part by a computer-readable medium comprising instructions that, when executed in a processor, performs one or more of the methods described above. The computer-readable medium may comprise a tangible computer-readable storage medium and may form part of a computer program product, which may include packaging materials. The computer-readable storage medium may comprise random access memory (RAM) such as synchronous dynamic random access memory (SDRAM), read-only memory (ROM), non-volatile random access memory (NVRAM), electrically erasable programmable read-only memory (EEPROM), FLASH memory, magnetic or optical data storage media, and the like. The computer-readable

storage medium may also comprise a non-volatile storage device, such as a hard-disk, magnetic tape, a compact disk (CD), digital versatile disk (DVD), Blu-ray disk, holographic data storage media, or other non-volatile storage device.

[0222] The term “processor,” as used herein may refer to any of the foregoing structure or any other structure suitable for implementation of the techniques described herein. In addition, in some aspects, the functionality described herein may be provided within dedicated software modules or hardware modules configured for performing the techniques of this disclosure. Even if implemented in software, the techniques may use hardware such as a processor to execute the software, and a memory to store the software. In any such cases, the computers described herein may define a specific machine that is capable of executing the specific functions described herein. Also, the techniques could be fully implemented in one or more circuits or logic elements, which could also be considered a processor.

[0223] In one or more examples, the functions described may be implemented in hardware, software, firmware, or any combination thereof. If implemented in software, the functions may be stored on or transmitted over, as one or more instructions or code, a computer-readable medium and executed by a hardware-based processing unit. Computer-readable media may include computer-readable storage media, which corresponds to a tangible medium such as data storage media, or communication media including any medium that facilitates transfer of a computer program from one place to another, e.g., according to a communication protocol. In this manner, computer-readable media generally may correspond to (1) tangible computer-readable storage media, which is non-transitory or (2) a communication medium such as a signal or carrier wave. Data storage media may be any available media that can be accessed by one or more computers or one or more processors to retrieve instructions, code and/or data structures for implementation of the techniques described in this disclosure. A computer program product may include a computer-readable medium.

[0224] By way of example, and not limitation, such computer-readable storage media can comprise RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage, or other magnetic storage devices, flash memory, or any other medium that can be used to store desired program code in the form of instructions or data structures and that can be accessed by a computer. Also, any connection is properly termed a computer-readable medium. For example, if instructions are transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared, radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of medium. It should be understood, however, that computer-readable storage media and data storage media do not include connections, carrier waves, signals, or other transient media, but are instead directed to non-transient, tangible storage media. Disk and disc, as used, includes compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk and Blu-ray disc, where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above should also be included within the scope of computer-readable media.

[0225] Instructions may be executed by one or more processors, such as one or more digital signal processors (DSPs), general purpose microprocessors, application specific integrated circuits (ASICs), field programmable logic arrays (FPGAs), or other equivalent integrated or discrete logic circuitry. Accordingly, the term “processor”, as used may refer to any of the foregoing structure or any other structure suitable for implementation of the techniques described. In addition, in some aspects, the functionality described may be provided within dedicated hardware and/or software modules. Also, the techniques could be fully implemented in one or more circuits or logic elements.

[0226] The techniques of this disclosure may be implemented in a wide variety of devices or apparatuses, including a wireless handset, an integrated circuit (IC) or a set of ICs (e.g., a chip set). Various components, modules, or units are described in this disclosure to emphasize functional aspects of devices configured to perform the disclosed techniques, but do not necessarily require realization by different hardware units. Rather, as described above, various units may be combined in a hardware unit or provided by a collection of interoperable hardware units, including one or more processors as described above, in conjunction with suitable software and/or firmware.

[0227] It is to be recognized that depending on the example, certain acts or events of any of the methods described herein can be performed in a different sequence, may be added, merged, or left out all together (e.g., not all described acts or events are necessary for the practice of the method). Moreover, in certain examples, acts or events may be performed concurrently, e.g., through multi-threaded processing, interrupt processing, or multiple processors, rather than sequentially.

