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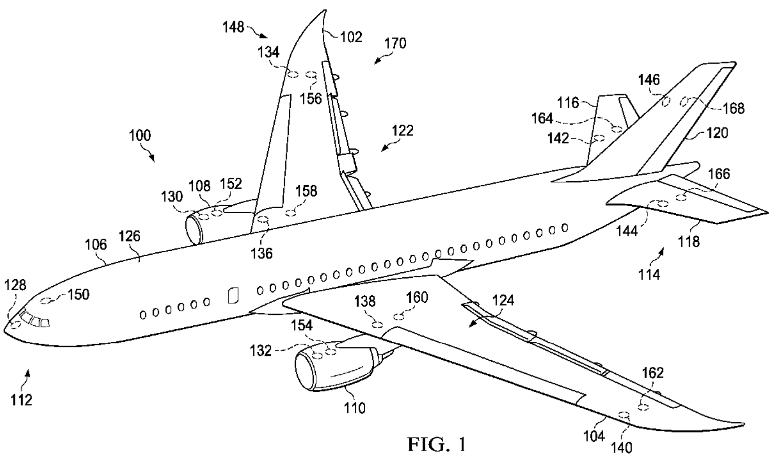

FIG. 1

(57) **Abstract**: An ice detection system (122) comprising a first group of sensors (148) and a second group of sensors (170). The first group of sensors (148) is located in a first group of locations on an aircraft (100). The first group of sensors (148) in the first group of locations is configured to detect a first type of icing condition for the aircraft (100). The second group of sensors (170) is located in a second group of locations on the aircraft (100). The second group of sensors (170) in the second group of locations is configured to detect a second type of icing condition for the aircraft (100).

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SUPERCOOLED LARGE DROP ICING CONDITION DETECTION SYSTEM

TECHNICAL FIELD

The present disclosure relates generally to detecting icing conditions and, in particular, to icing conditions for an aircraft. Still more particularly, the present disclosure relates to detecting supercooled water drops, including supercooled large drops (SLD).

BACKGROUND

In aviation, icing on an aircraft may occur when the atmospheric conditions lead to the formation of ice on the surfaces of the aircraft. Further, this ice also may occur within the engine. Ice forming on the surfaces of the aircraft, on inlets of an engine, and other locations are undesirable and potentially unsafe for operating the aircraft.

Icing conditions may occur when drops of supercooled liquid water are present. In these illustrative examples, water is considered to be supercooled when the water is cooled below the stated freezing point for water but is still in a liquid form. Icing conditions may be characterized by the size of the drops, the liquid water content, air temperature, and other parameters. These parameters may affect the rate and extent at which ice forms on an aircraft.

When icing occurs, the aircraft does not operate as desired. For example, ice on the wing of an aircraft will cause the aircraft to stall at a lower angle of attack and have an increased drag.

Aircraft may have mechanisms to prevent icing, remove ice, or some combination thereof to handle these icing conditions. For example, aircraft may include icing detection, prevention, and removal systems. Ice may be removed using deicing fluid, infrared heating, and other suitable mechanisms.

Aircraft may be certified for operating during different types of icing conditions. Some aircraft may be certified to operate in normal icing conditions, but not those that include supercooled large drops. Currently used sensors are unable to differentiate between normal and supercooled large drop icing conditions.

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

SUMMARY

According to a first aspect, the present disclosure provides an ice detection system for detecting a plurality of in-flight icing conditions comprising: a first group of sensors located in a first group of locations on an aircraft, wherein the first group of sensors in the first group of locations is configured to detect a first type of icing condition for the aircraft, wherein the first group of locations is selected to be on first areas of the aircraft where collision with water drops of a first size range is expected to occur more frequently during flight of the aircraft than collision with water drops of a second size range, and wherein the first type of icing condition is associated with water drops of the first size range; and a second group of sensors located in a second group of locations on the aircraft, wherein the second group of sensors in the second group of locations is configured to detect a second type of icing condition for the aircraft, wherein the second group of locations is selected to be on second areas of the aircraft where collision with water drops of the second size range is expected to occur more frequently during flight of the aircraft than collision with water drops of the first size range, wherein the second type of icing condition is associated with water drops of the second size range, and wherein the first size range is less than the second size range; and a processor unit configured to monitor in-flight data from the first group of sensors and responsive to the first group of sensors detecting the first type of icing condition for the aircraft, perform a first action in response to the data indicating a presence of at least one of the first type of icing condition, wherein the first action comprises generating, during flight, a first alert on a flight deck interface for the aircraft, wherein the processor unit is further to monitor in-flight data from the second group of sensors and responsive to the second group of sensors detecting the second type of icing condition for the aircraft, perform a second action in response to the data indicating a presence of at least one of the first type of icing condition, wherein the second action comprises generating, during flight, a second alert on the flight deck interface for the aircraft.

According to a secon aspect, the present invention provides a method for detecting a plurality of in-flight icing conditions for an aircraft, the method comprising: monitoring, during flight of the aircraft, a first group of sensors located in a first group of locations on the aircraft for first data indicating a first type of icing condition in the icing conditions for the aircraft, wherein the first group of locations is selected to be on first areas of the aircraft where collision with water drops of a first size range is expected to occur more frequently than collision with water drops of a second size range, and wherein the first type of icing condition is associated

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with water drops of the first size range; monitoring, during flight of the aircraft, a second group of sensors located in a second group of locations on the aircraft for second data indicating a second type of icing condition in the icing conditions for the aircraft, wherein the second group of locations is selected to be on second areas of the aircraft where collision with water drops of the second size range is expected to occur more frequently than collision with water drops of the first size range, wherein the second type of icing condition is associated with water drops of the second size range, and wherein the first size range is less than the second size range; and initiating a first action in response to detecting the first type of icing condition from the first data, wherein the first action comprises generating, during flight, a first alert on a flight deck interface for the aircraft, and initiating a second action in response to detecting the second type of icing condition from the second data, wherein the second action comprises generating, during flight, a second alert on the flight deck interface for the aircraft.

In one illustrative embodiment, an ice detection system comprises a first group of sensors and a second group of sensors. The first group of sensors is located in a first group of locations on an aircraft. The first group of sensors in the first group of locations is configured to detect a first type of icing condition for the aircraft. The second group of sensors is located in a second group of locations on the aircraft. The second group of sensors in the second group of locations is configured to detect a second type of icing condition for the aircraft.

In another illustrative embodiment, an ice detection system comprises a group of sensors and a processor unit. The group of sensors is located in a group of locations on a surface of an aircraft. The group of sensors in the group of locations is configured to detect a supercooled large drop icing condition on the surface of the aircraft. The processor unit is configured to monitor data from the group of sensors and perform an action in response to the data indicating a presence of the supercooled large drop icing condition on the surface of the aircraft.

In yet another illustrative embodiment, a method for detecting icing conditions for an aircraft is provided. A first group of sensors located in a first group of locations on the aircraft is monitored for first data indicating a first type of icing condition in the icing conditions for the aircraft. A second group of sensors located in a second group of locations on the aircraft is monitored for second data indicating a second type of icing condition in the icing conditions for the aircraft. An action is initiated in response to detecting at least one of the first type of icing condition from the first data and the second type of icing condition from the second data.

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

BRIEF DESCRIPTION OF THE DRAWINGS

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 features thereof will best be understood by reference to the following detailed description of an illustrative embodiment of the present disclosure when read in conjunction with the accompanying drawings, wherein:

Figure 1 is an illustration of an aircraft in accordance with an illustrative embodiment;

Figure 2 is an illustration of components in an ice detection system in accordance with an illustrative embodiment;

Figure 3 is an illustration of an airfoil in accordance with an illustrative embodiment;

Figure 4 is an illustration of a block diagram of a design environment in accordance with an illustrative embodiment;

Figure 5 is an illustration of a flowchart of a process for detecting icing conditions for an aircraft in accordance with an illustrative embodiment;

Figure 6 is an illustration of a flowchart of a process for designing an ice detection system in accordance with an illustrative embodiment;

Figure 7 is an illustration of a data processing system in accordance with an illustrative embodiment;

Figure 8 is an illustration of an aircraft manufacturing and service method in accordance with an illustrative embodiment; and

Figure 9 is an illustration of an aircraft in which an illustrative embodiment may be implemented.

DETAILED DESCRIPTION

The illustrative embodiments recognize and take into account a number of different considerations. For example, the different illustrative embodiments recognize and take into account that currently used systems for detecting icing conditions on an aircraft are unable to detect all of the different types of icing conditions that may occur. For example, the different illustrative embodiments recognize and take into account that as the size of the drops of water increase, currently used sensors may not detect icing caused by those drops of water. The different illustrative embodiments recognize and take into account that the locations at which different sizes of drops will collide with an airfoil during operation of an aircraft change depending on the size of the drops.

The illustrative embodiments recognize and take into account that it is desirable to detect different types of icing conditions that may be caused by different sizes of drops of water. In particular, the illustrative embodiments recognize and take into account that it may be desirable to detect drops of supercooled liquid water. These drops may take the form of supercooled large drops.

Thus, one or more illustrative embodiments provide a method and apparatus for detecting ice. In one illustrative embodiment, an ice detection system comprises a first group of sensors and a second group of sensors. The first group of sensors is located in a first group of locations on an aircraft. The first group of sensors in the first group of locations is configured to detect a first type of icing condition for the aircraft.

A second group of sensors is located in a second group of locations on the aircraft. The second group of sensors in the second group of locations is configured to detect a second type of icing condition for the aircraft. These two types of icing conditions are examples of icing conditions that may occur in different locations on the aircraft.

With reference now to the figures and, in particular, with reference to **Figure 1**, an illustration of an aircraft is depicted in accordance with an illustrative embodiment. In this illustrative example, aircraft **100** has wing **102** and wing **104** attached to fuselage **106.** Aircraft **100** also includes engine **108** attached to wing **102** and engine **110** attached to wing **104.**

Fuselage **106** has nose section **112** and tail section **114.** Nose section **112** is the forward part of aircraft **100,** while tail section **114** is the aft part of aircraft **100.** Horizontal stabilizer **116**, horizontal stabilizer **118,** and vertical stabilizer **120** are attached to tail section **114** of fuselage **106.**

Aircraft **100** is an example of an aircraft in which ice detection system **122** may be implemented in accordance with an illustrative embodiment. In these illustrative examples, ice detection system **122** comprises sensors **124** on surface **126** of aircraft **100.** As depicted, sensors **124** include sensors **128, 130**, **132**, **134**, **136**, **138**, **140**, **142**, **144**, and **146.** These sensors form first group of sensors **148** in sensors **124** for ice detection system **122.**

Additionally, sensors **124** also include sensors **150, 152, 154, 156**, **158**, **160**, **162**, **164**, **166**, and **168.** These sensors form second group of sensors **170** in sensors **124** for ice detection system **122.** In the illustrative examples, sensors **124** may detect when ice is formed on the sensors.

