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(54) **AIRCRAFT SYSTEM AND METHOD TO DISPLAY THREE-DIMENSIONAL THREAT IMAGE**

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G01S 13/89	(2006.01)

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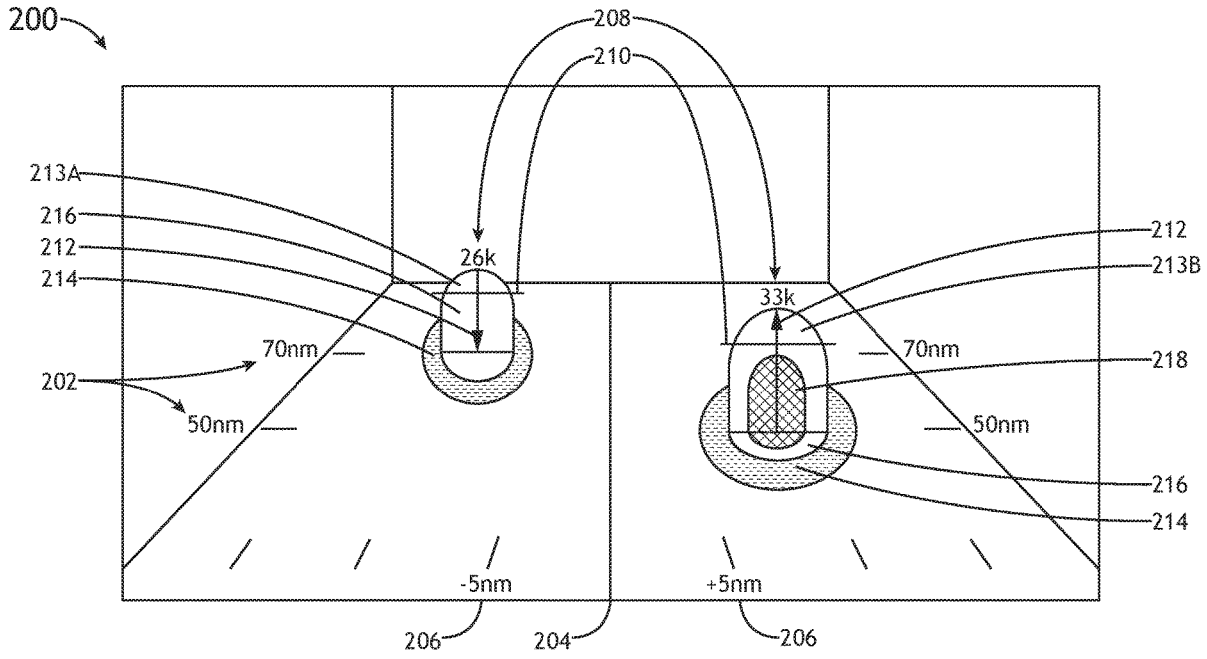
CPC ***G01S 13/953*** (2013.01); ***G01S 13/89*** (2013.01); ***G06F 3/14*** (2013.01); ***G06T 15/00*** (2013.01)

(57) **ABSTRACT**

A system may include at least one display and at least one processor installed in an aircraft. The at least one processor may be communicatively coupled to the at least one display. The at least one processor may be configured to: obtain aircraft data associated with the aircraft; obtain an azimuth value associated with an azimuth; obtain radar data associated with at least one threat; generate a three-dimensional threat image based at least on the aircraft data, the azimuth value, and the radar data; and output the three-dimensional threat image as graphical data. The at least one display may be configured to display the three-dimensional threat image to a user. The three-dimensional threat image may depict a three-dimensional relationship between the aircraft and the at least one threat. The three-dimensional threat image may convey a range dimension, a lateral dimension extended perpendicularly from the azimuth, and a height dimension.



