US 20250265937A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2025/0265937 A1**

Hiller et al. (43) **Pub. Date: Aug. 21, 2025**

(54) **LASER BEAM BASED FLIGHT PATH CLEARING SYSTEM**

(71) Applicant: **The Boeing Company**, Arlington, VA (US)

(72) Inventors: **Nathan D. Hiller**, Irvine, CA (US); **Stephen Lambert**, Maryland Heights, MO (US); **Todd Harding Tomkinson**, Newbury Park, CA (US); **Steven Fulton Griffin**, Kihei, HI (US)

(21) Appl. No.: **18/442,984**

(22) Filed: **Feb. 15, 2024**

Publication Classification

(51) **Int. Cl.**

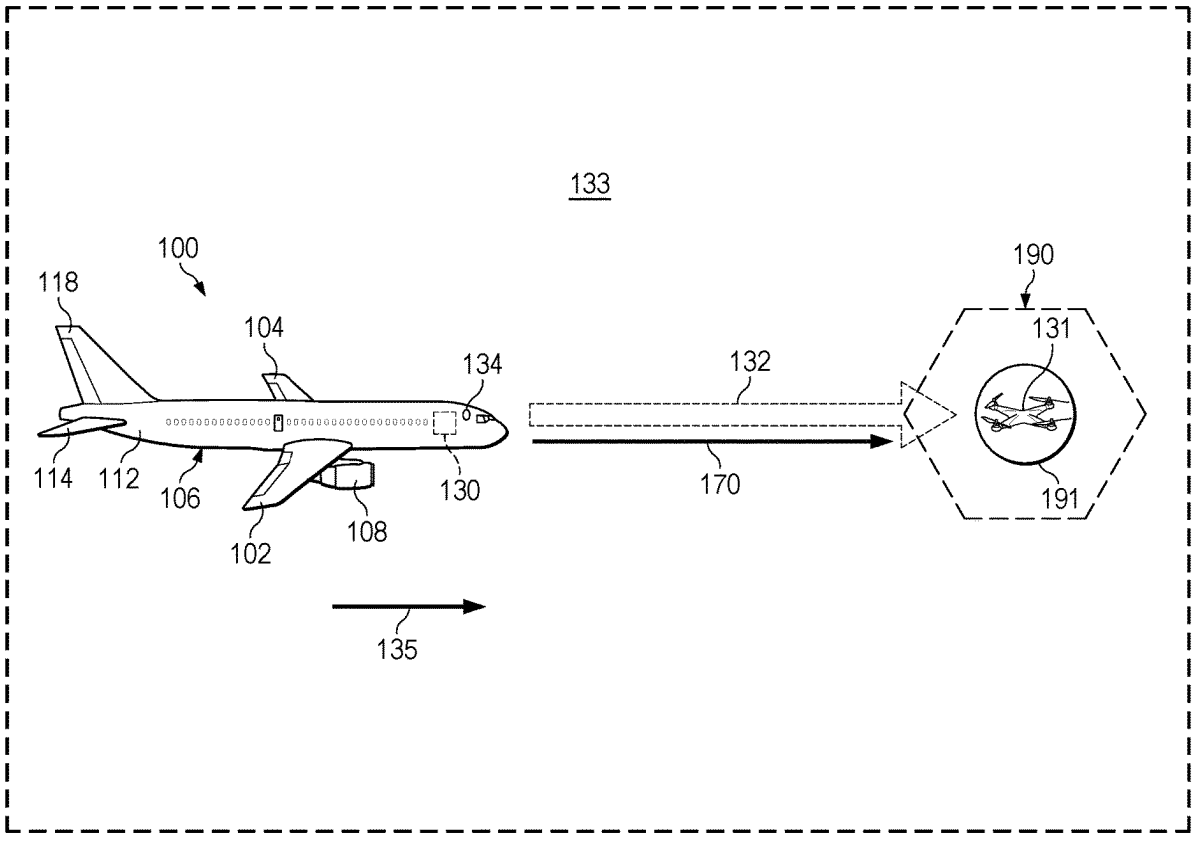
G08G 5/04	(2006.01)
B64D 47/06	(2006.01)
H01S 3/13	(2006.01)
H01S 3/22	(2006.01)

(52) **U.S. Cl.**

CPC ***G08G 5/80*** (2025.01); ***B64D 47/06*** (2013.01); ***H01S 3/13*** (2013.01); *H01S 3/22* (2013.01)

(57) **ABSTRACT**

A flight path clearing system comprising a laser beam system in an aircraft and a controller. The controller is configured to select a number of characteristics for a laser beam based on an object type. The controller is configured to control the laser beam system to emit the laser beam with the number of characteristics in a direction relative to a flight path of the aircraft. The controller is configured to control the laser beam system to move the laser beam with the number of characteristics selected for the object type to scan an area using a pattern that is based on a sequence of locations in the pattern being nearest to a center of the area, wherein a number of objects of the object type hit by the laser beam is cleared from the flight path.



