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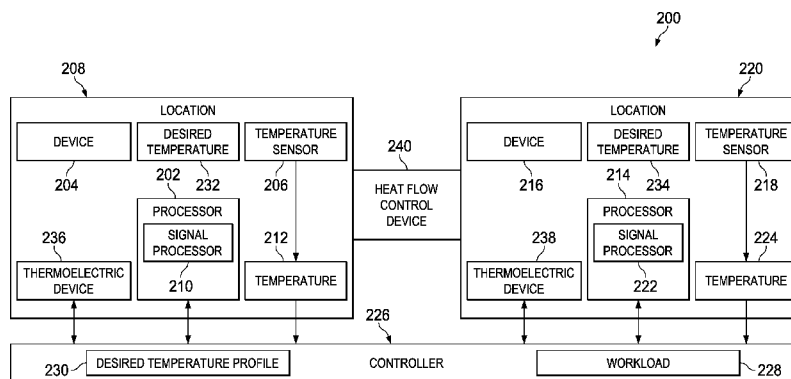


FIG. 2

(57) Abstract: An apparatus and method of controlling temperatures of a plurality of locations on a structure. A temperature at each of the plurality of locations is identified. A desired temperature for each of the plurality of locations is identified. Processing of a workload by a processor at each of the plurality of locations is controlled to control the temperature at each of the plurality of locations to match the corresponding desired temperature for each of the plurality of locations.

ELECTRONICS OPERATION FOR TEMPERATURE CONTROLLED SYSTEMS

BACKGROUND INFORMATION

5 **Field:**

 The present disclosure relates generally to data processing and to the operation of electronic devices that may affect temperature or be affected by temperature. Still more particularly, the present disclosure relates to controlling the operation of data processing devices and other devices on a structure, such as an aircraft, to process a workload and control the temperature of temperature sensitive devices at various locations on the structure.

Background:

 Various types of processors may be used to process various types of data. For example, processors may include general purpose microprocessors and specialized processors that are configured to process particular types of data. Signal processors that are configured to process particular types of signals may be one example of specialized processors.

 One characteristic of processors is that processors generate heat while in operation. Higher operating speeds generate more heat. Another characteristic of processors is that the temperature of a processor may affect the performance of the processor. For example, if the temperature of a processor is too high, the ability of the processor to process data may be affected in an undesired manner. In some cases, a processor may be damaged if the temperature of the processor reaches an excessively high level. Therefore, it is desirable that excess heat is removed from the operating processors.

 The operation of other electrical, electromechanical and micro-electromechanical devices also may be affected by temperature. A crystal oscillator is an example of a device that is affected by temperature. A crystal oscillator is an electronic oscillator circuit that uses the mechanical resonance of a vibrating crystal of piezoelectric material to create an electrical signal with a very precise frequency. However, the frequency of the electrical signal produced by such an oscillator may

change if the temperature of the oscillator is greater than or less than the desired operating temperature of the oscillator.

It may be desirable to control the temperature of a device, such as a crystal oscillator or another device, to maintain a desired level of accurate performance of the device. For example, the temperature of electronic devices used in navigation and timing circuits on aircraft may need to be increased or decreased to maintain predictability and consistency of operation. Currently, resistive heaters and hermetically sealed covers may be used to create oven structures around electronic devices to maintain the desired temperature of such devices.

Accordingly, it would be beneficial to have a method and apparatus that take into account one or more of the issues discussed above, as well as possibly other issues.

SUMMARY

The illustrative embodiments of the present disclosure provide a method of controlling temperatures of a plurality of locations on a structure. A temperature at each of the plurality of locations is identified. A desired temperature for each of the plurality of locations is identified. Processing of a workload by a processor at each of the plurality of locations is controlled to control the temperature at each of the plurality of locations to match the corresponding desired temperature for each of the plurality of locations.

The illustrative embodiments of the present disclosure also provide an apparatus comprising a temperature sensor at each of a plurality of locations on a structure, a processor at each of the plurality of locations, and a controller. Each temperature sensor is configured to identify a temperature at a corresponding one of the plurality of locations. The controller is configured to receive information identifying the temperature at each of the plurality of locations from the corresponding temperature sensor at each of the plurality of locations. The controller is further configured to control processing of a workload by the processor at each of the plurality of locations to control the temperature at each of the plurality of locations to match a desired temperature for each of the plurality of locations.

The illustrative embodiments of the present disclosure also provide a method of controlling a temperature at a location on a structure. The temperature at the

location is identified. A desired temperature for the location is identified. Processing of a workload by a processor at the location is controlled to increase the temperature at the location to match the desired temperature for the location.

The features, functions, and benefits 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

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

Figure 1 is an illustration of a block diagram of a system for controlling data processing operations and temperatures of a plurality of locations on a structure in accordance with an illustrative embodiment;

Figure 2 is an illustration of a block diagram of a temperature controlled system in accordance with an illustrative embodiment;

Figure 3 is an illustration of a temperature controlled structure in accordance with an illustrative embodiment;

Figure 4 is an illustration of processors at locations on a fuel tank in accordance with an illustrative embodiment;

Figure 5 is an illustration of controlling a temperature signature of an aircraft in accordance with an illustrative embodiment;

Figure 6 is an illustration of a flowchart of a process for controlling temperatures of a plurality of locations on a structure in accordance with an illustrative embodiment; and

Figure 7 is an illustration of a flowchart of a process for controlling the temperature of a location on a structure in accordance with an illustrative embodiment.

DETAILED DESCRIPTION

The different illustrative embodiments recognize and take into account a number of different considerations. “A number,” as used herein with reference to items, means one or more items. For example, “a number of different considerations” are one
5 or more different considerations.

The different illustrative embodiments recognize and take into account that processors operating to process a workload on a structure, such as an aircraft, produce heat. The different illustrative embodiments also recognize and take into account that it may be desirable to remove excess heat from such processors to maintain the
10 performance of such processors. The different illustrative embodiments further recognize and take into account that the temperature of other devices on an aircraft or other structure may need to be increased to maintain the desired performance of such devices.

The different illustrative embodiments recognize and take into account that
15 the heat produced by data processing on an aircraft or other structure may be used to maintain the desired temperature of other devices on the aircraft or other structure. In accordance with an illustrative embodiment, the processing of a workload by processors at various locations on an aircraft or other structure may be controlled to control the temperature of both the processors and other devices at the various locations on the
20 structure in a desired manner. In accordance with an illustrative embodiment, heat produced by processing a workload is not wasted, but may be used to increase and maintain the temperature of other components in a controlled manner. Thermoelectric devices may be provided at the various locations on an aircraft or other structure and controlled along with the processors at the locations to maintain the locations at desired
25 temperatures. The need for resistive heaters and oven structures to maintain desired temperatures of various devices on an aircraft or other structure thus may be managed.

Turning to **Figure 1**, an illustration of a block diagram of a system for controlling data processing operations and temperatures of a plurality of locations on a structure is depicted in accordance with an illustrative embodiment. Structure **100** may
30 be any appropriate structure on which data processing takes place. For example, structure **100** may be aircraft **102** or other structure **104**.

Aircraft **102** may be any appropriate type of aircraft. For example, without limitation, aircraft **102** may be a fixed wing aircraft, a rotary wing aircraft, or a lighter-

than-air vehicle. Aircraft **102** may be an aerospace vehicle that is configured to operate in the air, in outer space, or both. Aircraft **102** may be manned or unmanned.