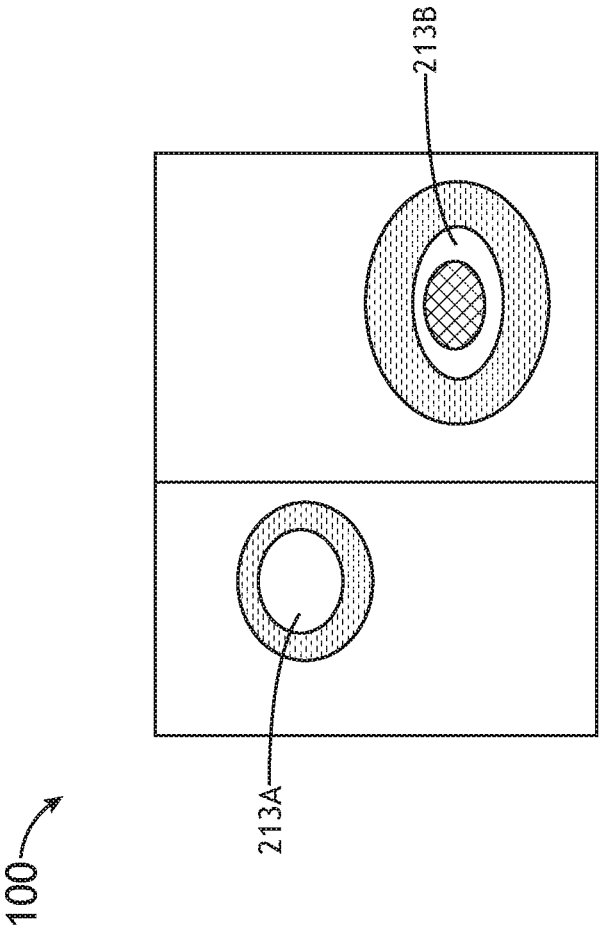


FIG. 1

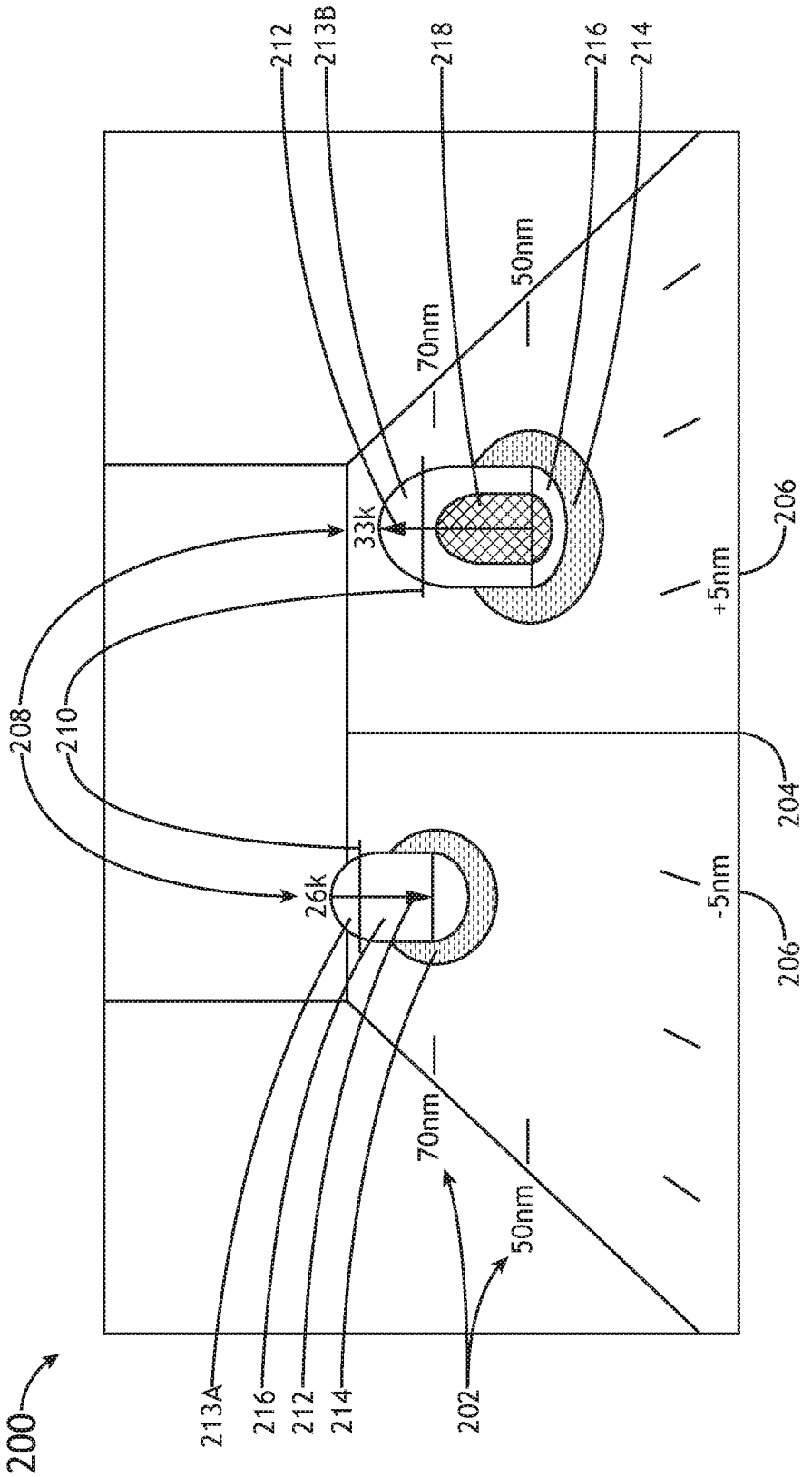

200
213A
216
212
214
202
70nm
50nm
26k
208
210
33k
70nm
50nm
212
213B
218
216
214
+5nm
-5nm
206
204
206

