



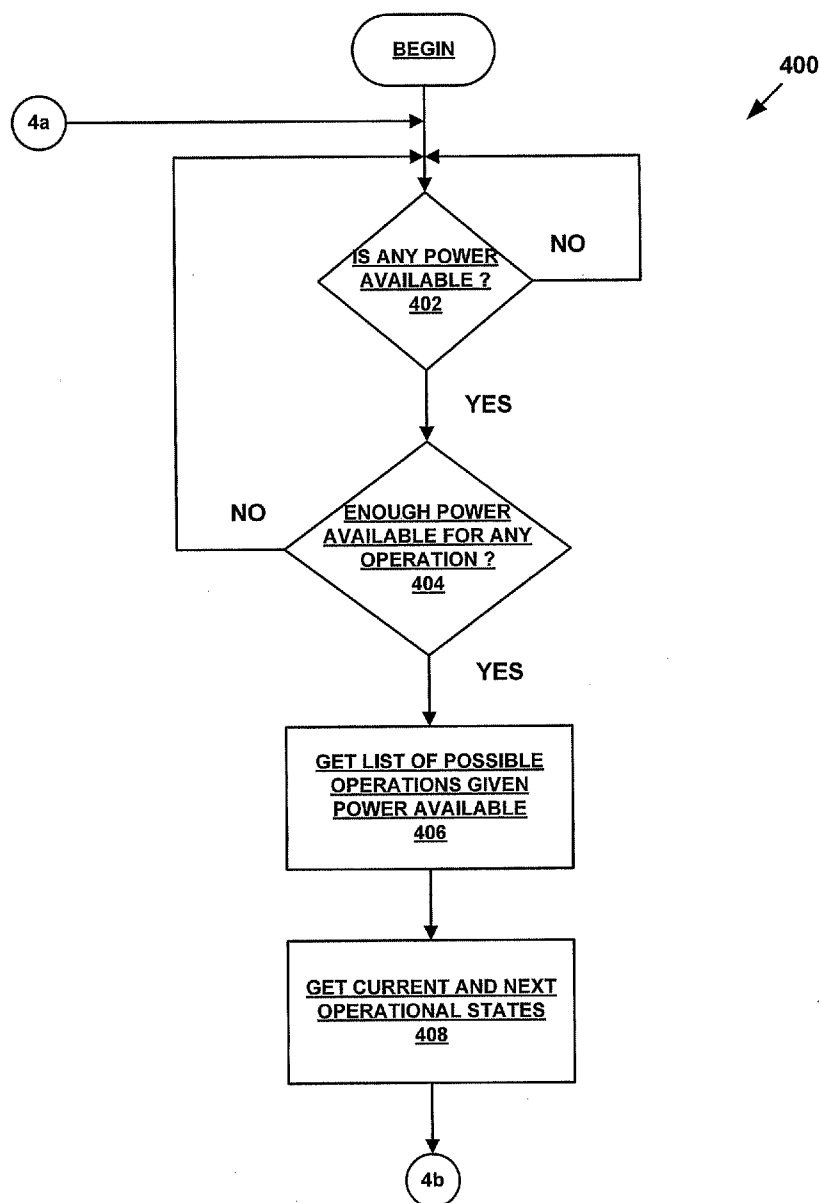
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(19) **United States**(12) **Patent Application Publication**  
**Andarawis et al.**(10) **Pub. No.: US 2010/0141377 A1**(43) **Pub. Date: Jun. 10, 2010**(54) **POWER AWARE TECHNIQUES FOR ENERGY  
HARVESTING REMOTE SENSOR SYSTEM**(73) Assignee: **Lockheed Martin Corporation,**  
Bethesda, MD (US)(75) Inventors: **Emad Andarawis**, Ballston Lake,  
NY (US); **Ertugrul Berkcan**,  
Clifton Park, NY (US); **C. Scott**  
**Sealing**, Clifton Park, NY (US);  
**Robert Wojnarowski**, Ballston,  
NY (US); **Eladio Delgado**, Burnt  
Hills, NY (US); **Richard H.**  
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**G05B 23/02** (2006.01)(52) **U.S. Cl.** ..... **340/3.1**

Correspondence Address:

**Bracewell & Giuliani LLP****P.O. Box 61389****Houston, TX 77208-1389 (US)**(57) **ABSTRACT**

A distributed monitoring system for a structure.