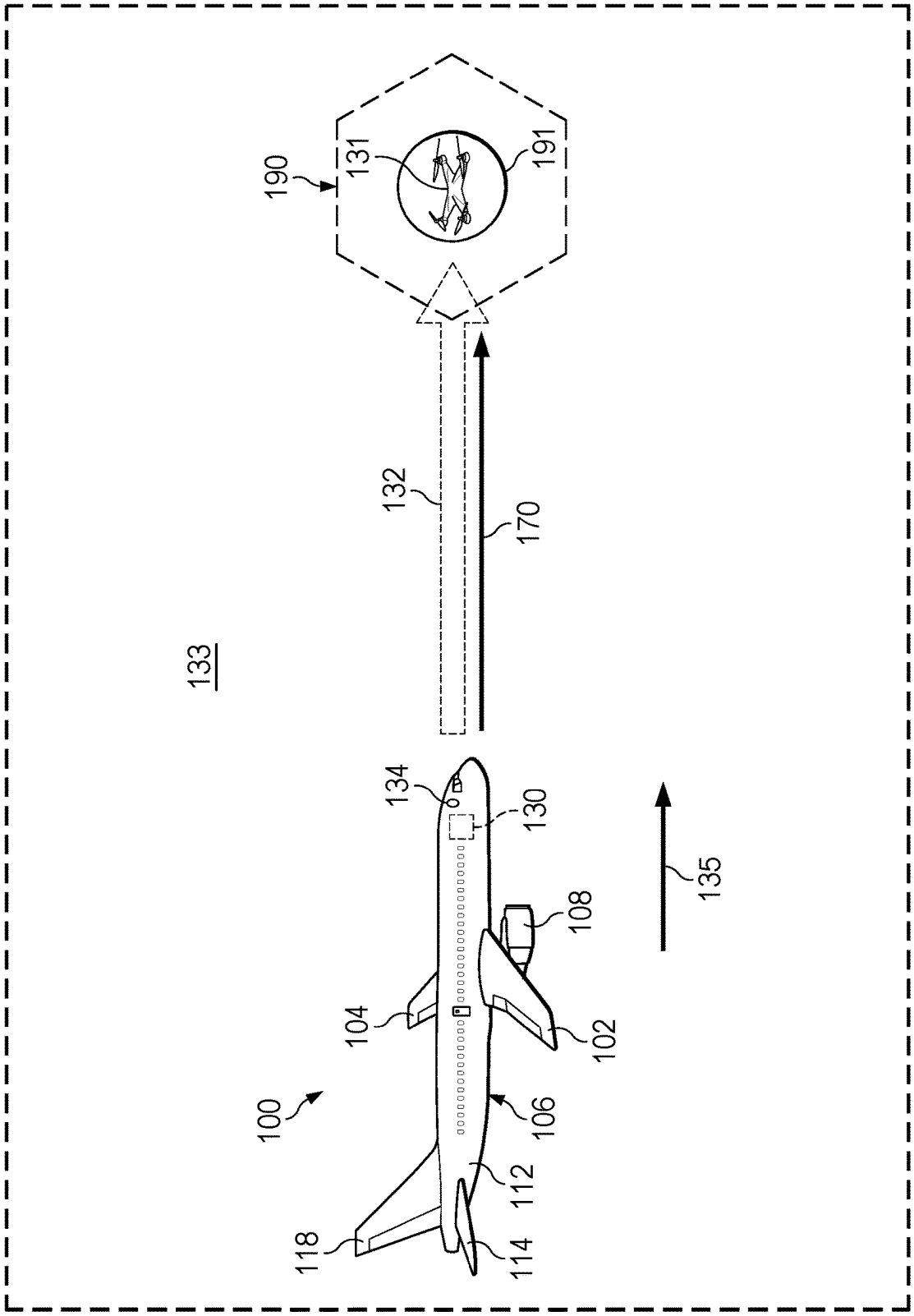