As depicted, first group of sensors **148** is in a first group of locations on surface **126** of aircraft **100.** First group of sensors **148** is configured to detect a first type of icing condition for aircraft **100.** Second group of sensors **170** is in a second group of locations on surface **126** of aircraft **100.** Second group of sensors **170** in the second locations is configured to detect a second type of icing condition for aircraft **100.**

In these illustrative examples, these icing conditions may occur at different altitudes and temperatures that cause the formation of ice on aircraft **100**. For example, icing conditions may be present at an altitude from about sea level to about 30,000 feet when the temperature is from about -40 degrees Celsius to about 0 degrees Celsius. Of course, other altitudes and temperatures may be present at which ice may be formed from water that contacts surface **126** of aircraft **100**. Icing conditions also may be present when the liquid water content in the drops is from about 0.4 to about 2.8 grams/cubic meter at the altitude and temperature range described above.

As depicted, the first type of icing condition and the second type of icing condition are caused by drops of water of different sizes. Although the altitude, temperature, and liquid water content ranges may be the same, one difference between the first and second types of icing conditions is the drop size.

In these illustrative examples, the first type of icing condition may be present when the size of the drops is from about 0.00465 millimeters in diameter to about 0.111 millimeters in diameter. Drops with these sizes may be referred to as normal drops. The second type of icing condition may be present when the size of the drops includes drops that have a diameter greater than about 0.111 millimeters. Drops having a size greater than about 0.111 millimeters may be referred to as large drops and, in particular, may be called supercooled large drops under the altitude, temperature, and liquid water content conditions described above. For example, the drops may have a diameter of a range from about 0.112 millimeters to about 2.2 millimeters. In addition, the second type of icing condition may include drops that are 0.111 millimeters or less when drops greater than 0.111 millimeters are present.

As depicted, first group of sensors **148** in the first group of locations may be configured to detect ice formed by drops of water in a first number of sizes. Second group of sensors **170** in the second group of locations is configured to detect ice formed by drops of water having a second number of sizes. In these illustrative examples, the first number of sizes is smaller than the second number of sizes.

For example, the first number of sizes may be from about 0.00465 millimeters in diameter to about 0.111 millimeters in diameter. The second number of sizes may be from about 0.112 millimeters to about 2.2 millimeters in diameter.

The second number of sizes of the drops of water may be drops of water that are considered to be drops of supercooled water. These drops of supercooled water may be supercooled large drops (SLD). First group of sensors **148** is configured to detect drops of water that are not supercooled large drops in these illustrative examples. The type of icing condition detected by sensors **124** is based on the locations for sensors **124** on surface **126** of aircraft **100** in these illustrative examples.

In the illustrative examples, the first type of icing condition may be referred to as a normal icing condition. The second type of icing condition may be referred to as a supercooled large drop icing condition.

In these illustrative examples, sensors **124** are depicted as flush-mounted sensors. In other words, sensors **124** are substantially flush or planar with surface **126** of aircraft **100**. Sensors **124** may be implemented using all of the same type of sensors or different types of sensors. Further, other numbers of sensors **124** and locations of sensors **124** may be used in addition to or in place of those illustrated for aircraft **100** in **Figure 1.**

Although particular conditions and sizes for drops have been described for the first icing condition and the second icing condition, the different illustrative embodiments are not limited to the conditions and sizes depicted. For example, other altitudes and drop sizes may be used to define when drops of water are present for the first icing condition and the second icing condition.

However, while **Figure 1** illustrates embodiments using a twin-engine aircraft for example, the illustrative embodiments recognize and take into account that the information contained is also applicable to aircraft with different numbers of engines. Further, the illustrative example depicts aircraft **100** as a commercial aircraft. The different illustrative embodiments may be applied to other types of aircraft, such as military aircraft.

With reference now to **Figure 2**, an illustration of components in an ice detection system is depicted in accordance with an illustrative embodiment. In this illustrative example, ice detection system **122** further comprises processor unit **200.** Processor unit **200** is a hardware device configured to perform operations with respect to detecting icing conditions for aircraft **100.** These operations may be implemented in software, hardware, or a combination of the two.

As illustrated, processor unit **200** is connected to sensors **124.** In these illustrative examples, sensors **124** generate data **202.** Data **202** may indicate whether sensors **124** detect the formation of ice on surface **126** of aircraft **100.** Ice is detected by sensors **124** when ice forms on one or more of sensors **124.** Sensors **124** send data **202** to processor unit **200.**

In these illustrative examples, processor unit **200** is configured to monitor the data from first group of sensors **148** and second group of sensors **170.** Further, processor unit **200** is configured to perform an action in response to the data indicating a presence of one of the icing conditions. The particular type of icing condition detected depends on which group of sensors generating data indicates a presence of ice. In other words, the first icing condition, the second icing condition, or both the first icing condition and the second icing condition may be present depending on the data generated by sensors **124**.

The action may include at least one of generating an alert, generating a log entry, activating anti-icing system **204**, sending a report, and other suitable actions. As used herein, the phrase "at least one of", when used with a list of items, means different combinations of one or more of the listed items may be used and only one of each item in the list may be needed. For example, "at least one of item A, item B, and item C" may include, without limitation, item A, or item A and item B. This example also may include item A, item B, and item C, or item B and item C.

In these illustrative examples, the alert may be generated on flight deck interface **206** for aircraft **100**. Flight deck interface **206** is a display system located in the flight deck of aircraft **100**. The display system comprises a number of displays on which information may be displayed to operators. These displays are hardware devices in the illustrative examples.

As used herein, a "number", when used with reference to items, means one or more items. For example, "a number of displays" is one or more displays. The number of displays may include, for example, without limitation, a primary flight display, a navigation display, and other suitable types of displays.

Further, the log entry may be generated in flight management system **208**. Flight management system **208** is a computer system in aircraft **100**. This computer system may be comprised of a number of computers. When more than one computer is present in the computer system, those computers may be in communication with each other using a communications media, such as a local area network.

Processor unit **200** may send a report to flight management system **208**. Alternatively, the report may be sent to a remote location in addition to or in place of sending the report to flight management system **208**. In these illustrative examples, the report may include an indication of what type of icing condition or conditions is present. This report also may include a location of the sensor or sensors detecting the icing condition.

Another action that processor unit **200** may take is to initiate the operation of anti-icing system **204**. Anti-icing system **204** may be implemented using any currently available anti-icing system. Anti-icing system **204** may employ different types of mechanisms to remove or prevent the formation of ice on surface **126** of aircraft **100**. For example, anti-icing system **204** may employ mechanical systems, chemical systems, infrared heating systems, and other types of systems to remove ice, prevent the formation of ice, or both on surface **126** of aircraft **100**.

In these illustrative examples, sensors **124** may be configured in ice detection assemblies. For example, sensors **124** may be grouped as ice detection assemblies **220**, **222**, **224**, **226**, **228**, **230**, **232**, **234**, **236**, and **238**. Each sensor in an ice detection assembly may be configured to detect a particular type of icing condition. This type of grouping of sensors **124** may be used in selecting locations for sensors **124**. Of course, in some illustrative examples, sensors **124** may not be grouped in ice detection assemblies.

With reference now to **Figure 3**, an illustration of an airfoil is depicted in accordance with an illustrative embodiment. In this illustrative example, airfoil **300** is wing **104** seen taken along lines **3-3** in **Figure 2**. A flow of drops **301** with respect to airfoil **300** is illustrated. Locations where drops **301** collide with surface **302** are depicted in this illustrative example.

As depicted, sensor **138** and sensor **160** may be configured as ice detection assembly **230** on surface **302**. In this illustrative example, sensor **138** is a first sensor located in first location

304 while sensor **160** is a second sensor located in second location **306.**

In these illustrative examples, first location **304** is located in first region **308** and second location **306** is located in second region **310.** As depicted, first region **308** is further forward on airfoil **300** than second region **310.**

In these illustrative examples, first region **308** is comprised of a number of locations. This number of locations may be contiguous or non-contiguous with each other depending on the particular implementation. In this example, these locations are all contiguous. First region **308** is a region in which first drops **312** collide with surface **302** of airfoil **300** for aircraft **100.**

Second region **310** is also a number of locations that may be contiguous or non-contiguous with each other. In this example, these locations are non-contiguous. For example, a first portion of the number of locations may be in section **314,** while a second portion of the number of locations may be in section **316.** Second region **310** is a region in which second drops **318** collide with surface **302** of airfoil **300** for aircraft **100.** First drops **312** collide with surface **302** in first region **308** when a first type of icing condition is present. Second drops **318** collide with surface **302** in second region **310** when a second type of icing condition is present. In these illustrative examples, first region **308** is further forward on airfoil **300** as compared to second region **310.**

In these illustrative examples, sensor **138** in first location **304** is configured to detect the formation of ice when a first type of icing condition is present while sensor **160** in second location **306** is configured to detect the formation of ice when a second type of icing condition is present. In some cases, both types of icing conditions may be present at the same time.

In these illustrative examples, first drops **312** and second drops **318** are supercooled drops of water. These drops of water may be rain drops. The drops may have sizes ranging from about 0.00465 millimeters to about 2.2 millimeters in average diameter.

In these illustrative examples, normal drops are drops of water typically with sizes less than 0.111 millimeters in average diameter. These drops may freeze when colliding with first region **308** of surface **302** of airfoil **300.** Drops of water in freezing drizzle drops may have a diameter that is less than about 0.5 millimeters. These drops may freeze when colliding with second region **310** of surface **302** of airfoil **300.** Drops of freezing rain may have a diameter that is up to about 2.2 millimeters. These drops may freeze when colliding even further aft on second region **310** of surface **302** of airfoil **300.**

In these illustrative examples, freezing drizzle is drizzle that may freeze on contact with surface **302** of airfoil **300.** Freezing drizzle may have a diameter that is less than about 0.5 millimeters. Freezing rain is rain that may freeze when colliding with surface **302** of airfoil **300** and may have a diameter that is up to about 2.2 millimeters.

