(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
16 February 2012 (16.02.2012)

PCT

(10) International Publication Number
WO 2012/021179 A2

(51) International Patent Classification:
B64F 5/00 (2006.01)

(21) International Application Number:
PCT/US2011/030150

(22) International Filing Date:
28 March 2011 (28.03.2011)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
12/854,671 11 August 2010 (11.08.2010) US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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(54) **Title**: SYSTEM AND METHOD TO ASSESS AND REPORT THE HEALTH OF LANDING GEAR RELATED COMPONENTS

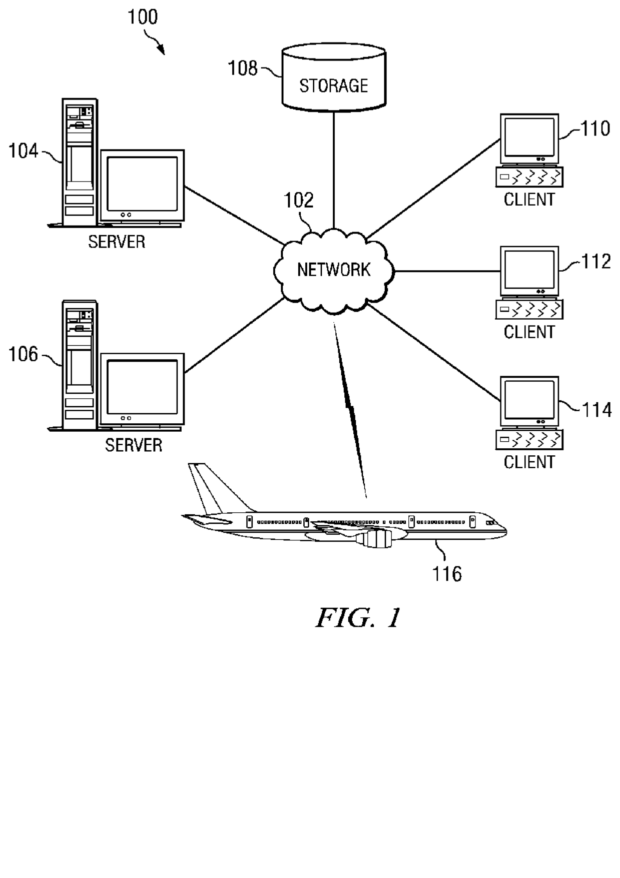


FIG. 1

(57) **Abstract**: The different advantageous embodiments provide an apparatus comprising a number of landing gear components for a vehicle, a number of systems, and a number of processor units. The number of systems is configured to generate data about the number of landing gear components and the vehicle. The number of processor units is configured to monitor the data and manage health of the number of landing gear components.

WO 2012/021179 A2

Published:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

SYSTEM AND METHOD TO ASSESS AND REPORT THE HEALTH OF LANDING GEAR RELATED COMPONENTS

BACKGROUND INFORMATION

1. Field:

[0001] The present disclosure relates generally to a data processing system, and more particularly to a system for health management. Still more particularly, the present disclosure relates to management of the health and status of landing gear components.

2. Background:

[0002] Aircraft include different undercarriage components to support an aircraft on the ground, during taxi, and for take-off and landing operations. These components are manually inspected at discrete intervals by ground personnel to assess and record appropriate measurements, as well as determine whether maintenance operations are required. These inspections typically occur at scheduled maintenance intervals for the aircraft. The health of these undercarriage components impact whether an aircraft is cleared for use or will encounter delay or even grounding in order to address issues detected.

[0003] Aircraft weight and center of gravity are other factors that impact flight delay and operational clearance. Aircraft weight is calculated based on the required fuel load, freight, and the number of passengers multiplied by the average weight of all the passengers and their baggage. Aircraft center of gravity is calculated based on aircraft weight and theoretical weight distribution. During loading operations of an aircraft, aircraft weight and aircraft center of gravity can be impacted when the actual weight and center of gravity differ from the theoretical calculations. This difference can result in unexpected fuel consumption and handling qualities for the aircraft during flight.

[0004] Therefore, it would be advantageous to have a method and apparatus that addresses one or more of the issues discussed above.

SUMMARY

[0005] The different advantageous embodiments provide an apparatus comprising a number of landing gear components for a vehicle, a number of systems, and a number of processor units. The number of systems is configured to generate data about the number of landing gear components and the vehicle. The number of processor units is configured to monitor the data and manage the health of the number of landing gear components.

[0006] The different advantageous embodiments further provide a method for managing the health of a number of landing gear components of a vehicle. Data is received from a number of systems associated with the number of landing gear components and the vehicle. A determination is made as to whether the data received is within pre-defined threshold values. In response to a determination that the data is not within the pre-defined threshold values, a number of component issues associated with the data are identified.

[0007] The different advantageous embodiments further provide a method for managing a center of gravity for a vehicle during load operations. Initiation of a load operation is detected for a vehicle. A weight is calculated on each landing gear of the vehicle to identify a center of gravity. Results having the center of gravity location are actively outputted to appropriate users during the load operation. The results are displayed on a user interface.

[0008] The features, functions, and advantages can be achieved independently in various embodiments of the present disclosure or may be combined in yet other embodiments in which further details can be seen with reference to the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The novel features believed characteristic of the advantageous embodiments are set forth in the appended claims. The advantageous embodiments, however, as well as a preferred mode of use, further objectives and advantages thereof, will best be understood by reference to the following detailed description of an advantageous embodiment of the present disclosure when read in conjunction with the accompanying drawings, wherein:

[0010] **Figure 1** is an illustration of a network of data processing systems in which an advantageous embodiment may be implemented;

[0011] **Figure 2** is an illustration of a data processing system in accordance with an advantageous embodiment;

[0012] **Figure 3** is an illustration of a transportation environment in accordance with an advantageous embodiment;

[0013] **Figure 4** is an illustration of a number of landing gear components in accordance with an advantageous embodiment;

[0014] **Figure 5** is an illustration of a sensor system in accordance with an advantageous embodiment;

[0015] **Figure 6** is an illustration of a flowchart of a process for managing the health of landing gear components on-board a vehicle in accordance with an advantageous embodiment;

[0016] **Figure 7** is an illustration of a flowchart of a process for managing the health of landing gear components off-board a vehicle in accordance with an advantageous embodiment; and

[0017] **Figure 8** is an illustration of a flowchart of a process for managing a vehicle center of gravity in accordance with an advantageous embodiment.

DETAILED DESCRIPTION

[0018] With reference now to the figures and in particular with reference to **Figures 1-2**, diagrams of data processing environments are provided in which the advantageous embodiments of the present invention may be implemented. It should be appreciated that **Figures 1-2** are only illustrative and are not intended to assert or imply any limitation with regard to the environments in which different embodiments may be implemented. Many modifications to the depicted environments may be made.

[0019] With reference now to the figures, **Figure 1** is an illustration of a network of data processing systems in which the advantageous embodiments of the present invention may be implemented. Network data processing system **100** is a network of computers in which embodiments may be implemented. Network data processing system **100** contains network **102**, which is the medium used to provide communications links between various devices and computers connected together within network data processing system **100**. Network **102** may include connections, such as wire, wireless communication links, or fiber optic cables.

In the depicted example, server **104** and server **106** connect to network **102** along with storage unit **108**. In addition, clients **110**, **112**, and **114** connect to network **102**. These clients **110**, **112**, and **114** may be, for example, personal computers, hand-held devices or network computers. In the depicted example, server **104** provides data, such as boot files, operating system images, and applications to clients **110**, **112**, and **114**. Clients **110**, **112**, and **114** are clients to server **104** in this example. Aircraft **116** also is a client that may exchange information with clients **110**, **112**, and **114**. Aircraft **116** also may exchange information with servers **104** and **106**. Aircraft **116** may exchange data with different computers through a wireless communications link while in-flight or any other type of communications link while on the ground. In these examples, server **104**, server **106**, client **110**, client **112**, and client **114** may be computers. Network data processing system **100** may include additional servers, clients, and other devices not shown.

[0020] In the depicted example, network data processing system **100** is the Internet with network **102** representing a worldwide collection of networks and gateways that use the Transmission Control Protocol/Internet Protocol (TCP/IP) suite of protocols to communicate with one another. Of course, network data processing system **100** also may be implemented as a number of different types of networks, such as for example, an intranet, a local area network (LAN), or a wide area network (WAN). **Figure 1** is intended as an example, and not as an architectural limitation for different embodiments.

[0021] Turning now to **Figure 2**, an illustration of a block diagram of a data processing system is depicted in accordance with an advantageous embodiment. Data processing system **200** is an example of a data processing system that may be used to implement servers and clients, such as server **104** and client **110** in **Figure 1.** Further, data processing system **200** is an example of a data processing system that may be found in aircraft **116** in **Figure 1**.

[0022] In this illustrative example, data processing system **200** includes communications fabric **202**, which provides communications between processor unit **204**, memory **206**, persistent storage **208**, communications unit **210**, input/output (I/O) unit **212**, and display **214**.

[0023] Processor unit **204** serves to execute instructions for software that may be loaded into memory **206**. Processor unit **204** may be a number of processors, a multi-processor core, a shared processor, or some other type of processor, depending on the particular implementation. A number, as used herein with reference to an item, means one or more items. Further, processor unit **204** may be implemented using a number of heterogeneous processor systems in which a main processor is present with secondary processors on a single chip. As another illustrative example, processor unit **204** may be a symmetric multi-processor system containing multiple processors of the same type.