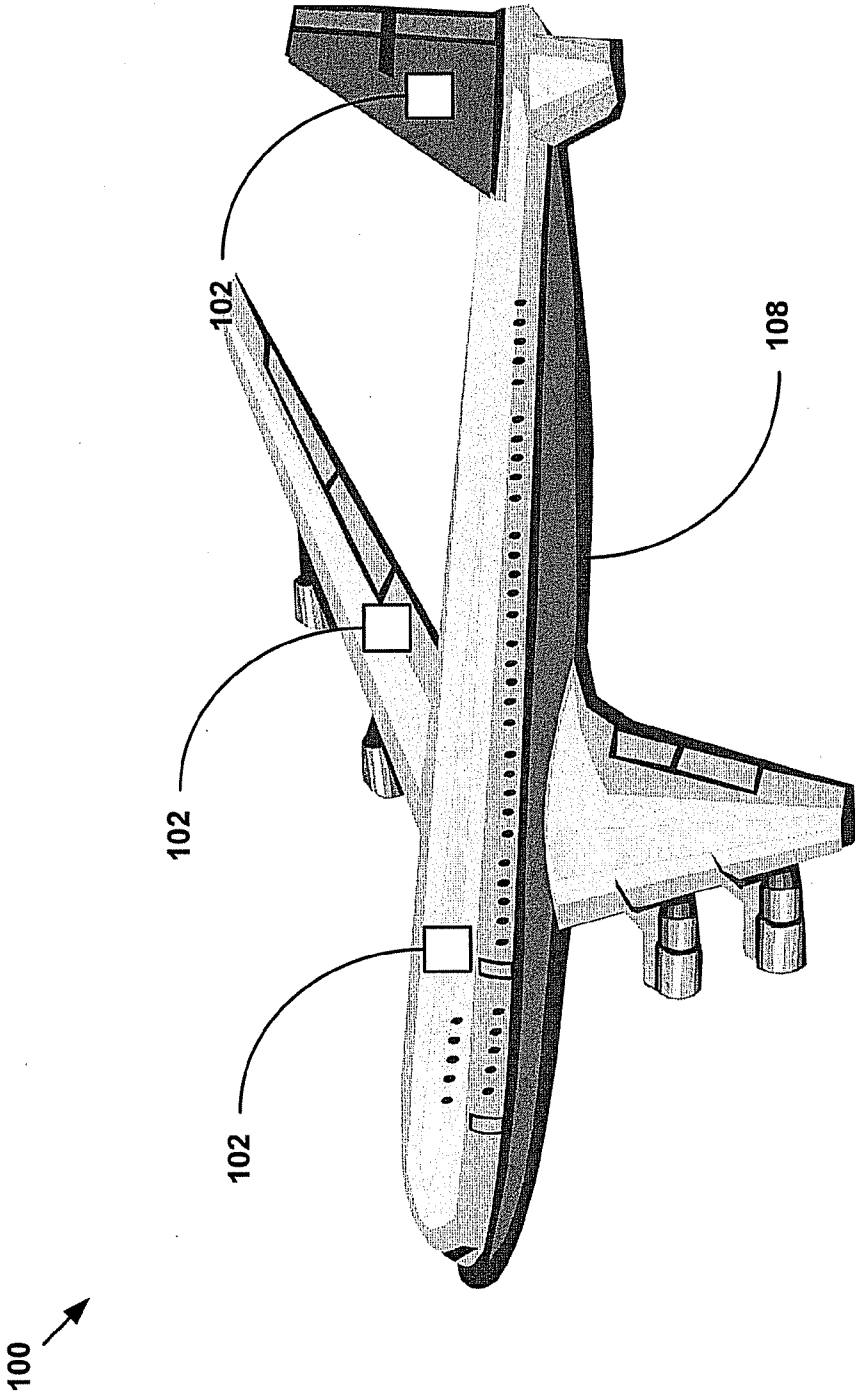



Fig. 1

100 

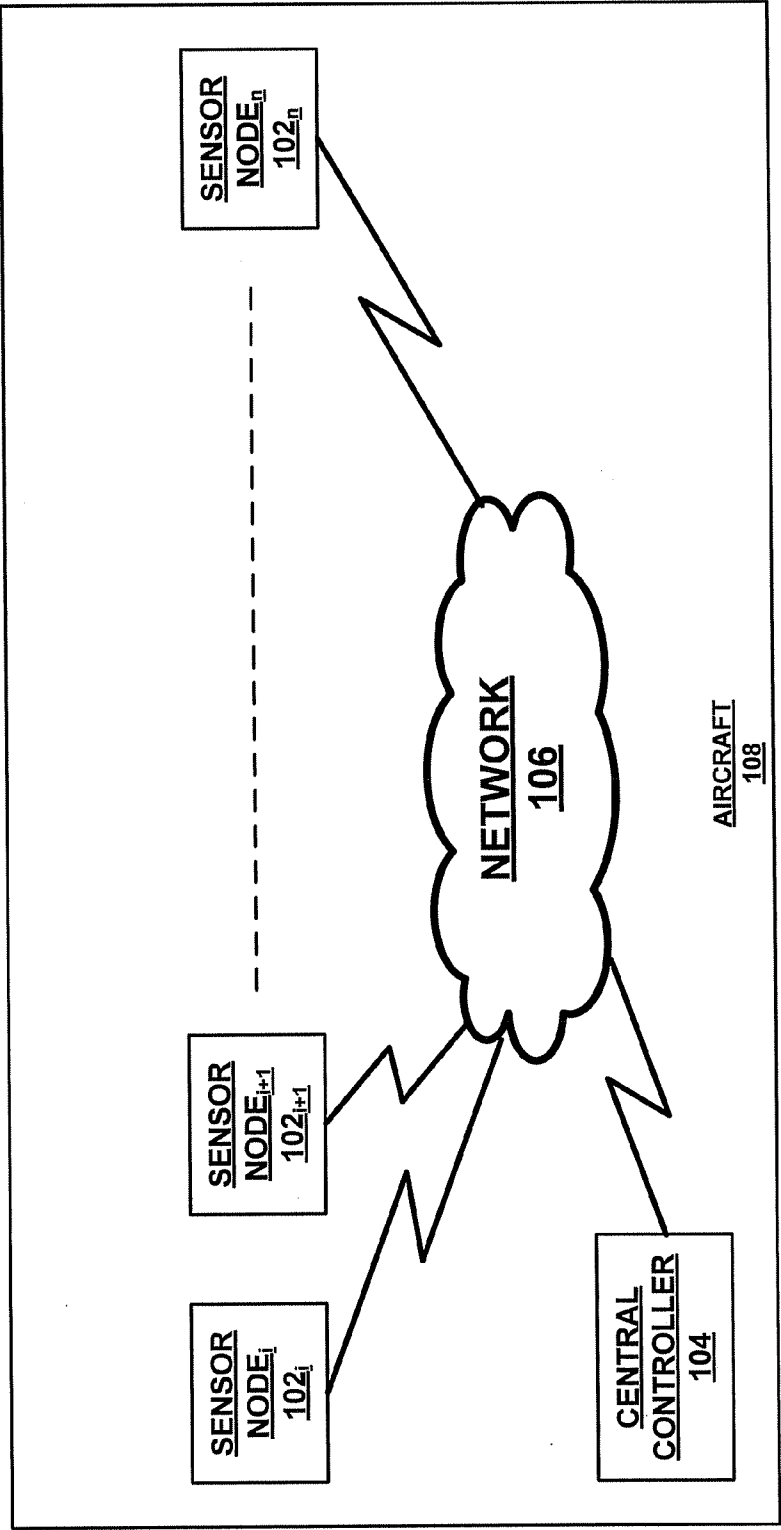


Fig. 2

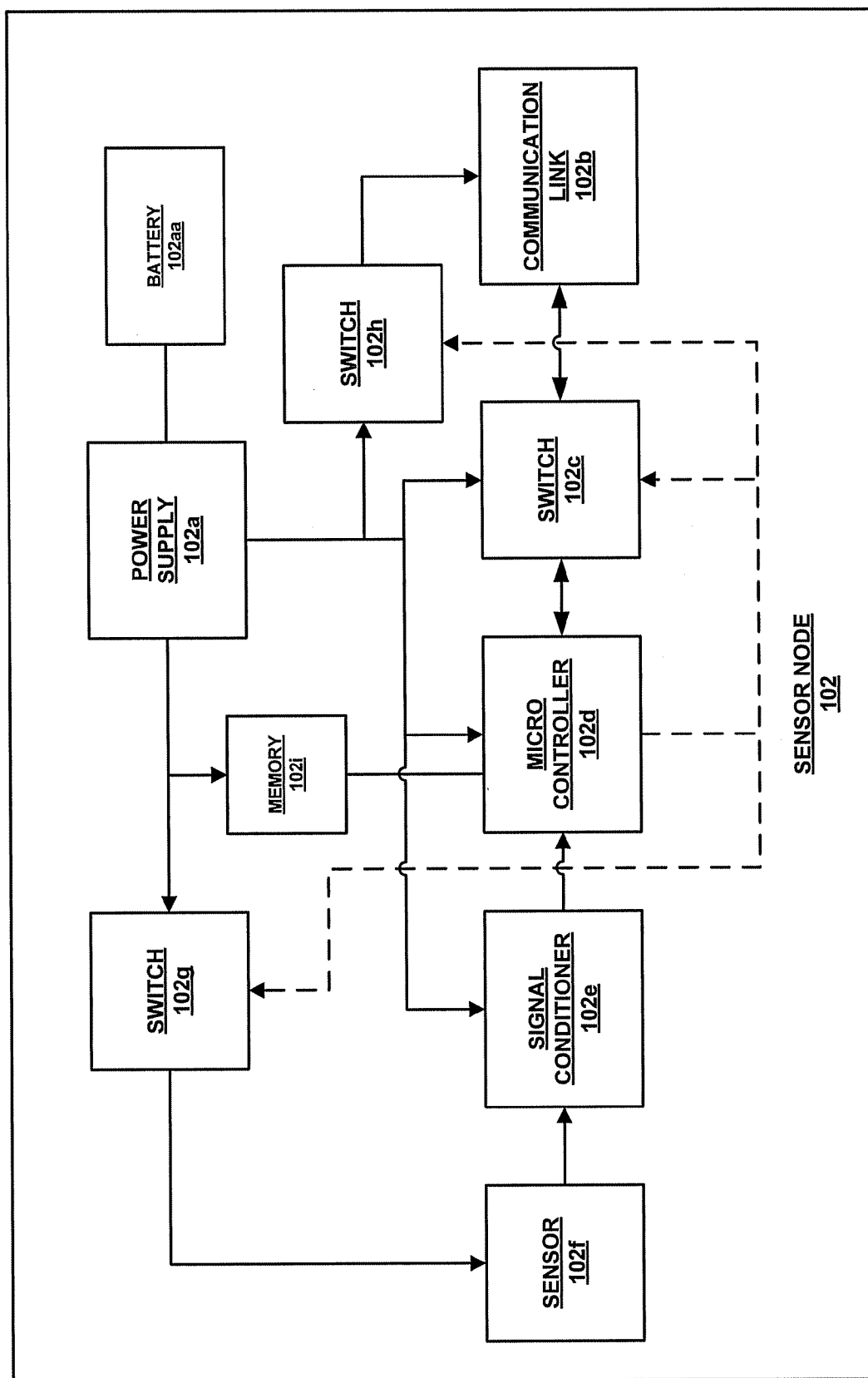


Fig. 3

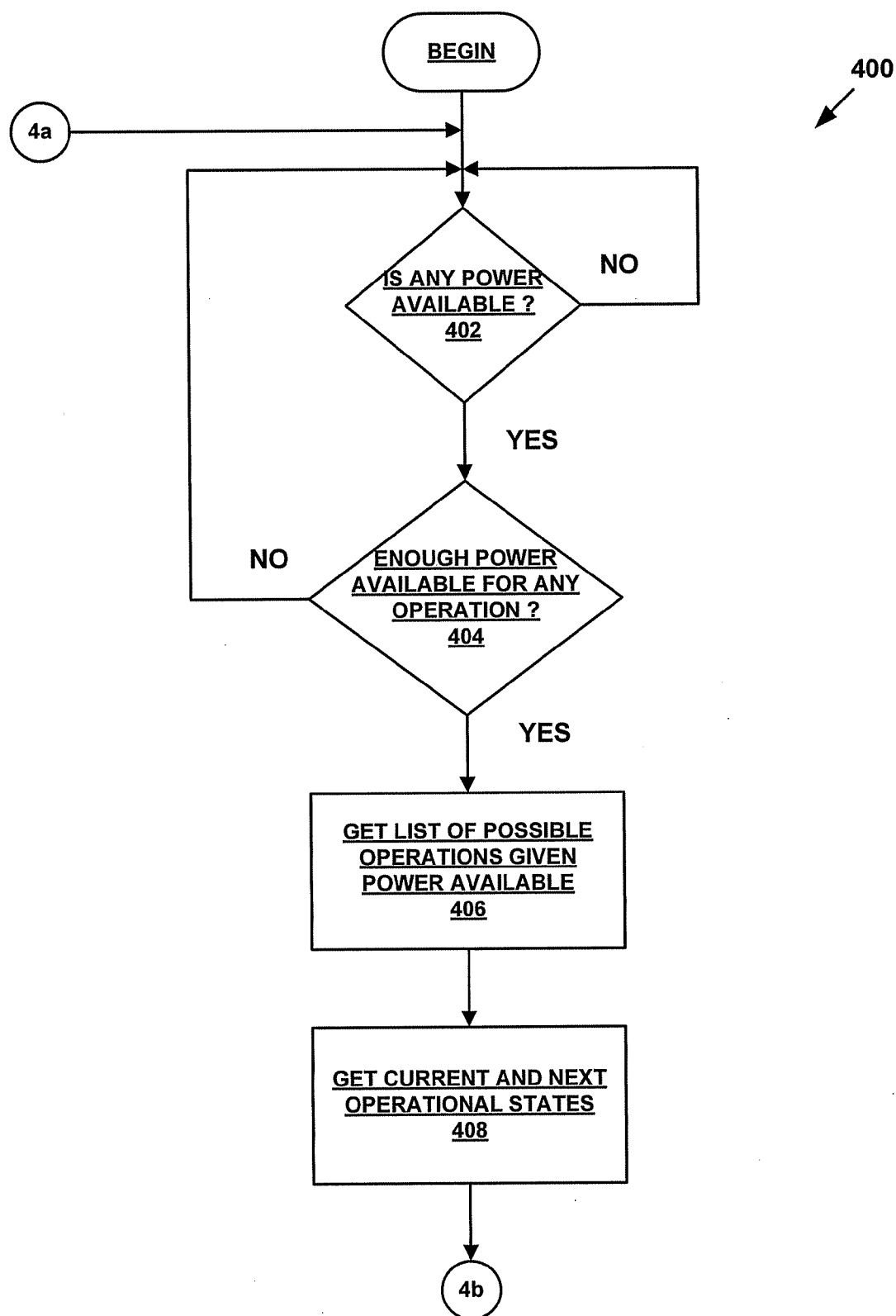


Fig. 4a

400

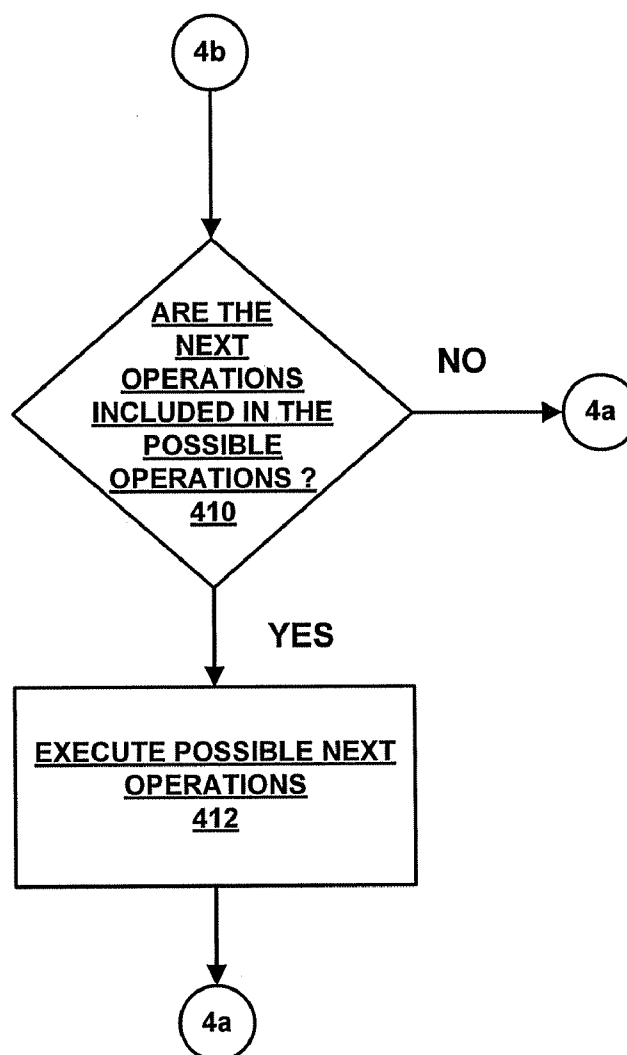


Fig. 4b