[0228] In some examples, a computer-readable storage medium includes a non-transitory medium. The term “non-transitory” indicates, in some examples, that the storage medium is not embodied in a carrier wave or a propagated signal. In certain examples, a non-transitory storage medium stores data that can, over time, change (e.g., in RAM or cache).

[0229] Various examples have been described. These and other examples are within the scope of the following claims.

1. A system comprising:

- a set of personal protection equipment (PPE) controlled by a particular user, wherein at least one article of PPE in the set of PPE is of a particular type and comprises a first communication device, and wherein the at least one article of PPE includes at least one physical characteristic that is unique to the particular type of the at least one article of PPE;
- a computing device controlled by the particular user comprising:
 - a second communication device;
 - one or more computer processors; and
 - a memory comprising instructions that, when executed by the one or more computer processors, cause the one or more computer processors to:
 - execute, based on receiving a message that is generated by the at least one article of PPE in response to a PPE-handshake input received by the at least one physical characteristic that is unique to the particular type of the at least one article of PPE, a set of PPE-handshake operations to establish a connection with the at least one article of PPE; and

output for display, using data received by the second communication device from the first communication device via the connection, a graphical user interface that is based at least in part on the data received from the at least one article of PPE that sent the message.

2. The system of claim 1, wherein the message is a first message, wherein to execute the set of PPE-handshake operations to establish the connection with the at least one article of PPE, the memory comprises instructions that, when executed by the one or more computer processors, cause the one or more computer processors to:

output for display a graphical user interface that instructs the user to provide a PPE-handshake confirmation input;

start a timer configured with a pre-defined interval;

in response to a determination that a second message from the at least one article of PPE is received prior to expiration of the pre-defined interval of the timer and in response to the PPE-handshake confirmation input, establish the connection as a persistent connection.

3. The system of claim 1, wherein to output for display the graphical user interface, the memory comprises instructions that, when executed by the one or more computer processors, cause the one or more computer processors to:

output for display, based at least in part on the data received from the at least one article of PPE, the graphical user interface that contemporaneously includes a set of one or more graphical elements, wherein each respective graphical element corresponds to a respective article of PPE in the set of PPE, wherein at least one graphical element in the set of one or more graphical elements indicates the particular type of the at least one article of PPE.

4. The system of claim 3, wherein the graphical user interface is a first graphical user interface, wherein the memory comprises instructions that, when executed by the one or more computer processors, cause the one or more computer processors to:

receive an indication of user input to select the at least one graphical element that indicates the particular type of the at least one article of PPE; and

in response to the indication of user input, transition from display of the first graphical user interface to display of a second graphical user interface that contemporaneously includes at least one identifier of the at least one article of PPE and a graphical element that indicates at least one time-based event.

5. The system of claim 3, wherein the graphical user interface is a first graphical user interface, wherein the memory comprises instructions that, when executed by the one or more computer processors, cause the one or more computer processors to:

receive an indication of user input that causes a transition from display of at least one of the first graphical user interface or another graphical user interface subsequently output for display after the first graphical user interface and to a second graphical user interface;

in response to the indication of user input, transition from display of the at least one of the first graphical user interface or another graphical user interface subsequently output for display after the first graphical user interface and to display of the second user interface that is output for display initially in a pre-defined set of

graphical user interfaces that are individually displayed in sequence, in response to successive indications of user inputs, to complete an inspection of the at least one article of PPE.

6. The system of claim 5, wherein the memory comprises instructions that, when executed by the one or more computer processors, cause the one or more computer processors to:

receive an indication of user input that causes a transition from display of the second graphical user interface to a third graphical user interface included in the pre-defined set of graphical user interfaces;

in response to the indication of user input, transition from display of the second user interface to display of the third graphical user interface that includes an indication of an inspection irregularity and a graphical element selectable by an indication of user input to indicate the inspection irregularity.