[0024] Memory **206** and persistent storage **208** are examples of storage devices **216**. A storage device is any piece of hardware that is capable of storing information, such as, for example without limitation, data, program code in functional form, and/or other suitable information either on a temporary basis and/or a permanent basis. Memory **206**, in these examples, may be, for example, a random access memory or any other suitable volatile or non-volatile storage device. Persistent storage **208** may take various forms depending on the particular implementation.

[0025] For example, persistent storage **208** may contain one or more components or devices. For example, persistent storage **208** may be a hard drive, a flash memory, a rewritable optical disk, a rewritable magnetic tape, or some combination of the above. The media used by persistent storage **208** also may be removable. For example, a removable hard drive may be used for persistent storage **208**.

[0026] Communications unit **210,** in these examples, provides for communications with other data processing systems or devices. In these examples, communications unit **210** is a network interface card. Communications unit **210** may provide communications through the use of either or both physical and wireless communications links.

[0027] Input/output unit **212** allows for input and output of data with other devices that may be connected to data processing system **200**. For example, input/output unit **212** may provide a connection for user input through a keyboard, a mouse, and/or some other suitable input device. Further, input/output unit **212** may send output to a printer. Display **214** provides a mechanism to display information to a user.

[0028] Instructions for the operating system, applications and/or programs may be located in storage devices **216,** which are in communication with processor unit **204** through communications fabric **202.** In these illustrative examples the instruction are in a functional form on persistent storage **208**. These instructions may be loaded into memory **206** for execution by processor unit **204**. The processes of the different embodiments may be performed by processor unit **204** using computer implemented instructions, which may be located in a memory, such as memory **206**.

[0029] These instructions are referred to as program code, computer usable program code, or computer readable program code that may be read and executed by a processor in processor unit **204**. The program code in the different embodiments may be embodied on different physical or tangible computer readable media, such as memory **206** or persistent storage **208**.

[0030] Program code **218** is located in a functional form on computer readable media **220** that is selectively removable and may be loaded onto or transferred to data processing system **200** for execution by processor unit **204**. Program code **218** and computer readable media **220** form computer program product **222** in these examples. In one example, computer readable media **220** may be computer readable storage media **224** or computer readable signal media **226.** Computer readable storage media **224** may include, for example, an optical or magnetic disk that is inserted or placed into a drive or other device that is part of persistent storage **208** for transfer onto a storage device, such as a hard drive, that is part of persistent storage **208**. Computer readable storage media **224** also may take the form of a persistent storage, such as a hard drive, a thumb drive, or a flash memory, that is connected to data processing system **200**. In some instances, computer readable storage media **224** may not be removable from data processing system **200**. In these illustrative examples, computer readable storage media **224** is a non-transitory computer readable storage medium.

[0031] Alternatively, program code **218** may be transferred to data processing system **200** using computer readable signal media **226**. Computer readable signal media **226** may be, for example, a propagated data signal containing program code **218**. For example, computer readable signal media **226** may be an electromagnetic signal, an optical signal, and/or any other suitable type of signal. These signals may be transmitted over communications links, such as wireless communications links, optical fiber cable, coaxial cable, a wire, and/or any other suitable type of communications link. In other words, the communications link and/or the connection may be physical or wireless in the illustrative examples.

[0032] In some advantageous embodiments, program code **218** may be downloaded over a network to persistent storage **208** from another device or data processing system through computer readable signal media **226** for use within data processing system **200**. For instance, program code stored in a computer readable storage medium in a server data processing system may be downloaded over a network from the server to data processing system **200**. The data processing system providing program code **218** may be a server computer, a client computer, or some other device capable of storing and transmitting program code **218**.

[0033] The different components illustrated for data processing system **200** are not meant to provide architectural limitations to the manner in which different embodiments may be implemented. The different advantageous embodiments may be implemented in a data processing system including components in addition to or in place of those illustrated for data processing system **200**. Other components shown in **Figure 2** can be varied from the illustrative examples shown. The different embodiments may be implemented using any hardware device or system capable of running program code.

[0034] As another example, a storage device in data processing system **200** is any hardware apparatus that may store data. Memory **206**, persistent storage **208**, and computer readable media **220** are examples of storage devices in a tangible form.

[0035] In another example, a bus system may be used to implement communications fabric **202** and may be comprised of one or more buses, such as a system bus or an input/output bus. Of course, the bus system may be implemented using any suitable type of architecture that provides for a transfer of data between different components or devices attached to the bus system. Additionally, a communications unit may include one or more devices used to transmit and receive data, such as a modem or a network adapter. Further, a memory may be, for example, memory **206**, or a cache such as found in an interface and memory controller hub that may be present in communications fabric **202**.

[0036] As used herein, the phrase “at least one of”, when used with a list of items, means that different combinations of one or more of the items may be used and only one of each item in the list may be needed. For example, “at least one of item A, item B, and item C” may include, for example, without limitation, item A or item A and item B. This example also may include item A, item B, and item C or item B and item C.

[0037] As used herein, when a first component is connected to a second component, the first component may be connected to the second component without any additional components. The first component also may be connected to the second component by one or more other components. For example, one electronic device may be connected to another electronic device without any additional electronic devices between the first electronic device and the second electronic device. In some cases, another electronic device may be present between the two electronic devices connected to each other.

[0038] The different advantageous embodiments recognize and take into account that current inspection frequency of landing gear suite components by maintenance personnel requires aircraft operators to employ additional personnel and locate them strategically within their network. Personnel are required to manually and visually inspect appropriate measurands, record the results, and take appropriate actions. Human error is a by-product of the manual inspection and calculation of these processes.

[0039] Current inspection processes result in maintenance actions that are reactive in nature, resulting in gate delays and cancelled flights. These inspections occur at discrete intervals, which encompass multiple flights, thus providing the potential for issues to arise unnoticed between individual flights. The information collected during these current processes is not available to maintenance and operation planners in a sufficiently timely manner to make the most efficient use of the aircraft.

[0040] Thus, the different advantageous embodiments provide an apparatus comprising a number of landing gear components for a vehicle, a number of systems, and a number of processor units. The number of systems is configured to generate data about the number of landing gear components and the vehicle. The number of processor units is configured to monitor the data and manage the health of the number of landing gear components.

[0041] The different advantageous embodiments further provide a method for managing the health of a number of landing gear components of a vehicle. Data is received from a number of systems associated with the number of landing gear components and the vehicle. A determination is made as to whether the data received is within pre-defined threshold values. In response to a determination that the data is not within the pre-defined threshold values, a number of component issues associated with the data are identified.

[0042] The different advantageous embodiments further provide a method for managing a center of gravity for a vehicle during load operations. Initiation of a load operation is detected for a vehicle. A weight is calculated on each landing gear of the vehicle to identify a center of gravity. Results having the center of gravity location are actively outputted during the load operation. The results are displayed on a user interface.

[0043] With reference now to **Figure 3,** an illustration of a transportation environment is depicted in accordance with an advantageous embodiment. Transportation environment **300** may be implemented using a network environment, such as network data processing system **100** in **Figure 1**, for example.

[0044] Transportation environment **300** includes health management system **302**. Health management system **302** may be implemented using one or more data processing systems, such as data processing system **200** in **Figure 2**. Health management system **302** includes number of vehicles **303** and remote location **304**. Number of vehicles **303** and remote location **304** may communicate using a wireless network, in an illustrative example.

[0045] Number of vehicles **303** may be any type of vehicle suitable for transportation. Number of vehicles **303** may include, for example, without limitation, aircraft, rotorcraft, ground vehicles, sea vessels, submarines, spacecraft, manned vehicles, unmanned vehicles, and/or any other suitable vehicle. Aircraft **306** is an illustrative example of one implementation of number of vehicles **303**.

[0046] Aircraft **306** includes onboard processor **308**, number of landing gear components **310**, sensor system **312**, other aircraft systems **314**, data storage device **316**, communications unit **318**, user interface **320**, cargo space **322**, passenger seating **324**, and storage space **326**.

[0047] Cargo space **322** may be any location or area suitable for storing cargo **328**. Passenger seating **324** may be any location or area suitable for holding number of passengers **330** during transport of aircraft **306**. Storage space **326** may be any location or area suitable for storing equipment **332** and/or resources **334**. Equipment **332** may include, for example, without limitation, beverage carts, galley equipment, first aid equipment, and/or any other suitable aircraft equipment. Resources **334** may include, for example, without limitation, fuel, food, beverages, oxygen, and/or any other suitable resources for aircraft **306**.

[0048] Onboard processor **308** is an illustrative example of one implementation of processor unit **204** in **Figure 2**. Onboard processor **308** includes health manager **336**. Health manager **336** is a software agent that continually receives data from sensor system **312** and/or other aircraft systems **314**. Health manager **336** uses the data to assess, diagnose, transmit, and report on the health of number of landing gear components **310** and/or the status of aircraft center of gravity **337**. Health manager **336** uses communications unit **318** to transmit information about the health of number of landing gear components **310** and/or status of center of gravity **337** to remote location **304**. Communications unit **318** is an illustrative example of one implementation of communications unit **210** in **Figure 2**.