Drops of water may be supercooled in various environments, such as in stratiform and in cumulous clouds. However, supercooled large drops typically only form in cumulous clouds.

In these illustrative examples, first drops **312** may be, for example, normal supercooled drops. Normal supercooled drops are drops of supercooled water that may have a diameter from about 0.00465 millimeters to about 0.111 millimeters. As depicted, second drops **318** may be supercooled large drops. These drops may have a diameter with a size from about 0.112 millimeters to about 2.2 millimeters.

In these illustrative examples, the different sizes between first drops **312** and second drops **318** result in first drops **312** and second drops **318** colliding with surface **302** of airfoil **300** in different locations. In these illustrative examples, the locations for the different drops are defined by first region **308** and second region **310.**

As a result, placement of sensor **138** is selected such that sensor **138** will detect a first type of icing condition caused by first drops **312.** Sensor **160** is in second location **306** and is configured to detect a second type of icing condition caused by second drops **318** in these illustrative examples. In other words, the placement of sensor **138** and sensor **160** on surface **302** of airfoil **300** may be selected to detect different types of icing conditions. The location selected may depend on the configuration of airfoil **300.**

The illustrations of aircraft **100** with ice detection system **122** in **Figures 1-3** are not meant to imply physical or architectural limitations to the manner in which an illustrative embodiment 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, some components are shown in physical implementations while other components are shown as blocks. Blocks are presented to illustrate some functional components. One or more of the blocks illustrated may be combined, divided, or combined and divided into different blocks when implemented in an illustrative embodiment.

For example, aircraft **100** is shown in the form of an airplane. Of course, aircraft **100** may take other forms. For example, without limitation, aircraft **100** also may take the form of a helicopter. Also, although aircraft **100** is illustrated as a commercial aircraft, the different illustrative embodiments may be applied to military aircraft and other types of aircraft depending on the particular implementation. For example, aircraft **100** also may be applied to an aircraft that may fly in the air as well as enter outer space, although icing conditions do not exist at altitudes that are considered outer space.

In still another illustrative example, although sensors **124** are shown as grouped into ice detection assemblies, other illustrative embodiments may not employ ice detection assemblies. In other words, groupings of sensors into assemblies may not be used, depending on the particular implementation. In some illustrative examples, processor unit **200** may be considered part of flight management system **208** instead of a separate component in the illustrative examples.

Further, other numbers of sensors may be used other than those illustrated for aircraft **100**. The number of sensors used may depend on the particular type of aircraft. For example, the number of sensors and their locations may change depending on the size and configuration of airfoils on aircraft **100**. In still other illustrative examples, the sensors may all be of the same type of sensors or different types of sensors. For example, sensors **124** may be implemented using a sensor configured to detect a presence or formation of ice in these illustrative examples.

Turning now to **Figure 4**, an illustration of a block diagram of a design environment is depicted in accordance with an illustrative embodiment. Design environment **400** may be used to design an ice detection system for an aircraft in which the ice detection system is configured to detect a number of types of icing conditions. In this illustrative example, designer **402** may be implemented to generate ice detection system design **404** for ice detection system **406**. Ice detection system **406** may be, for example, without limitation, ice detection system **122** in **Figure 1**.

As illustrated, designer **402** may be implemented using software, hardware, or a combination of the two. In these illustrative examples, designer **402** may be implemented in computer system **408**. Computer system **408** comprises a number of computers. When more than one computer is present in computer system **408**, those computers may be in communication with each other. This communication may be facilitated using a communications medium, such as a network.

When designer **402** is implemented using software, designer **402** may take the form of program code that is configured to run on one or more computers. When hardware is employed, the hardware may include circuits that operate to perform the operations in designer **402**.

In the illustrative examples, the hardware may take the form of a circuit system, an integrated circuit, 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, a programmable array logic, a field programmable logic array, a field programmable gate array, and other suitable hardware devices. Additionally, the processes may be implemented in organic components integrated with inorganic components and/or may be comprised entirely of organic components excluding a human being.

In this illustrative example, ice detection system design **404** may be generated using aircraft design **410** for aircraft **412**. In other words, aircraft design **410** may be an input to designer **402** that is used to generate ice detection system **406**. In particular, parameters **414** in aircraft design **410** for components **416** in aircraft **412** may be used to generate parameters **418** for ice detection system **406** in ice detection system design **404**. Aircraft **412** may be, for example, aircraft **100** in **Figure 1**.

In this illustrative example, parameters **418** in ice detection system design **404** are for components **420** in ice detection system **406**. In these illustrative examples, components **420** in ice detection system **406** include processor unit **422** and sensor system **424.**

Sensor system **424** comprises sensors **426.** Sensors **426** include first group of sensors **428** and second group of sensors **430.** In these illustrative examples, parameters **418** include locations **432** for sensors **426** in sensor system **424.** In particular, locations **432** are locations on surface **434** of aircraft **412.** Locations **432** may be defined using coordinates for aircraft **412.**

In these illustrative examples, locations **432** include first group of locations **436** and second group of locations **438.** First group of locations **436** is for first group of sensors **428.** Second group of locations **438** is for second group of sensors **430.** Additionally, first group of sensors **428** and second group of sensors **430** may be arranged in ice detection assemblies **440** in which a first sensor in first group of sensors **428** and a second sensor in second group of sensors **430** are in an ice detection assembly in ice detection assemblies **440.**

Simulation **442** may be performed by computer system **408** to identify locations **432** for sensors **426.** In these illustrative examples, simulation **442** may simulate drops **444** for icing conditions **446.**

For example, simulation **442** may be performed to identify locations **448** on surface **434** of aircraft **412** where drops **444** will collide with surface **434** of aircraft **412.** In these examples, drops **444** include first drops **450** and second drops **452.** In this manner, simulation **442** may be used to identify first region **454** in which first drops **450** will collide with surface **434** and second region **456** in which second drops **452** will collide with surface **434** for different structures on aircraft **412.** The identification of locations **448** in simulation **442** may be used to identify locations **432** for sensors **426.**

In these illustrative examples, first group of locations **436** is selected such that first drops **450** in drops **444** for first type of icing condition **458** in icing conditions **446** collide with surface **434** in first group of locations **436.** Second group of locations **438** is selected such that second drops **452** in drops **444** for second type of icing condition **460** in icing conditions **446** collide with surface **434** of aircraft **412** in second group of locations **438.** In these illustrative examples, first drops **450** for first type of icing condition **458** may be normal supercooled drops. Second drops **452** for second type of icing condition **460** may be supercooled large drops in these illustrative examples.

In the depicted examples, first group of locations **436** may be within first region **454** on surface **434** of structure **462** in structures **464** in aircraft **412.** Second group of locations **438** may be located in second region **456** on surface **434** of structure **462.** In these illustrative examples, structure **462** in aircraft **412** may take the form of airfoil **466**, fuselage **468**, engine housing **470**, engine inlet **471**, and other suitable types of structures on aircraft **412.**

Further, simulation **442** also may be used to select the number of sensors within sensors **426** in addition to locations **432** for sensors **426.** Also, simulation **442** may be used to determine number of types of sensors **472** that may be used to implement sensors **426** in sensor system **424.**

The illustration of design environment **400** in **Figure 4** is not meant to imply physical or architectural limitations the manner in which an illustrative embodiment may be implemented. Other components in addition to and/or in place of the ones illustrated may be used. Some components may be unnecessary. Also, the blocks are presented to illustrate some functional components. One or more of these blocks may be combined, divided, or combined and divided into different blocks when implemented in an illustrative embodiment.

For example, ice detection system design **404** may be used to identify additional locations in locations **432** for sensors **426** to detect one or more additional types of icing conditions in addition to first type of icing condition **458** and second type of icing condition **460.**

In still other illustrative examples, designer **402** may be used to modify ice detection system design **404** instead of creating ice detection system design **404.** For example, ice detection system design **404** may already include first group of sensors **428** in first group of locations **436.** Ice detection system design **404** may be modified to identify second group of locations **438** for second group of sensors **430.** In this manner, designer **402** may be used to identify modifications to existing ice detection systems in these illustrative examples. In still other illustrative examples, ice detection system design **404** may be part of aircraft design **410** instead of a separate design.

The different components illustrated in **Figures 1-3** may be combined with components shown in **Figure 4**, used with components in **Figure 4**, or a combination of the two. Additionally, some of the components illustrated in **Figures 1-3** may be examples of how components shown in block form in **Figure 4** may be implemented as physical structures.

With reference now to **Figure 5**, an illustration of a flowchart of a process for detecting icing conditions for an aircraft is depicted in accordance with an illustrative embodiment. The process illustrated in **Figure 5** may be implemented in an ice detection system such as ice detection system **406** as specified by ice detection system design **404** in **Figure 4.** Further, the process may be implemented in ice detection system **122** for aircraft **100** in **Figure 1.** In particular, one or more operations performed in this flowchart may be implemented using processor unit **200** in **Figure 2.**

The process begins by monitoring a first group of sensors located at a first group of locations on the aircraft for first data indicating a first type of icing condition in the icing conditions for the aircraft (operation **500**). The first group of sensors in operation **500** may be first group of sensors **148** in ice detection system **122** in **Figure 1**. The process then monitors a second group of sensors located at a second group of locations on the aircraft for second data indicating a second type of icing condition for the aircraft (operation **502**). The second group of sensors in operation **502** may be second group of sensors **170** in ice detection system **122** in **Figure 1**.

A determination is made as to whether at least one of the first data and the second data indicates that an icing condition is present (operation **504**). If an icing condition is not present, the process returns to operation **500** as described above. Otherwise, the process initiates an action in response to detecting at least one of the first type of icing condition from the first data and the second type of icing condition from the second data (operation **506**), with the process then returning to operation **500** as described above.

With reference now to **Figure 6**, an illustration of a flowchart of a process for designing an ice detection system is depicted in accordance with an illustrative embodiment. The process illustrated in **Figure 6** may be implemented in design environment **400** in **Figure 4**. In particular, the process may be implemented using designer **402** in **Figure 4**.