Other structure **104** may be a vehicle or other mobile structure other than aircraft **102**. For example, without limitation, other structure **104** may be a vehicle
5 configured for operation on land, on water, under water, or in any other medium or combination of mediums. Other structure **104** may be a part of aircraft **102** or another mobile structure. Alternatively, other structure **104** may be a non-mobile platform or other appropriate structure.

Structure **100** includes processors **106** at a plurality of locations **108** on
10 structure **100**. Any appropriate number of processors **106** may be located at each of the plurality of locations **108** on structure **100**. Processors **106** may be arranged in any appropriate configuration with respect to each other at the plurality of locations **108** on structure **100**.

Processors **106** may include any appropriate devices configured to
15 process any appropriate data. For example, without limitation, processors **106** may include general purpose data processing devices, special purpose data processing devices, or both. For example, without limitation, processors **106** may include signal processors **110** or other appropriate data processing devices at one or more of locations **108** on structure **100**.

Locations **108** may be characterized by temperatures **112**. Temperatures
20 **112** also may be referred to as the current temperatures or actual temperatures of locations **108**. Temperatures **112** at locations **108** may correspond to the temperatures of processors **106** at corresponding ones of locations **108**.

Temperatures **112** may be identified using any appropriate temperature
25 sensors **114**. Temperature sensors **114** may be implemented in any appropriate manner along with processors **106** at locations **108** on structure **100**. Temperature sensors **114** may be configured to generate information **115** in any appropriate form to identify temperatures **112** or from which temperatures **112** may be identified.

Devices **116** other than processors **106** may be located along with
30 processors **106** at one or more of locations **108**. Devices **116** may include any devices that may be affected by temperatures **112** at locations **108**. In other words, devices **116** may be temperature sensitive devices. Devices **116** may include electrical device **117**, electromechanical device **118**, micro-electromechanical device **119**, or any appropriate

combination of such devices. For example, without limitation, devices **116** may include, inertial measurement unit **120**, software defined radio **122**, crystal oscillator **124**, other device **126**, or any combination of such devices. For example, without limitation, other device **126** may include a camera or other device that may be affected by temperatures **112** at locations **108**. Devices **116** may be implemented in any appropriate manner along with processors **106** at locations **108** on structure **100**.

In cases where devices **116** are located along with processors **106** at locations **108**, temperatures **112** may refer to the temperatures of processors **106**, the temperatures of devices **116**, or both. In this case, temperature sensors **114** may be configured in an appropriate manner to identify temperatures **112** of processors **106**, temperatures **112** of devices **116**, or both.

In cases where devices **116** are located along with processors **106** at locations **108**, processors **106** may comprise signal processors **110** configured to process signals **127** associated with devices **116** at corresponding locations **108**. Signals **127** associated with devices **116** may include any signals or other data that is provided by devices **116**, provided to devices **116**, or both.

Thermoelectric devices **128** also may be located along with processors **106**, or along with processors **106** and devices **116**, at one or more of locations **108**. Thermoelectric devices **128** may include any devices that use the thermoelectric effect for the direct conversion of an electric voltage to a temperature difference across the device, and vice versa. Thermoelectric devices **128** may be referred to as Peltier devices, Peltier heat pumps, solid state refrigerators, thermoelectric coolers, or in any other appropriate manner. Thermoelectric devices **128** may be used for heating or cooling, or both heating and cooling, at locations **108**. Alternatively, or in addition, thermoelectric devices **128** may be used as thermoelectric generators that generate a voltage in response to a temperature difference across the device. Thermoelectric devices **128** may be implemented in any appropriate manner along with processors **106**, or along with processors **106** and devices **116**, at locations **108** on structure **100**.

Heat flow control devices **129** may be located at one or more of locations **108**, between one or more of locations **108**, or both. Heat flow control devices **129** may include any appropriate devices or structures that permit a greater flow of heat in one direction than in the opposite direction. For example, without limitation, heat flow control devices **129** may comprise thermal rectifiers. Heat flow control devices **129** may

be configured and positioned to control the flow of heat between locations **108** in a desired manner. Alternatively, or in addition, heat flow control devices **129** may be configured and positioned to control the flow of heat within individual ones of locations **108** in a desired manner.

5 In accordance with an illustrative embodiment, controller **130** is configured to control the processing of workload **132** by processors **106** and temperatures **112** of locations **108** in an integrated manner such that workload **132** is processed in an appropriate manner and desired temperature profile **134** of structure **100** is achieved and maintained. Workload **132** may comprise any number of data processing tasks that
10 are to be performed on structure **100**.

Desired temperature profile **134** may be defined, for example, by desired temperatures **136** for locations **108** on structure **100**. Desired temperature profile **134** may be defined for use by controller **130** in any appropriate manner. For example, desired temperature profile **134** may be fixed or changeable. For example, without
15 limitation, desired temperature profile **134** may be changeable by a user, changeable automatically in response to changing conditions, or changeable in another appropriate manner or combination of manners.

Desired temperatures **136** may be the desired operating temperatures of processors **106** at locations **108**, the desired operating temperatures of devices **116** at
20 locations **108**, or other desired temperatures for locations **108** on structure **100**. Desired temperatures **136** may be specific temperatures, ranges of temperatures, temperature thresholds, or may be expressed in any other appropriate manner or combination of manners.

Any appropriate algorithm may be implemented by controller **130** to
25 control processing of workload **132** and temperatures **112** of locations **108** on structure **100** in an integrated manner. For example, controller **130** may be configured to receive information **115** from temperature sensors **114** identifying temperatures **112** at locations **108**. Controller **130** may be configured to compare temperatures **112** at locations **108** to desired temperatures **136** for locations **108** as defined by desired temperature profile
30 **134** for structure **100**. Controller **130** may then distribute the processing of workload **132** among processors **106** such that workload **132** is processed in an appropriate manner and such that the heat generated by processors **106** processing workload **132** causes temperatures **112** of locations **108** to match desired temperatures **136** for

locations **108** on structure **100**. Controller **130** also may be configured to control thermoelectric devices **128** along with the processing of workload **132** by processors **106** in an integrated manner to achieve and maintain desired temperature profile **134** of structure **100**.

5 Controller **130** may be configured to change the portions of workload **132** processed by individual ones of processors **106** to increase or decrease temperatures **112** at locations **108** to match desired temperatures **136** for locations **108**. For example, without limitation, controller **130** may be configured to increase the processing of workload **132** by selected ones of processors **106** to increase temperatures **112** at
10 corresponding locations **108**. Controller **130** may be configured to decrease the processing of workload **132** at selected ones of processors **106** to reduce temperatures **112** at corresponding locations **108**. For example, without limitation, controller **130** may be configured to change the processing of workload **132** by processors **106** by moving threads and clocking among processors **106** to locations **108** where heat is needed to
15 achieve and maintain desired temperature profile **134**.

The functions performed by controller **130** may be implemented in hardware or in hardware in combination with software in processor unit **138**. For example, without limitation, controller **130** may be implemented in processor unit **138** that may include one or more of processors **106** at one or more of locations **108** on
20 structure **100**. Alternatively, or in addition, functions performed by controller **130** may be implemented in processor unit **138** on structure **100** other than processors **106**.

Processor unit **138** may serve to execute instructions for software that may be loaded into memory **140**. Processor unit **138** may be a number of processors, a multi-processor core, or some other type of processor, depending on the particular
25 implementation. A number, as used herein with reference to an item, means one or more items. Further, processor unit **138** 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 **138** may be a symmetric multi-processor system containing multiple processors of the same type.

30 Memory **140** and persistent storage **142** are examples of storage devices **144**. 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.