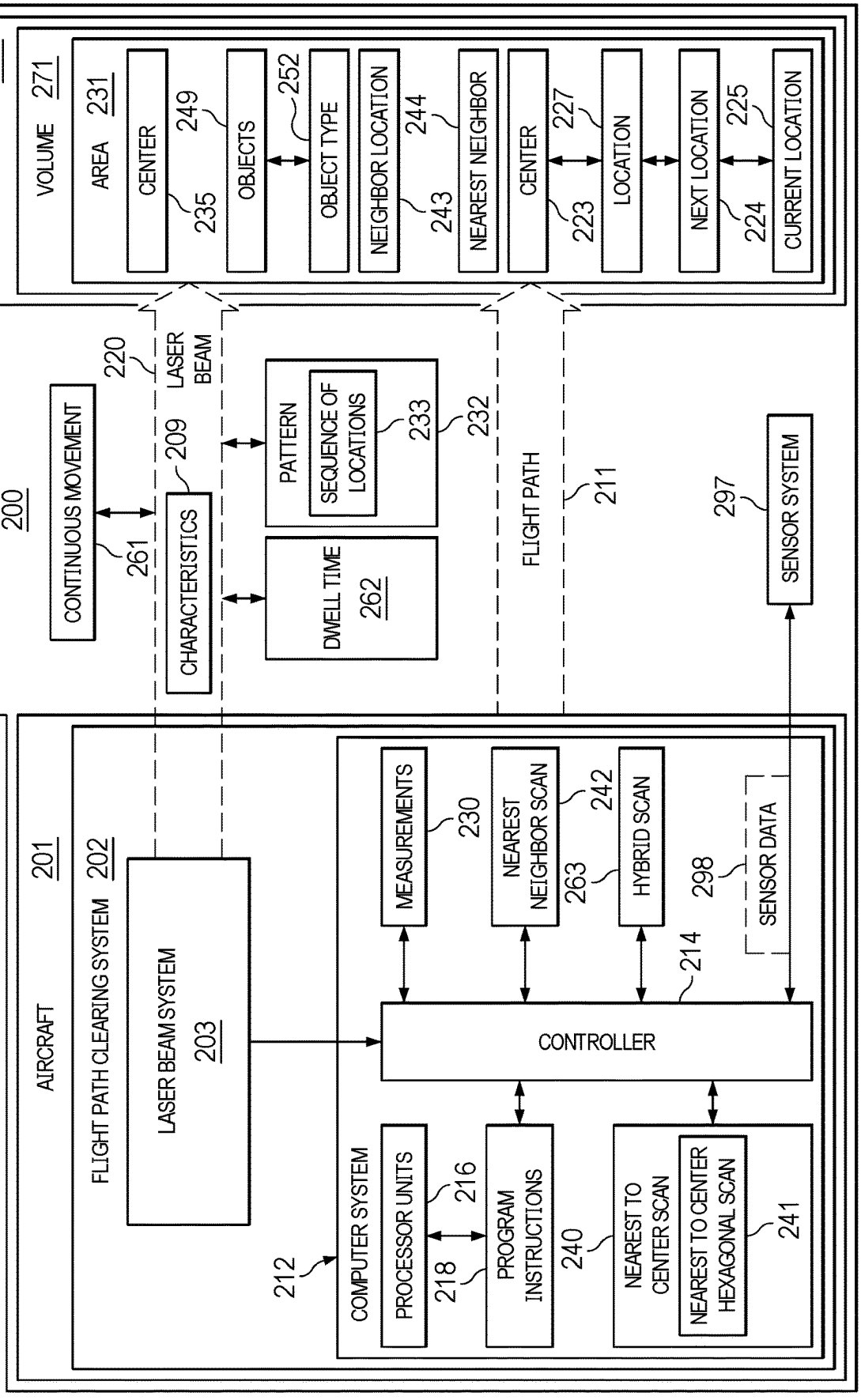