FIG. 2

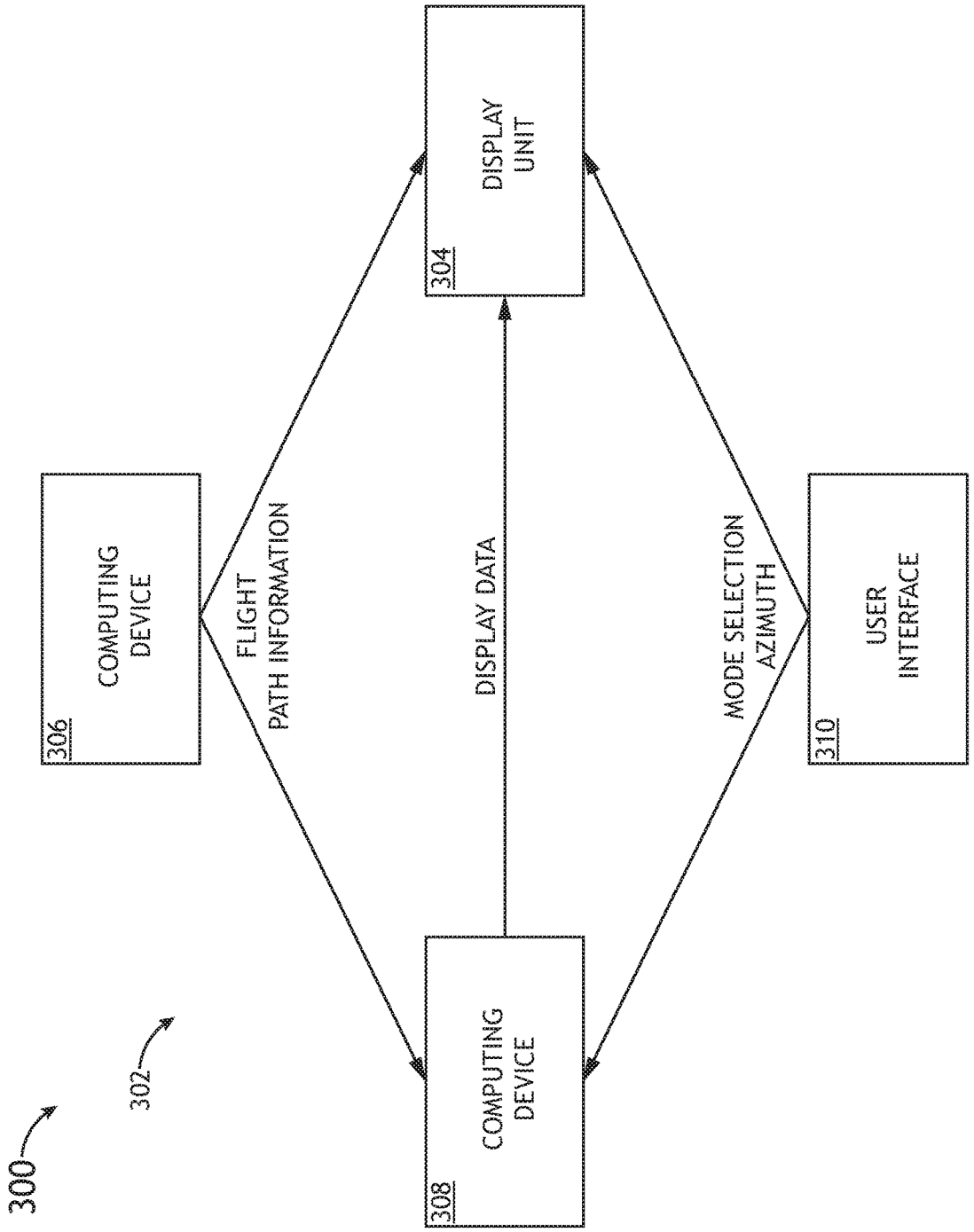

300
302
COMPUTING DEVICE
306
DISPLAY UNIT
304
USER INTERFACE
310
COMPUTING DEVICE
308
FLIGHT PATH INFORMATION
DISPLAY DATA
MODE SELECTION AZIMUTH