Storage devices **144** may also be referred to as computer readable storage devices in these examples. Memory **140**, in these examples, may be, for example, a random access memory or any other suitable volatile or non-volatile storage device. Persistent storage **142** may take various forms, depending on the particular implementation.

5 For example, persistent storage **142** may contain one or more components or devices. For example, persistent storage **142** 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 **142** also may be removable. For example, a removable hard drive may be used for persistent storage
10 **142**.

Instructions for the operating system, applications, and/or programs may be located in storage devices **144**, which are in communication with processor unit **138** through an appropriate communications fabric. In these illustrative examples, the instructions are in a functional form on persistent storage **142**. These instructions may
15 be loaded into memory **140** for execution by processor unit **138**. The processes of the different embodiments may be performed by processor unit **138** using computer-implemented instructions, which may be located in a memory, such as memory **140**.

These instructions are referred to as program instructions, program code, computer usable program code, or computer readable program code that may be read
20 and executed by a processor in processor unit **138**. The program code in the different embodiments may be embodied on different physical or computer readable storage media, such as memory **140** or persistent storage **142**.

Program code **146** is located in a functional form on computer readable media **148** that is selectively removable and may be loaded onto or transferred to
25 processor unit **138** for execution by processor unit **138**. Program code **146** and computer readable media **148** form computer program product **150** in these examples. In one example, computer readable media **148** may be computer readable storage media **152** or computer readable signal media **154**.

Computer readable storage media **152** may include, for example, an
30 optical or magnetic disk that is inserted or placed into a drive or other device that is part of persistent storage **142** for transfer onto a storage device, such as a hard drive, that is part of persistent storage **142**. Computer readable storage media **152** 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 processor unit **138**. In some instances, computer readable storage media **152** may not be removable.

5 In these examples, computer readable storage media **152** is a physical or tangible storage device used to store program code **146** rather than a medium that propagates or transmits program code **146**. Computer readable storage media **152** is also referred to as a computer readable tangible storage device or a computer readable physical storage device. In other words, computer readable storage media **152** is a media that can be touched by a person.

10 Alternatively, program code **146** may be transferred to processor unit **138** using computer readable signal media **154**. Computer readable signal media **154** may be, for example, a propagated data signal containing program code **146**. For example, computer readable signal media **154** 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, 15 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.

In some illustrative embodiments, program code **146** may be downloaded over a network to persistent storage **142** from another device or data processing system 20 through computer readable signal media **154** for use within processor unit **138**. 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 processor unit **138**. The data processing system providing program code **146** may be a server computer, a client computer, or some other device capable of storing and transmitting 25 program code **146**.

The different components illustrated for processor unit **138** are not meant to provide architectural limitations to the manner in which different embodiments may be implemented. The different illustrative embodiments may be implemented in a processor unit including components in addition to or in place of those illustrated for 30 processor unit **138**.

Other components shown in **Figure 1** 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. As one example, controller **130**

may include organic components integrated with inorganic components and/or may be comprised entirely of organic components excluding a human being. For example, a storage device may be comprised of an organic semiconductor.

In another illustrative example, processor unit **138** may take the form of a hardware unit that has circuits that are manufactured or configured for a particular use. This type of hardware may perform operations without needing program code **146** to be loaded into a memory from a storage device to be configured to perform the operations.

For example, when processor unit **138** takes the form of a hardware unit, processor unit **138** may be a circuit system, an application specific integrated circuit (ASIC), a programmable logic device, or some other suitable type of hardware configured to perform a number of operations. With a programmable logic device, the device is configured to perform the number of operations. The device may be reconfigured at a later time or may be permanently configured to perform the number of operations. Examples of programmable logic devices include, for example, a programmable logic array, programmable array logic, a field programmable logic array, a field programmable gate array, and other suitable hardware devices. With this type of implementation, program code **146** may be omitted, because the processes for the different embodiments are implemented in a hardware unit.

In still another illustrative example, processor unit **138** may be implemented using a combination of processors found in computers and hardware units. Processor unit **138** may have a number of hardware units and a number of processors that are configured to run program code **146**. With this depicted example, some of the processes may be implemented in the number of hardware units, while other processes may be implemented in the number of processors.

Communications between and among processors **106**, temperature sensors **114**, devices **116**, thermoelectric devices **128**, and controller **130** may be implemented in any appropriate manner. For example, without limitation, communications between and among processors **106**, temperature sensors **114**, devices **116**, thermoelectric devices **128**, and controller **130** may be wired, wireless, optical or implemented in any other appropriate manner or combination of manners using any appropriate method or protocol or combination of methods and protocols for communications.

Turning to **Figure 2**, an illustration of a block diagram of a temperature controlled system is depicted in accordance with an illustrative embodiment. In this example, temperature controlled system **200** may be an example of one implementation of a temperature controlled system on structure **100** in **Figure 1**.

5 Temperature controlled system **200** includes processor **202**, device **204**, and temperature sensor **206** at location **208**. Processor **202** may include any appropriate data processing device configured to process any appropriate data at location **208**. Device **204** may be any device other than processor **202** at location **208**. For example, without limitation, processor **202** may comprise signal processor **210**
10 configured to process signals associated with device **204**. Device **204** may be a temperature sensitive device that is affected by temperature **212** at location **208**. Temperature sensor **206** may be configured to identify temperature **212** at location **208**. For example, without limitation, temperature sensor **206** may be configured to identify temperature **212** of processor **202**, temperature **212** of device **204**, or other appropriate
15 temperature **212** at location **208**. Location **208** may be referred to as a first location, processor **202** may be referred to as a first processor, device **204** may be referred to as a first device, temperature sensor **206** may be referred to as a first temperature sensor, and temperature **212** may be referred to as a first temperature.

 Temperature controlled system **200** also includes processor **214**, device
20 **216**, and temperature sensor **218** at location **220**. Location **220** and location **208** are different locations. Processor **214** may include any appropriate data processing device configured to process any appropriate data at location **220**. Device **216** may be any device other than processor **214** at location **220**. For example, without limitation, processor **214** may comprise signal processor **222** configured to process signals
25 associated with device **216**. Device **216** may be a temperature sensitive device that is affected by temperature **224** at location **220**. Temperature sensor **218** may be configured to identify temperature **224** at location **220**. For example, without limitation, temperature sensor **218** may be configured to identify temperature **224** of processor **214**, temperature **224** of device **216**, or other appropriate temperature **224** at location
30 **220**. Location **220** may be referred to as a second location, processor **214** may be referred to as a second processor, device **216** may be referred to as a second device, temperature sensor **218** may be referred to as a second temperature sensor, and temperature **224** may be referred to as a second temperature.

Temperature controlled system **200** also includes controller **226**. Controller **226** is configured to control the processing of workload **228** and temperatures **212** and **224** of locations **208** and **220**, respectively. Workload **228** may comprise any number of data processing tasks that are to be performed by temperature controlled system **200**. Controller **226** may be configured to control temperatures **212** and **224** of locations **208** and **220** in accordance with desired temperature profile **230**. For example, desired temperature profile **230** may indicate desired temperature **232** for location **208** and desired temperature **234** for location **220**. Desired temperature **232** may be referred to as a first desired temperature and desired temperature **234** may be referred to as a second desired temperature.

Controller **226** may be configured to receive information from temperature sensors **206** and **218** identifying temperatures **212** and **224** at locations **208** and **220**, respectively. Controller **226** may be configured to compare temperatures **212** and **224** at locations **208** and **220** to desired temperatures **232** and **234**, respectively. Controller **226** may then distribute the processing of workload **228** between processors **202** and **214** such that workload **132** is processed in an appropriate manner and such that the heat generated by processors **202** and **214** causes temperatures **212** and **224** of locations **208** and **220** to match desired temperatures **232** and **234**, respectively.