[0049] Center of gravity **337** is the point at which aircraft **306** would balance if it were possible to suspend it at that point. It is the mass center of aircraft **306**, or the theoretical point at which the entire weight of aircraft **306** is assumed to be concentrated.

[0050] Other aircraft systems **314** may include, for example, without limitation, flight control systems, guidance systems, navigation systems, and/or any other suitable aircraft systems. Parametric data may be received by onboard processor **308** from other aircraft systems **314** and used by health manager **336** in conjunction with sensor data from sensor system **312,** for example.

[0051] Remote location **304** may be any location off-board number of vehicles **303**. Remote location **304** may be, for example, without limitation, a back office, a ground station, a vehicle serving as a remote location, and/or any other suitable location remote from number of vehicles **303**. Remote location **304** includes data repository **338**, off-board processor **340**, communications unit **342**, and user interface **344**.

[0052] Data repository **338** may be used to store information received from health manager **336** of aircraft **306**, in an illustrative example. Data repository **338** may also support a number of algorithms used by off-board processor **340** to assess information received from health manager **336**. In an illustrative example, health manager **336** of aircraft **306** may receive data from sensor system **312** and/or other aircraft systems **314,** and transmit the data to off-board processor **340** for health assessment, diagnoses, and reporting. In another illustrative example, health manager **336** may process and assess the data received from sensor system **312** and/or other aircraft systems **314** to diagnose a number of issues, and send the diagnostic results to off-board processor **340** for further processing, such as maintenance or operational planning.

[0053] Off-board processor **340** may be a number of processors, such as one or more of processor unit **204** in **Figure 2**. Off-board processor **340** includes health manager **346** and planner **348**. In an advantageous embodiment, health manager **346** receives data collected by sensor system **312** and transmitted by health manager **336** to off-board processor **340**. Health manager **346** uses the data received to assess, diagnose, transmit, and report on the health of number of landing gear components **310** and/or the status of center of gravity **337.** Health manager **346** may also transmit information about the health of number of landing gear components **310** and/or the status of center of gravity **337** to planner **348.**

[0054] Planner **348** is a software agent that uses information about the health of number of landing gear components **310** and/or the status of center of gravity **337** to plan maintenance and operational tasks. Planner **348** may display plans on user interface **344**, in an illustrative example. User interface **344** is an illustrative example of one implementation of display **214** in **Figure 2.** In another advantageous embodiment, user interface **344** may also include peripheral devices, such as a keyboard and mouse, for example.

[0055] During operation of aircraft **306**, sensor system **312** sends sensor data and other aircraft systems **314** sends other data to onboard processor **308**, where the data is monitored by health manager **336** and/or transmitted to health manager **346** at remote location **304** for management. The data may be sent continually or the data transmission may be triggered by an event, such as initiating landing gear retraction or extension, for example. The event may be, for example, a periodic event, such as the expiration of a timer. In an illustrative example, the periodic event may occur every second, every minute, or after some other suitable period of time. In other examples, the event may be non-periodic. For example, the data may be received when the landing gear is activated. The data may continue to be received until the aircraft reaches a taxiway from the runway, the gate or some other location. This allows for real-time management of landing gear component health. Real-time may refer to sending the data to and/or from the systems as fast as possible, in an illustrative example. The data transmitted may be synchronous or asynchronous, in an illustrative example. Sensor system **312** detects a number of different measurements from number of landing gear components **310**. Health manager **336** and/or health manager **346** continually monitors the data received to perform a number of processes including, without limitation, determining whether the measurements detected are within pre-defined threshold values, monitoring and recording actual values even if within thresholds, calculating other metrics such as center of gravity, number of landings remaining for tires or brakes, fatigue life expended, and/or any other suitable process. A pre-defined threshold value may be any value that represents a normal operation value, for example.

[0056] When health manager **336** detects a value outside a pre-defined threshold value, health manager **336** assesses the data, which may include the value, identification of the component, configuration information for the component, location of the component, and any other suitable information used to assess the health of the component. Health manager **336** may transmit the information to remote location **304** for further processing and/or generate an alert with information about the health of the component. Health manager **336** may display the alert using user interface **320**.

[0057] Number of landing gear components **310** may include number of radio frequency identification (RFID) tags **350**. Number of RFID tags **350** may include configuration information associated with number of landing gear components **310**. In an advantageous embodiment, each component in number of landing gear components **310** is associated with a RFID tag from number of RFID tags **350**.

[0058] Configuration information may be any type of historical information about a particular component. For example, configuration information may include, without limitation, part numbers, serial numbers, manufacturing data, lot codes, maintenance history, and/or any other historical information about a particular component. Sensor system **312** may include a RFID reader that detects this configuration information along with other information about the component, and transmits the configuration information to health manager **336** for assessment.

[0059] The illustration of transportation environment **300** in **Figure 3** is not meant to imply physical or architectural limitations to the manner in which different advantageous embodiments may be implemented. Other components in addition and/or in place of the ones illustrated may be used. Some components may be unnecessary in some advantageous embodiments. Also, the blocks are presented to illustrate some functional components. One or more of these blocks may be combined and/or divided into different blocks when implemented in different advantageous embodiments.

[0060] For example, health management system **302** may include one instance of health manager **346** at remote location **304**, and process sensor data at remote location **304**, transmitting alerts and information to aircraft **306** over a network, in one advantageous embodiment. In another advantageous embodiment, aircraft **306** may be implemented without one or more of cargo space **322**, passenger seating **324**, and storage space **326**.

[0061] With reference now to **Figure 4,** an illustration of a number of landing gear components is depicted in accordance with an advantageous embodiment. Number of landing gear components **400** is an illustrative example of one implementation of number of landing gear components **310** in **Figure 3**.

[0062] Number of landing gear components **400** may include, for example, without limitation, tires **402**, wheels **404**, brakes **406**, struts **408**, actuators **410**, dampers

412, landing gear assembly **414**, skis **416**, floats **418**, skids **420**, pontoons **422**, undercarriage bogie **424**, doors/fairings **426**, and number of consumables **428**.

[0063] Landing gear assembly **414** may be any combination of one or more tires **402**, wheels **404**, brakes **406**, struts **408**, actuators **410**, dampers **412**, skis **416**, floats **418**, skids **420**, and pontoons **422**. Landing gear assembly **414** may be retractable or non-retractable in different illustrative examples. A retractable gear assembly is any landing gear assembly that is configured to extend and retract. Undercarriage bogie **424** is a chassis or framework carrying a number of wheels. Doors/fairings **426** is an opening in the fuselage or wing sections of an aircraft through which a retractable gear assembly may extend and retract. Number of consumables **428** are any type of product, substance, or material used in conjunction with one or more other components of number of landing gear components **400**. Number of consumables **428** may be, for example, without limitation, oil **430**, nitrogen **432**, brake fluid **434**, and/or any other suitable consumable.

[0064] The illustration of number of landing gear components **400** in **Figure 4** is not meant to imply physical or architectural limitations to the manner in which different advantageous embodiments may be implemented. Other components in addition and/or in place of the ones illustrated may be used. Some components may be unnecessary in some advantageous embodiments. Also, the blocks are presented to illustrate some functional components. One or more of these blocks may be combined and/or divided into different blocks when implemented in different advantageous embodiments.

[0065] With reference now to **Figure 5**, an illustration of a sensor system is depicted in accordance with an advantageous embodiment. Sensor system **500** is an illustrative example of one implementation of sensor system **312** in **Figure 3**.

[0066] Sensor system **500** may include, without limitation, accelerometer **502**, strain gauge **504**, pressure transducer **506**, infrared sensors **508**, lidar **510**, number of cameras **512**, laser **514**, fluid level sensors **516**, radio frequency identification reader **518**, rotary potentiometer **520**, thermal sensor **522**, linear potentiometer **524**, number of discrete switches **526**, crack detectors **528**, and torque detectors **530.**

[0067] Accelerometer **502** measures the acceleration of an object, such as aircraft **306** in **Figure 3**. Accelerometer **502** may also measure the vibration of actuators, in this illustrative example. Strain gauge **504** measures strain experienced by an object, such as aircraft **306** in **Figure 3**. Measurements taken by strain gauge **504** may be used to calculate the weight of the object, such as aircraft **306** in **Figure 3**, or the torque of brakes, for example. Pressure transducer **506** measures the force per unit area and generates a signal as a function of the pressure imposed. Infrared sensors **508** is a number of infrared imaging sensors that detect wavelengths longer and lower than that of visible light and can be used to measure the temperature of landing gear components, such as a tire or brake.

[0068] Lidar **510** is an optical remote sensing technology that measures properties of scattered light to measure landing gear component wear and damage, such as tire wear and damage profiles, for example. Number of cameras **512** may be any type of device used to capture images, including black and white cameras, color cameras, thermal imaging cameras, video cameras, and the like, which can be used to inspect wear and damage on tires and brakes. Laser **514** emits electromagnetic radiation which can be used to measure landing gear component wear and damage profiles, such as tire or wheel wear and damage profiles, for example. Fluid level sensors **516** is a number of sensors configured to detect the level of a consumable fluid, such as number of consumables **428** in **Figure 4**, for example. Fluid level sensors **516** may be, in one illustrative example, capacitive probes which measure the level of a fluid in a reservoir.