FIG. 3

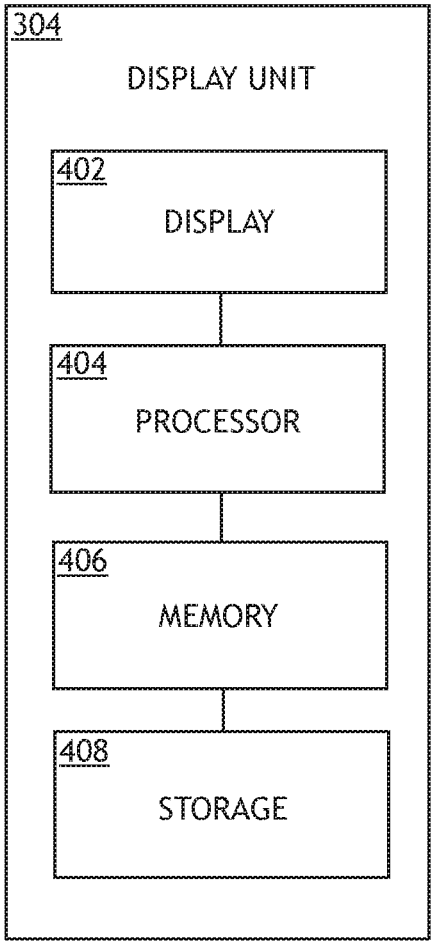

304
DISPLAY UNIT
402
DISPLAY
404
PROCESSOR
406
MEMORY
408
STORAGE

FIG.4

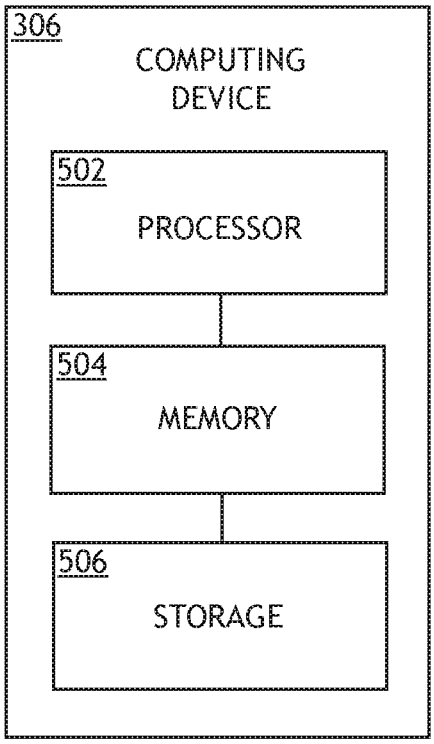


FIG.5

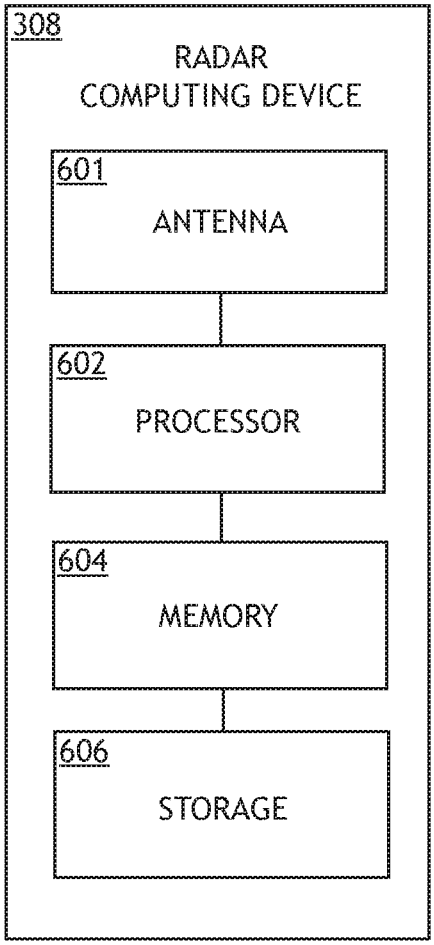

308
RADAR
COMPUTING DEVICE
601
ANTENNA
602
PROCESSOR
604
MEMORY
606
STORAGE

FIG.6

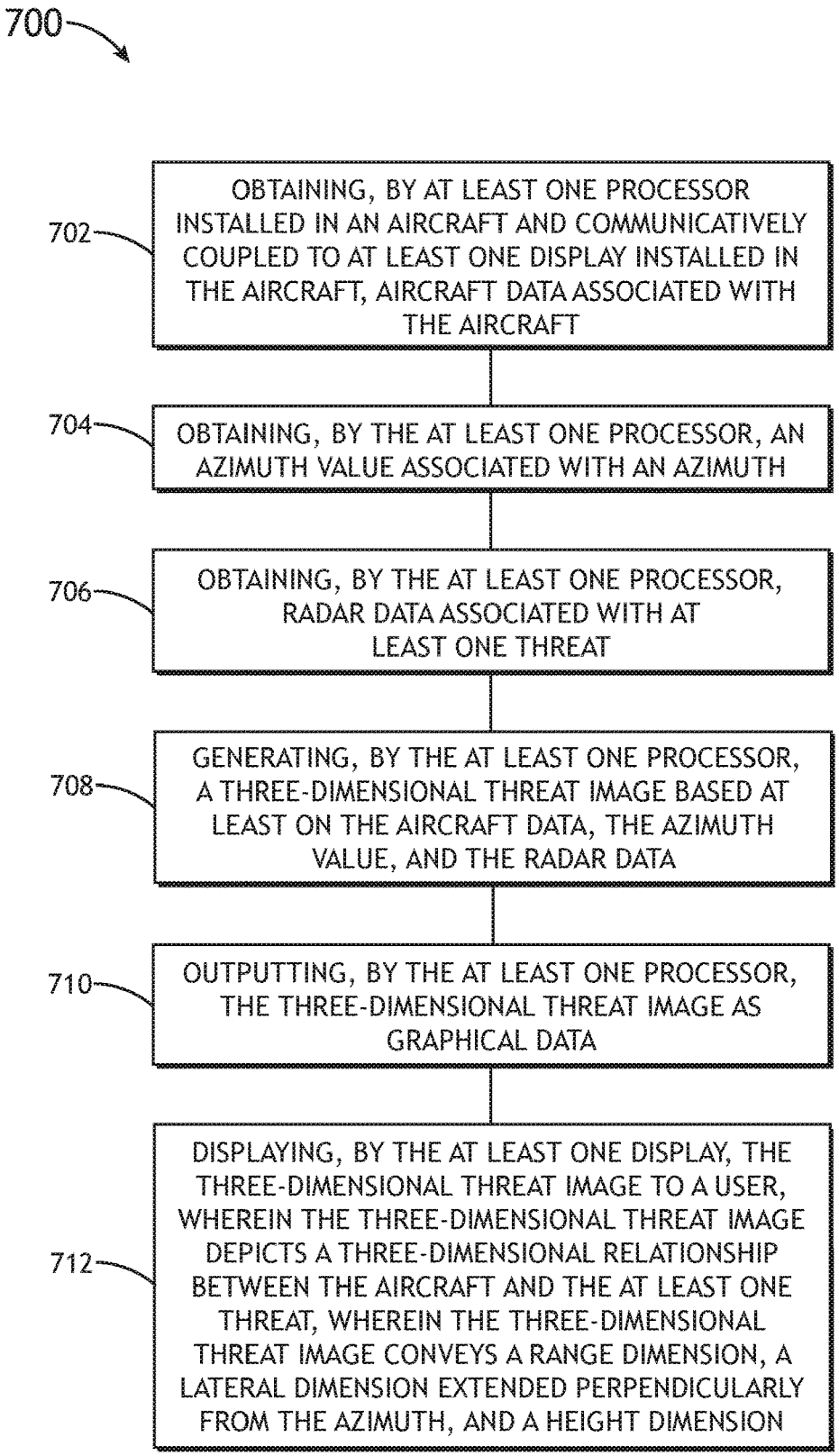

700
702
OBTAINING, BY AT LEAST ONE PROCESSOR INSTALLED IN AN AIRCRAFT AND COMMUNICATIVELY COUPLED TO AT LEAST ONE DISPLAY INSTALLED IN THE AIRCRAFT, AIRCRAFT DATA ASSOCIATED WITH THE AIRCRAFT
704
OBTAINING, BY THE AT LEAST ONE PROCESSOR, AN AZIMUTH VALUE ASSOCIATED WITH AN AZIMUTH
706
OBTAINING, BY THE AT LEAST ONE PROCESSOR, RADAR DATA ASSOCIATED WITH AT LEAST ONE THREAT
708
GENERATING, BY THE AT LEAST ONE PROCESSOR, A THREE-DIMENSIONAL THREAT IMAGE BASED AT LEAST ON THE AIRCRAFT DATA, THE AZIMUTH VALUE, AND THE RADAR DATA
710
OUTPUTTING, BY THE AT LEAST ONE PROCESSOR, THE THREE-DIMENSIONAL THREAT IMAGE AS GRAPHICAL DATA
712
DISPLAYING, BY THE AT LEAST ONE DISPLAY, THE THREE-DIMENSIONAL THREAT IMAGE TO A USER, WHEREIN THE THREE-DIMENSIONAL THREAT IMAGE DEPICTS A THREE-DIMENSIONAL RELATIONSHIP BETWEEN THE AIRCRAFT AND THE AT LEAST ONE THREAT, WHEREIN THE THREE-DIMENSIONAL THREAT IMAGE CONVEYS A RANGE DIMENSION, A LATERAL DIMENSION EXTENDED PERPENDICULARLY FROM THE AZIMUTH, AND A HEIGHT DIMENSION

FIG.7

AIRCRAFT SYSTEM AND METHOD TO DISPLAY THREE-DIMENSIONAL THREAT IMAGE

BACKGROUND

[0001] Current implementations of a vertical weather display only show the vertical profile along a single azimuth. In order to obtain additional weather information along the selected azimuth, continual control panel adjustments are required of the pilot. The vertical display is also limited in range compared to the horizontal display, requiring constant "switching" between displays.

SUMMARY

[0002] In one aspect, embodiments of the inventive concepts disclosed herein are directed to a system. The system may include at least one display and at least one processor installed in an aircraft. The at least one processor may be communicatively coupled to the at least one display. The at least one processor may be configured to: obtain aircraft data associated with the aircraft; obtain an azimuth value associated with an azimuth; obtain radar data associated with at least one threat; generate a three-dimensional threat image based at least on the aircraft data, the azimuth value, and the radar data; and output the three-dimensional threat image as graphical data. The at least one display may be configured to display the three-dimensional threat image to a user. The three-dimensional threat image may depict a three-dimensional relationship between the aircraft and the at least one threat. The three-dimensional threat image may convey a range dimension, a lateral dimension extended perpendicularly from the azimuth, and a height dimension.

[0003] In a further aspect, embodiments of the inventive concepts disclosed herein are directed to a method. The method may include: obtaining, by at least one processor installed in an aircraft and communicatively coupled to at least one display installed in the aircraft, aircraft data associated with the aircraft; obtaining, by the at least one processor, an azimuth value associated with an azimuth; obtaining, by the at least one processor, radar data associated with at least one threat; generating, by the at least one processor, a three-dimensional threat image based at least on the aircraft data, the azimuth value, and the radar data; outputting, by the at least one processor, the three-dimensional threat image as graphical data; and displaying, by the at least one display, the three-dimensional threat image to a user; wherein the three-dimensional threat image depicts a three-dimensional relationship between the aircraft and the at least one threat, wherein the three-dimensional threat image conveys a range dimension, a lateral dimension extended perpendicularly from the azimuth, and a height dimension.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] Implementations of the inventive concepts disclosed herein may be better understood when consideration is given to the following detailed description thereof. Such description makes reference to the included drawings, which are not necessarily to scale, and in which some features may be exaggerated and some features may be omitted or may be represented schematically in the interest of clarity. Like reference numerals in the drawings may represent and refer to the same or similar element, feature, or function. In the drawings:

[0005] FIG. **1** is a view of an exemplary embodiment of a horizontal two-dimensional threat image according to the inventive concepts disclosed herein.