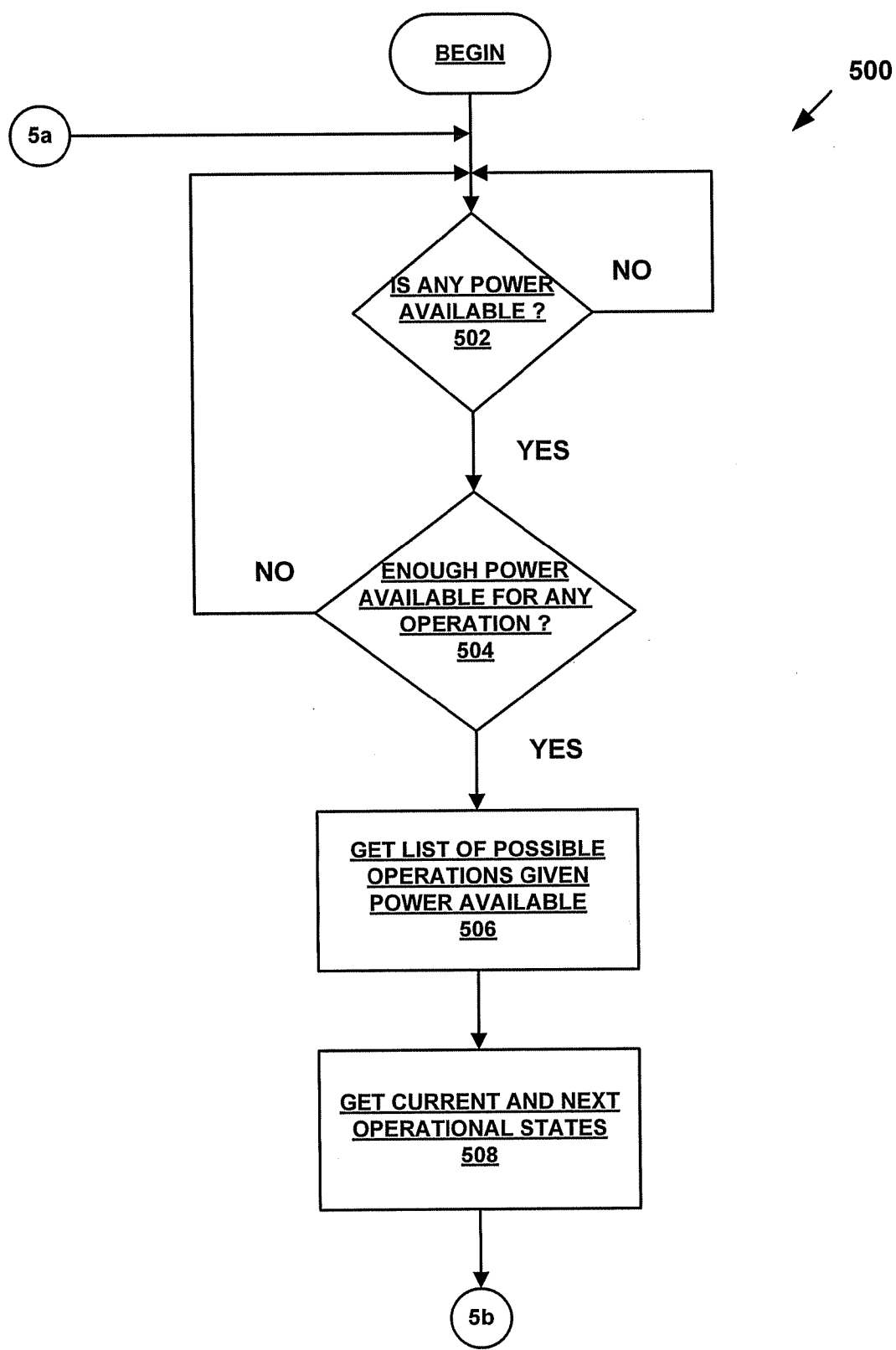


Fig. 5a

500

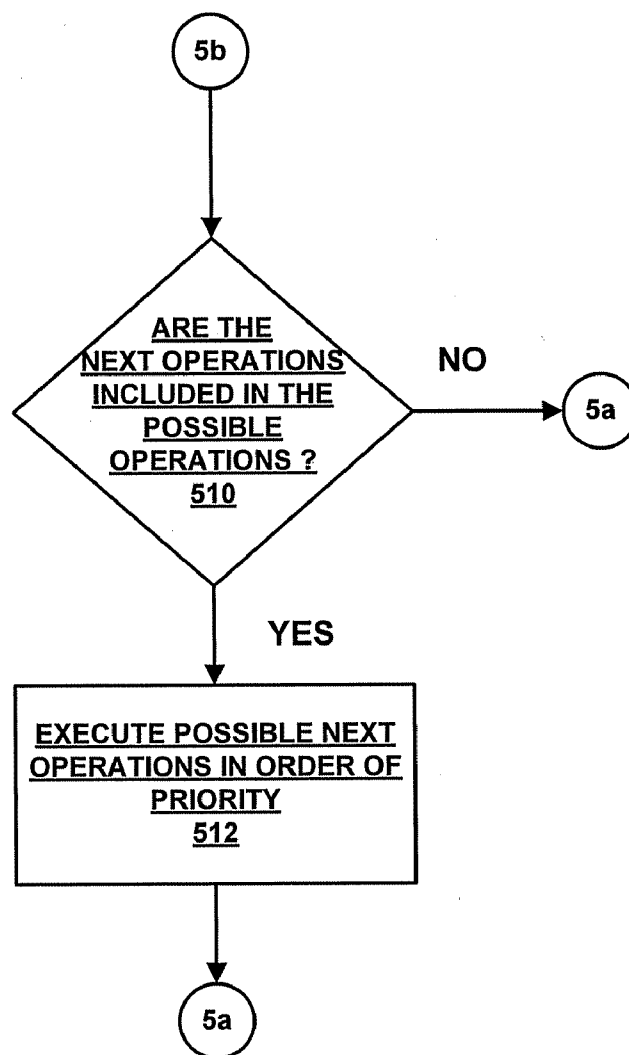


Fig. 5b



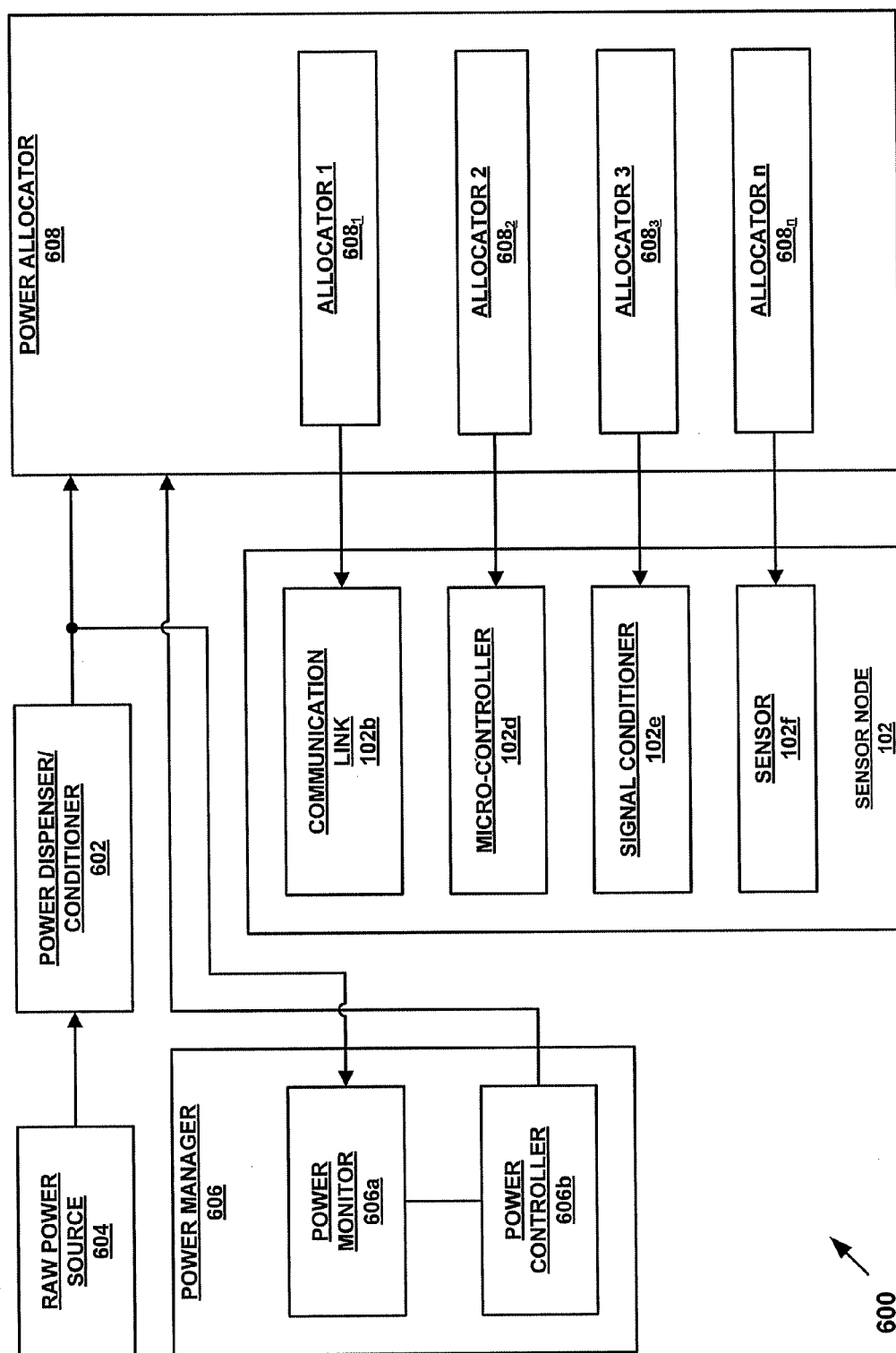


Fig. 6

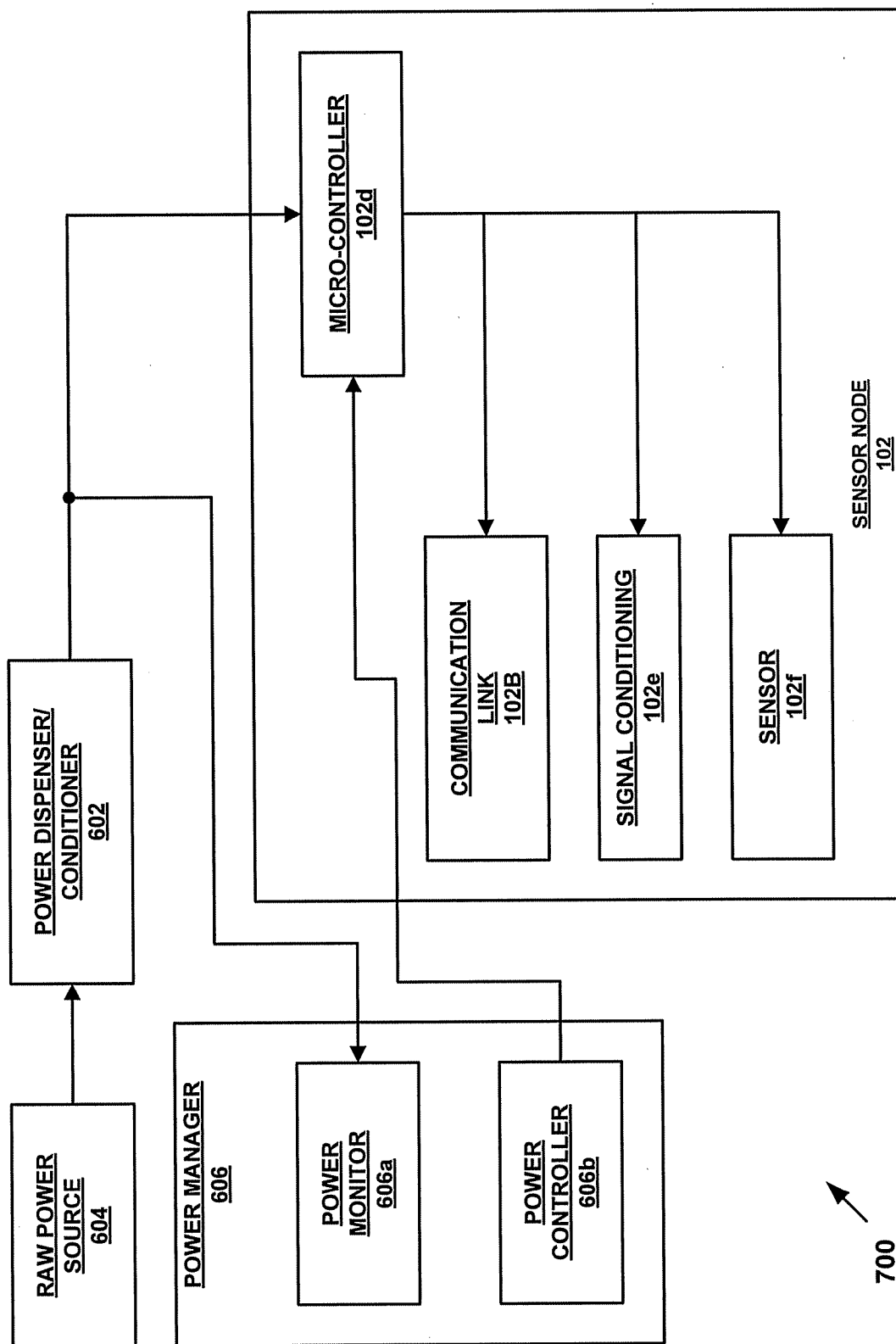


Fig. 7

800

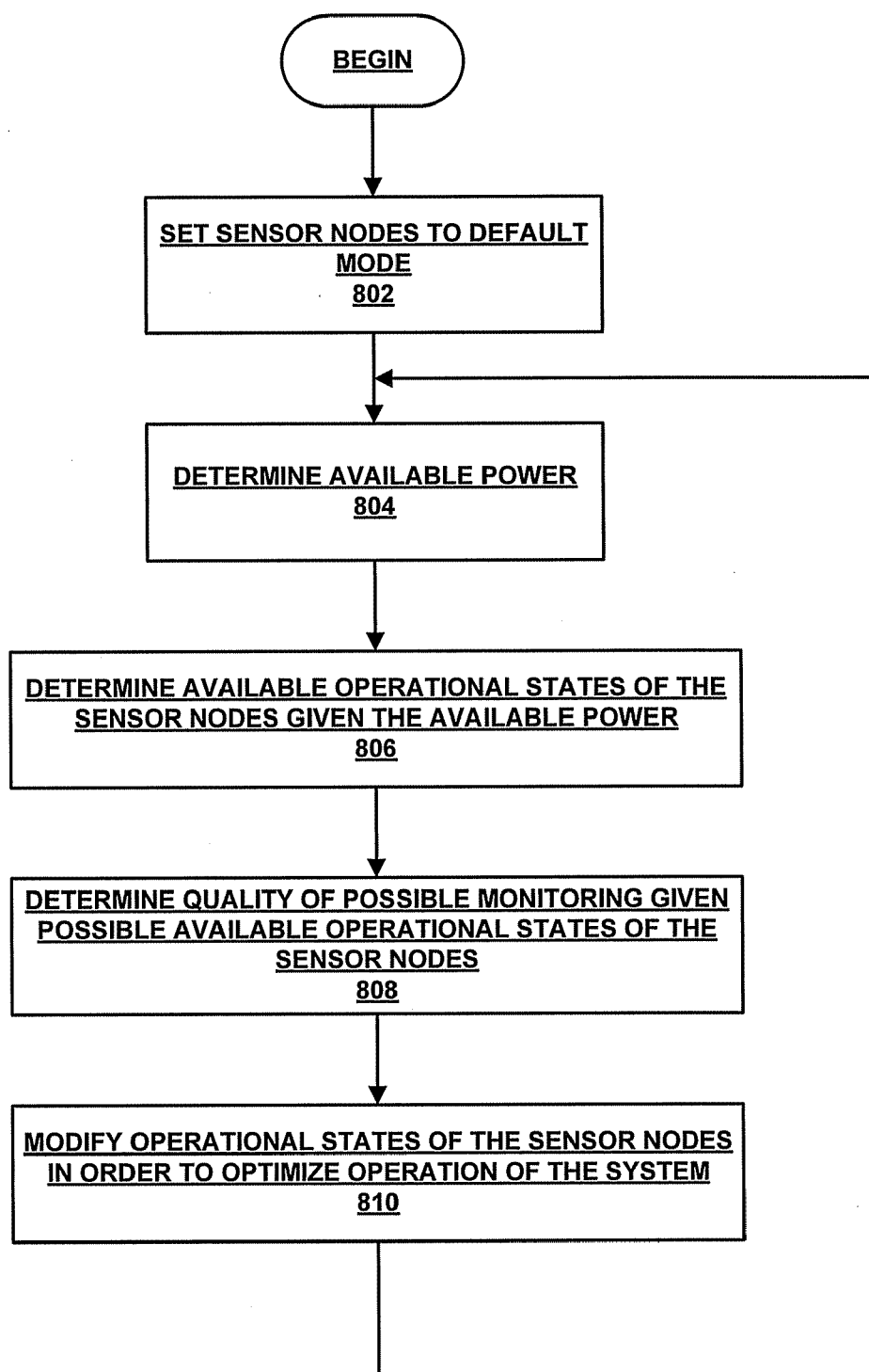


Fig. 8