[0069] Radio frequency identification tag reader **518** detects and reads information from radio identification tags, such as number of RFID tags **350** of number of landing gear components **310** in **Figure 3**. Rotary potentiometer **520**,or a rotary variable differential transformer (RVDT), is a device to measure the rotary position and/or movement of a number of components or the relationship between a number of components. Rotary potentiometers and RVDT may be used to monitor the extension of the landing gear strut. Thermal sensor **522** is a device for measuring temperature. Thermal sensor **522** may measure ambient temperature, component temperature, and/or any other suitable temperature. Linear potentiometer **524**,or a linear variable differential transformer (LVDT), measures the linear position and movement of a number of components, and measures the wear of landing gear components, such as brake wear, for example.

[0070] Number of discrete switches **526** is used to determine where a number of components are located. For example, number of discrete switches **526** may be configured to measure an actuator if an actuator is locked in the open or closed position. The time between the open or closed position can be used to determine actuation time which can infer the health of the actuator, for example. Crack detectors **528** are sensors used to detect the presence of cracks in the number of components. Torque detectors **530** are sensors that detect the amount of torsional load a number of components are subjected to. For example, a torque detector can be used to measure the braking force or the force applied by a rotary actuator.

[0071] In an illustrative example, sensor system **500** may generate sensor data for a number of landing gear components, such as number of landing gear components **400** in **Figure 4**. For example, pressure transducer **506** may generate data on the pressure of tires **402** in **Figure 4.** In another illustrative example, pressure transducer **506** may generate data on the pressure of fluids in struts **408** in **Figure 4**.

[0072] The illustration of number of sensors **500** in **Figure 5** is not meant to imply physical or architectural limitations to the manner in which different advantageous embodiments may be implemented. Other components in addition and/or in place of the ones illustrated may be used. Some components may be unnecessary in some advantageous embodiments. Also, the blocks are presented to illustrate some functional components. One or more of these blocks may be combined and/or divided into different blocks when implemented in different advantageous embodiments.

[0073] With reference now to **Figure 6**, an illustration of a flowchart of a process for managing the health of landing gear components on-board a vehicle is depicted in accordance with an advantageous embodiment. The process in **Figure 6** may be implemented by a health management system, such as health management system **302** in **Figure 3** using health manager **336,** for example.

[0074] The process begins by receiving sensor data from a number of systems (operation **602**). The number of systems may be systems such as sensor system **312** and/or other aircraft systems **314** in **Figure 3.** The data received may be from the vehicle control systems relative to the vehicle speed, attitude, and control inputs, for example. The data received may also be from a sensor system associated with landing gear components and configured to detect the health and status of a number of landing gear components. The process determines whether the data received is within pre-defined threshold values (operation **604**). The pre-defined threshold values may be configured by a user or default values associated with a specific vehicle and/or landing gear component, for example.

[0075] If a determination is made that the data is within the pre-defined threshold values, the process determines whether the data is needed for status or other applications (operation **606**). If a determination is made that the data is needed for status or for other applications, such as to calculate other metrics, the process generates a status message or stores information (operation **608**), and returns to operation **602.** Status and other applications may include, for example, monitoring and recording actual values, even if within thresholds, to calculate other metrics such as center of gravity, number of landings remaining for tires or brakes, fatigue life expended, tire pressure, tire temperature, and the like.

[0076] If a determination is made in operation **604** that the data is not within the pre-defined threshold values, the process identifies a number of component issues associated with the data (operation **610**). A component issue may be, for example, a tire pressure outside an expected value.

[0077] The process generates an alert with the number of component issues (operation **612**). The alert may be generated by a processor unit, such as onboard processor unit **308** in **Figure 3**, for example. The alert may be a status message, in one illustrative example. In another illustrative example, the alert may be a warning of a value outside a threshold. The process displays the alert on a user interface (operation **614**). The user interface may be, for example, user interface **320** of aircraft **306**. The process then stores information about the alert and the data in a number of storage devices (operation **616**), with the process terminating thereafter. In another advantageous embodiment, the process may continually loop from operation **616** back to operation **602**, for example.

[0078] With reference now to **Figure 7,** an illustration of a flowchart of a process for managing the health of landing gear components off-board a vehicle is depicted in accordance with an advantageous embodiment. The process in **Figure 7** may be implemented by a health management system, such as health management system **302** in **Figure 3**.

[0079] The process begins by receiving data from a number of systems (operation **702**). The number of systems may include, for example, sensor system **312** and/or other aircraft systems **314** in **Figure 3** using health manager **336.** The process transmits the data to an off-board processor (operation **704**),such as health manager **346** in **Figure 3,** for example. The off-board processor may be located in a remote location, such as remote location **304** in **Figure 3**, for example. The information may be processed at the remote location, in this example. The process determines whether the data received is within pre-defined threshold values (operation **706**). The pre-defined threshold values may be configured by a user or default values associated with a specific vehicle and/or landing gear component, for example.

[0080] If a determination is made that the data is within the pre-defined threshold, the process determines whether the data is needed for status or other applications (operation **708**). If a determination is made that the data is not needed for status or other applications, the process returns to operation **702.** If a determination is made that the data is needed for status or other applications, the process generates a status message or stores information (operation **710**), before returning to operation **702.**

[0081] If a determination is made that the data is not within the pre-defined threshold values, . the process receives an alert identifying a number of component issues (operation **712**). The process displays the alert on a user interface (operation **714**, with the process terminating thereafter. In another advantageous embodiment, the process may return to operation **702** from operation **714**, maintaining a continuous looping process, for example.

[0082] With reference now to **Figure 8**, an illustration of a flowchart of a process for managing a vehicle center of gravity is depicted in accordance with an advantageous embodiment. The process in **Figure 8** may be implemented by a health management system, such as health management system **302** in **Figure 3** using health manager **336** and/or health manager **346,** for example.

[0083] The process begins by detecting initiation of a load operation for a vehicle (operation **802**). A load operation may include cargo loading, baggage loading, passenger loading, resource loading, fueling of the aircraft, and/or any other suitable load operation.

[0084] The process calculates a weight on each landing gear of the vehicle to identify a center of gravity for the vehicle (operation **804**). The process may identify the center of gravity using an algorithm to process the weight from each landing gear, for example. The process actively outputs results indicating the center of gravity location during the load operation (operation **806**). The process displays the results on a user interface (operation **808**), where a user may view the results and determine the desired location for a load being placed on the vehicle, for example. The process optionally generates instructions on where to place a load on the vehicle to achieve the desired center of gravity (operation **810**), with the process terminating thereafter.

[0085] The flowcharts and block diagrams in the different depicted embodiments illustrate the architecture, functionality, and operation of some possible implementations of apparatus, methods and computer program products. In this regard, each block in the flowchart or block diagrams may represent a module, segment, or portion of computer usable or readable program code, which comprises one or more executable instructions for implementing the specified function or functions. In some alternative implementations, the function or functions noted in the block may occur out of the order noted in the figures. For example, in some cases, two blocks shown in succession may be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved.

[0086] The different advantageous embodiments can take the form of an entirely hardware embodiment, an entirely software embodiment, or an embodiment containing both hardware and software elements. Some embodiments are implemented in software, which includes but is not limited to forms, such as, for example, firmware, resident software, and microcode.

[0087] Furthermore, the different embodiments can take the form of a computer program product accessible from a computer usable or computer readable medium providing program code for use by or in connection with a computer or any device or system that executes instructions. For the purposes of this disclosure, a computer-usable or computer readable medium can generally be any tangible apparatus that can contain, store, communicate, propagate, or transport the program for use by or in connection with the instruction execution system, apparatus, or device.

[0088] The computer usable or computer readable medium can be, for example, without limitation an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, or a propagation medium. Non limiting examples of a computer readable medium include a semiconductor or solid state memory, magnetic tape, a removable computer diskette, a random access memory (RAM), a read-only memory (ROM), a rigid magnetic disk, and an optical disk. Optical disks may include compact disk – read only memory (CD-ROM), compact disk – read/write (CD-R/W) and DVD.

[0089] Further, a computer usable or computer-readable medium may contain or store a computer readable or usable program code such that when the computer readable or usable program code is executed on a computer, the execution of this computer readable or usable program code causes the computer to transmit another computer readable or usable program code over a communications link. This communications link may use a medium that is, for example without limitation, physical or wireless.

[0090] A data processing system suitable for storing and/or executing computer readable or computer usable program code will include one or more processors coupled directly or indirectly to memory elements through a communications fabric, such as a system bus. The memory elements may include local memory employed during actual execution of the program code, bulk storage, and cache memories which provide temporary storage of at least some computer readable or computer usable program code to reduce the number of times code may be retrieved from bulk storage during execution of the code.

[0091] Input/output or I/O devices can be coupled to the system either directly or through intervening I/O controllers. These devices may include, for example, without limitation to keyboards, touch screen displays, and pointing devices. Different communications adapters may also be coupled to the system to enable the data processing system to become coupled to other data processing systems or remote printers or storage devices through intervening private or public networks. Non-limiting examples are modems and network adapters are just a few of the currently available types of communications adapters.

[0092] The different advantageous embodiments recognize and take into account that current inspection frequency of landing gear suite components by maintenance personnel requires aircraft operators to employ additional personnel and locate them strategically within their network. Personnel are required to manually and visually inspect appropriate measurands, record the results, and take appropriate actions. Human error is a by-product of the manual inspection and calculation of these processes.