[0006] FIG. **2** is a view of an exemplary embodiment of three-dimensional threat image **200** according to the inventive concepts disclosed herein.

[0007] FIG. **3** is a view of an exemplary embodiment of a system according to the inventive concepts disclosed herein.

[0008] FIG. **4** is a view of an exemplary embodiment of a display unit computing device of the system of FIG. **3** according to the inventive concepts disclosed herein.

[0009] FIG. **5** is a view of an exemplary embodiment of an aircraft computing device of the system of FIG. **3** according to the inventive concepts disclosed herein.

[0010] FIG. **6** is a view of an exemplary embodiment of an radar computing device of the system of FIG. **3** according to the inventive concepts disclosed herein.

[0011] FIG. **7** is a diagram of an exemplary embodiment of a method according to the inventive concepts disclosed herein.

DETAILED DESCRIPTION

[0012] Before explaining at least one embodiment of the inventive concepts disclosed herein in detail, it is to be understood that the inventive concepts are not limited in their application to the details of construction and the arrangement of the components or steps or methodologies set forth in the following description or illustrated in the drawings. In the following detailed description of embodiments of the instant inventive concepts, numerous specific details are set forth in order to provide a more thorough understanding of the inventive concepts. However, it will be apparent to one of ordinary skill in the art having the benefit of the instant disclosure that the inventive concepts disclosed herein may be practiced without these specific details. In other instances, well-known features may not be described in detail to avoid unnecessarily complicating the instant disclosure. The inventive concepts disclosed herein are capable of other embodiments or of being practiced or carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein is for the purpose of description and should not be regarded as limiting.

[0013] As used herein a letter following a reference numeral is intended to reference an embodiment of the feature or element that may be similar, but not necessarily identical, to a previously described element or feature bearing the same reference numeral (e.g., **1**, **1***a*, **1***b*). Such shorthand notations are used for purposes of convenience only, and should not be construed to limit the inventive concepts disclosed herein in any way unless expressly stated to the contrary.

[0014] Further, unless expressly stated to the contrary, "or" refers to an inclusive or and not to an exclusive or. For example, a condition A or B is satisfied by anyone of the following: A is true (or present) and B is false (or not present), A is false (or not present) and B is true (or present), and both A and B are true (or present).

[0015] In addition, use of the "a" or "an" are employed to describe elements and components of embodiments of the instant inventive concepts. This is done merely for conve-

nience and to give a general sense of the inventive concepts, and "a" and "an" are intended to include one or at least one and the singular also includes the plural unless it is obvious that it is meant otherwise.

[0016] Finally, as used herein any reference to "one embodiment," or "some embodiments" means that a particular element, feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the inventive concepts disclosed herein. The appearances of the phrase "in some embodiments" in various places in the specification are not necessarily all referring to the same embodiment, and embodiments of the inventive concepts disclosed may include one or more of the features expressly described or inherently present herein, or any combination of sub-combination of two or more such features, along with any other features which may not necessarily be expressly described or inherently present in the instant disclosure.

[0017] Broadly, embodiments of the inventive concepts disclosed herein may be directed to a system (e.g., an aircraft system) and a method configured to display at least one three-dimensional threat image. In some embodiments, the three-dimensional threat image may be a three-dimensional weather threat image. In some embodiments, the three-dimensional threat image may be a three-dimensional comprehensive airborne threat display image.

[0018] Some embodiments may provide a way to display all relevant threats at a glance without increasing pilot workload.

[0019] Some embodiments may provide a comprehensive display image capable of correlating all relevant horizontal and vertical information. This image may show relevant threats not just along the azimuth of interest but along a lateral area on either or both sides of the azimuth. For example, for a single pilot operation, this method can easily be integrated into threat objects. For normal operation, this method can give the flight crew more situational awareness in case they need to make a quick deviation decision. For example, the displayed image may include simplified depictions of threats to reduce processor processing requirements; for example, threats may be simplified into a horizontal two-dimensional planar portion (e.g., at a base of the threat) and a vertical two-dimensional planar portion extending perpendicularly from the horizontal two-dimensional planar portion. For example, the displayed image may be created by aligning a horizontal image along an azimuth (e.g., a selected azimuth) and by creating vertical image cutouts aligned to highest storm top portions of storm cores. For example, threats may be displayed as a horizontal footprint of the threat at a low altitude and a dome-shaped cross-section extending from the footprint to a peak of the threat. An aircraft intercept altitude indicator may also be shown on each cutout to show the aircraft altitude at a time that the aircraft would be expected to intercept the storm.

[0020] Some embodiments may provide significant cost savings and improve aircraft operating safety. For example, upgrading display systems in a cockpit can cost millions of dollars. Some embodiments may provide a way to show all relevant information including a vertical profile of a storm without hardware updates to existing displays. This may be especially true in case of current generation single-aisle aircraft where there is no dedicated vertical situation display (VSD). Providing all of the relevant information at a glance can enhance the situational awareness of the flight crew and may have a potential to improve safety.

[0021] Referring now to FIG. **1**, an exemplary embodiment of an overhead view of a horizontal two-dimensional threat image **100** depicting threats **213**A, **213**B is shown. For example, the threats **213**A, **213**B may be weather threats, such as storm cells; however, in some embodiments, the horizontal two-dimensional threat image **100** may depict any type of threats, such as air traffic or other objects detectable by radar. For example, the horizontal two-dimensional threat image **100** may be generated by at least one processor **602** of a radar computing device **308**, as shown in FIG. **6**.