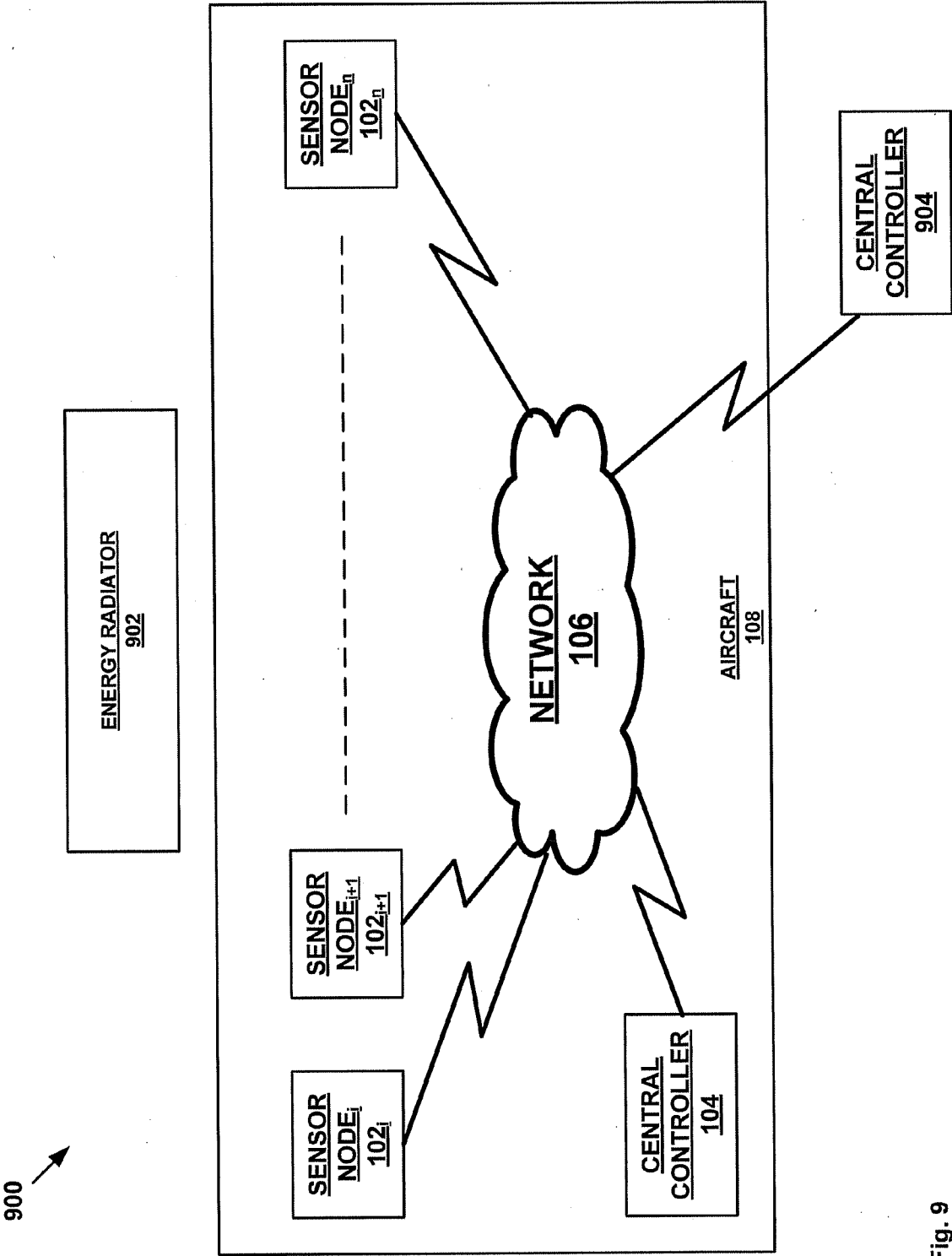


Fig. 9

1000

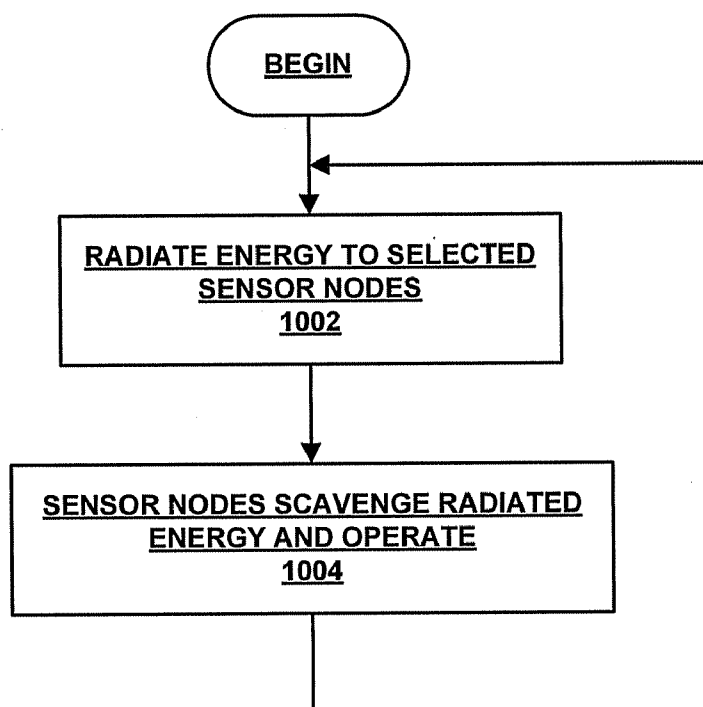


Fig. 10

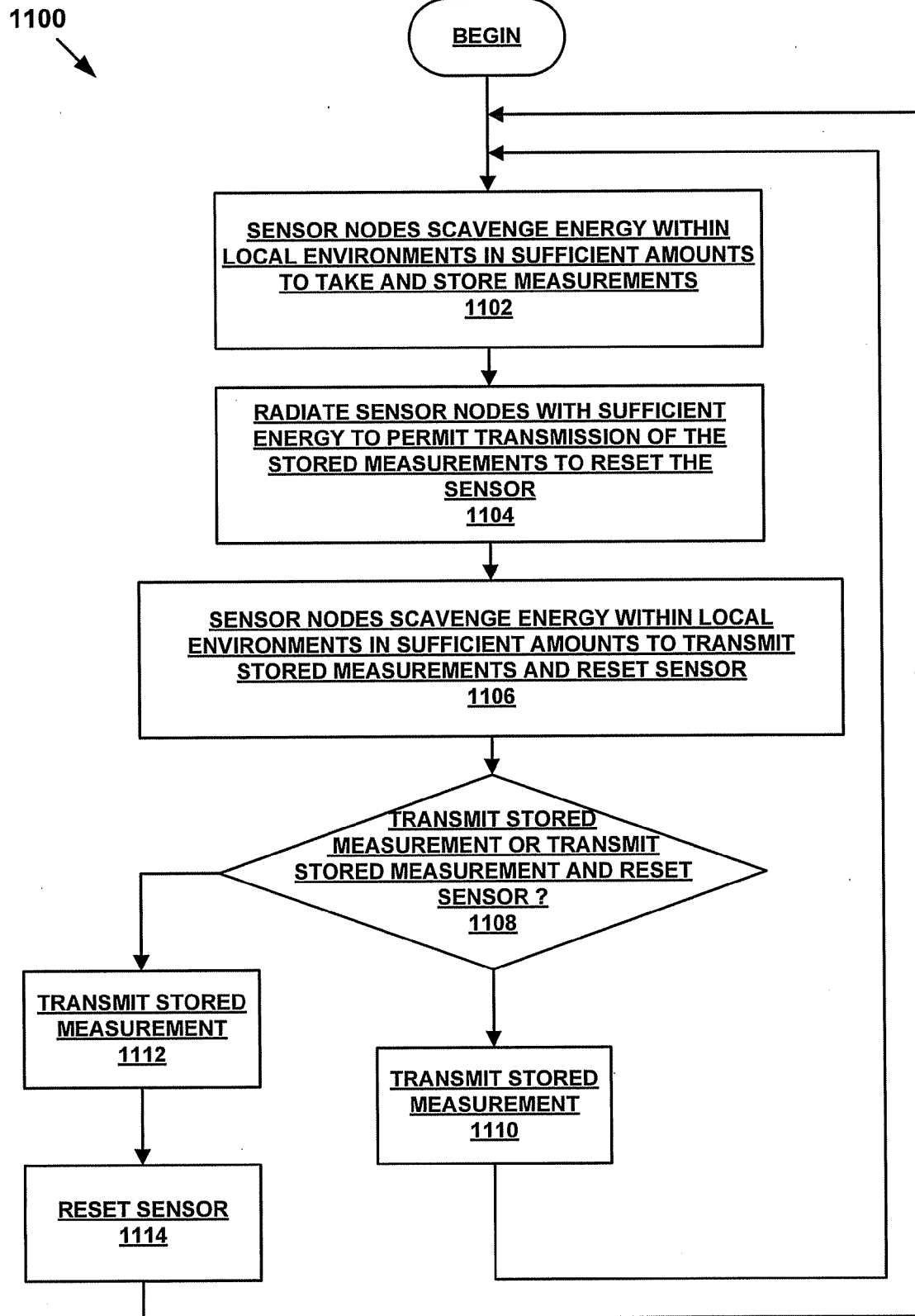


Fig. 11

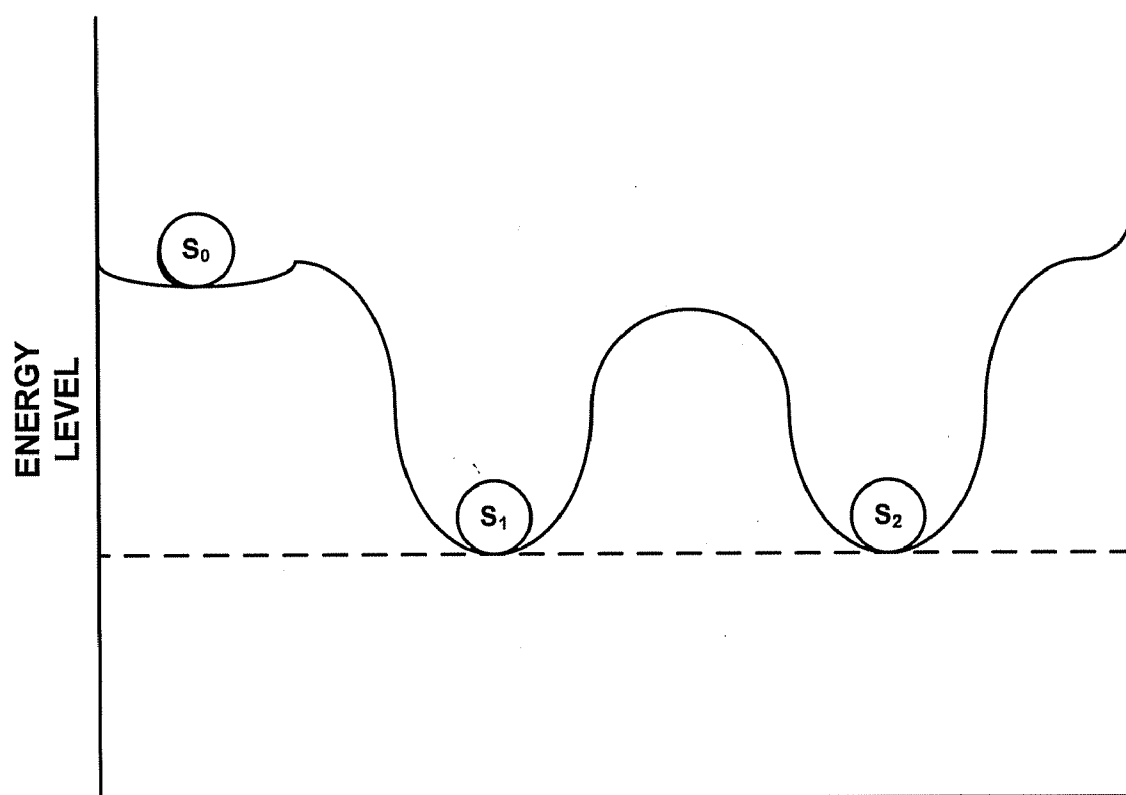


Fig. 12

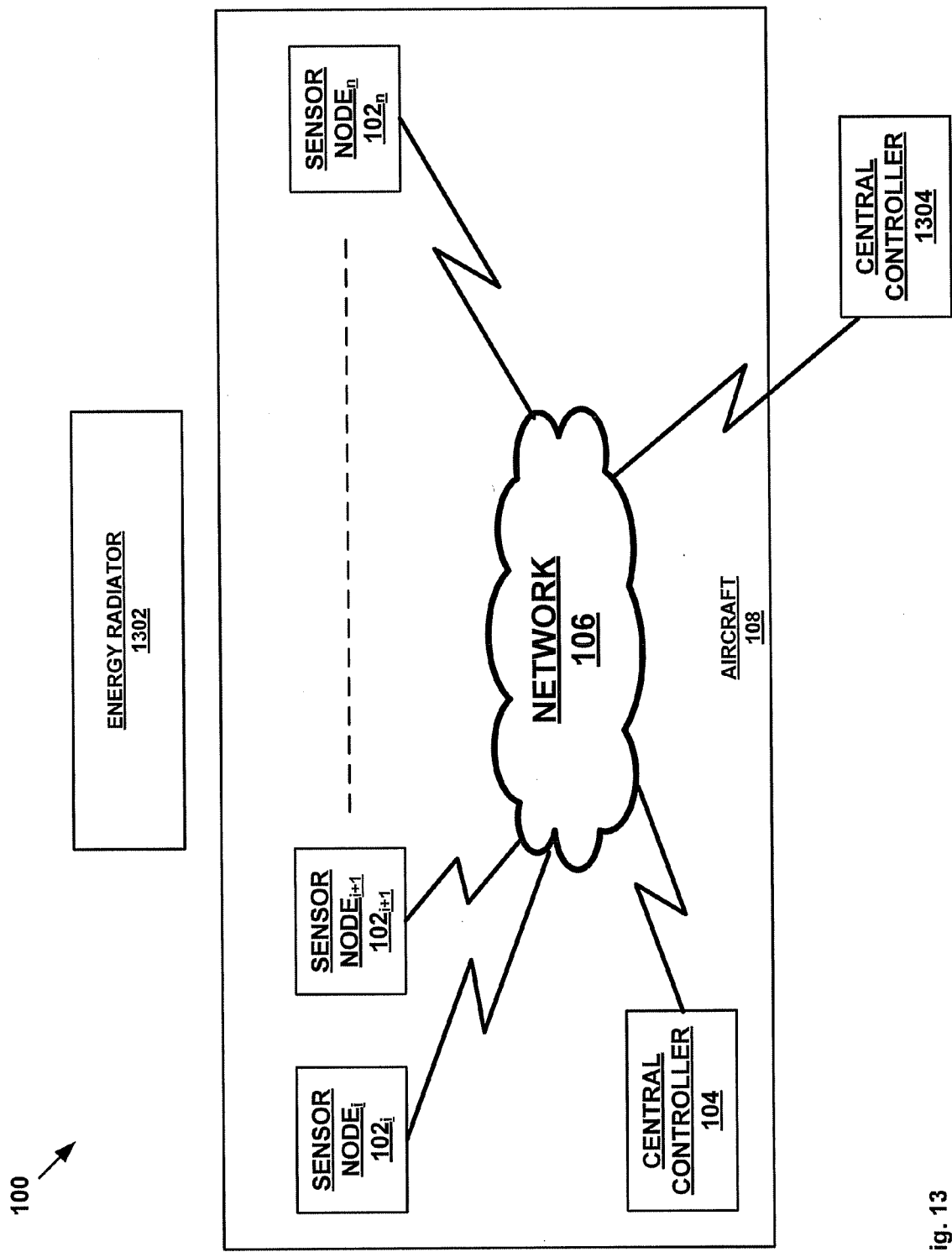


Fig. 13



## POWER AWARE TECHNIQUES FOR ENERGY HARVESTING REMOTE SENSOR SYSTEM

### CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application is related to patent application Ser. No. 12/208,222, attorney docket no. 0408RF.045856, filed on Sep. 10, 2008, the disclosure of which is incorporated by reference.