[0093] Current inspection processes result in maintenance actions that are reactive in nature, resulting in gate delays and cancelled flights. These inspections occur at discrete intervals, which encompass multiple flights, thus providing the potential for issues to arise unnoticed between individual flights. The information collected during these current processes is not available to maintenance and operation planners in a sufficiently timely manner to make the most efficient use of the aircraft.

[0094] Thus, the different advantageous embodiments provide a system and methods for evaluating and managing the current and future health of the landing gear suite of components. The aircraft's center of gravity is also actively managed during loading operations. Appropriate measurands are sensed, sensor data is collected and processed, transmitted when necessary, and reasoning is performed on the data to generate and present actionable maintenance and operationally pertinent information to appropriate users.

[0095] The description of the different advantageous embodiments has been presented for purposes of illustration and description, and is not intended to be exhaustive or limited to the embodiments in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. Further, different advantageous embodiments may provide different advantages as compared to other advantageous embodiments. The embodiment or embodiments selected are chosen and described in order to best explain the principles of the embodiments, the practical application, and to enable others of ordinary skill in the art to understand the disclosure for various embodiments with various modifications as are suited to the particular use contemplated.

CLAIMS:

What is claimed is:

1. An apparatus comprising:

a number of landing gear components for a vehicle;

a number of systems configured to generate data about the number of landing gear components and the vehicle; and

a number of processor units configured to monitor the data and manage health of the number of landing gear components.

2. The apparatus of claim 1, wherein the number of systems includes a sensor system configured to generate sensor data used by the number of processor units to identify a weight and a center of gravity for the vehicle.

3. The apparatus of claim 2, wherein the center of gravity is identified in response to an event.

4. The apparatus of claim 2, wherein the center of gravity is identified continuously during a load operation.

5. The apparatus of claim 1 further comprising:

a user interface, wherein the number of processor units provides information to the user interface to display the information about the number of landing gear components.

6. The apparatus of claim 1, wherein the number of processor units is further configured to identify a number of status messages or a number of issues associated with the number of landing gear components.

7. A method for managing health of a number of landing gear components of a vehicle, the method comprising:

receiving data from a number of systems associated with the number of landing gear components and the vehicle;

determining whether the data received is within pre-defined threshold values; and

responsive to a determination that the data is not within the pre-defined threshold values, identifying a number of component issues associated with the data.

8. The method of claim 7, wherein the number of systems includes a vehicle control system, and wherein the data includes a vehicle speed, attitude, rates, accelerations and control inputs.

9. The method of claim 7, wherein the number of systems includes a sensor system, and wherein the data is sensor data from a number of sensors configured to detect health and status information about the number of landing gear components.

10. The method of claim 7 further comprising:

generating an alert with the number of component issues identified; and

displaying the alert on a user interface.

11. The method of claim 10, wherein the alert is a status message associated with the number of landing gear components.

12. The method of claim 10 further comprising:

storing information about the alert and the data in a number of storage devices.

13. A method for managing a center of gravity for a vehicle during load operations, the method comprising:

detecting initiation of a load operation for the vehicle;

calculating a weight on each landing gear of the vehicle to identify the center of gravity;

actively outputting results having the center of gravity location during the load operation; and

displaying the results on a user interface.

14. The method of claim 13, wherein calculating the weight on the each landing gear of the vehicle to identify the center of gravity includes using an algorithm to operate on the weight calculated for the each landing gear.

15. The method of claim 13 further comprising:

generating instructions on where to put a load being placed on the vehicle using the center of gravity identified; and

displaying the instructions on the user interface.