[0022] Referring now to FIG. **2**, an exemplary embodiment of a view of a three-dimensional threat image **200** depicting the threats **213**A, **213**B is shown. For example, the threats **213**A, **213**B may be weather threats, such as storm cells; however, in some embodiments, the three-dimensional threat image **200** may depict any type of threats, such as air traffic or other objects detectable by radar. For example, the at least one threat **213**A, **213**B may be at least one storm threat, the radar data may be weather radar data, and the three-dimensional threat image **200** may be a three-dimensional storm threat image, as shown in FIG. **2**. For example, the three-dimensional threat image **200** may be generated by at least one processor **602** of a radar computing device **308**, as shown in FIG. **6**. In some embodiments, the three-dimensional threat image **200** may be generated based at least in part on the horizontal two-dimensional threat image **100** and/or radar data. For example, the three-dimensional threat image **200** may be displayed by a display **402**, as shown in FIG. **4**.

[0023] For example, the three-dimensional threat image **200** may depict a three-dimensional relationship between an aircraft **302** and the at least one threat **213**A, **213**B. The three-dimensional threat image **200** may convey a range dimension, a lateral dimension extended perpendicularly from an azimuth **204** (e.g., from both sides of the azimuth **204**), and a height dimension.

[0024] The three-dimensional threat image **200** may include: a graphical depiction of a height and width of each of the at least one threat **213**A, **213**B; a graphical depiction of an aircraft intercept altitude **210** for the aircraft **302** at each of the at least one threat **213**A, **213**B; a textual depiction of a threat height **208** (e.g., a storm top height) for each of the at least one threat **213**A, **213**B; a growth or decay indicator **212** (e.g., an upward pointing arrow for a growth indicator or a downward pointing arrow for a decay indicator) for each of the at least one threat **213**A, **2136** to indicate whether the threat **213**A, **213**B is growing or decaying; a graphical depiction of severity regions (e.g., a first severity region **214**, a second severity region **216**, and/or a third severity region **218**) for each of the at least one threat **213**A, **213**B, each severity region associated with a different predetermined range of severity levels (e.g., ranges of wind speed levels, ranges of density of lightning strike occurrence levels, and/or ranges of turbulence levels) and depicted differently (e.g., different colors, such as green, yellow, and red); a depiction of range indicators **202** for the range dimension and lateral distance indicators **206** for the lateral dimension; and/or a depiction of the azimuth **204**.

[0025] In some embodiments, a graphical depiction of each of the at least one threat **213**A, **213**B may include a horizontal two-dimensional planar portion and a vertical two-dimensional planar portion extending perpendicularly

from the horizontal two-dimensional planar portion so as to reduce processing requirements as compared to a three-dimensionally rendered representation of surface contours for each of the at least one threat **213**A, **213**B.

[0026] As exemplarily shown, the three-dimensional threat image **200** has a lateral dimension of 40 nautical miles (nm) (e.g., 20 nm from each side of the aircraft **302**) with a range of 100 nm and with a height of at least 33,000 feet; however, any suitable dimensions may be used. In some embodiments, a user and/or at least one processor of the system may be configured to set and/or adjust the dimensions.

[0027] Referring now to FIGS. **3-6**, an exemplary embodiment of a system **300** according to the inventive concepts disclosed herein is depicted. In some embodiments, the system may include an aircraft **302**, which may include at least one user (e.g., flight crew and/or pilot(s)), at least one display unit computing device **304**, at least one aircraft computing device **306**, at least one radar computing device **308**, and/or at least one user interface **310**, some or all of which may be communicatively coupled at any given time. In some embodiments, the at least one display unit computing device **304**, the at least one aircraft computing device **306**, the at least one radar computing device **308**, and/or the at least one user interface **310** may be implemented as a single computing device or any number of computing devices configured to perform (e.g., collectively perform if more than one computing device) any or all of the operations disclosed throughout. The at least one display unit computing device **304**, the at least one aircraft computing device **306**, the at least one radar computing device **308**, and/or the at least one user interface **310** may be installed in the aircraft **302**.

[0028] The user may be a pilot or crew member. The user may interface with the system **300** via the at least one user interface **310**. The at least one user interface **310** may be implemented as any suitable user interface, such as a touchscreen (e.g., of the display unit computing device **304** and/or another display unit), a multipurpose control panel, a control panel integrated into a flight deck, a cursor control panel (CCP) (sometimes referred to as a display control panel (DCP)), a keyboard, a mouse, a trackpad, at least one hardware button, a switch, an eye tracking system, and/or a voice recognition system. The user interface **310** may be configured to receive at least one user input and to output the at least one user input to a computing device (e.g., **304**, **306**, and/or **308**). For example, a pilot of the aircraft **104** may be able to interface with the user interface **310** to: select an azimuth to be used for an azimuth value; engage (or disengage) a mode (e.g., a "comprehensive display mode") to cause the three-dimensional threat image **200** to be displayed; command an azimuth mode to be based on at least one of a track of the aircraft **302**, a pilot selected azimuth, and/or aircraft information from the aircraft computing device **306** (e.g., a flight management system (FMS) or flight data computer). For example, such user inputs may be output to the radar computing device **308** and/or the display unit computing device **304**.

[0029] The display unit computing device **304** may be implemented as any suitable computing device, such as a primary flight display (PFD) computing device and/or a multi-function window (MFW) display computing device. As shown in FIG. **4**, the display unit computing device **304** may include at least one display **402**, at least one processor **404**, at least one memory **406**, and/or at least one storage **410**, some or all of which may be communicatively coupled at any given time. For example, the at least one processor **404** may include at least one central processing unit (CPU), at least one graphics processing unit (GPU), at least one field-programmable gate array (FPGA), at least one application specific integrated circuit (ASIC), at least one digital signal processor, at least one virtual machine (VM) running on at least one processor, and/or the like configured to perform (e.g., collectively perform) any of the operations disclosed throughout. For example, the at least one processor **404** may include a CPU and a GPU configured to perform (e.g., collectively perform) any of the operations disclosed throughout. The processor **404** may be configured to run various software applications (e.g., a PFD application and/or an MFW application) or computer code stored (e.g., maintained) in a non-transitory computer-readable medium (e.g., memory **406** and/or storage **410**) and configured to execute various instructions or operations. The processor **404** may be configured to perform any or all of the operations disclosed throughout. For example, the processor **404** may be configured to: receive the aircraft data from the at least one aircraft computing device processor **502**; and/or overlay the three-dimensional threat image **200** over other information from the aircraft data or to overlay the other information from the aircraft data over the three-dimensional threat image **200**. The display **402** may be configured to display the three-dimensional threat image **200** to a user.