### BACKGROUND

[0002] This disclosure relates to distributed monitoring systems for a structure.

### BRIEF DESCRIPTION OF THE DRAWINGS

[0003] FIG. 1 is an illustration of an exemplary embodiment of an aircraft monitoring system.

[0004] FIG. 2 is a schematic illustration of the aircraft monitoring system of FIG. 1.

[0005] FIG. 3 is a schematic illustration of an exemplary embodiment of sensor nodes of the aircraft monitoring system of FIG. 2.

[0006] FIGS. 4a and 4b are flow chart illustrations of an exemplary embodiment of a method of operating the sensor nodes of FIG. 3.

[0007] FIGS. 5a and 5b are flow chart illustrations of an exemplary embodiment of a method of operating the sensor nodes of FIG. 3.

[0008] FIG. 6 is a schematic illustration of an exemplary embodiment of an aircraft monitoring system.

[0009] FIG. 7 is a schematic illustration of an exemplary embodiment of an aircraft monitoring system.

[0010] FIG. 8 is a flow chart illustration of a method of operating an aircraft monitoring system.

[0011] FIG. 9 is a schematic illustration of an exemplary embodiment of an aircraft monitoring system.

[0012] FIG. 10 is a flow chart illustration of an exemplary embodiment of a method of operating an aircraft monitoring system.

[0013] FIG. 11 is a flow chart illustration of an exemplary embodiment of a method of operating an aircraft monitoring system.

[0014] FIG. 12 is a graphical illustration of an exemplary embodiment of a sensor of a sensor node that includes one or more stable operating states.

[0015] FIG. 13 is a schematic illustration of an exemplary embodiment of an aircraft monitoring system.

### DETAILED DESCRIPTION

[0016] In the drawings and description that follows, like parts are marked throughout the specification and drawings with the same reference numerals, respectively. The drawings are not necessarily to scale. Certain features of the invention may be shown exaggerated in scale or in somewhat schematic form and some details of conventional elements may not be shown in the interest of clarity and conciseness. The present invention is susceptible to embodiments of different forms. Specific embodiments are described in detail and are shown in the drawings, with the understanding that the present disclosure is to be considered an exemplification of the principles of the invention, and is not intended to limit the invention to that illustrated and described herein. It is to be fully recognized that the different teachings of the embodiments

discussed below may be employed separately or in any suitable combination to produce desired results. The various characteristics mentioned above, as well as other features and characteristics described in more detail below, will be readily apparent to those skilled in the art upon reading the following detailed description of the embodiments, and by referring to the accompanying drawings.

[0017] Referring to FIGS. 1-3, an exemplary embodiment of a system 100 for monitoring an aircraft includes one or more sensors nodes 102 that are operably coupled to a central controller 104 by a network 106. In an exemplary embodiment, the sensor nodes 102 are distributed within an aircraft 108 for monitoring one or more operational states of the aircraft that may, for example, include stresses, strains, temperatures, and pressures. In an exemplary embodiment, one or more of the sensor nodes 102 communicate the operational states of the aircraft 108 to the central controller 106 that is housed within the aircraft using, for example, a network 106 that may, for example, include a hard wired, fiber optic, infra red, radio frequency, packet data, acoustic, or other communication pathway.

[0018] In an exemplary embodiment, each sensor node 102 includes a power supply 102a that is adapted to scavenge energy from the immediate environment. In an exemplary embodiment, the power supply 102a may, for example, scavenge electromagnetic energy, solar energy, radio-frequency energy, vibrational energy, heat energy, wind energy, radiated electromagnetic and/or other forms of energy from the environment. In an exemplary embodiment, the power supply 102a further includes a rechargeable battery 102aa operably coupled thereto. In this manner, short bursts of energy that may be scavenged can be scavenged by the power supply 102a and stored for later use in the battery 102aa. In an exemplary embodiment, the power supply 102a is operably coupled, and supplies power, to a communication link 102b, a switch 102c, a micro-controller 102d, a signal conditioner 102e, a sensor 102f, a switch 102g, a switch 102h, and a memory 102i.

[0019] In an exemplary embodiment, the communication link 102b is also operably coupled to the switch 102c and adapted to transmit and receive communication signals between the sensor node 102 and the network 106. In this manner, the sensor node 102 may communicate with other sensor nodes and the central controller 104.

[0020] In an exemplary embodiment, the switch 102c is also operably coupled to the communication link 102b and the micro-controller 102d and adapted to be controlled by the micro-controller to thereby communications between the communication link and the micro-controller. In this manner, in the event that the micro-controller 102d determines that communication should not occur between the communication link 102b and the micro-controller such as, for example, if the sensor node 102 lacks sufficient power, the micro-controller may operate the switch to prevent communication between the communication link and the micro-controller.

[0021] In an exemplary embodiment, the micro-controller 102d is also operably coupled to the communication link 102b, the switch 102c, the signal conditioner 102e, the sensor 102f, and the switch 102g for monitoring and controlling the operation of each. In an exemplary embodiment, the micro-controller 102d may include, for example, a conventional general purpose programmable controller.

[0022] In an exemplary embodiment, the signal conditioner 102e is also operably coupled to the micro-controller 102d

and the sensor **102** and adapted to condition signals transmitted by the sensor before they are further processed by the micro-controller. In an exemplary embodiment, the signal conditioner **102e** may, for example, include one or more conventional signal processing elements such as, for example, filters, amplifiers, and analog to digital converters.

[0023] In an exemplary embodiment, the sensor **102f** is also operably coupled to the signal conditioner **102e** and the switch **102g** and adapted to sense one or more operating conditions of the aircraft **108** in the immediate environment. In an exemplary embodiment, the sensor **102f** may include, for example, one or more of the following: a strain gauge, a stress sensor, a temperature gauge, a pressure gauge, a radiation detector, a radar detector, a chemical sensor, a corrosion sensor and/or a detector of electromagnetic energy.

[0024] In an exemplary embodiment, the switch **102g** is also operably coupled to the micro-controller **102d** and the sensor **102f** and adapted to control the operation of the sensor under the controller of the micro-controller. In this manner, in the event that the micro-controller **102d** determines that the sensor **102f** should not operate such as, for example, if the sensor node **102** lacks sufficient power, the micro-controller may operate the switch **102g** to prevent power from being supplied by the power supply **102a** to the sensor.

[0025] In an exemplary embodiment, the switch **102h** is also operably coupled to the micro-controller **102d** and the communication link **102b** and adapted to control the operation of the communication link under the controller of the micro-controller. In this manner, in the event that the micro-controller **102d** determines that the communication link **102b** should not operate such as, for example, if the sensor node **102** lacks sufficient power, the micro-controller may operate the switch **102h** to prevent power from being supplied by the power supply **102a** to the communication link.

[0026] In an exemplary embodiment, the memory **102i** is also coupled to the micro-controller **102d** in order to store the operating system of the sensor node **102** as well as other operating parameters and measurements taken by the sensor **102f**. The memory **102i** may, for example, include one or more conventional memory devices such as, for example, DRAMS, Flash memory, optical storage, hard disk drive, or other memory devices. In an exemplary embodiment, the memory **102i** is adapted to store at least one of the mechanical, electrical, chemical, bistable, or multi-stable states of the sensor **102f**.

[0027] Referring now to FIGS. **4a** and **4b**, in an exemplary embodiment, one or more of the sensor nodes **102** of the system **100** implement a method **400** of operating in which, in **402**, the sensor node determines if there is any power available to the sensor node. If there is any power available to the sensor node **102**, then the sensor node determines if there is enough power available to the sensor node to permit the sensor node to execute at least one operation in **404**.

[0028] If there is enough power available to permit the sensor node **102** to execute at least one operation, then the sensor gets a listing of the possible operations given the amount of available power in **406**. The sensor node **102** then gets a listing of the current and next operational states for the sensor node in **408**.

[0029] The sensor node **102** then determines if the next operational states of the sensor node are included in the possible operations given the amount of available power in **410**. If the next operational states of the sensor node **102** are included in the possible operations given the amount of avail-

able power, then the sensor node executes the next operational states that are possible to execute given the amount of available power in **412**.

[0030] Referring now to FIGS. **5a** and **5b**, in an exemplary embodiment, one or more of the sensor nodes **102** of the system **100** implement a method **500** of operating in which, in **502**, the sensor node determines if there is any power available to the sensor node. If there is any power available to the sensor node **102**, then the sensor node determines if there is enough power available to the sensor node to permit the sensor node to execute at least one operation in **504**.

[0031] If there is enough power available to permit the sensor node **102** to execute at least one operation, then the sensor gets a listing of the possible operations given the amount of available power in **506**. The sensor node **102** then gets a listing of the current and next operational states for the sensor node in **508**.

[0032] The sensor node **102** then determines if the next operational states of the sensor node are included in the possible operations given the amount of available power in **510**. If the next operational states of the sensor node **102** are included in the possible operations given the amount of available power, then the sensor node executes the next operational states, based upon their pre-determined priority, that are possible to execute given the amount of available power in **512**.

[0033] Referring now to FIG. **6**, an exemplary embodiment of a system **600** for monitoring an aircraft is substantially identical in design and operation as the system **100** with the addition of a power dispenser and conditioner **602** that is operably coupled to a source of raw power **604**, a power manager **606**, a power allocator **608**.

[0034] In an exemplary embodiment, the source of raw power **608** may include one or more of the power supplies **102a** of one or more of the sensor nodes **102**. In an exemplary embodiment, the power dispenser and conditioner **602** is adapted to receive time varying raw power,  $P(t)_{raw}$ , from the source of raw power **604**, condition the raw power, and then transmit time varying available power,  $P(t)_{avail}$ , to the power allocator **608**. In an exemplary embodiment, the power dispenser and conditioner **602** includes one or more elements for conditioning the raw power such as, for example, a rectifier, a filter, and a regulator.

[0035] In an exemplary embodiment, the power manager **606** includes a power monitor **606a** and a power controller **606b**. In an exemplary embodiment, the power monitor **606a** is operably coupled to the output of the power dispenser and conditioner **602** for monitoring the available power,  $P(t)_{avail}$ . In an exemplary embodiment, the power monitor **606a** is also operably coupled to the power controller **606b** for communicating the available power,  $P(t)_{avail}$ , to the power controller. In an exemplary embodiment, the power controller **606b** is also operably coupled to the power allocator **608** for controlling the operation of the power allocator.