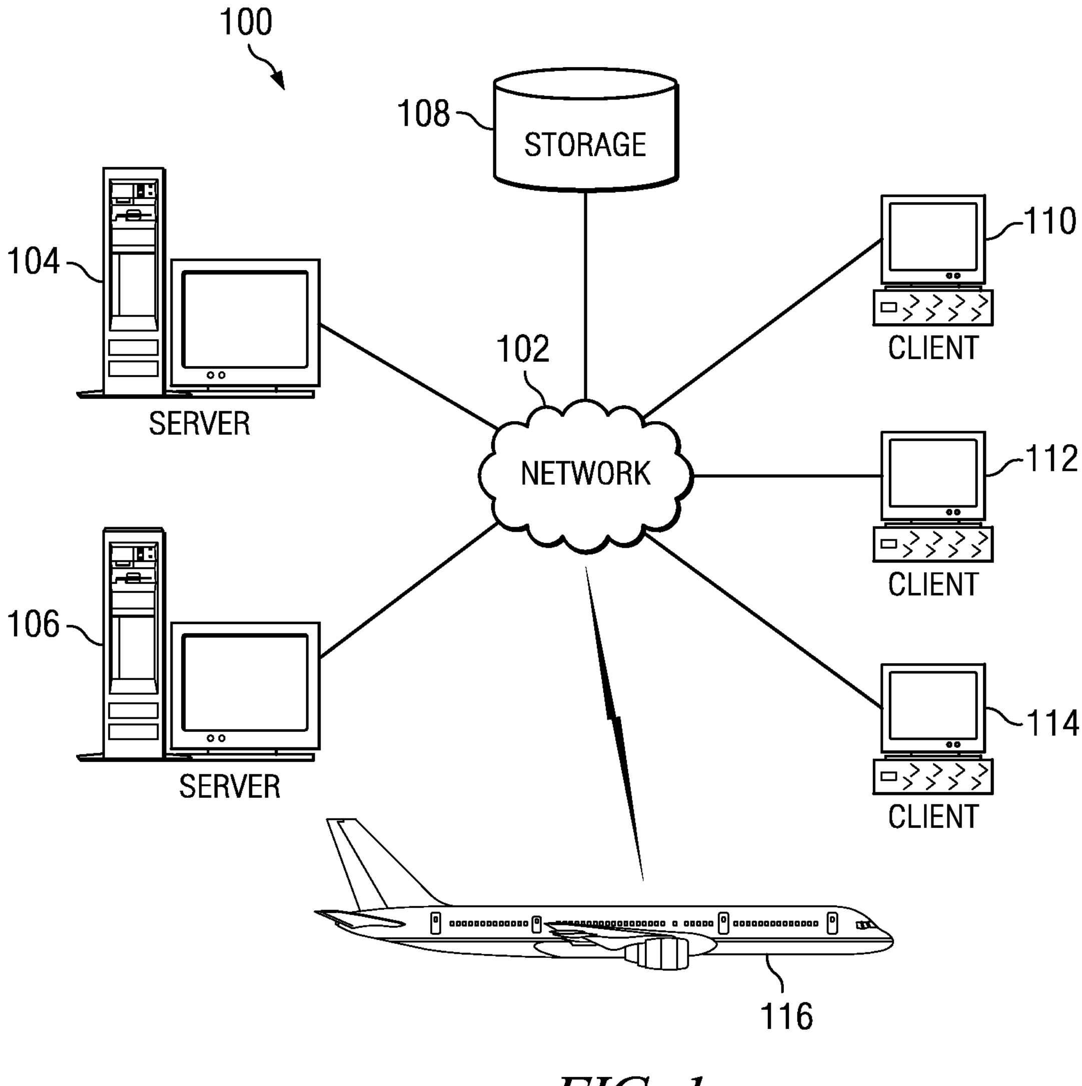

100
108
STORAGE
104
SERVER
110
CLIENT
102
NETWORK
112
CLIENT
106
SERVER
114
CLIENT
116

FIG. 1

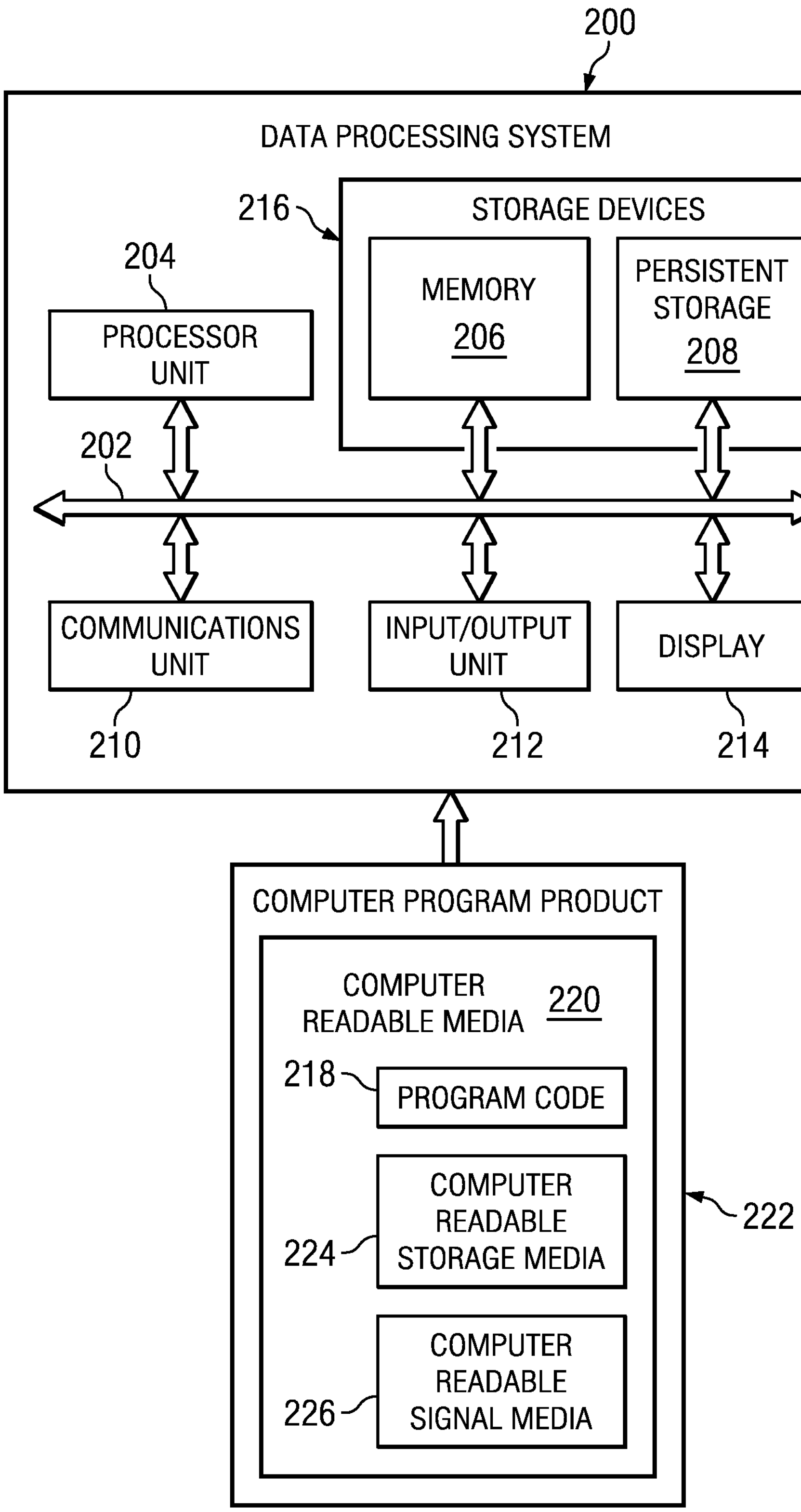
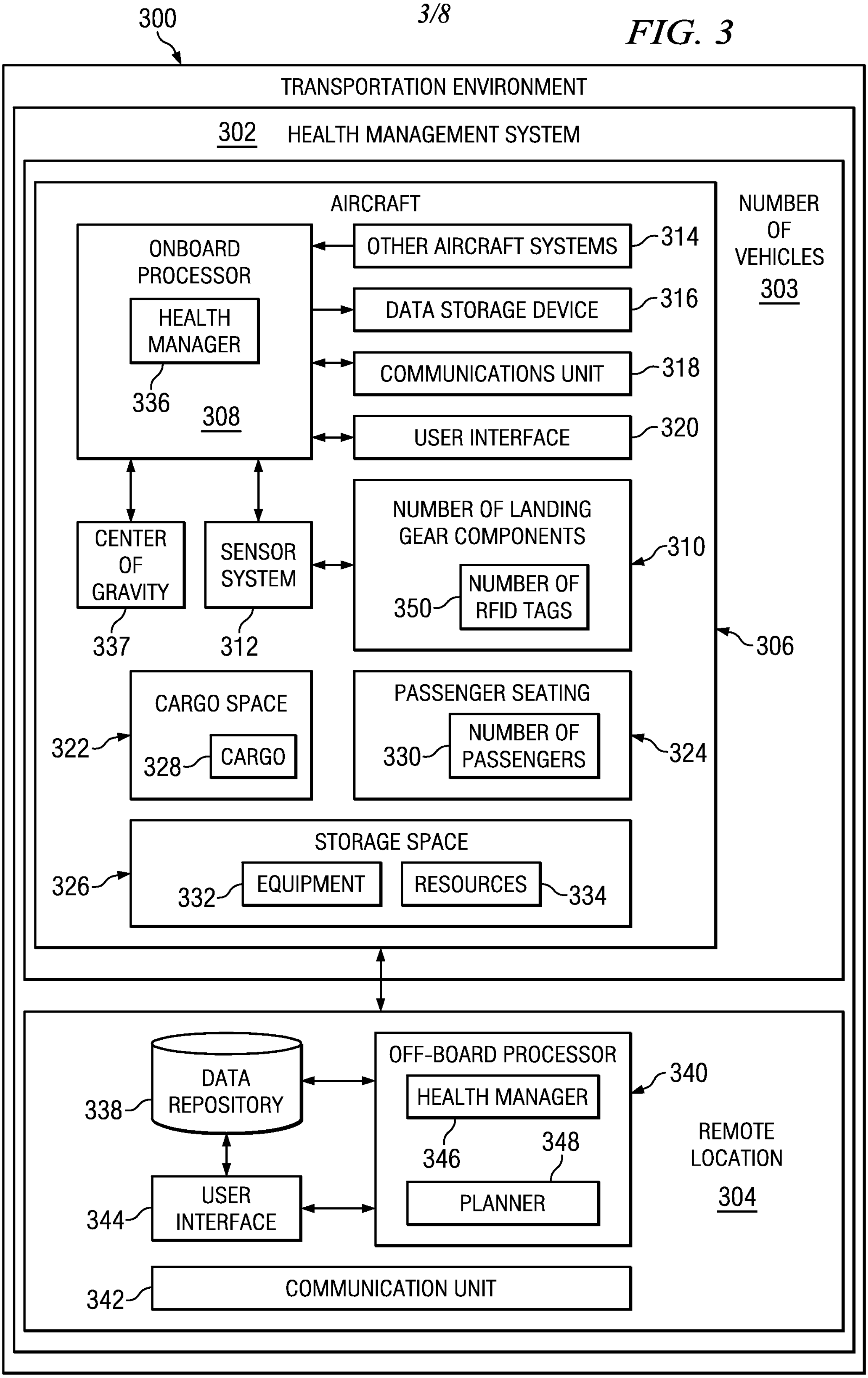

200
DATA PROCESSING SYSTEM
216
STORAGE DEVICES
204
PROCESSOR UNIT
MEMORY 206
PERSISTENT STORAGE 208
202
COMMUNICATIONS UNIT
INPUT/OUTPUT UNIT
DISPLAY
210
212
214
COMPUTER PROGRAM PRODUCT
COMPUTER READABLE MEDIA 220
218
PROGRAM CODE
COMPUTER READABLE STORAGE MEDIA
224
222
COMPUTER READABLE SIGNAL MEDIA
226

FIG. 2

FIG. 3


300
TRANSPORTATION ENVIRONMENT
302 HEALTH MANAGEMENT SYSTEM
AIRCRAFT
ONBOARD PROCESSOR
HEALTH MANAGER
336
308
OTHER AIRCRAFT SYSTEMS
314
DATA STORAGE DEVICE
316
COMMUNICATIONS UNIT
318
USER INTERFACE
320
NUMBER OF VEHICLES 303
CENTER OF GRAVITY
337
SENSOR SYSTEM
312
NUMBER OF LANDING GEAR COMPONENTS
310
350
NUMBER OF RFID TAGS
306
CARGO SPACE
322
328
CARGO
PASSENGER SEATING
330
NUMBER OF PASSENGERS
324
STORAGE SPACE
326
332
EQUIPMENT
RESOURCES
334
DATA REPOSITORY
338
OFF-BOARD PROCESSOR
340
HEALTH MANAGER
346
348
PLANNER
REMOTE LOCATION 304
USER INTERFACE
344
COMMUNICATION UNIT
342