The process begins by identifying a structure for an aircraft (operation **600**). These structures may be any structure on which ice may form when one or more types of icing conditions are present. The process then selects a structure from the aircraft for processing (operation **602**).

The process then identifies a first region and a second region on the structure (operation **604**). The first region is a region in which first drops for a first type of icing condition collide with the surface of the aircraft. The second region is a region in which second drops for a second type of icing condition collide with the surface of the aircraft. The process then identifies a number of sensors for placement in the first region and the second region (operation **606**). In some cases, sensors may be absent from one region on the structure depending on the implementation.

The process then identifies a first group of locations in the first region for a first group of sensors in the sensors (operation **608**). The process then identifies a second group of locations in the second region for a second group of sensors in the sensors (operation **610**). A determination is made as to whether additional unprocessed structures are present for the aircraft (operation **612**). If additional unprocessed structures are present, the process returns to operation **602** as described above. Otherwise, the process terminates. When the process is completed, the design for the ice detection system may be finished and ready for implementation.

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

Turning now to **Figure 7**, an illustration of a data processing system is depicted in accordance with an illustrative embodiment. Data processing system **700** may be used to implement flight management system **208** in **Figure 2**, computer system **408** in **Figure 4**, and other computers that may be used in different illustrative embodiments. In this illustrative example, data processing system **700** includes communications framework **702**, which provides communications between processor unit **704**, memory **706**, persistent storage **708**, communications unit **710**, input/output (I/O) unit **712**, and display **714**. In this example, communications framework **702** may take the form of a bus system.

Processor unit **704** serves to execute instructions for software that may be loaded into memory **706**. Processor unit **704** may be a number of processors, a multi-processor core, or some other type of processor, depending on the particular implementation. In these illustrative examples, processor unit **704** is an example of a processor unit that may be used to implement processor unit **200** in **Figure 2**.

Memory **706** and persistent storage **708** are examples of storage devices **716**. 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 other suitable information either on a temporary basis or a permanent basis. Storage devices **716** also may be referred to as computer readable storage devices in these illustrative examples. Memory **706**, in these examples, may be, for example, a random access memory or any other suitable volatile or non-volatile storage device. Persistent storage **708** may take various forms, depending on the particular implementation.

For example, persistent storage **708** may contain one or more components or devices. For example, persistent storage **708** 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 **708** also may be removable. For example, a removable hard drive may be used for persistent storage **708**.

Communications unit **710**, in these illustrative examples, provides for communications with other data processing systems or devices. In these illustrative examples, communications unit **710** is a network interface card.

Input/output unit **712** allows for input and output of data with other devices that may be connected to data processing system **700.** For example, input/output unit **712** may provide a connection for user input through a keyboard, a mouse, and/or some other suitable input device. Further, input/output unit **712** may send output to a printer. Display **714** provides a mechanism to display information to a user.

Instructions for the operating system, applications, and/or programs may be located in storage devices **716**, which are in communication with processor unit **704** through communications framework **702.** The processes of the different embodiments may be performed by processor unit **704** using computer-implemented instructions, which may be located in a memory, such as memory **706.**

These instructions are referred to as program code, computer usable program code, or computer readable program code that may be read and executed by a processor in processor unit **704.** The program code in the different embodiments may be embodied on different physical or computer readable storage media, such as memory **706** or persistent storage **708.**

Program code **718** is located in a functional form on computer readable media **720** that is selectively removable and may be loaded onto or transferred to data processing system **700** for execution by processor unit **704.** Program code **718** and computer readable media **720** form computer program product **722** in these illustrative examples. In one example, computer readable media **720** may be computer readable storage media **724** or computer readable signal media **726.**

In these illustrative examples, computer readable storage media **724** is a physical or tangible storage device used to store program code **718** rather than a medium that propagates or transmits program code **718.** Alternatively, program code **718** may be transferred to data processing system **700** using computer readable signal media **726.** Computer readable signal media **726** may be, for example, a propagated data signal containing program code **718.** For example, computer readable signal media **726** may be an electromagnetic signal, an optical signal, and/or any other suitable type of signal. These signals may be transmitted over communications links, such as wireless communications links, optical fiber cable, coaxial cable, a wire, and/or any other suitable type of communications link.

The different components illustrated for data processing system **700** are not meant to provide physical or architectural limitations to the manner in which different embodiments may be implemented. The different illustrative embodiments may be implemented in a data processing system including components in addition to and/or in place of those illustrated for data processing system **700.** Other components shown in **Figure 7** 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 **718.**

Illustrative embodiments of the disclosure may be described in the context of aircraft manufacturing and service method **800** as shown in **Figure 8** and aircraft **900** as shown in **Figure 9.** Turning first to **Figure 8**, an illustration of an aircraft manufacturing and service method is depicted in accordance with an illustrative embodiment. During pre-production, aircraft manufacturing and service method **800** may include specification and design **802** of aircraft **900** in **Figure 9** and material procurement **804.**

During production, component and subassembly manufacturing **806** and system integration **808** of aircraft **900** in **Figure 9** takes place. Thereafter, aircraft **900** in **Figure 9** may go through certification and delivery **810** in order to be placed in service **812.** While in service **812** by a customer, aircraft **900** in **Figure 9** is scheduled for routine maintenance and service **814**, which may include modification, reconfiguration, refurbishment, and other maintenance or service.

Each of the processes of aircraft manufacturing and service method **800** may be performed or carried out by a system integrator, a third party, and/or an operator. In these examples, the operator may be a customer. For the purposes of this description, a system integrator may include, without limitation, any number of aircraft manufacturers and major-system subcontractors; a third party may include, without limitation, any number of vendors, subcontractors, and suppliers; and an operator may be an airline, a leasing company, a military entity, a service organization, and so on.

With reference now to **Figure 9**, an illustration of an aircraft is depicted in which an illustrative embodiment may be implemented. In this example, aircraft **900** is produced by aircraft manufacturing and service method **800** in **Figure 8** and may include airframe **902** with plurality of systems **904** and interior **906.** Examples of systems **904** include one or more of propulsion system **908**, electrical system **910**, hydraulic system **912**, environmental system **914**, and ice detection system **916.** Any number of other systems may be included. Although an aerospace example is shown, different illustrative embodiments may be applied to other industries, such as the automotive industry.

Apparatuses and methods embodied herein may be employed during at least one of the stages of aircraft manufacturing and service method **800** in **Figure 8.** In one illustrative example, components or subassemblies produced in component and subassembly manufacturing **806** in **Figure 8** may be fabricated or manufactured in a manner similar to components or subassemblies produced while aircraft **900** is in service **812** in **Figure 8.**

As yet another example, one or more apparatus embodiments, method embodiments, or a combination thereof may be utilized during different stages of aircraft manufacturing and service method **800.** For example, ice detection system **916** may be designed during specification and design **802.** Components for ice detection system **916** may be manufactured during component and subassembly manufacturing **806.** Ice detection system **916** may be installed in aircraft **900** during system integration **808.** Ice detection system **916** may be used while aircraft **900** is in service **812.**

In another illustrative example, ice detection system **916** may be an existing ice detection system in aircraft **900.** Upgrades, modifications, and other operations may be performed to modify ice detection system **916** on aircraft **900** to include features in accordance with an illustrative embodiment.

In the figures and the text, one or more aspect, variations, instances, and examples are illustrated below including:

In one aspect, an ice detection system 406 is disclosed including: a first group of sensors 428 located in a first group of locations 436 on an aircraft 412, wherein the first group of sensors 428 in the first group of locations 436 is configured to detect a first type of icing condition 458 for the aircraft 412, and a second group of sensors 430 located in a second group of locations 438 on the aircraft 412, wherein the second group of sensors 430 in the second group of locations 438 is configured to detect a second type of icing condition 460 for the aircraft 412.

In one variant, the ice detection system 406 includes wherein the first group of sensors 428 and the second group of sensors 430 generate data 202 and further including: a processor unit 422 configured to monitor the data 202 from the first group of sensors 428 and the second group of sensors 430 and perform an action in response to the data 202 indicating a presence of at least one of the first type of icing condition 458 and the second type of icing condition 460. In another variant, the ice detection system 406 includes wherein the first group of locations 436 is a first number of locations 448 in which first drops 450 for the first type of icing condition 458 collide with a surface 434 of the aircraft 412 and the second group of locations 438 is a second number of locations 432 in which second drops 452 for the second type of icing condition 460 collide with the surface 434 of the aircraft 412.

In yet another variant, the ice detection system 406 includes wherein the surface 434 is a surface 434 of an airfoil 466 for the aircraft 412 and wherein the first drops 450 collide with the surface 434 in a first region 454 on the surface 434 of the airfoil 466, the second drops 452 collide with the surface 434 in a second region 456 on the surface 434 of the airfoil 466, and the first region 454 is further forward on the airfoil 466 than the second region 456. In one example, the ice detection system 406 includes wherein the first type of icing condition 458 is caused by first drops 450 having a first number of sizes, the second type of icing condition 460 is caused by second drops 452 having a second number of sizes, and the first number of sizes is smaller than the second number of sizes.

In another example, the ice detection system 406 includes wherein the second type of icing condition 460 is a supercooled large drop icing condition. In one example, the ice detection system 406 includes wherein the action is selected from at least one of generating an alert, generating a log entry, activating an anti-icing system 204, and sending a report. In yet another example, the ice detection system 406 includes wherein the first group of locations 436 and the second group of locations 438 are on a structure 462 for the aircraft 412 and the structure 462 is selected from one of an airfoil 466, a wing, a horizontal stabilizer, a vertical stabilizer, a fuselage 468, an engine inlet 471, and a nose portion 112 of the fuselage 468.

In one instance, the ice detection system 406 includes wherein a first sensor 138 in the first group of sensors 428 and a second sensor 160 in the second group of sensors 430 form a sensor pair, wherein the first sensor 138 is a forward sensor and the second sensor 160 is an aft sensor that is located in a location that is aft of the forward sensor. In another instance, the ice detection system includes wherein sensors in the first group of sensors 428 and the second group of sensors 430 are configured to detect a presence of ice. In yet another instance, the ice detection system 406 includes wherein the aircraft 412 is selected from one of a commercial aircraft, a military aircraft, an airplane, and a helicopter.