Controller **226** may be configured to change the portions of workload **228** processed by processor **202** and processor **214** to increase and decrease temperatures **212** and **224** at locations **208** and **220**, respectively. For example, without limitation, controller **226** may be configured to change the processing of workload **228** by moving threads and clocking between processor **202** and processor **214** to achieve and maintain desired temperature profile **230**.

For example, controller **226** may be configured to increase temperature **224** at location **220** by moving the processing of a portion of workload **228** from processor **202** at location **208** to processor **214** at location **220**. In this case, more heat may be generated by processor **214**, causing temperature **224** at location **220** to be increased. Less heat may be generated by processor **202**, causing temperature **212** at location **208** to be reduced.

As another example, controller **226** may be configured to increase temperature **224** at location **220** by duplicating the processing of a portion of workload **228** by processor **202** at location **208** by processor **214** at location **220**. In this case,

temperature **224** at location **220** may be increased due to the increased processing by processor **214** without reducing temperature **212** at location **208**. For example, without limitation, data processing results provided by the first one of processor **202** or processor **214** to complete processing the portion of workload **228** may be used.

5 Temperature controlled system **200** also may include thermoelectric device **236** at location **208** and thermoelectric device **238** at location **220**. Thermoelectric device **236** may be referred to as a first thermoelectric device. Thermoelectric device **238** may be referred to as a second thermoelectric device. In this case, controller **226** may be configured to control thermoelectric devices **236** and
10 **238** along with the processing of workload **228** by processors **202** and **214** in an integrated manner to achieve and maintain desired temperatures **232** and **234** at locations **208** and **220**, respectively.

 Temperature controlled system **200** also may include heat flow control device **240**. For example, without limitation, heat flow control device **240** may be
15 located at one or more of location **208** and location **220**, between location **208** and location **220**, or both. Heat flow control device **240** may be configured and positioned to control the flow of heat between location **208** and location **220**, within location **208** or location **220**, or both, in a desired manner.

 The illustrations of **Figure 1** and **Figure 2** are not meant to imply physical
20 or architectural limitations to the manner in which different illustrative embodiments may be implemented. Other components in addition to and/or in place of the ones illustrated may be used. Some components may be unnecessary in some illustrative 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
25 implemented in different illustrative embodiments.

 For example, illustrative embodiments may be used to control the temperature at more than two locations on a structure or in a temperature controlled system. Each location on such a structure or in such a temperature controlled system may include any appropriate combination of processors, temperature sensitive devices, thermoelectric devices, and heat flow control devices. Different locations on such a
30 structure or in such a temperature controlled system may include the same or different combinations of processors, temperature sensitive devices, thermoelectric devices, and heat flow control devices.

Turning to **Figure 3**, an illustration of a temperature controlled structure is depicted in accordance with an illustrative embodiment. In this example, structure **300** is an example of one implementation of structure **100** in **Figure 1**. In this example, structure **300** is a generic three-dimensional block structure comprising cubic blocks. Illustrative embodiments may be implemented and used in other appropriate three-dimensional and two-dimensional structures. For example, without limitation, illustrative embodiments may be implemented in three-dimensional structures with geodesic or other geometries.

Structure **300** includes block **302**. Block **302** has a number of faces **304**. Each of faces **304** of block **302** may correspond to a different location on structure **300**.

Temperature sensors may be implemented in any appropriate manner on one or more faces **304** of block **302**. These temperature sensors may be configured to identify the temperatures at faces **304** of block **302**. Processors also may be implemented in any appropriate manner on one or more faces **304** of block **302**. Alternatively, or in addition, processors may be implemented in one or more blocks **306** adjacent to faces **304** of block **302**.

Temperature sensitive devices may be implemented in blocks **306** adjacent to faces **304** of block **302**. In this case, the temperatures identified by temperature sensors on faces **304** of block **302** may correspond to the temperatures of the devices implemented in blocks **306** adjacent to block **302**. Block **302** and blocks **306** may be made in any appropriate manner of any appropriate material. For example, without limitation, block **302** and blocks **306** may be implemented on integrated circuit dies to create a consistent and controllable thermal interface between block **302** and blocks **306**. Any appropriate interface may be provided for communications between devices implemented in blocks **306** and processors implemented on faces **304** of block **302**.

Data processing performed by the processors on faces **304** of block **302**, in blocks **306** adjacent to block **302**, or both, may be controlled to control the temperatures at faces **304** of block **302** and thus the temperatures of the temperature sensitive devices in blocks **306** adjacent to faces **304** of block **302**.

Turning to **Figure 4**, an illustration of processors at locations on a fuel tank is depicted in accordance with an illustrative embodiment. In this example, fuel tank **400** is an example of one implementation of structure **100** in **Figure 1**. For

example, without limitation, fuel tank **400** may be an example of structure **100** on aircraft **102** in **Figure 1**.

Fuel tank **400** may be configured to contain any appropriate fuel. For example, without limitation, fuel tank **400** may be configured to contain fuel for an aircraft. In this example, side **402** of fuel tank **400** is cut away to show level **404** of fuel **406** in fuel tank **400**.

Processors **408**, **410**, and **412** may be positioned at various locations on side **402** of fuel tank **400**. For example, processors **408**, **410**, and **412** may be positioned on side **402** of fuel tank **400** so that processors **408**, **410**, and **412** may be cooled by fuel **406** in fuel tank **400**. Alternatively, processors **408**, **410**, and **412** may be positioned on side **402** of fuel tank **400** so that the temperature of fuel **406** in fuel tank **400** may be controlled using the heat produced by processors **408**, **410**, and **412**. In any case, the processing of a workload by processors **408**, **410**, and **412** may be controlled and changed in an appropriate manner as level **404** of fuel **406** in fuel tank **400** changes to maintain fuel **406**, processors **408**, **410**, and **412**, or both at desired temperatures.

Turning to **Figure 5**, an illustration of controlling a temperature signature of an aircraft is depicted in accordance with an illustrative embodiment. In this example, aircraft **500** may be an example of one implementation of aircraft **102** in **Figure 1**.

Processors **502** may be positioned at a plurality of different locations on aircraft **500**. The processing of a workload by processors **502** at the various locations on aircraft **500** may be controlled to control the temperatures at the various locations on aircraft **500** in the manner described above. For example, without limitation, the temperatures of various locations on aircraft **500** may be controlled in this manner to make it more difficult for aircraft **500** to be detected or identified by sensor **504**.

Sensor **504** may be configured to detect and identify aircraft **500** by the heat signature produced by aircraft **500**. Moving the processing of a workload between processors **502** at various different locations on aircraft **500** may allow individual ones of processors **502** more time to cool between operating cycles, thereby keeping the heat signature of aircraft **500** lower. Aircraft **500** having a lower heat signature may be more difficult to detect by sensor **504**.

Alternatively, or in addition, the processing of a workload by processors **502** on aircraft **500** may be controlled to mask or change the heat signature of aircraft

500 in other ways. For example, without limitation, the processing of a workload by processors **502** on aircraft **500** may be controlled to create a heat signature for aircraft **500** that more closely resembles a type of aircraft other than aircraft **500**. Changing the heat signature of aircraft **500** may make it more difficult for sensor **504** to identify aircraft **500** correctly, even when aircraft **500** is detected by sensor **504**.