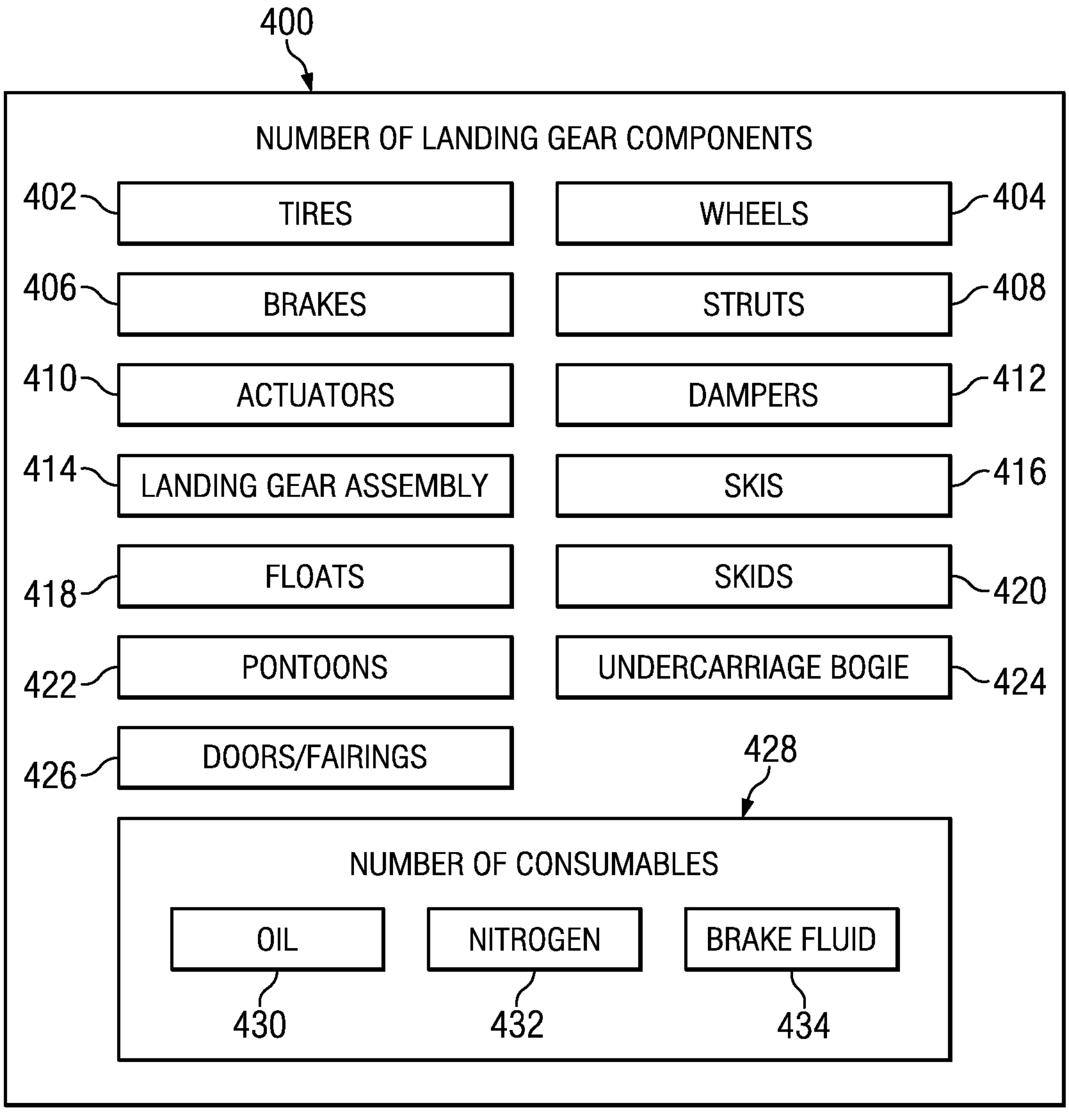

400
NUMBER OF LANDING GEAR COMPONENTS
402
TIRES
404
WHEELS
406
BRAKES
408
STRUTS
410
ACTUATORS
412
DAMPERS
414
LANDING GEAR ASSEMBLY
416
SKIS
418
FLOATS
420
SKIDS
422
PONTOONS
424
UNDERCARRIAGE BOGIE
426
DOORS/FAIRINGS
428
NUMBER OF CONSUMABLES
OIL
NITROGEN
BRAKE FLUID
430
432
434

FIG. 4

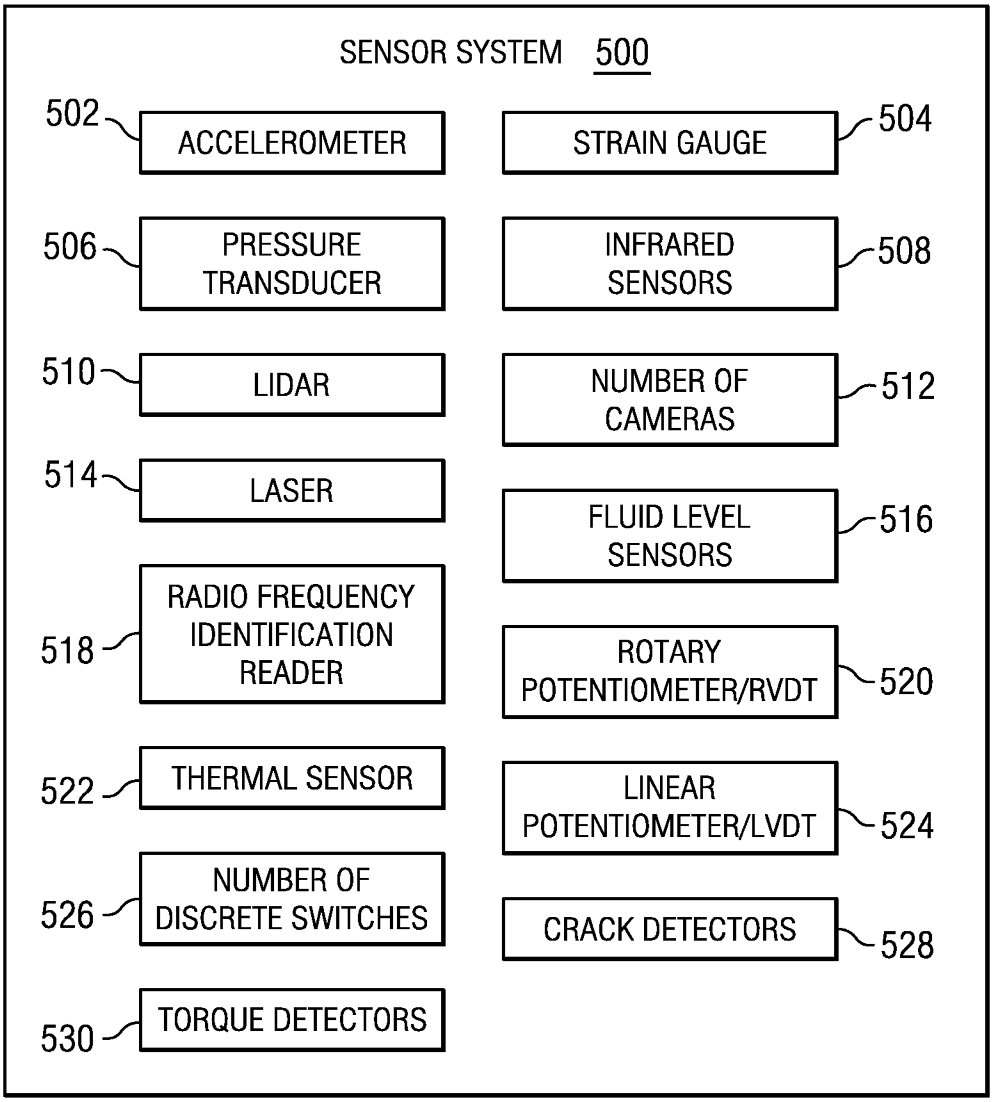

SENSOR SYSTEM 500
502
ACCELEROMETER
STRAIN GAUGE
504
506
PRESSURE TRANSDUCER
INFRARED SENSORS
508
510
LIDAR
NUMBER OF CAMERAS
512
514
LASER
FLUID LEVEL SENSORS
516
518
RADIO FREQUENCY IDENTIFICATION READER
ROTARY POTENTIOMETER/RVDT
520
522
THERMAL SENSOR
LINEAR POTENTIOMETER/LVDT
524
526
NUMBER OF DISCRETE SWITCHES
CRACK DETECTORS
528
530
TORQUE DETECTORS