[0030] The at least one aircraft computing device **306** may be implemented as any suitable computing device, such as an FMS computing device or a flight data computer. The at least one aircraft computing device **306** may include any or all of the elements, as shown in FIG. **5**. For example, the aircraft computing device **306** may include at least one processor **502**, at least one memory **504**, and/or at least one storage **506**, some or all of which may be communicatively coupled at any given time. For example, the at least one processor **502** may include at least one central processing unit (CPU), at least one graphics processing unit (GPU), at least one field-programmable gate array (FPGA), at least one application specific integrated circuit (ASIC), at least one digital signal processor, at least one virtual machine (VM) running on at least one processor, and/or the like configured to perform (e.g., collectively perform) any of the operations disclosed throughout. For example, the at least one processor **502** may include a CPU and a GPU configured to perform (e.g., collectively perform) any of the operations disclosed throughout. The processor **502** may be configured to run various software applications (e.g., an FMS application) or computer code stored (e.g., maintained) in a non-transitory computer-readable medium (e.g., memory **504** and/or storage **506**) and configured to execute various instructions or operations. The processor **502** of the aircraft computing device **306** may be configured to perform any or all of the operations disclosed throughout. For example, the processor **502** of the computing device **210**A may be configured to: output aircraft data (e.g., FMS data, flight path data, inertial reference unit (IRU) data, flight data, and/or flight computer data) to the display unit computing device **304** and/or the radar computing device **308**.

[0031] The at least one radar computing device **308** may be implemented as any suitable computing device, such as a weather radar computing device. The at least one radar computing device **308** may include any or all of the elements

shown in FIG. **6**. For example, the radar computing device **308** may include at least one radar antenna **601**, at least one processor **602**, at least one memory **604**, and/or at least one storage **606**, some or all of which may be communicatively coupled at any given time. For example, the at least one processor **602** may include at least one central processing unit (CPU), at least one graphics processing unit (GPU), at least one field-programmable gate array (FPGA), at least one application specific integrated circuit (ASIC), at least one digital signal processor, at least one virtual machine (VM) running on at least one processor, and/or the like configured to perform (e.g., collectively perform) any of the operations disclosed throughout. For example, the at least one processor **602** may include a CPU and a GPU configured to perform (e.g., collectively perform) any of the operations disclosed throughout. The processor **602** may be configured to run various software applications (e.g., a radar application) or computer code stored (e.g., maintained) in a non-transitory computer-readable medium (e.g., memory **604** and/or storage **606**) and configured to execute various instructions or operations. The processor **602** of the radar computing device **308** may be configured to perform any or all of the operations disclosed throughout. For example, the processor **602** may be configured to: obtain the aircraft data from the at least one aircraft computing device processor **502**; obtain the azimuth value associated with the azimuth **204**; obtain the radar data associated with the at least one threat **213**A, **213**B; generate the three-dimensional threat image **200** based at least on the aircraft data, the azimuth value, and the radar data; output the three-dimensional threat image **200** as the graphical data to the at least one display unit computing device processor **404**; use the aircraft data to accurately compute weather information to be displayed; and/or based at least on a mode and/or azimuth user input (e.g., from the user interface **310** and/or a processor of the system **300**), compute dimensions for the three-dimensional threat image **200** to be displayed.

[0032] For example, at least one processor (e.g., the at least one processor **404**, the at least one processor **502**, and/or the at least one processor **602**) may be configured to (e.g., collectively configured to, if more than one processor): obtain aircraft data associated with the aircraft **302**; obtain an azimuth value associated with an azimuth **204**; obtain radar data associated with at least one threat **213**A, **2136**; generate a three-dimensional threat image **200** based at least on the aircraft data, the azimuth value, and/or the radar data; and/or output the three-dimensional threat image **200** as graphical data.

[0033] At least one processor (e.g., the at least one processor **404**, the at least one processor **502**, and/or the at least one processor **602**) of the aircraft **302** may be configured to perform (e.g., collectively perform) any or all of the operations disclosed throughout.

[0034] Referring now to FIG. **7**, an exemplary embodiment of a method **700** according to the inventive concepts disclosed herein may include one or more of the following steps. Additionally, for example, some embodiments may include performing one or more instances of the method **700** iteratively, concurrently, and/or sequentially. Additionally, for example, at least some of the steps of the method **700** may be performed in parallel and/or concurrently. Additionally, in some embodiments, at least some of the steps of the method **700** may be performed non-sequentially.

[0035] A step **702** may include obtaining, by at least one processor installed in an aircraft and communicatively coupled to at least one display installed in the aircraft, aircraft data associated with the aircraft.

[0036] A step **704** may include obtaining, by the at least one processor, an azimuth value associated with an azimuth.

[0037] A step **706** may include obtaining, by the at least one processor, radar data associated with at least one threat.

[0038] A step **708** may include generating, by the at least one processor, a three-dimensional threat image based at least on the aircraft data, the azimuth value, and the radar data.

[0039] A step **710** may include outputting, by the at least one processor, the three-dimensional threat image as graphical data.

[0040] A step **712** may include displaying, by the at least one display, the three-dimensional threat image to a user, wherein the three-dimensional threat image depicts a three-dimensional relationship between the aircraft and the at least one threat, wherein the three-dimensional threat image conveys a range dimension, a lateral dimension extended perpendicularly from the azimuth, and a height dimension.

[0041] Further, the method **700** may include any of the operations disclosed throughout.

[0042] As will be appreciated from the above, embodiments of the inventive concepts disclosed herein may be directed to a system (e.g., an aircraft system) and a method configured to display at least one three-dimensional threat image.

[0043] As used throughout and as would be appreciated by those skilled in the art, "at least one non-transitory computer-readable medium" may refer to as at least one non-transitory computer-readable medium (e.g., at least one computer-readable medium implemented as hardware; e.g., at least one non-transitory processor-readable medium, at least one memory (e.g., at least one nonvolatile memory, at least one volatile memory, or a combination thereof; e.g., at least one random-access memory, at least one flash memory, at least one read-only memory (ROM) (e.g., at least one electrically erasable programmable read-only memory (EEPROM)), at least one on-processor memory (e.g., at least one on-processor cache, at least one on-processor buffer, at least one on-processor flash memory, at least one on-processor EEPROM, or a combination thereof), or a combination thereof), at least one storage device (e.g., at least one hard-disk drive, at least one tape drive, at least one solid-state drive, at least one flash drive, at least one readable and/or writable disk of at least one optical drive configured to read from and/or write to the at least one readable and/or writable disk, or a combination thereof), or a combination thereof).