[0036] In an exemplary embodiment, the power allocator **608** includes one or more allocators **608i** that are each coupled to one or more elements of the sensor node **102** for controllably supplying power to the corresponding elements of the sensor node. In this manner, the power manager **606** and the power allocator **608** collectively determine the power available to the sensor node **102** and then allocate the available power to the elements of the sensor node.

[0037] In an exemplary embodiment, the system **600** may implement one or more aspects of the methods **400** and **500**, described and illustrated above with reference to FIGS. **4a**,

**4b, 5a, and 5b.** In an exemplary embodiment, the elements and functionality of the power dispenser and conditioner **602**, the raw power source **604**, the power manager **606**, and the power allocator **608** may be provided within one or more of the sensor nodes **102** and/or provided within the central controller **104**.

**[0038]** Referring now to FIG. 7, an exemplary embodiment of a system **700** for monitoring an aircraft is substantially identical in design and operation as the system **600** except that the power allocator **608** is omitted and the functionality formerly provided by the power allocator is provided by the micro-controller **102d** within the sensor nodes **102**.

**[0039]** In particular, in the system **700**, the power controller **606b** is operably coupled to the micro-controller **102d** of the sensor node **102** for directing the allocation of the available power by the micro-controller to the elements of the sensor node.

**[0040]** In an exemplary embodiment, the system **700** may implement one or more aspects of the methods **400** and **500**, described and illustrated above with reference to FIGS. **4a, 4b, 5a, and 5b**. In an exemplary embodiment, the elements and functionality of the power dispenser and conditioner **602**, the raw power source **604**, and the power manager **606** may be provided within one or more of the sensor nodes **102** and/or provided within the central controller **104**.

**[0041]** Referring now to FIG. 8, in an exemplary embodiment, one or more of the systems **100, 600, and 700** may implement a method **800** of operating in which, in **802**, the sensor nodes **102** are placed into a default mode of operation which may, for example, include a sleep mode in which the sensor node is inactive, a fully active mode in which the sensor node is fully active, or one or more intermediate active modes in which the sensor node has functionality that is less than in the fully active mode. In **804**, the system, **100, 600, or 700**, will then determine the amount of power available to the system. In an exemplary embodiment, in **806**, the system, **100, 600, or 700**, will then determine the available operational states of the sensor nodes **102** of the system given the amount of power available to the system.

**[0042]** In an exemplary embodiment, in **808**, the system, **100, 600, or 700**, will then determine the quality of the possible monitoring of the aircraft **108** given the available operational states of the sensor nodes **102** of the system given the amount of power available to the system. In an exemplary embodiment, the quality of the possible monitoring of the aircraft **108** may be a function of what monitoring is adequate based upon the operating envelope and actual operating condition of the aircraft. For example, when the aircraft **108** is cruising at high altitudes with minimal turbulence, the level of detail and sampling rate in the monitored conditions may be less than when the aircraft is climbing to, or diving from, altitude with heavy turbulence.

**[0043]** In an exemplary embodiment, in **810**, the system, **100, 600, or 700**, will then modify the operational states of the sensor nodes **102** in order to optimize one or more of: 1) the available operational states of the sensor nodes, 2) the volume of data collected by the sensor nodes, 3) the sampling rate of the data collected by the sensor nodes, 4) the communication throughput of data within the network **106**, and/or 5) the quality of the possible monitoring.

**[0044]** In an exemplary embodiment, during the operation of the systems, **100, 600 and/or 700**, the switches, **102c, 102g and 102h**, may be operated by the micro-controller **102d** to place the sensor node **102** in a sleep mode by not permitting

operation of the communication link **102b** and the sensor **102f**. In this manner, the use of power by the sensor node **102** is minimized.

**[0045]** In an exemplary embodiment, during the operation of the systems, **100, 600 and/or 700**, the sensor node **102** may be operated in a sleep mode of operation that may, for example, include a range of sleeping mode that may vary from a deep sleep to a light sleep. In an exemplary embodiment, in a deep sleep mode of operation, the sensor node **102** may be completely asleep and then may be awakened by a watch dog timer, external interrupt, or other alert. In an exemplary embodiment, in a light sleep mode of operation, some of the functionality of the sensor node **102** may be reduced. In an exemplary embodiment, in one or more intermediate sleeping modes of operation, the functionality of the sensor node **102** will range from a light sleep to a deep sleep.

**[0046]** In an exemplary embodiment, in one or more of the systems **100, 600 and 700**, one or more of the elements and functionality of the power dispenser and conditioner **602**, the raw power source **604**, the power manager **606**, and the power allocator **608** may be provided within a sensor node **102**, within one or more groups of sensor nodes, and/or within the central controller **104**.

**[0047]** In an exemplary embodiment, in one or more of the systems, **100, 600 and 700**, one or more of the elements and functionality of the raw power source **604** may be provided within a single sensor node **102**, within one or more groups of sensor nodes, or by all of the sensor nodes. For example, if the power supply **102a** in each of the sensor nodes **102** within one of the systems, **100, 600 or 700**, is a solar cell, then the level of solar energy at each sensor node **102** will vary as a function of its location on the aircraft **108**. In an exemplary embodiment, the allocation of power within the sensor nodes **102** of the systems, **100, 600 and 700**, will determine the mapping of the power generated by the sensor nodes and then allocate power among the sensor nodes in order to optimize the operation of the systems in monitoring the aircraft **108**.

**[0048]** In an exemplary embodiment, in one or more of the systems **100, 600 and 700**, one or more of the sensor nodes **102** may provide one or more of the elements and functionality of the central controller **104**.

**[0049]** In an exemplary embodiment, one or more of the systems **100, 600 and 700**, may be operated to provide an optimal quality of the possible monitoring of the aircraft **108** by placing one or more determined sensor nodes **102** into a sleep mode, even in the presence of adequate power to operate the determined sensor nodes if the systems determine that the optimal quality of the possible monitoring of the aircraft can still be achieved. In this manner, the determined sensor nodes **102** placed into a sleep mode may do one or more of: store power or store data within the determined sensor node. In this manner, data may be warehoused within a sensor node **102** for later use and/or power may be stored within the sensor node for later use.

**[0050]** In an exemplary embodiment, one or more of the systems **100, 600 and 700**, may be operated to place one or more determined sensor nodes **102** into a sleep mode if the data for the determined sensor node may be extrapolated using the data available for adjacent sensor nodes.

**[0051]** Referring now to FIG. 9, an exemplary embodiment of a system **900** for monitoring an aircraft is substantially identical in design and operation as the system **100** except that

an energy radiator **902** is positioned proximate the aircraft **108** and a central controller **904** is operably coupled to the network **106**.

[0052] In an exemplary embodiment, the energy radiator **902** includes one or more radiators of energy such as, for example, electromagnetic energy, solar energy, radio-frequency energy, vibrational energy, heat energy, and/or wind energy. In this manner, the energy radiator **902** may permit the power supplies **102a** of the sensor nodes **102** to scavenge energy for operating the sensor nodes from the energy radiated by the energy radiator **902**.

[0053] In an exemplary embodiment, the central controller **904** is operably coupled to the network **106** in order to monitor and control the operation of the sensor nodes **102**. In an exemplary embodiment, the central controller **904** may include a plurality of central controllers positioned proximate the aircraft **100**.

[0054] Referring to FIG. 10, in an exemplary embodiment, the system **900** implements a method **1000** of monitoring an aircraft in which, in **1002**, selected ones of the sensor nodes **102** are radiated with energy by operating the energy radiator **902**. In an exemplary embodiment, the amount of energy radiated in **1002** is selected to provide at least a threshold level of energy that may be scavenged by the selected sensor nodes **102** thereby permitting a predetermined level of desired functionality to be achieved by the sensor nodes.

[0055] In **1004**, the selected ones of the sensor nodes **102** scavenge the radiated energy using the power supplies **102**. In an exemplary embodiment, at least some of the scavenged radiated power is stored in a power storage battery provided in at least some of the power supplies. In this manner, a relatively short burst of radiated energy may provide functionality of the selected sensors nodes **102** for an extended period of time.

[0056] In an exemplary embodiment, the method **1000** is implemented as part of a static test of the aircraft **108** while the aircraft is housed within a hangar.

[0057] In an exemplary embodiment, the energy radiator **902** may radiate electromagnetic energy using a planar wave whose energy level does not decay substantially with distance. In an exemplary embodiment, the energy radiator **902** may include a phased array antenna for radiating energy. In an exemplary embodiment, the energy radiator **902** may include an arbitrarily large antenna and/or one or more directional antennas.

[0058] In an exemplary embodiment, the energy radiator **902** may radiate a large enough pulse of energy such that the batteries **102aa** of the power supplies **102** of the sensor nodes **102** are fully charged such that continued static testing of the aircraft **108** may continue with or without the need for further radiation of energy to the sensor nodes.

[0059] In an exemplary embodiment, the energy radiator **902** may include a light source operably coupled to a leaky fiber optic cable or light pipe that is positioned proximate the sensor nodes **102** to which it is desired to radiate energy. In an exemplary embodiment, the energy radiator **902** may include a source of thermal energy that may create temperature gradients within the aircraft **108** that may be used by the power supplies **102a** of the sensor nodes **102** to generate energy.

[0060] In an exemplary embodiment, the energy radiated by the energy radiator **902** is selected to include forms of energy that will not effect the structure and/or the measurements to be taken of the aircraft **100**.

[0061] Referring to FIG. 11, in an exemplary embodiment, the system **100** implements a method **1100** of monitoring an aircraft in which, in **1102**, the sensor nodes **102** scavenge sufficient energy from the local environment to permit the sensors **102f** of the sensor nodes to sense one or more operating conditions and store the measured operating condition within the sensor and/or the memory **102i**. In an exemplary embodiment, in **1102**, the sensors **102f** of the sensor nodes **102** recognize that a threshold measured value has been obtained and thereby latch to that sensed value.

[0062] In an exemplary embodiment, as illustrated in FIG. 12, the sensors **102f** of the sensor nodes **102** are provided with one or more stable operating states that are each reflective of a value of an operating condition. For example, as illustrated in FIG. 12, one or more of the sensors **102f** of the sensor nodes **102** may include an initial operating state  $S_0$ . Upon the sensing of an operating condition, which would include some form of input energy to the sensor **102f**, the operational state may then change to a stable sensed state  $S_1$ . The sensor **102f** of the sensor node **102** would remain in this stable latched operational state unless and until another event reflective of a change in operating conditions, which would include some form of input energy to the sensor **102f**, occurred which would move the sensor to a new stable operational state  $S_2$ . In this manner, the sensor **102f** of the sensor **102** would latch onto the sensed operational state and the sensor could be a mechanical latch and/or an electronic latch. In an exemplary embodiment, the number of stable operational states could be any value and such value could determine the level of granularity in the sensor **102f**. In an exemplary embodiment, the number of stable operational states also may be used to provide an electrical and/or mechanical analog to digital converter in which the number of stable operational states of the sensor **102f** determines the number of levels in the analog to digital converter.