Turning to **Figure 6**, an illustration of a flowchart of a process for controlling temperatures of a plurality of locations on a structure is depicted in accordance with an illustrative embodiment. For example, without limitation, process **600** may be implemented in controller **130** to control temperatures **112** at plurality of locations **108** on structure **100** in **Figure 1**.

Process **600** may begin by identifying the temperature at each of a plurality of locations on a structure (operation **602**). For example, the temperature at each of the plurality of locations may be identified using an appropriate temperature sensor at each of the plurality of locations. A desired temperature for each of the plurality of locations then may be identified (operation **604**). For example, the desired temperature for each of the plurality of locations may be identified in a desired temperature profile for the structure. The processing of a workload by a processor at each of the plurality of locations then may be controlled to control the temperature at each of the plurality of locations to match the corresponding desired temperature for each of the plurality of locations (operation **606**), with the process terminating thereafter.

Turning to **Figure 7**, an illustration of a flowchart of a process for controlling the temperature of a location on a structure is depicted in accordance with an illustrative embodiment. For example, without limitation, process **700** may be implemented in controller **130** to control the temperature at one of locations **108** on structure **100** in **Figure 1**.

Process **700** may begin by identifying the temperature of a location (operation **701**). For example, the temperature of the location may be identified using an appropriate temperature sensor at the location. A desired temperature for the location may be identified (operation **702**).

It then may be determined whether the temperature of the location identified at operation **701** is less than the desired temperature for the location identified at operation **702** (operation **704**). If the temperature of the location is less than the desired temperature of the location, processing of a workload by a processor at the

location may be increased (operation **706**) to increase the temperature at the location to the desired temperature, with the process terminating thereafter.

In response to a determination at operation **704** that the temperature at the location is not less than the desired temperature for the location, it may be determined whether the temperature at the location is greater than the desired temperature for the location (operation **708**). If the temperature at the location is greater than the desired temperature for the location, processing of the workload by a processor unit at the location may be reduced (operation **710**) to reduce the amount of heat generated by the processor at the location, with the process terminating thereafter.

If the temperature at the location is not greater than or less than the desired temperature, the process may terminate without changing the processing of the workload performed at the location. Process **700** may be repeated continuously or periodically to maintain the temperature of the location at the desired temperature for the location.

The flowcharts and block diagrams in the different depicted embodiments illustrate the architecture, functionality, and operation of some possible implementations of apparatuses and methods in illustrative embodiments. In this regard, each block in the flowcharts or block diagrams may represent a module, segment, function, and/or a portion of an operation or step. For example, one or more of the blocks may be implemented as program code, in hardware, or a combination of program code and hardware. When implemented in hardware, the hardware may, for example, take the form of integrated circuits that are manufactured or configured to perform one or more operations in the flowcharts or block diagrams.

In some alternative implementations of an illustrative embodiment, the function or functions noted in the blocks may occur out of the order shown in the figures. For example, in some cases, the functions of two blocks shown in succession may be executed substantially concurrently, or the functions may sometimes be performed in the reverse order, depending upon the functionality involved. Also, other functions may be added in addition to the functions illustrated in a flowchart or block diagram.

The description of the different illustrative embodiments has been presented for purposes of illustration and description and is not intended to be exhaustive or to limit the embodiments in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. Further, different

illustrative embodiments may provide different benefits as compared to other illustrative 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
5 embodiments with various modifications as are suited to the particular use contemplated.

CLAIMS:

What is claimed is:

- 5 1. A method of controlling temperatures (112) of a plurality of locations (108) on a structure (100), comprising:
identifying (602) a temperature (212) at each of the plurality of locations (108);
identifying (604) a desired temperature (232) for the each of the plurality of
locations (108); and
10 controlling (606) processing of a workload (132) by a processor (202) at the each of the plurality of locations (108) to control the temperature (212) at the each of the plurality of locations (108) to match a corresponding desired temperature for the each of the plurality of locations (108).
- 15 2. The method of claim 1, wherein the desired temperature (232) for the each of the plurality of locations (108) is selected from a range of temperatures and a temperature threshold.
3. The method of claim 1, further comprising controlling a thermoelectric device
20 (236) at the each of the plurality of locations (108) to control the temperature (212) at the each of the plurality of locations (108) to match the corresponding desired temperature for the each of the plurality of locations (108).
4. The method of claim 1, wherein:
25 the temperature (212) at the each of the plurality of locations (108) is the temperature (212) of a device (204) other than the processor (202) at the each of the plurality of locations (108) and the desired temperature (232) for the each of the plurality of locations (108) is the desired temperature (232) for the device (204) other than the processor (202) at the each of the plurality of locations (108); and
30 the device (204) other than the processor (202) is selected from an electrical device (117), an electromechanical device (118), a micro-electromechanical device (119), an inertial measurement unit (120), a software defined radio (122), and a crystal oscillator (124).

5. The method of claim 4, wherein the processor (202) at one of the plurality of locations (108) comprises a signal processor (210) configured to process a signal associated with the device (204) other than the processor (202) at the one of the plurality of locations (108).

6. The method of claim 1, wherein controlling processing of the workload (132) is performed by the processor (202) at one of the plurality of locations (108).

7. The method of claim 1, wherein controlling processing of the workload (132) comprises changing processing of a portion of the workload (132) from a first processor (202) at a first one of the plurality of locations (108) to a second processor (214) at a second one of the plurality of locations (108) to reduce the temperature (212) at the first one of the plurality of locations (108) and to increase the temperature (224) at the second one of the plurality of locations (108).

8. The method of claim 1, wherein controlling processing of the workload (132) comprises duplicating at a second processor (214) at a second one of the plurality of locations (108) processing of a portion of the workload (132) processed by a first processor (202) at a first one of the plurality of locations (108) to increase the temperature (224) at the second one of the plurality of locations (108) without reducing the temperature (212) at the first one of the plurality of locations (108).

9. The method of claim 1, wherein the structure (100) is an aircraft (102).

10. An apparatus, comprising:
a temperature sensor (206) at each of a plurality of locations (108) on a structure (100), wherein each temperature sensor is configured to identify a temperature (212) at a corresponding one of the plurality of locations (108);
a processor (202) at the each of the plurality of locations (108); and
a controller (130) configured to receive information (115) identifying the temperature (212) at the each of the plurality of locations (108) from the temperature sensor (206) at the each of the plurality of locations (108) and to control processing of a

workload (132) by the processor (202) at the each of the plurality of locations (108) to control the temperature (212) at the each of the plurality of locations (108) to match a desired temperature (232) for the each of the plurality of locations (108).

5 11. The apparatus of claim 10, wherein the desired temperature (232) for the each of the plurality of locations (108) is selected from a range of temperatures and a temperature threshold.

10 12. The apparatus of claim 10 further comprising a thermoelectric device (236) at the each of the plurality of locations (108) and wherein the controller (130) is configured to control the thermoelectric device (236) at the each of the plurality of locations (108) to control the temperature (212) at the each of the plurality of locations (108) to match a corresponding desired temperature for the each of the plurality of locations (108).

15 13. The apparatus of claim 10 further comprising a device (204) other than the processor (202) at the each of the plurality of locations (108), wherein the temperature (212) at the each of the plurality of locations (108) is the temperature (212) of the device (204) other than the processor (202) at the each of the plurality of locations (108) and the desired temperature (232) for the each of the plurality of locations (108) is the
20 desired temperature (232) for the device (204) other than the processor (202) at the each of the plurality of locations (108), and wherein the device (204) other than the processor (202) is selected from an electrical device (117), an electromechanical device (118), a micro-electromechanical device (119), an inertial measurement unit (120), a software defined radio (122), and a crystal oscillator (124).