[0044] As used throughout, "at least one" means one or a plurality of; for example, "at least one" may comprise one, two, three, . . . , one hundred, or more. Similarly, as used throughout, "one or more" means one or a plurality of; for example, "one or more" may comprise one, two, three, . . . , one hundred, or more. Further, as used throughout, "zero or more" means zero, one, or a plurality of; for example, "zero or more" may comprise zero, one, two, three, . . . , one hundred, or more.

[0045] In the present disclosure, the methods, operations, and/or functionality disclosed may be implemented as sets of instructions or software readable by a device. Further, it is understood that the specific order or hierarchy of steps in

the methods, operations, and/or functionality disclosed are examples of exemplary approaches. Based upon design preferences, it is understood that the specific order or hierarchy of steps in the methods, operations, and/or functionality can be rearranged while remaining within the scope of the inventive concepts disclosed herein. The accompanying claims may present elements of the various steps in a sample order, and are not necessarily meant to be limited to the specific order or hierarchy presented.

[0046] It is to be understood that embodiments of the methods according to the inventive concepts disclosed herein may include one or more of the steps described herein. Further, such steps may be carried out in any desired order and two or more of the steps may be carried out simultaneously with one another. Two or more of the steps disclosed herein may be combined in a single step, and in some embodiments, one or more of the steps may be carried out as two or more sub-steps. Further, other steps or sub-steps may be carried in addition to, or as substitutes to one or more of the steps disclosed herein.

[0047] From the above description, it is clear that the inventive concepts disclosed herein are well adapted to carry out the objects and to attain the advantages mentioned herein as well as those inherent in the inventive concepts disclosed herein. While presently preferred embodiments of the inventive concepts disclosed herein have been described for purposes of this disclosure, it will be understood that numerous changes may be made which will readily suggest themselves to those skilled in the art and which are accomplished within the broad scope and coverage of the inventive concepts disclosed and claimed herein.

What is claimed is:

1. A system, comprising:

at least one display installed in an aircraft; and

at least one processor installed in the aircraft and communicatively coupled to the at least one display, the at least one processor configured to:

obtain aircraft data associated with the aircraft;

obtain an azimuth value associated with an azimuth;

obtain radar data associated with at least one threat;

generate a three-dimensional threat image based at least on the aircraft data, the azimuth value, and the radar data; and

output the three-dimensional threat image as graphical data;

wherein the at least one display is configured to display the three-dimensional threat image to a user;

wherein the three-dimensional threat image depicts a three-dimensional relationship between the aircraft and the at least one threat, wherein the three-dimensional threat image conveys a range dimension, a lateral dimension extended perpendicularly from the azimuth, and a height dimension.

2. The system of claim **1**, wherein the three-dimensional threat image comprises a graphical depiction of a horizontal two-dimensional planar portion and a vertical two-dimensional planar portion extending perpendicularly from the horizontal two-dimensional planar portion for each of the at least one threat so as to reduce processing requirements as compared to a three-dimensionally rendered representation of surface contours for each of the at least one threat.

3. The system of claim **2**, wherein the at least one threat is at least one weather threat, wherein the radar data is weather radar data, wherein the three-dimensional threat image is a three-dimensional weather threat image.

4. The system of claim **2**, wherein the three-dimensional threat image further comprises a graphical depiction of an aircraft intercept altitude for the aircraft at each of the at least one threat.

5. The system of claim **4**, wherein the three-dimensional threat image further comprises a textual depiction of a threat height for each of the at least one threat.

6. The system of claim **5**, wherein the three-dimensional threat image further comprises a growth or decay indicator for each of the at least one threat.

7. The system of claim **6**, wherein the three-dimensional threat image further comprises a graphical depiction of a first severity region and a second severity region for each of the at least one threat, the first severity region associated with a first predetermined range of severity levels, the second severity region associated with a second predetermined range of severity levels, the first severity region being depicted differently from the second severity region.

8. The system of claim **7**, wherein the three-dimensional threat image further comprises a depiction of range indicators for the range dimension and lateral distance indicators for the lateral dimension.

9. The system of claim **8**, wherein the three-dimensional threat image further comprises a depiction of the azimuth.

10. The system of claim **9**, wherein the at least one threat is at least one storm threat, wherein the radar data is weather radar data, wherein the three-dimensional threat image is a three-dimensional storm threat image.

11. The system of claim **1**, wherein the azimuth value is based on at least one of a track of the aircraft, a user input of a selected azimuth, or the aircraft data.

12. The system of claim **1**, wherein the at least one processor comprises at least one aircraft computing device processor, at least one display unit computing device processor, and at least one radar computing device processor, the at least one aircraft computing device processor, the at least one display unit computing device processor, and the at least one radar computing device processor being communicatively coupled, wherein the at least one radar computing device processor is configured to: obtain the aircraft data from the at least one aircraft computing device processor; obtain the azimuth value associated with the azimuth; obtain the radar data associated with the at least one threat; generate the three-dimensional threat image based at least on the aircraft data, the azimuth value, and the radar data; and output the three-dimensional threat image as the graphical data to the at least one display unit computing device processor.

13. The system of claim **12**, wherein the at least one display unit computing device processor is configured to receive the aircraft data from the at least one aircraft computing device processor.

14. The system of claim **13**, wherein the at least one display unit computing device processor is further configured to overlay the three-dimensional threat image over other information from the aircraft data or to overlay the other information from the aircraft data over the three-dimensional threat image.

15. A method, comprising:

obtaining, by at least one processor installed in an aircraft and communicatively coupled to at least one display installed in the aircraft, aircraft data associated with the aircraft;

obtaining, by the at least one processor, an azimuth value associated with an azimuth;

obtaining, by the at least one processor, radar data associated with at least one threat;

generating, by the at least one processor, a three-dimensional threat image based at least on the aircraft data, the azimuth value, and the radar data;

outputting, by the at least one processor, the three-dimensional threat image as graphical data; and

displaying, by the at least one display, the three-dimensional threat image to a user;

wherein the three-dimensional threat image depicts a three-dimensional relationship between the aircraft and the at least one threat, wherein the three-dimensional threat image conveys a range dimension, a lateral dimension extended perpendicularly from the azimuth, and a height dimension.

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