In one aspect, an ice detection system 406 is disclosed including: a group of sensors located in a group of locations on a surface 434 of an aircraft 412, wherein the group of sensors in the group of locations is configured to detect a supercooled large drop icing condition on the surface 434 of the aircraft 412; and

a processor unit 422 configured to monitor data 202 from the group of sensors and perform an action in response to the data 202 indicating a presence of the supercooled large drop icing condition on the surface 434 of the aircraft 412. In one variant, the ice detection system 406 includes wherein the group of sensors 430 is a second group of sensors and further including: a first group of sensors 428 configured to detect another type of icing condition on the surface 434 of the aircraft 412. In one variant, the ice detection system 406 includes wherein the group of locations is a number of locations in which drops for the supercooled large drop icing condition collide with the surface 434 of the aircraft 412.

In another variant, the ice detection system 406 includes wherein the surface 434 is a surface 434 of an airfoil 466 for the aircraft 412 and wherein the drops collide with the surface 434 in a region on the surface 434 of the airfoil 466 that is further aft as compared to drops from another type of icing condition on the surface 434 of the airfoil 466. In yet another variant, the ice detection system 406 includes wherein the drops have a diameter from about 0.112 millimeters to about 2.2

millimeters. In still another variant, the ice detection system 406 includes wherein the action is selected from at least one of generating an alert, generating a log entry, activating an anti-icing system 204, and sending a report.

In one aspect, a method is disclosed for detecting icing conditions for an aircraft 412, the method includes: monitoring a first group of sensors 428 located in a first group of locations 436 on the aircraft 412 for first data 202 indicating a first type of icing condition 458 in the icing conditions for the aircraft 412; monitoring a second group of sensors 430 located in a second group of locations 438 on the aircraft 412 for second data 202 indicating a second type of icing condition in the icing conditions 460 for the aircraft 412; and initiating an action in response to detecting at least one of the first type of icing condition 458 from the first data and the second type of icing condition 460 from the second data 202. In one variant, the method further includes: responsive to detecting an icing condition from at least one of the first data (202) and the second data 202, identifying a location on the aircraft 212 in which the icing condition is detected.

In another variant, the method includes wherein initiating the action in response to detecting the at least one of the first type of icing condition 458 from the first data 202 and the second type of icing condition 460 from the second data 202 includes: initiating the action in response to detecting the at least one of the first type of icing condition 458 from the first data 202 and the second type of icing condition 460 from the second data 202, wherein the action is selected from at least one of generating an alert 204, generating a log entry, activating an anti-icing system, and sending a report.

Thus, one or more illustrative embodiments provide a method and apparatus for identifying different types of icing conditions. In particular, an illustrative embodiment provides an ability to identify a first type of icing condition and a second type of icing condition. The first type of icing condition may be one typically encountered while the second type of icing condition may be a supercooled large drop icing condition. In these illustrative examples, the ability to identify more than one type of icing condition may allow an aircraft to be certified for flight in different types of icing conditions under various regulations that may be present from government or other regulatory entities, such as the Federal Aviation Administration.

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

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CLAIMS

1. An ice detection system for detecting a plurality of in-flight icing conditions comprising: a first group of sensors located in a first group of locations on an aircraft, wherein the first group of sensors in the first group of locations is configured to detect a first type of icing condition for the aircraft, wherein the first group of locations is selected to be on first areas of the aircraft where collision with water drops of a first size range is expected to occur more frequently during flight of the aircraft than collision with water drops of a second size range, and wherein the first type of icing condition is associated with water drops of the first size range; and a second group of sensors located in a second group of locations on the aircraft, wherein the second group of sensors in the second group of locations is configured to detect a second type of icing condition for the aircraft, wherein the second group of locations is selected to be on second areas of the aircraft where collision with water drops of the second size range is expected to occur more frequently during flight of the aircraft than collision with water drops of the first size range, wherein the second type of icing condition is associated with water drops of the second size range, and wherein the first size range is less than the second size range; and a processor unit configured to monitor in-flight data from the first group of sensors and responsive to the first group of sensors detecting the first type of icing condition for the aircraft, perform a first action in response to the data indicating a presence of at least one of the first type of icing condition, wherein the first action comprises generating, during flight, a first alert on a flight deck interface for the aircraft, wherein the processor unit is further to monitor in-flight data from the second group of sensors and responsive to the second group of sensors detecting the second type of icing condition for the aircraft, perform a second action in response to the data indicating a presence of at least one of the first type of icing condition, wherein the second action comprises generating, during flight, a second alert on the flight deck interface for the aircraft.

2. The ice detection system of claim 1, wherein the first group of locations is a first number of locations in which first drops for the first type of icing condition collide with a surface of the aircraft and the second group of locations is a second number of locations in which second drops for the second type of icing condition collide with the surface of the aircraft.

3. The ice detection system of claim 2, wherein the surface is a surface of an airfoil for the aircraft and wherein the first drops collide with the surface in a first region on the surface of the

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airfoil, the second drops collide with the surface in a second region on the surface of the airfoil, and the first region is further forward on the airfoil than the second region.

4. The ice detection system of claim 1, wherein the second type of icing condition is a supercooled large drop icing condition.

5. The ice detection system of claim 1, wherein the action is selected from at least one of generating an alert, generating a log entry, activating an anti-icing system, and sending a report.

6. The ice detection system of claim 1, wherein the first group of locations and the second group of locations are on a structure for the aircraft and the structure is selected from one of an airfoil, a wing, a horizontal stabilizer, a vertical stabilizer, a fuselage, an engine inlet, and a nose portion of the fuselage

7. The ice detection system of claim 1, wherein a first sensor in the first group of sensors and a second sensor in the second group of sensors form a sensor pair, wherein the first sensor is a forward sensor and the second sensor is an aft sensor that is located in a location that is aft of the forward sensor.

8. The ice detection system of claim 1, wherein sensors in the first group of sensors and the second group of sensors are configured to detect a presence of ice.

9. The ice detection system of claim 1, wherein the aircraft is selected from one of a commercial aircraft, a military aircraft, an airplane, and a helicopter.

10. A method for detecting a plurality of in-flight icing conditions for an aircraft, the method comprising:

monitoring, during flight of the aircraft, a first group of sensors located in a first group of locations on the aircraft for first data indicating a first type of icing condition in the icing conditions for the aircraft, wherein the first group of locations is selected to be on first areas of the aircraft where collision with water drops of a first size range is expected to occur more frequently than collision with water drops of a second size range, and wherein the first type of icing condition is associated with water drops of the first size range; monitoring, during flight of the aircraft, a second group of sensors located in a second group of locations on the aircraft for

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second data indicating a second type of icing condition in the icing conditions for the aircraft, wherein the second group of locations is selected to be on second areas of the aircraft where collision with water drops of the second size range is expected to occur more frequently than collision with water drops of the first size range, wherein the second type of icing condition is associated with water drops of the second size range, and wherein the first size range is less than the second size range; and initiating a first action in response to detecting the first type of icing condition from the first data, wherein the first action comprises generating, during flight, a first alert on a flight deck interface for the aircraft, and initiating a second action in response to detecting the second type of icing condition from the second data, wherein the second action comprises generating, during flight, a second alert on the flight deck interface for the aircraft.

11. The method of claim 10 further comprising:

responsive to detecting an icing condition from at least one of the first data and the second data, identifying a location on the aircraft in which the icing condition is detected.

12. The method of claim 10, wherein initiating the action in response to detecting the at least one of the first type of icing condition from the first data and the second type of icing condition from the second data comprises: initiating the action in response to detecting the at least one of the first type of icing condition from the first data and the second type of icing condition from the second data, wherein the action is selected from at least one of generating an alert, generating a log entry, activating an anti-icing system, and sending a report.

The Boeing Company
Patent Attorneys for the Applicant/Nominated Person
SPRUSON & FERGUSON