25 14. The apparatus of claim 13, wherein the processor (202) at one of the plurality of locations (108) comprises a signal processor (210) configured to process a signal associated with the device (204) other than the processor (202) at the one of the plurality of locations (108).

30 15. The apparatus of claim 10, wherein the controller (130) is implemented in the processor (202) at one of the plurality of locations (108).

16. The apparatus of claim 10, wherein the controller (130) is configured to change processing of a portion of the workload (132) from a first processor (202) at a first one of the plurality of locations (108) to a second processor (214) at a second one of the plurality of locations (108) to reduce the temperature (212) at the first one of the plurality of locations (108) and to increase the temperature (224) at the second one of the plurality of locations (108).

17. The apparatus of claim 10, wherein the controller (130) is configured to duplicate at a second processor (214) at a second one of the plurality of locations (108) processing of a portion of the workload (132) processed by a first processor (202) at a first one of the plurality of locations (108) to increase the temperature (224) at the second one of the plurality of locations (108) without reducing the temperature (212) at the first one of the plurality of locations (108).

18. The apparatus of claim 10, wherein the structure (100) is an aircraft (102).

19. A method of controlling a temperature (212) at a location (208) on a structure (100), comprising:

identifying the temperature (212) at the location (208);

identifying a desired temperature (232) for the location (208); and

controlling processing of a workload (132) by a processor (202) at the location (208) to increase the temperature (212) at the location (208) to match the desired temperature (232) for the location (208).

20. The method of claim 19 further comprising controlling a thermoelectric device (236) at the location (208) to control the temperature (212) at the location (208).

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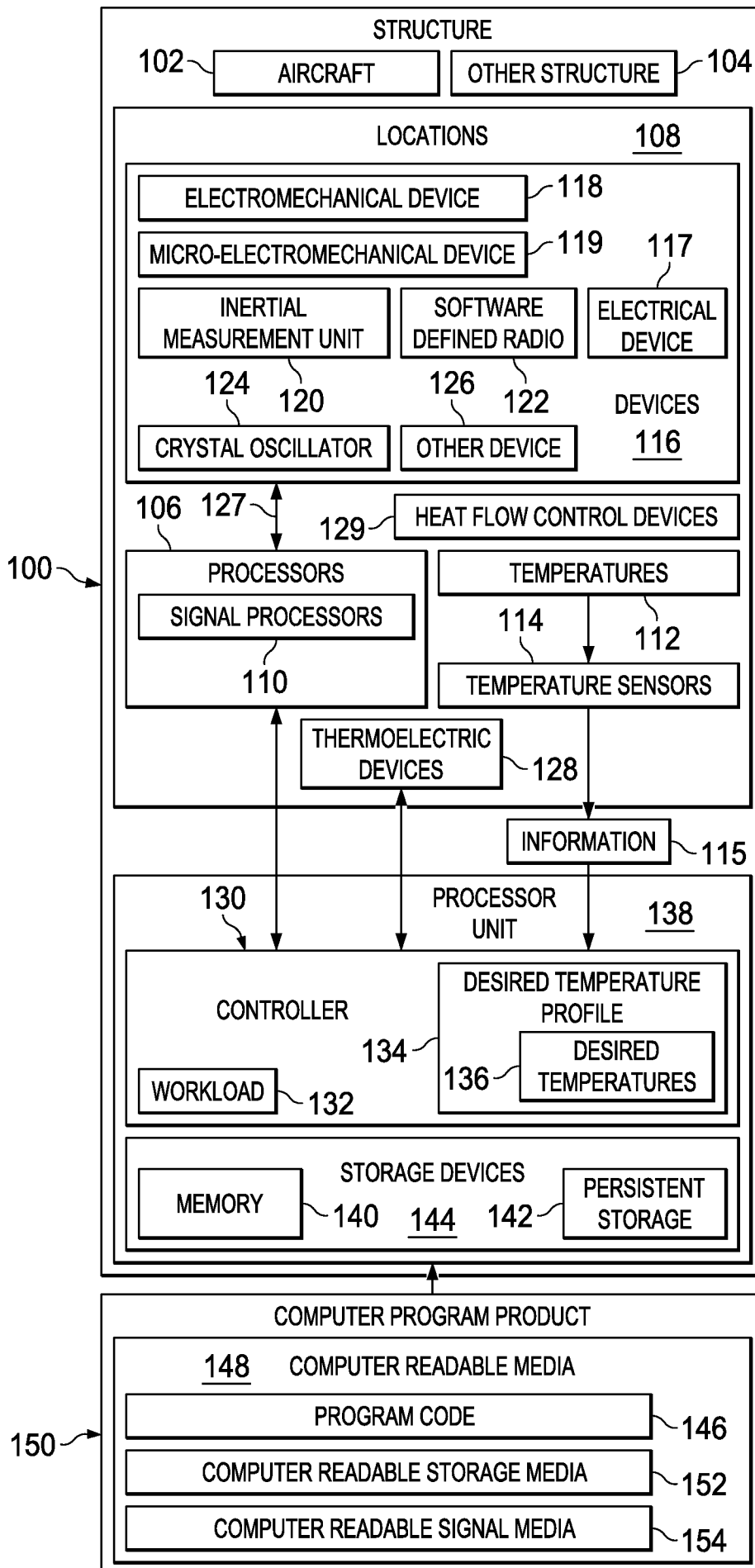