FIG. 5

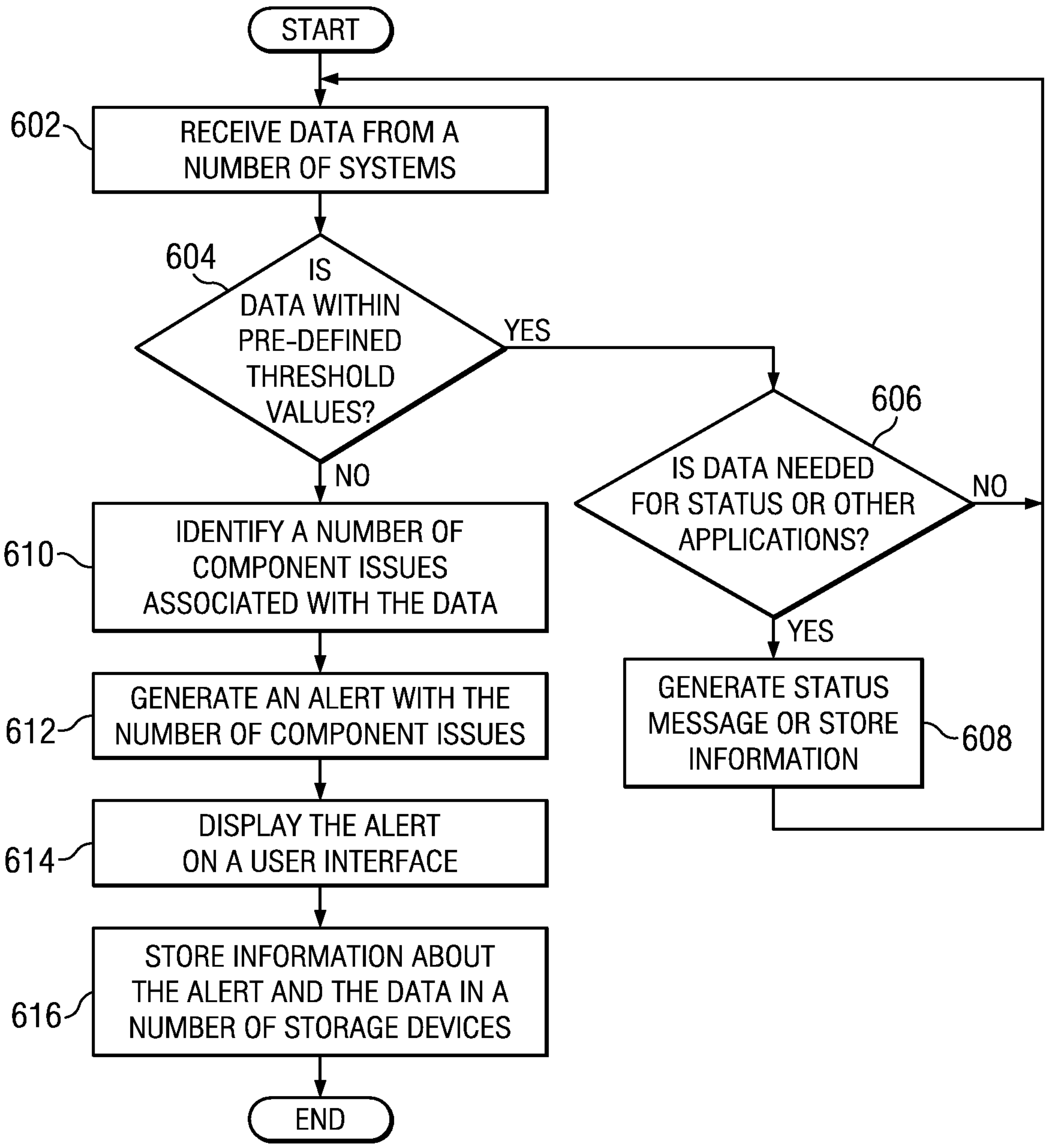

START
602
RECEIVE DATA FROM A NUMBER OF SYSTEMS
604
IS DATA WITHIN PRE-DEFINED THRESHOLD VALUES?
YES
NO
606
IS DATA NEEDED FOR STATUS OR OTHER APPLICATIONS?
NO
YES
608
GENERATE STATUS MESSAGE OR STORE INFORMATION
610
IDENTIFY A NUMBER OF COMPONENT ISSUES ASSOCIATED WITH THE DATA
612
GENERATE AN ALERT WITH THE NUMBER OF COMPONENT ISSUES
614
DISPLAY THE ALERT ON A USER INTERFACE
616
STORE INFORMATION ABOUT THE ALERT AND THE DATA IN A NUMBER OF STORAGE DEVICES
END

FIG. 6

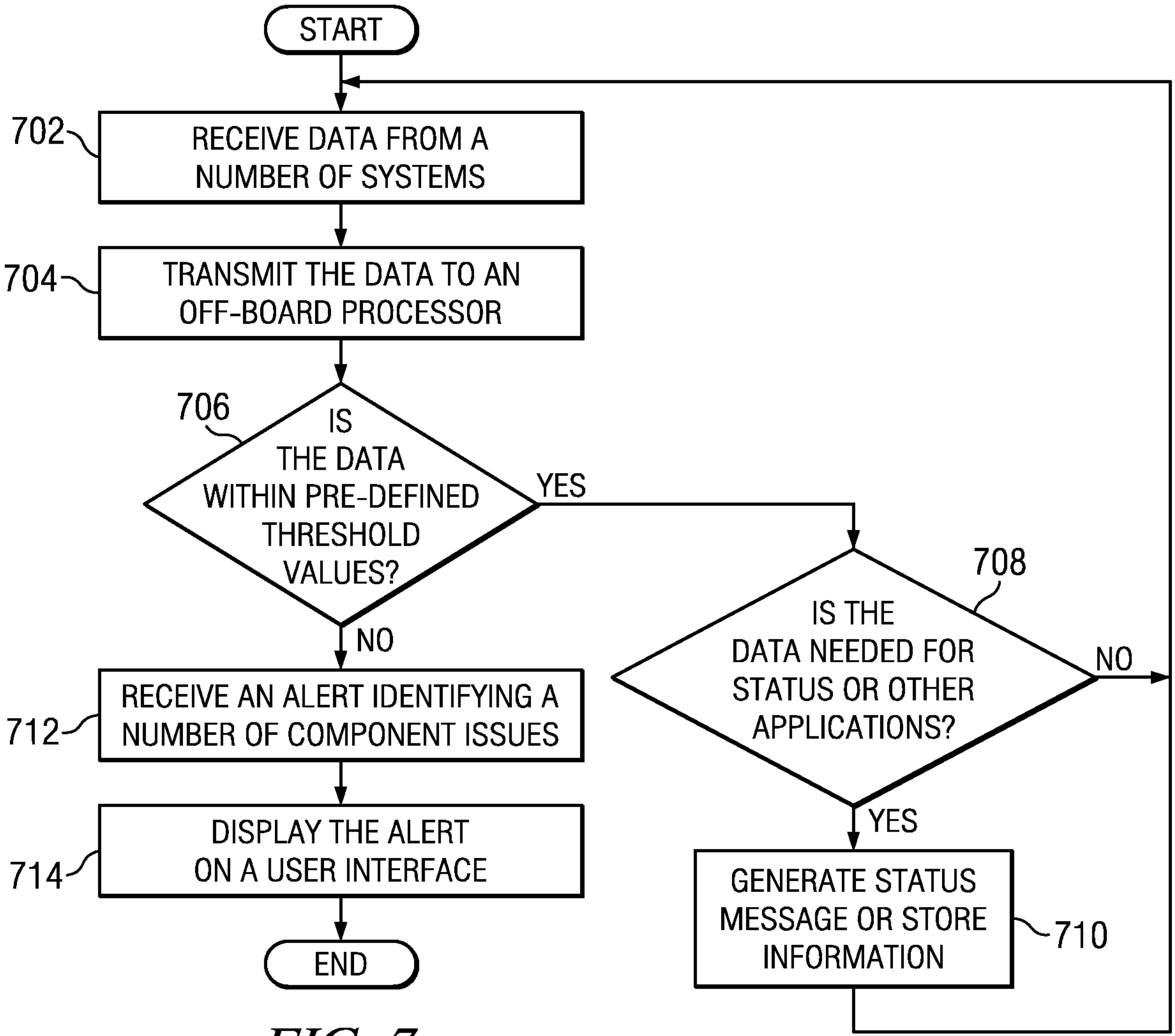

START
702
RECEIVE DATA FROM A NUMBER OF SYSTEMS
704
TRANSMIT THE DATA TO AN OFF-BOARD PROCESSOR
706
IS THE DATA WITHIN PRE-DEFINED THRESHOLD VALUES?
YES
NO
708
IS THE DATA NEEDED FOR STATUS OR OTHER APPLICATIONS?
NO
YES
712
RECEIVE AN ALERT IDENTIFYING A NUMBER OF COMPONENT ISSUES
714
DISPLAY THE ALERT ON A USER INTERFACE
END
GENERATE STATUS MESSAGE OR STORE INFORMATION
710

FIG. 7

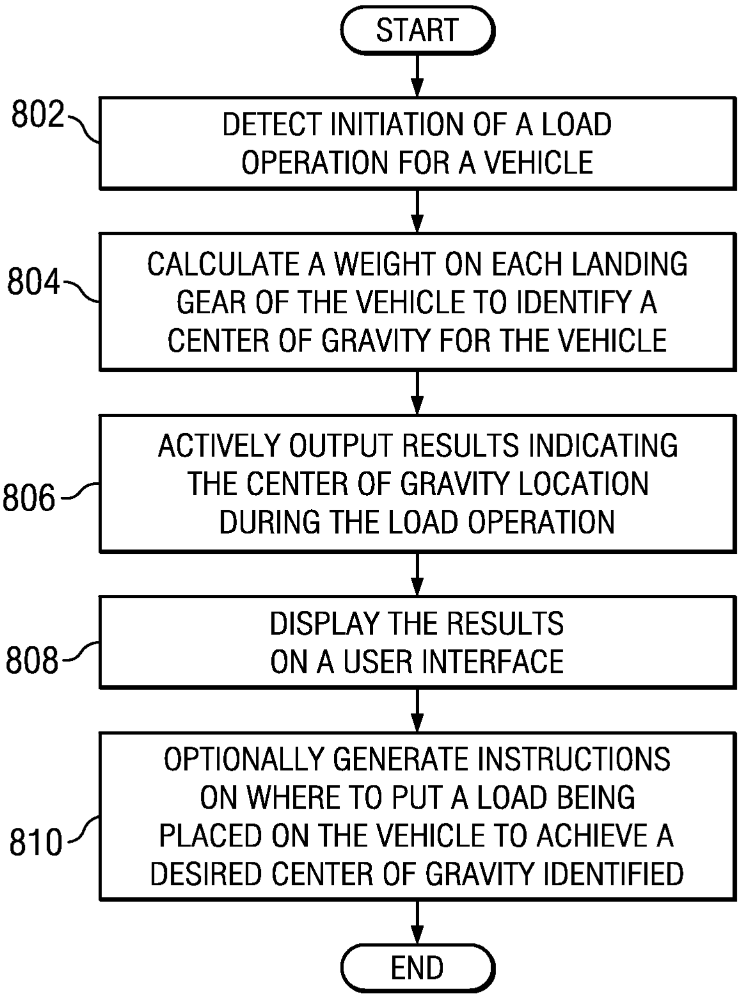

START
802
DETECT INITIATION OF A LOAD OPERATION FOR A VEHICLE
804
CALCULATE A WEIGHT ON EACH LANDING GEAR OF THE VEHICLE TO IDENTIFY A CENTER OF GRAVITY FOR THE VEHICLE
806
ACTIVELY OUTPUT RESULTS INDICATING THE CENTER OF GRAVITY LOCATION DURING THE LOAD OPERATION
808
DISPLAY THE RESULTS ON A USER INTERFACE
810
OPTIONALLY GENERATE INSTRUCTIONS ON WHERE TO PUT A LOAD BEING PLACED ON THE VEHICLE TO ACHIEVE A DESIRED CENTER OF GRAVITY IDENTIFIED
END

FIG. 8