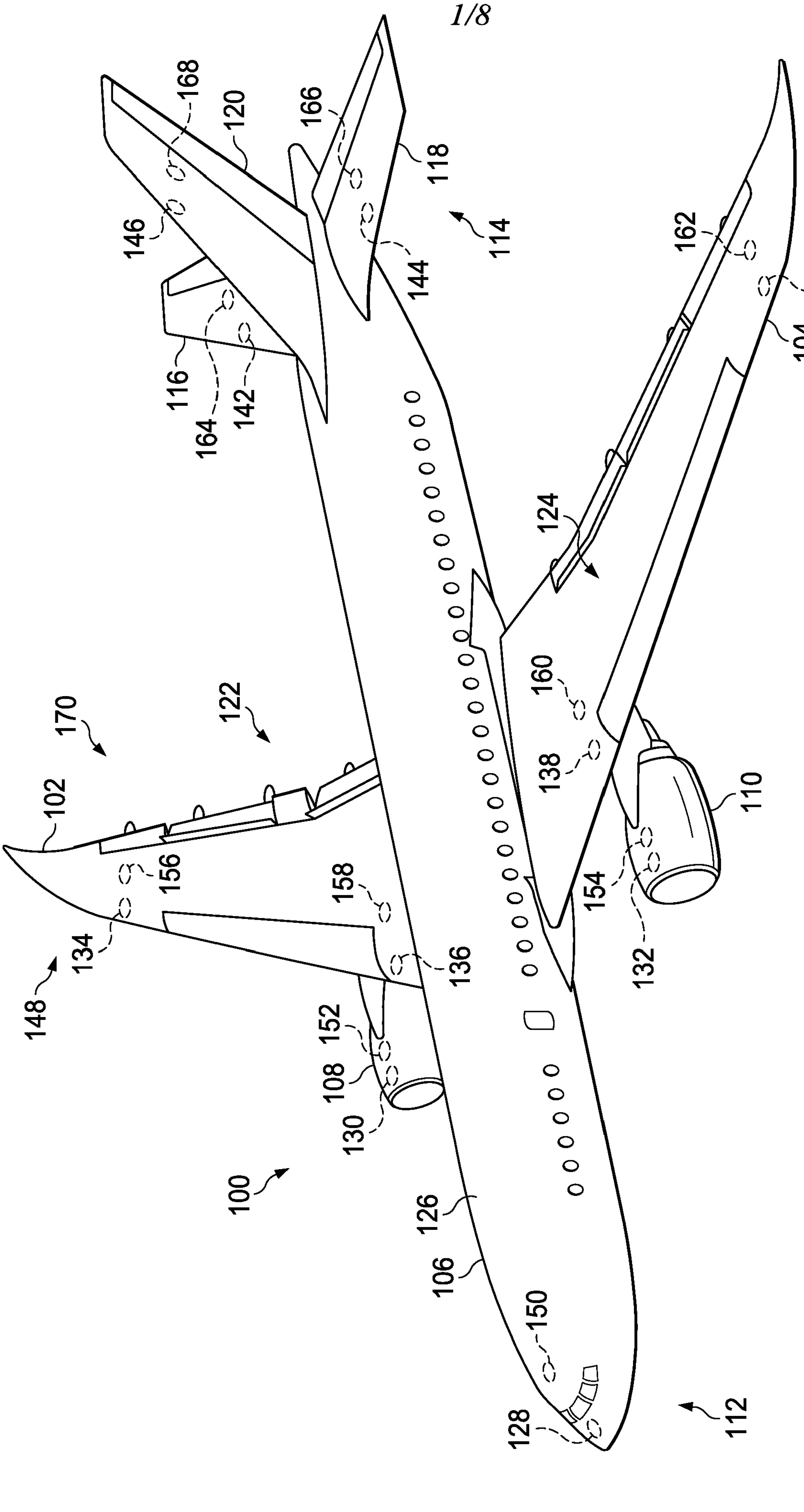
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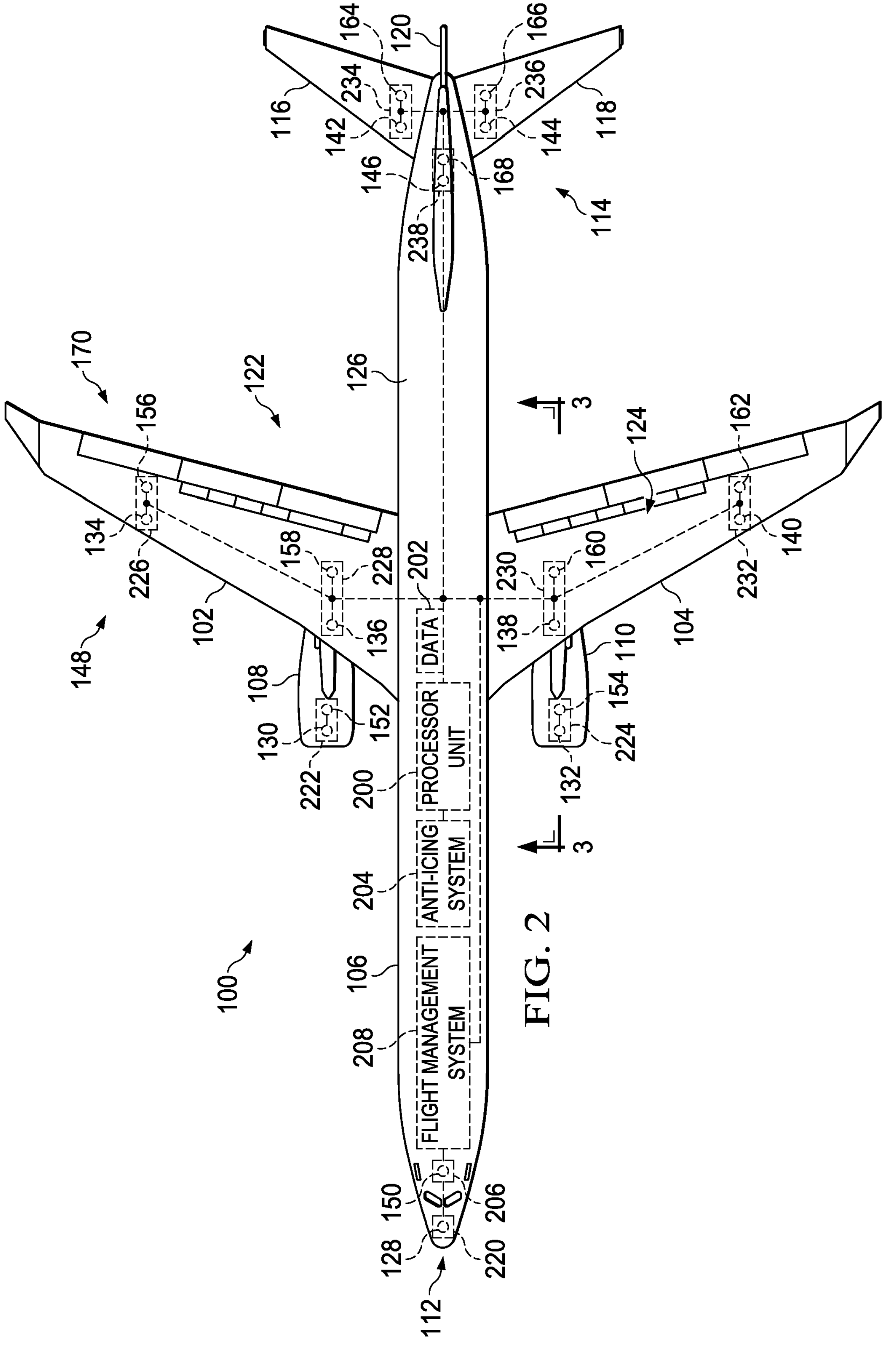
FIG. 1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ANTI-ICING SYSTEM
FLIGHT MANAGEMENT SYSTEM
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134
136
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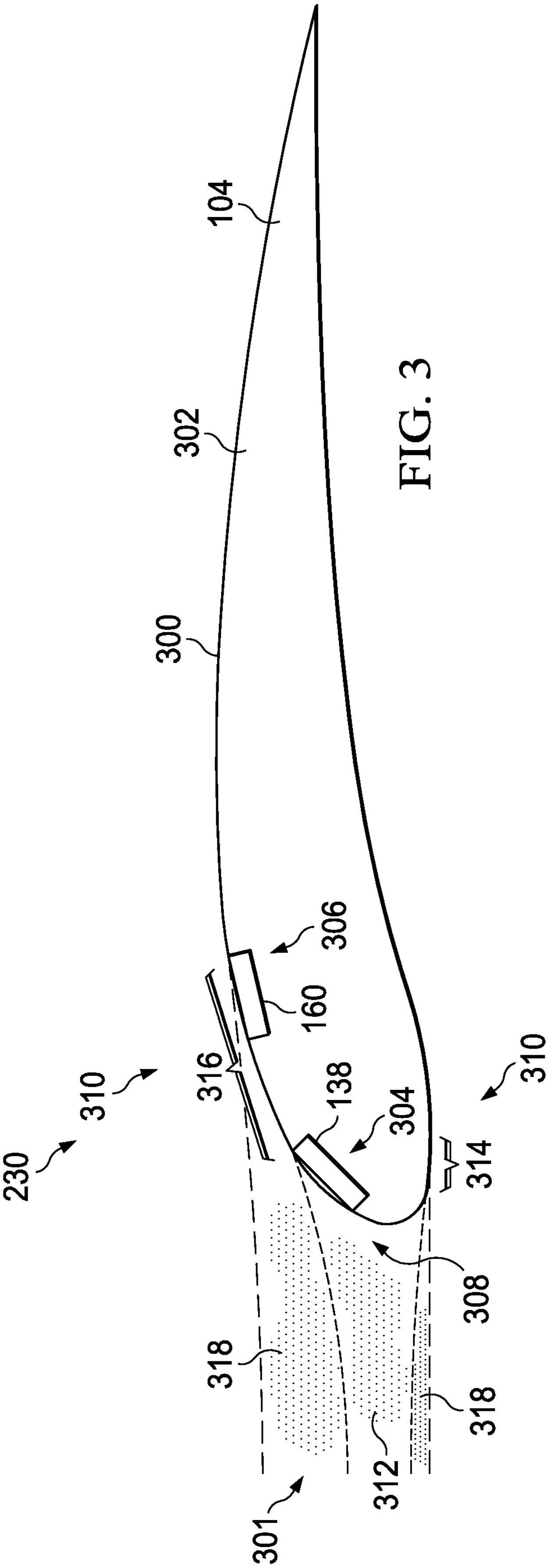
3
3

FIG. 2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302
300
306
160
310
316
138
304
310
230
314
308
318
318
312
301