FIG. 1

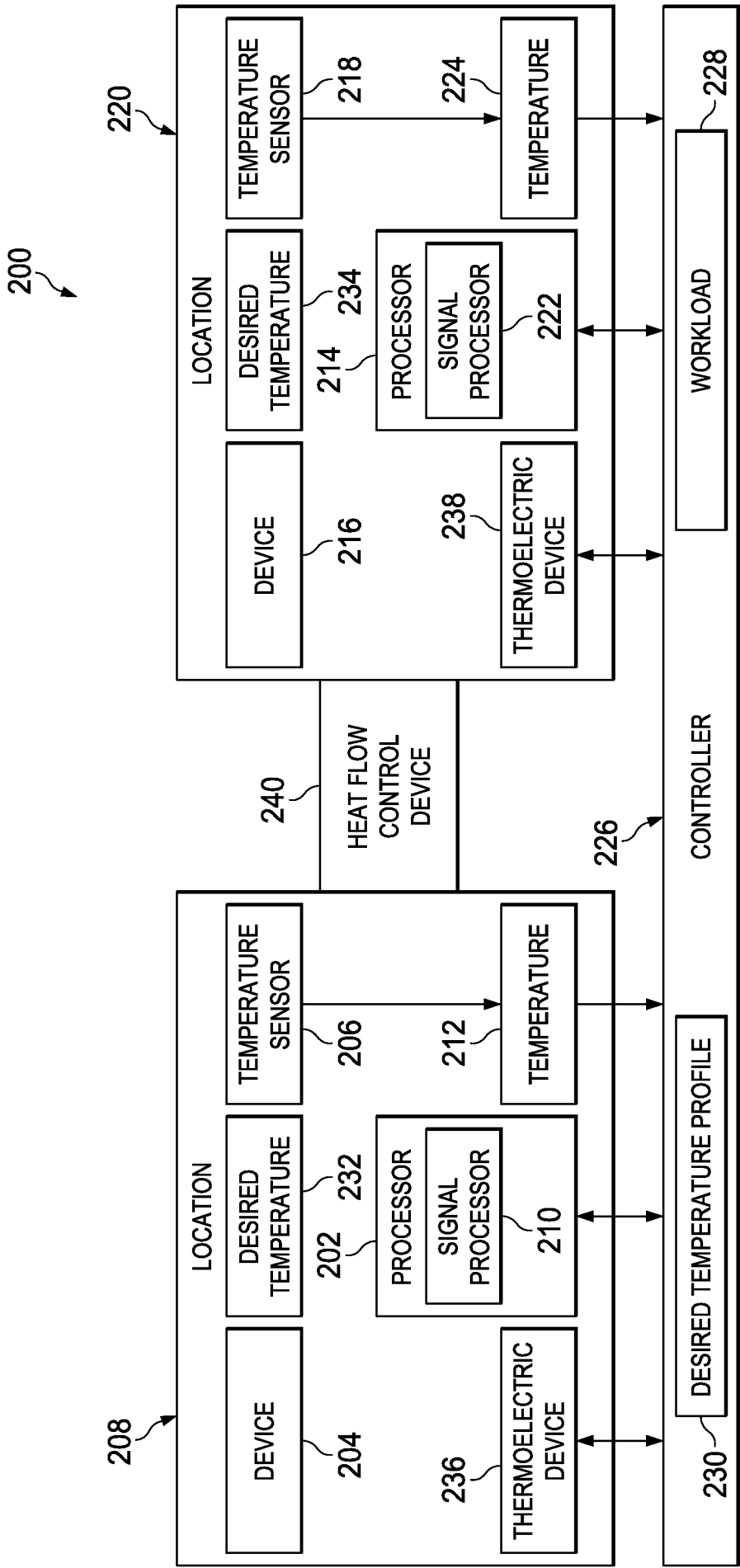


FIG. 2

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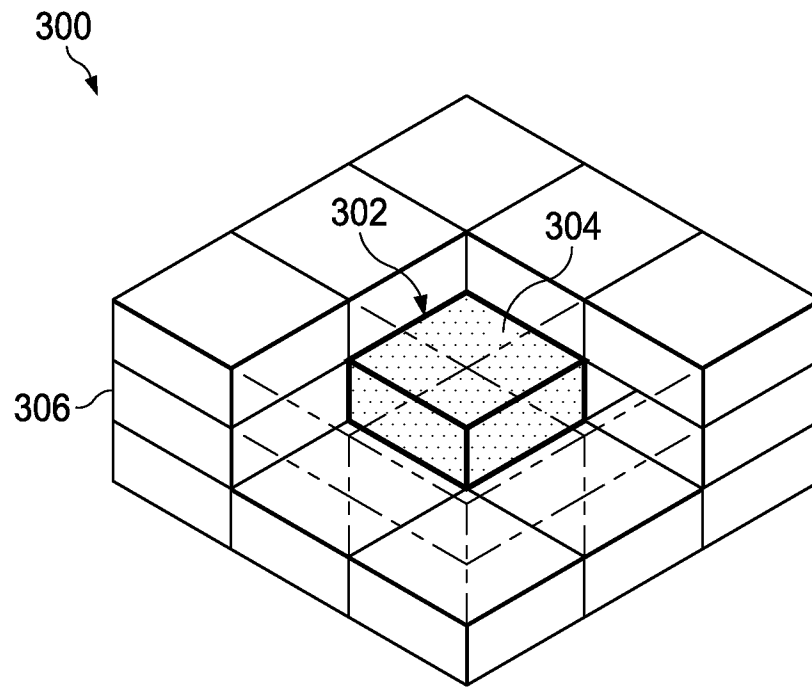


FIG. 3

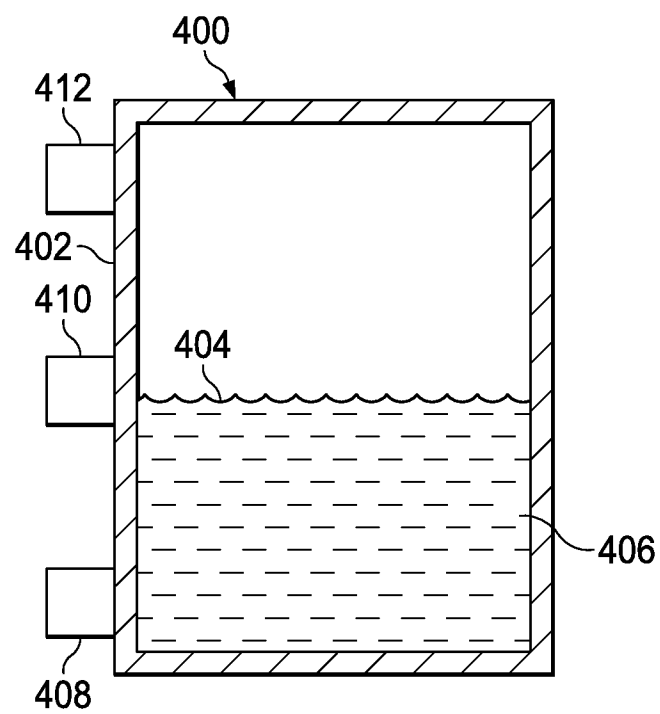


FIG. 4

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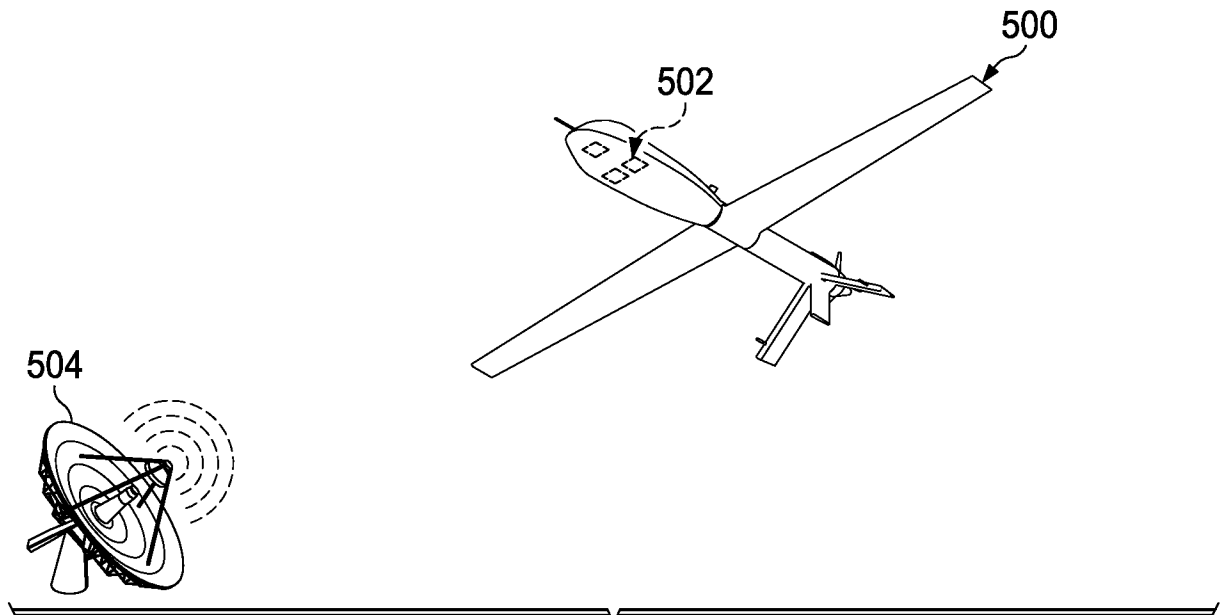