7. The system of claim 6, wherein the memory comprises instructions that, when executed by the one or more computer processors, cause the one or more computer processors to:

in response to receiving the indication of user input that indicates the inspection irregularity, store data that indicates an association between the inspection irregularity and the at least one article of PPE.

8. The system of claim 5, wherein the memory comprises instructions that, when executed by the one or more computer processors, cause the one or more computer processors to:

receive an indication of user input that causes a transition from display of the second graphical user interface to a third graphical user interface included in the pre-defined set of graphical user interfaces;

in response to the indication of user input, transition from display of the second user interface to display of the third graphical user interface that indicates an instruction to perform an action at the at least one article of PPE; and

receive, from the at least one article of PPE in response to performance of the action at the at least one article of PPE, a message.

9. The system of claim 8, wherein the memory comprises instructions that, when executed by the one or more computer processors, cause the one or more computer processors to:

perform at least one operation based at least in part on the message.

10. The system of claim 5, wherein the memory comprises instructions that, when executed by the one or more computer processors, cause the one or more computer processors to:

in response to completion of successive indications of user inputs, determine that no inspection irregularities exist for the at least one article of PPE; and

in response to the determination that no inspection irregularities exist for the at least one article of PPE, output a fourth graphical user interface that indicates information that is based at least in part on the determination that no inspection irregularities exist for the at least one article of PPE.

11. The system of claim 5, wherein the memory comprises instructions that, when executed by the one or more computer processors, cause the one or more computer processors to:

in response to completion of successive indications of user inputs, determine that at least one inspection irregularity exists for the at least one article of PPE; and in response to the determination that at least one inspection irregularity exists for the at least one article of PPE, output a fourth graphical user interface that indicates information that is based at least in part on the determination that at least one inspection irregularity exists for the at least one article of PPE.

12. The system of claim 11, wherein the information that is based at least in part on the determination that at least one inspection irregularity exists for the at least one article of PPE includes remedial information usable by the particular user to remedy the at least one inspection irregularity.

13. The system of claim 3, wherein the graphical user interface is a first graphical user interface, wherein the memory comprises instructions that, when executed by the one or more computer processors, cause the one or more computer processors to:

receive an indication of user input to select the at least one graphical element that indicates the particular type of the at least one article of PPE; and

in response to the indication of user input, transition from display of the first graphical user interface to display of a second graphical user interface that contemporaneously includes at least one identifier of the at least one article of PPE and a graphical element that indicates usage of the article of PPE.

14. The system of claim 13, wherein the graphical element that indicates usage of the article of PPE indicates one or more instances of quantitative data that correspond to usage of the article of PPE.

15. The system of claim 14, wherein the one or more instances of quantitative data comprise one or more of numerical statistics or graphical representations of the numerical statistics.

16-22. (canceled)

23. A method comprising:

executing, by a computing device and based on receiving a message that is generated by at least one article of personal protection equipment (PPE) in response to a PPE-handshake input received by a physical characteristic that is unique to a particular type of the at least one article of PPE, a set of PPE-handshake operations to establish a connection with the at least one article of PPE, wherein a set of PPE controlled by a particular user includes the at least one article of PPE, the at least one article of PPE is of the particular type and comprises a first communication device, and the computing device comprises a second communication device; and outputting for display, by the computing device and using data received by the second communication device from the first communication device via the connection, a graphical user interface that is based at least in part on the data received from the least one article of PPE that generated the message.

24. The method of claim 23, further comprising performing any of the operations of claim 2.

25. A computing device comprising one or more computer processors; and

a memory comprising instructions that, when executed by the one or more computer processors, cause the one or more computer processors to perform any of the method of claim 23.

26. A non-transitory, computer-readable medium comprising instructions that, when executed in a computer processor, causes the computer processor to perform any of the method of claim 23.

27. An apparatus comprising means for performing any of the method of claim 23.

28-30. (canceled)

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