FIG. 3

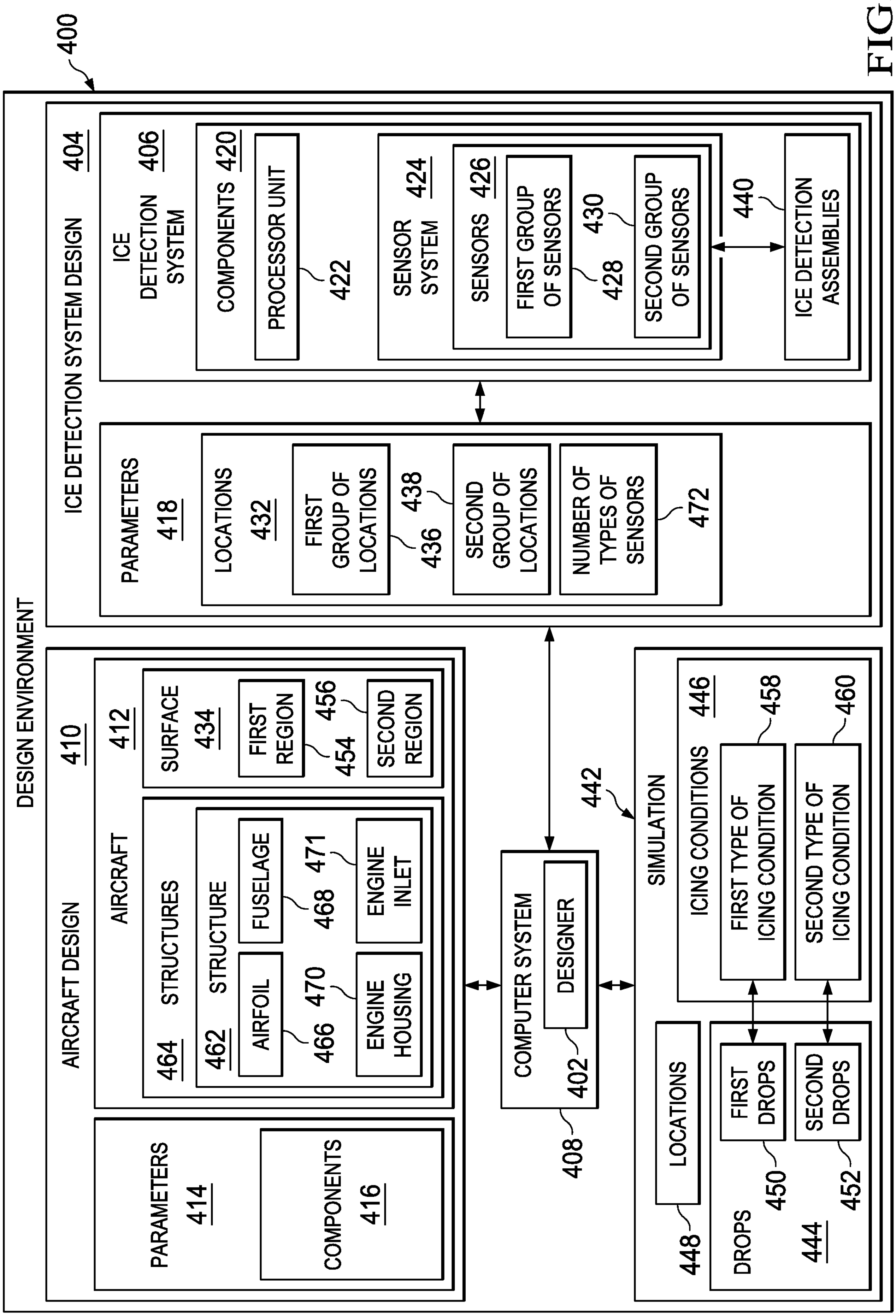
400
DESIGN ENVIRONMENT
ICE DETECTION SYSTEM DESIGN 404
ICE DETECTION SYSTEM 406
COMPONENTS 420
PROCESSOR UNIT
422
SENSOR SYSTEM 424
SENSORS 426
FIRST GROUP OF SENSORS
428
430
SECOND GROUP OF SENSORS
440
ICE DETECTION ASSEMBLIES
PARAMETERS 418
LOCATIONS 432
FIRST GROUP OF LOCATIONS
436
438
SECOND GROUP OF LOCATIONS
NUMBER OF TYPES OF SENSORS
472
AIRCRAFT DESIGN 410
AIRCRAFT 412
SURFACE 434
FIRST REGION
454
456
SECOND REGION
STRUCTURES 464
STRUCTURE 462
AIRFOIL
466
FUSELAGE
468
470
471
ENGINE HOUSING
ENGINE INLET
PARAMETERS 414
COMPONENTS 416
COMPUTER SYSTEM
DESIGNER
402
408
442
SIMULATION
ICING CONDITIONS 446
458
FIRST TYPE OF ICING CONDITION
460
SECOND TYPE OF ICING CONDITION
LOCATIONS
448
DROPS 444
FIRST DROPS
450
SECOND DROPS
452

FIG. 4

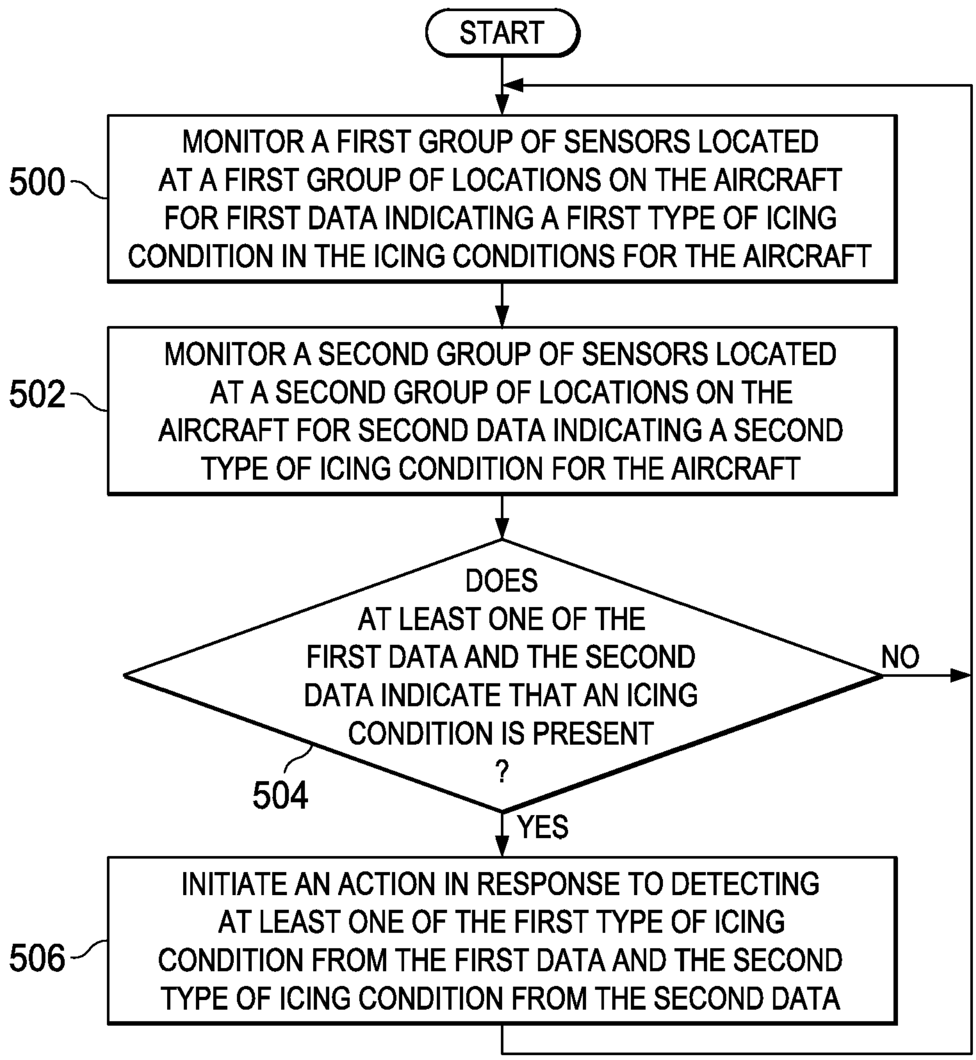
START
500
MONITOR A FIRST GROUP OF SENSORS LOCATED AT A FIRST GROUP OF LOCATIONS ON THE AIRCRAFT FOR FIRST DATA INDICATING A FIRST TYPE OF ICING CONDITION IN THE ICING CONDITIONS FOR THE AIRCRAFT
502
MONITOR A SECOND GROUP OF SENSORS LOCATED AT A SECOND GROUP OF LOCATIONS ON THE AIRCRAFT FOR SECOND DATA INDICATING A SECOND TYPE OF ICING CONDITION FOR THE AIRCRAFT
DOES AT LEAST ONE OF THE FIRST DATA AND THE SECOND DATA INDICATE THAT AN ICING CONDITION IS PRESENT ?
504
NO
YES
506
INITIATE AN ACTION IN RESPONSE TO DETECTING AT LEAST ONE OF THE FIRST TYPE OF ICING CONDITION FROM THE FIRST DATA AND THE SECOND TYPE OF ICING CONDITION FROM THE SECOND DATA

FIG. 5

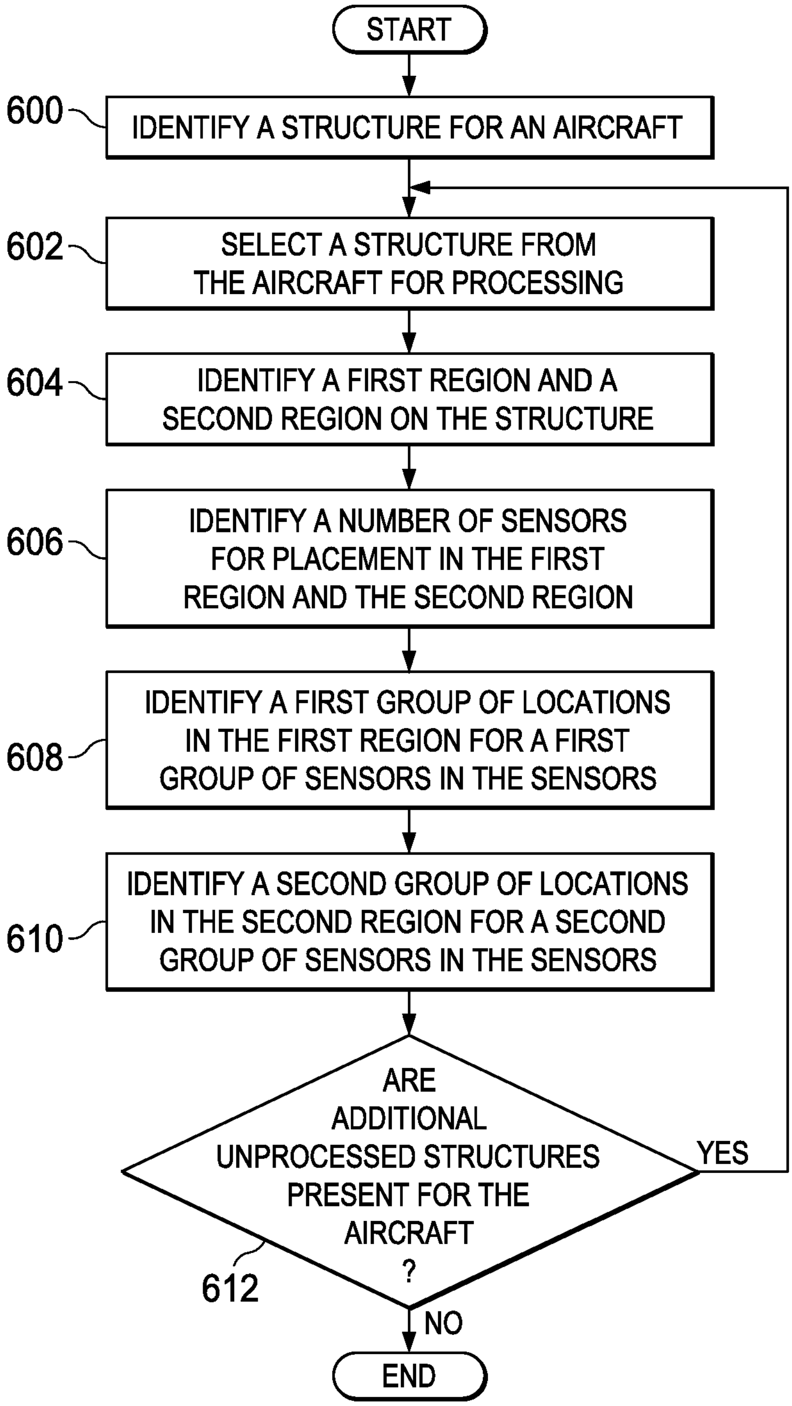
START
600
IDENTIFY A STRUCTURE FOR AN AIRCRAFT
602
SELECT A STRUCTURE FROM THE AIRCRAFT FOR PROCESSING
604
IDENTIFY A FIRST REGION AND A SECOND REGION ON THE STRUCTURE
606
IDENTIFY A NUMBER OF SENSORS FOR PLACEMENT IN THE FIRST REGION AND THE SECOND REGION
608
IDENTIFY A FIRST GROUP OF LOCATIONS IN THE FIRST REGION FOR A FIRST GROUP OF SENSORS IN THE SENSORS
610
IDENTIFY A SECOND GROUP OF LOCATIONS IN THE SECOND REGION FOR A SECOND GROUP OF SENSORS IN THE SENSORS
ARE ADDITIONAL UNPROCESSED STRUCTURES PRESENT FOR THE AIRCRAFT ?
YES
612
NO
END