FIG. 5

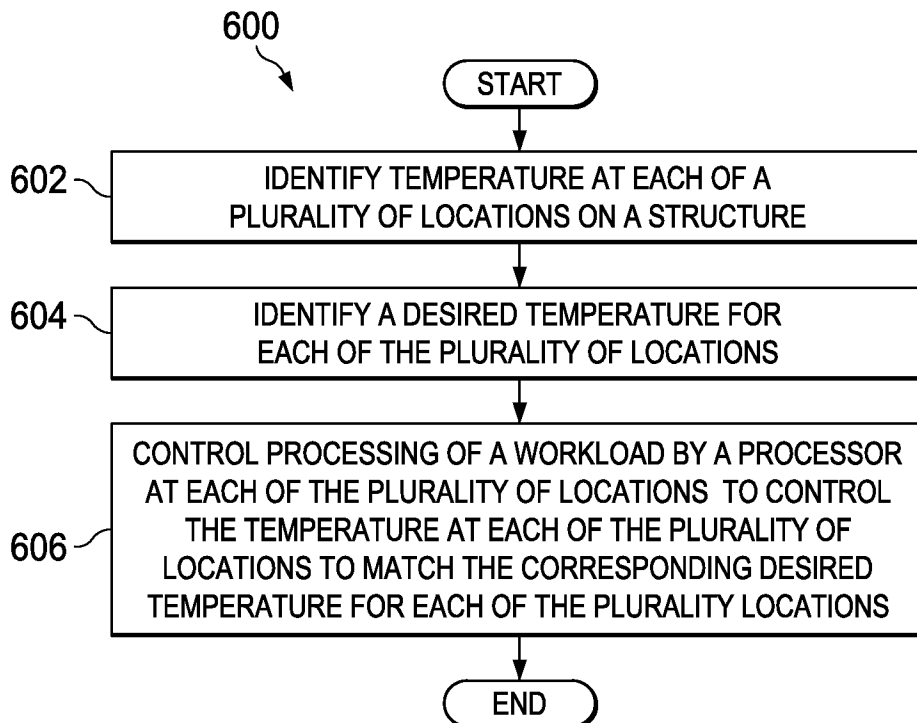


FIG. 6

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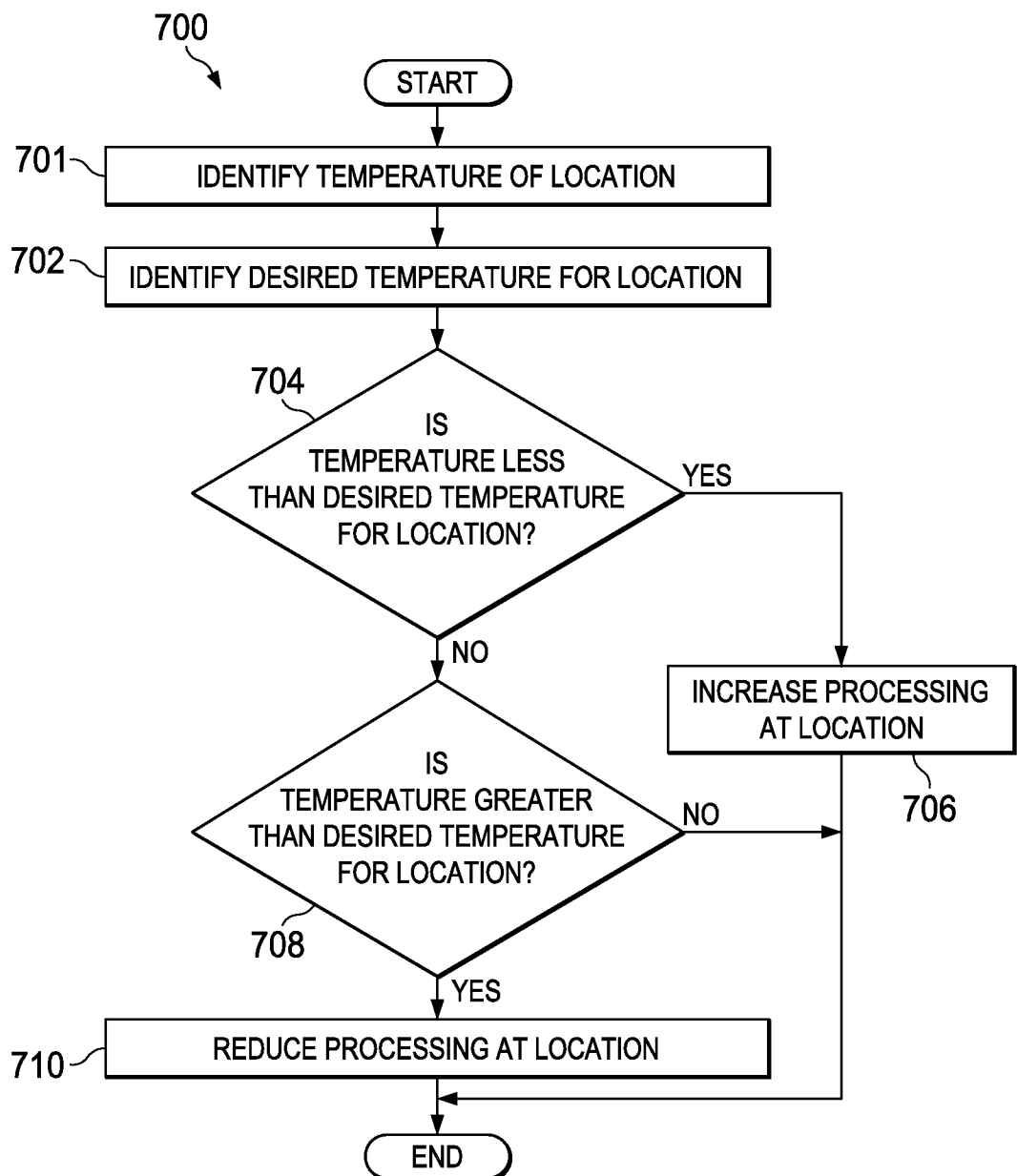


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/011562

A. CLASSIFICATION OF SUBJECT MATTER INV. G05D23/19 G06F1/20 G06F9/50 ADD.		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) G05D G06F F24D F24F		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2012/158190 A1 (BELADY CHRISTIAN L [US] ET AL) 21 June 2012 (2012-06-21)	1-8, 10-17, 19,20
Y	the whole document	9,18
Y	US 2008/282252 A1 (PRASANNA DEEPAK [US] ET AL) 13 November 2008 (2008-11-13)	9,18
A	paragraphs [0002], [0044]; figure 4	1-8, 10-17, 19,20
X	US 2009/099705 A1 (HARRIS SCOTT C [US]) 16 April 2009 (2009-04-16)	1-3,6,7, 10-12, 15,16
Y	the whole document	9,18
A		4,5,8, 13,14, 17,19,20
----- -/-		
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search		Date of mailing of the international search report
9 April 2015		16/04/2015
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Vaño Gea, Joaquín

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2015/011562

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 091 255 A (GODFREY GARY M [US]) 18 July 2000 (2000-07-18)	1,2,6,7, 10,11, 15,16
Y	column 4, line 52 - column 5, line 60;	9,18
A	figures 4-6 -----	3-5,8, 12-14, 17,19,20

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2015/011562

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2012158190	A1	21-06-2012	NONE
US 2008282252	A1	13-11-2008	NONE
US 2009099705	A1	16-04-2009	NONE
US 6091255	A	18-07-2000	NONE