[0063] In an exemplary embodiment, the sensors **102f** of one or more of the sensor nodes **102** are further adapted to stored measure values of operating conditions using the energy associated with the operating condition itself. In this manner, the sensors **102f** are able to store stored measure values of operating conditions using the energy associated with the operating condition for indefinite periods of time. For example, as illustrated in FIG. 12, the sensor **102f** may include one or more stable operating states that are each entered into by injecting energy into the sensor, where the injected energy is the operating condition being measured.

[0064] In an exemplary embodiment, in **1104**, sensor nodes **102** are then radiated with energy in sufficient amounts to permit the sensor nodes to transmit the stored measurements and to reset the sensors **102f**. In an exemplary embodiment, in **1104**, as illustrated in FIG. 13, the sensor nodes **102** are radiated with energy in sufficient amounts to permit the sensor nodes to transmit the stored measurements by operating an energy radiator **1302** proximate the sensor nodes. In an exemplary embodiment, the design and operation of the energy radiator **1302** is substantially the same as the energy radiator **902**.

[0065] In an exemplary embodiment, in **1106**, the sensor nodes **102** scavenge the radiated energy using the power supplies **102**. In an exemplary embodiment, at least some of the scavenged radiated power is stored in a power storage battery provided in at least some of the power supplies. In this manner, a relatively short burst of radiated energy may provide functionality of the selected sensors nodes **102** for an

extended period of time. In an exemplary embodiment, in **1106**, the sensor nodes **102** scavenge the radiated energy using the power supplies **102** in sufficient amount to permit the sensor nodes to transmit the stored measurements and to reset the sensor **102f**.

[0066] In an exemplary embodiment, in **1108**, the sensor nodes **102** determine whether to transmit the stored measurements or, in the alternative, to transmit the stored measurements and then reset the sensor **102f**. In an exemplary embodiment, each sensor **102** will be programmed by a user of the system **100** in order to determine which action should be taken. Alternatively, the desired action to be taken may be altered by downloading instructions to the sensor nodes **102** and/or may be adaptively determined as a function of the type or location of the sensor **102f** of the sensor node, the magnitude of the stored measurements, or other factors.

[0067] If a particular sensor node **102** has been instructed to only transmit the stored measurements, then, in **1110**, the sensor node will only transmit the stored measurements to one or more of the central controllers **104**. In an exemplary embodiment, in **1110**, the transmission of the stored measurements by the sensor node may be a singlecast or multicast transmission, and may, for example, be transmitted using data packets protocols.

[0068] If a particular sensor node **102** has been instructed to transmit the stored measurements and reset the sensor **102f**, then, in **1112**, the sensor node will transmit the stored measurements to one or more of the central controllers **104** and then the sensor node **102** will then reset the associated sensor **102f** in **1114**. In an exemplary embodiment, in **1112**, the transmission of the stored measurements by the sensor node may be a singlecast or multicast transmission, and may, for example, be transmitted using data packets protocols. In an exemplary embodiment, in **1114**, the sensor **102** node **102** will reset the sensor **102f** by, for example, resetting the operational state of the sensor to an earlier operational state.

[0069] In an exemplary embodiment, as illustrated in FIG. **13**, in **1110** and/or **1112**, the sensors **102** and/or the central controllers **104** may transmit the stored measurements to one or more external central controllers **1304**. In an exemplary embodiment, the energy radiator **1302** may include, or at least be operably coupled to, the central controller **1304**. In this manner, a portable device that may include both the energy radiator **1302** and the central controller **1304** may be used to wand over selected sensor nodes **102** to thereby interrogate the sensor nodes, capture the stored measurements contained therein, and, if required, also reset the sensors **102f** in one or more of the selected sensor nodes **102**.

[0070] In an exemplary embodiment, after completing **1110** and/or **1112**, one or more of the central controllers **104** may send an acknowledgement to the sensor node **102** that transmitted the stored measurements and, in an exemplary embodiment, upon the receipt of the acknowledgement by the sensor node, the sensor node will reset the sensor node's operational state.

[0071] In an exemplary embodiment, the method **1100** may be used, for example, to provide a regular diagnostic program for the aircraft **108** by mounting the energy radiator **1302** and the central controller **1304** at a fixed location such as, for example, in the ceiling of an aircraft hangar. Then, as the aircraft **108** is moved into or out of the hangar, the stored measurements within the sensors **102f** of the sensor nodes **102** may be extracted for processing by the central controller **1304** to determine the health of the aircraft.

[0072] In an exemplary embodiment, the method **1100** may be used, for example, to provide a regular diagnostic program for a carrier based aircraft **108** by mounting the energy radiator **1302** and the central controller **1304** at a fixed location such as, for example, the aircraft elevator on the carrier. Then, as the aircraft **108** is moved onto or off of the deck of the carrier, the stored measurements within the sensors **102f** of the sensor nodes **102** may be extracted for processing by the central controller **1304** to determine the health of the carrier based aircraft.

[0073] It is understood that variations may be made in the above without departing from the scope of the invention. For example, the teachings of the exemplary embodiments may be applied to monitoring an aircraft, a ship, a vehicle, a building, the environment, or any other application in which a distributed monitoring system would provide value. While specific embodiments have been shown and described, modifications can be made by one skilled in the art without departing from the spirit or teaching of this invention. The embodiments as described are exemplary only and are not limiting. Many variations and modifications are possible and are within the scope of the invention. Accordingly, the scope of protection is not limited to the embodiments described, but is only limited by the claims that follow, the scope of which shall include all equivalents of the subject matter of the claims.

1. A distributed monitoring system for monitoring one or more operating conditions of a structure, comprising:

one or more sensor nodes coupled to the structure, each sensor node comprising:

a power supply adapted to scavenge energy directed at the power supply;

a sensor operably coupled to the power supply for sensing one or more operating conditions of the structure in the environment; and

a communications interface operably coupled to the power supply and the sensor for communicating the sensed operating conditions of the structure;

a communication network operably coupled to the sensor nodes;

one or more controllers operably coupled to the communication network for monitoring the sensor nodes; and

an energy radiator positioned proximate the structure adapted to radiate energy at the power supplies of the sensor nodes.

2. The system of claim 1, wherein one or more of the sensor nodes comprise a rechargeable battery operably coupled to the power supply.

3. The system of claim 1, wherein one or more of the sensor nodes comprise a memory operably coupled to the sensor.

4. The system of claim 3, wherein the memory comprises one or more of the following states of the sensor: mechanical, electrical, chemical, bistable, and multi-stable.

5. The system of claim 1, wherein the power supply of one or more of the sensor nodes is adapted to scavenge enough directed energy to permit the sensor of the corresponding sensor node to sense one or more operating conditions.

6. The system of claim 5, wherein the power supply of one or more of the sensor nodes is adapted to scavenge enough directed energy to permit the sensor of the corresponding sensor node to sense one or more operating conditions and reset an operating state of the sensor of the corresponding sensor node.

7. The system of claim 5, wherein the power supply of one or more of the sensor nodes is adapted to scavenge enough directed energy to permit the sensor of the corresponding sensor node to sense one or more operating conditions and provides power to enable to reset an operating state of the sensor of the corresponding sensor node as directed by one or more of the controllers.

8. The system of claim 1; wherein the sensor of one or more of the sensor nodes comprises at least one stable operating state representative of a corresponding measurement value of an operating condition.

9. The system of claim 8, wherein said stable operating state remains unchanged until reset by one or more of the controllers.

10. The system of claim 8, wherein the sensor of one or more of the sensor nodes comprises one or more of: an electrical device, a mechanical device, a chemical device, and an electromechanical device, that comprises at least one stable operating state representative of a corresponding measurement value of an operating condition.

11. The system of claim 8, wherein the sensor of one or more of the sensor nodes is adapted to change to a stable operating state of the sensor using energy provided by the operating condition measured by the sensor.

12. The system of claim 1, wherein the energy radiator and one or more of the controllers are positioned proximate the structure.

13. The system of claim 1, wherein the energy radiator comprises a radiator of one or more of the following: radiofrequency energy, optical energy, and thermal energy.

14. The system of claim 12, wherein the energy radiator and one or more of the controllers are positioned within a common housing.

15. The system of claim 1, wherein the structure comprises an aircraft.

16. A method of operating a system for monitoring one or more operating conditions of a structure, comprising:  
providing sensor nodes at locations around the structure for sensing operating conditions of the structure;  
directing radiated energy at one or more of the sensor nodes;  
scavenging the radiated energy at one or more of the sensor nodes; and  
using the scavenged energy at one or more of the sensor nodes to transmit sensed operating conditions from one or more of the sensor nodes.

17. The method of claim 16, wherein one or more of the sensor nodes store a measurement of one or more sensed operating conditions.

18. The method of claim 17, wherein using the scavenged energy at one or more of the sensor nodes to transmit sensed operating conditions from one or more of the sensor node locations comprises using the scavenged energy at one or more of the sensor nodes to transmit the stored sensed operating conditions.

19. The method of claim 16, further comprising using the scavenged energy at one or more of the sensor nodes to reset an operating condition of a sensor of one or more of the sensor nodes.

20. The method of claim 17, wherein using the scavenged energy at one or more of the sensor nodes to transmit sensed

operating conditions from one or more of the sensor node locations comprises using the scavenged energy at one or more of the sensor nodes to transmit the stored sensed operating conditions and reset an operating condition of a sensor of one or more of the sensor nodes.

21. The method of claim 16, wherein the structure comprises an aircraft.

22. The method of claim 16, wherein one or more of the sensor nodes use energy associated with the sensed operating condition to store a measurement of the sensed operating condition.

23. A sensor node for use in a distributed monitoring system for monitoring one or more operating conditions of a structure, comprising:

a power supply;

a sensor operably coupled to the power supply for sensing one or more operating conditions of the structure in the immediate environment;

a communications interface operably coupled to the power supply and the sensor for communicating the sensed operating conditions of the structure; and

a controller operably coupled to the power supply, the sensor, and the communications interface;

wherein the sensor comprises one or more stable operating states that are each reflective of a corresponding value of one or more operating conditions.

24. The sensor node of claim 23, wherein the power supply comprises a rechargeable battery for storing energy provided by the power supply.

25. The sensor node of claim 24, wherein the sensor is adapted to use energy associated with the sensed operating condition to store the sensed operating condition.

26. A distributed monitoring system for monitoring one or more operating conditions of a structure, comprising:

one or more sensor nodes coupled to the structure, each sensor node comprising:

a power supply adapted to scavenge energy directed at the power supply;

a sensor operably coupled to the power supply for sensing one or more operating conditions of the structure in the environment; and

a communications interface operably coupled to the power supply and the sensor for communicating the sensed operating conditions of the structure;

a communication network operably coupled to the sensor nodes; and

one or more controllers operably coupled to the communication network for monitoring the sensor nodes;

wherein one or more of the sensors comprise at least one stable operating state representative of a corresponding measurement value of an operating condition.

27. The system of claim 26, wherein said stable operating state remains unchanged until reset by one or more of the controllers.

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