FIG. 6

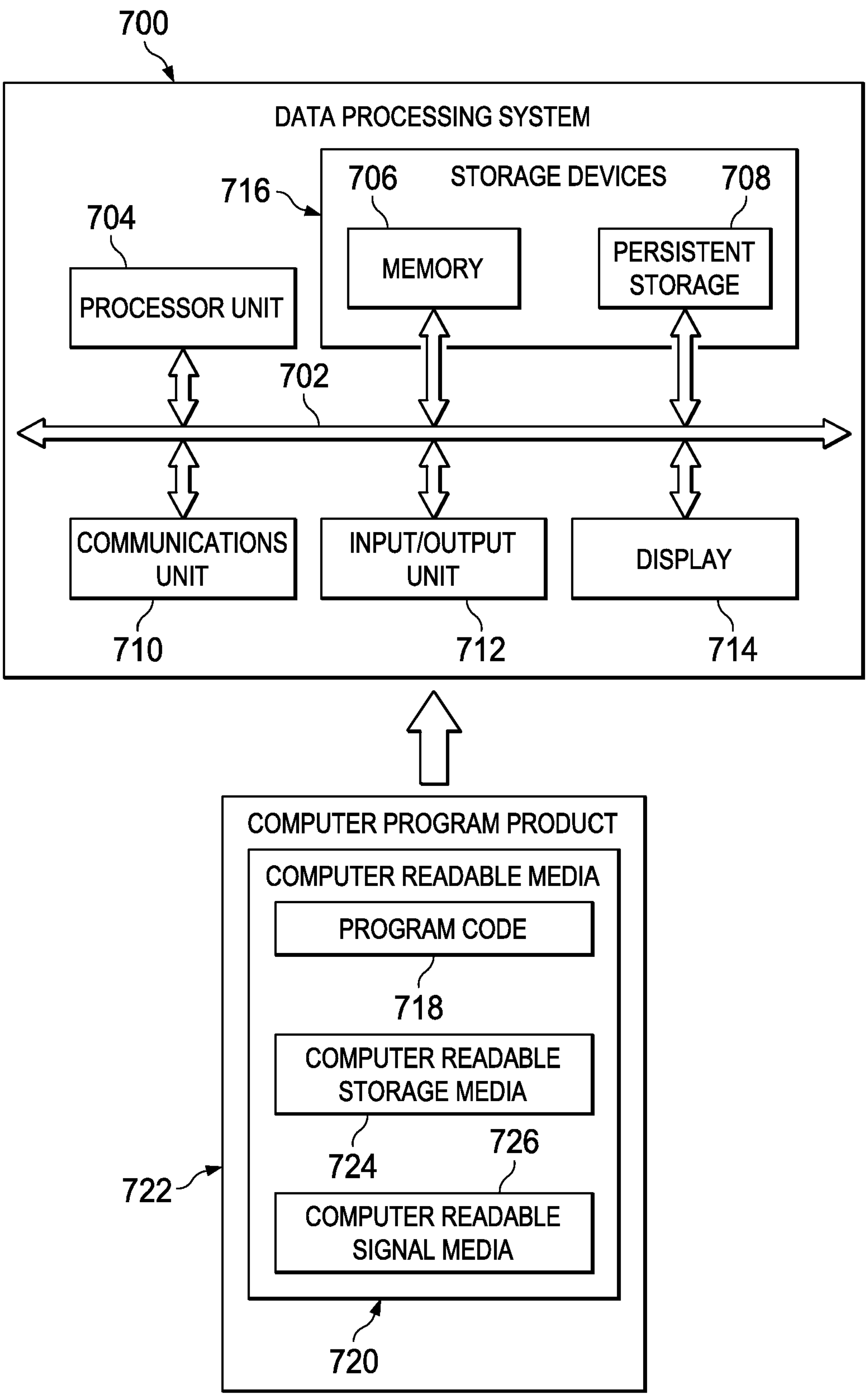
700
DATA PROCESSING SYSTEM
716
STORAGE DEVICES
706
708
704
MEMORY
PERSISTENT STORAGE
PROCESSOR UNIT
702
COMMUNICATIONS UNIT
INPUT/OUTPUT UNIT
DISPLAY
710
712
714
COMPUTER PROGRAM PRODUCT
COMPUTER READABLE MEDIA
PROGRAM CODE
718
COMPUTER READABLE STORAGE MEDIA
724
726
722
COMPUTER READABLE SIGNAL MEDIA
720

FIG. 7

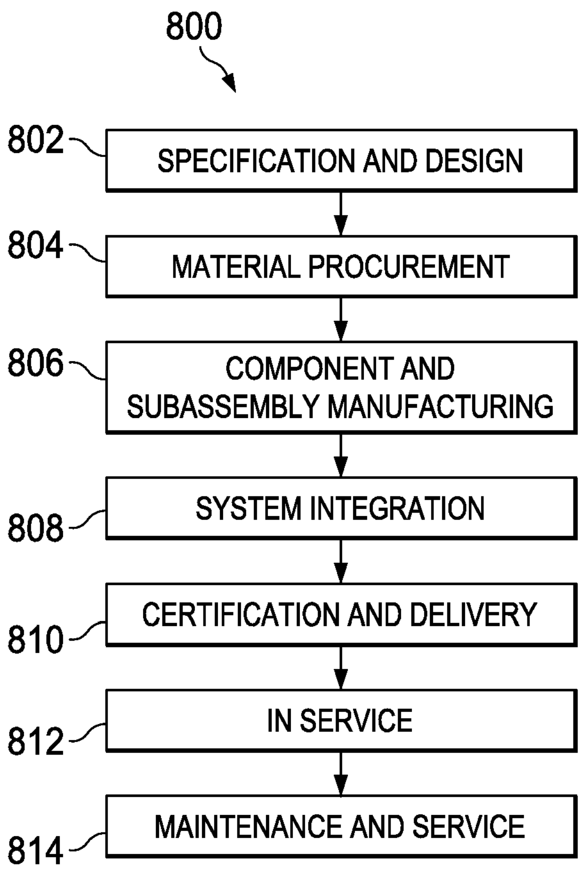
800
802
SPECIFICATION AND DESIGN
804
MATERIAL PROCUREMENT
806
COMPONENT AND
SUBASSEMBLY MANUFACTURING
808
SYSTEM INTEGRATION
810
CERTIFICATION AND DELIVERY
812
IN SERVICE
814
MAINTENANCE AND SERVICE

FIG. 8

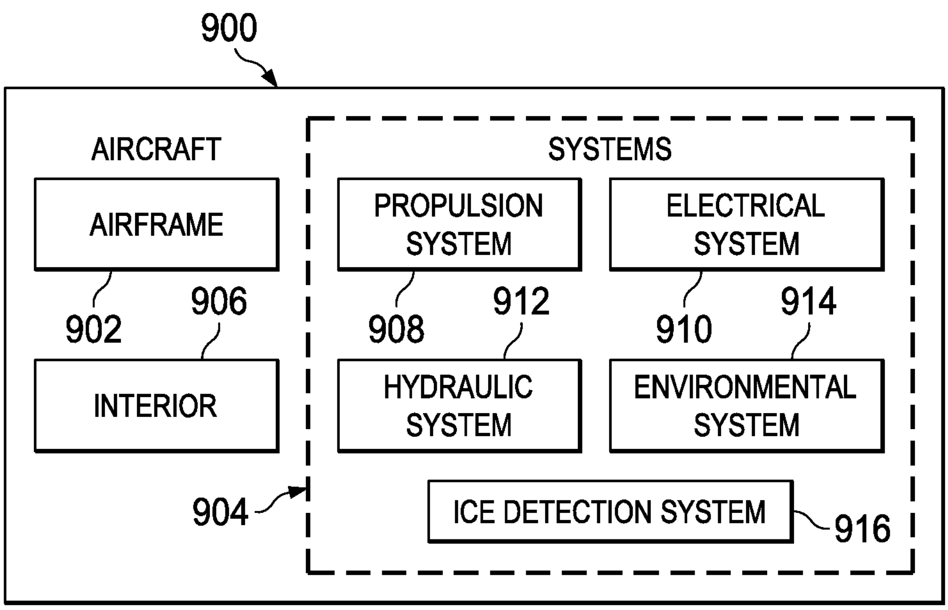
900
AIRCRAFT
AIRFRAME
902
906
INTERIOR
SYSTEMS
PROPULSION
SYSTEM
ELECTRICAL
SYSTEM
908
912
910
914
HYDRAULIC
SYSTEM
ENVIRONMENTAL
SYSTEM
904
ICE DETECTION SYSTEM
916

FIG. 9