190
131
191
132
170
133
134
130
135
108
104
102
100
106
112
118
114

FIG. 1

FIG. 2


ATMOSPHERE 210
VOLUME 271
AREA 231
CENTER
235
249
OBJECTS
252
OBJECT TYPE
NEIGHBOR LOCATION
243
244
NEAREST NEIGHBOR
CENTER
223
227
LOCATION
NEXT LOCATION
224
225
CURRENT LOCATION
AIRCRAFT ENVIRONMENT
200
CONTINUOUS MOVEMENT
261
220
LASER BEAM
CHARACTERISTICS
209
PATTERN
SEQUENCE OF LOCATIONS
233
232
DWELL TIME
262
FLIGHT PATH
211
297
SENSOR SYSTEM
AIRCRAFT
201
FLIGHT PATH CLEARING SYSTEM
202
LASER BEAM SYSTEM
203
MEASUREMENTS
230
NEAREST NEIGHBOR SCAN
263
242
HYBRID SCAN
298
SENSOR DATA
214
CONTROLLER
212
COMPUTER SYSTEM
PROCESSOR UNITS
216
218
PROGRAM INSTRUCTIONS
240
NEAREST TO CENTER SCAN
NEAREST TO CENTER HEXAGONAL SCAN
241

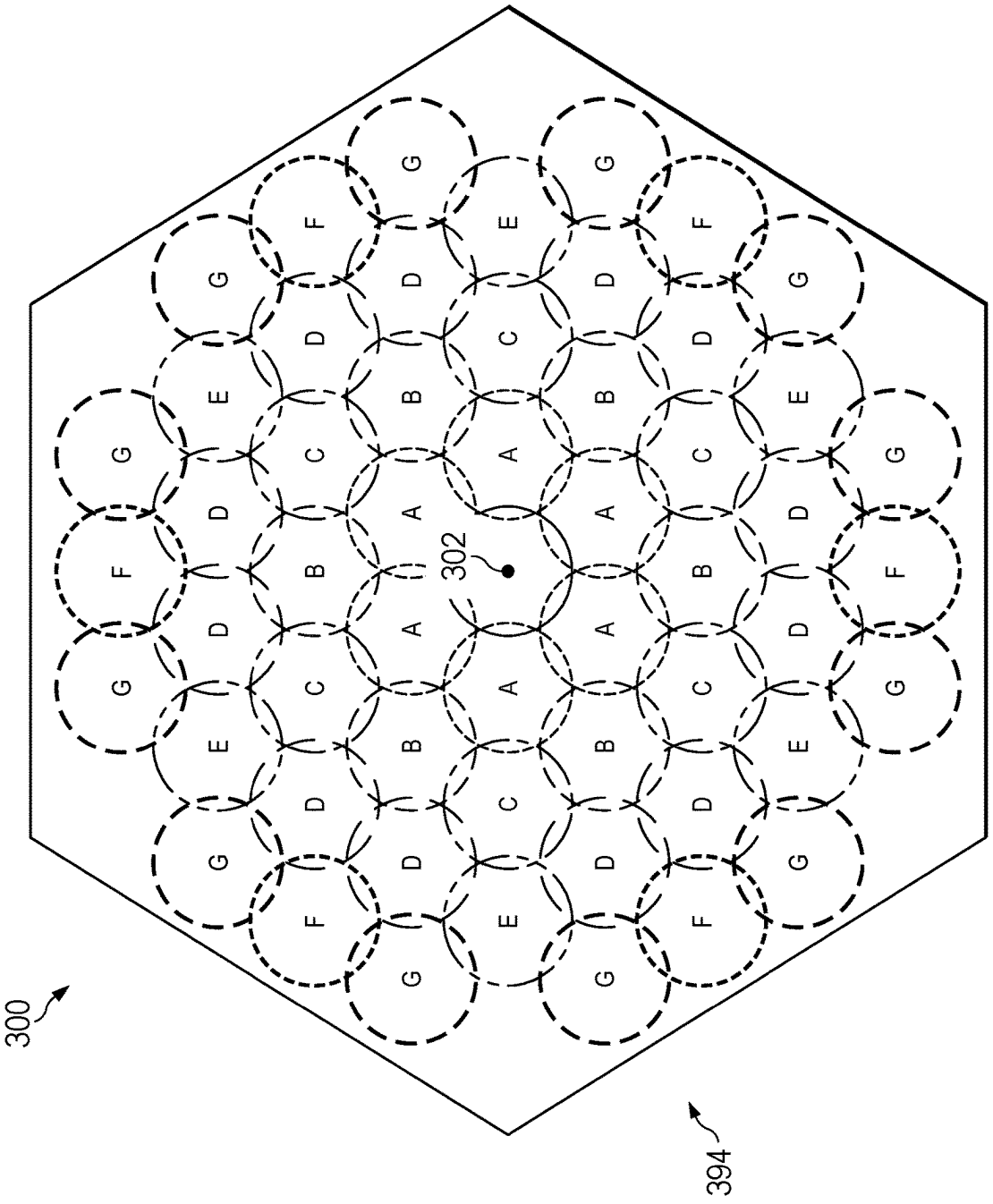


FIG. 3

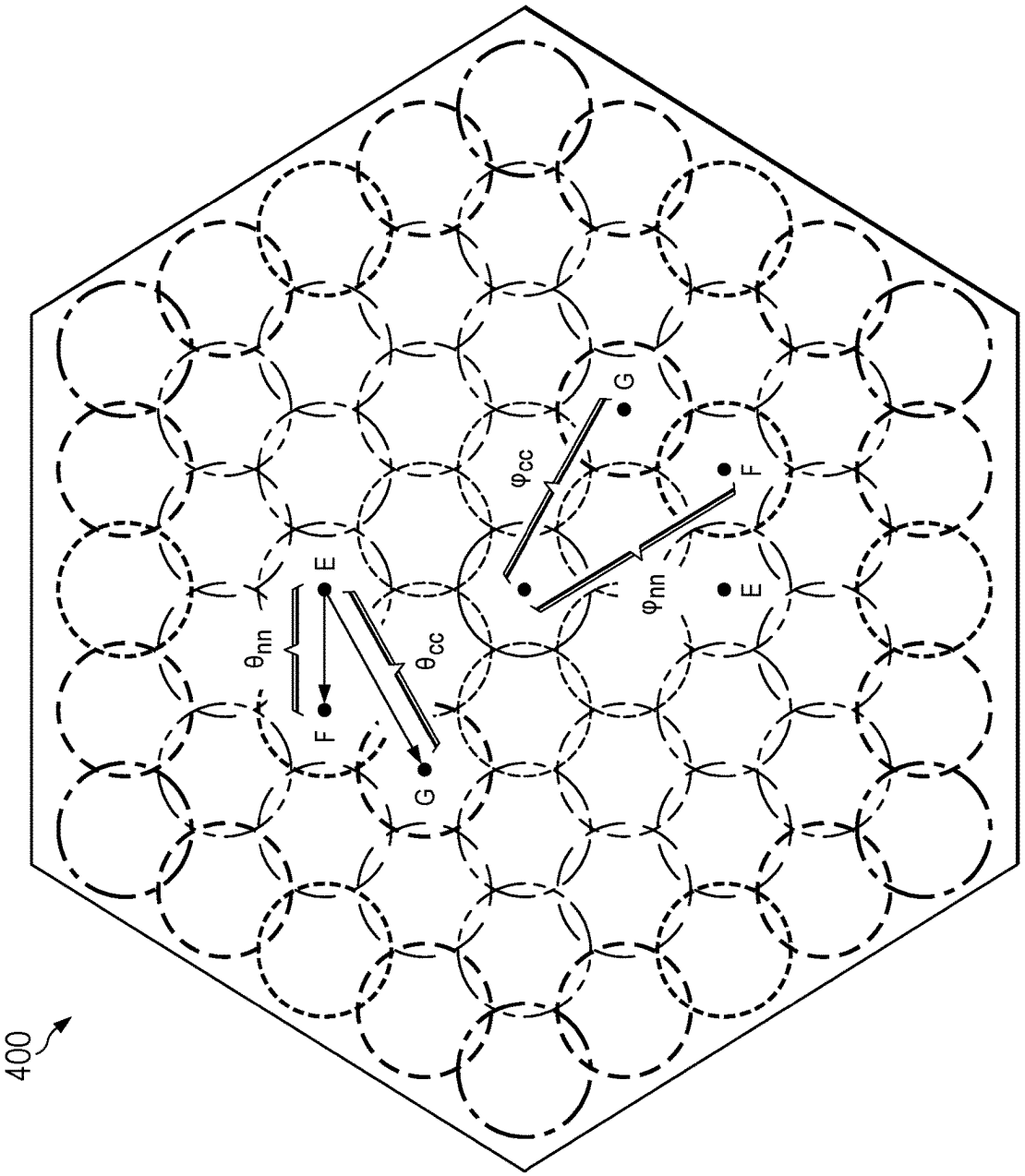


FIG. 4

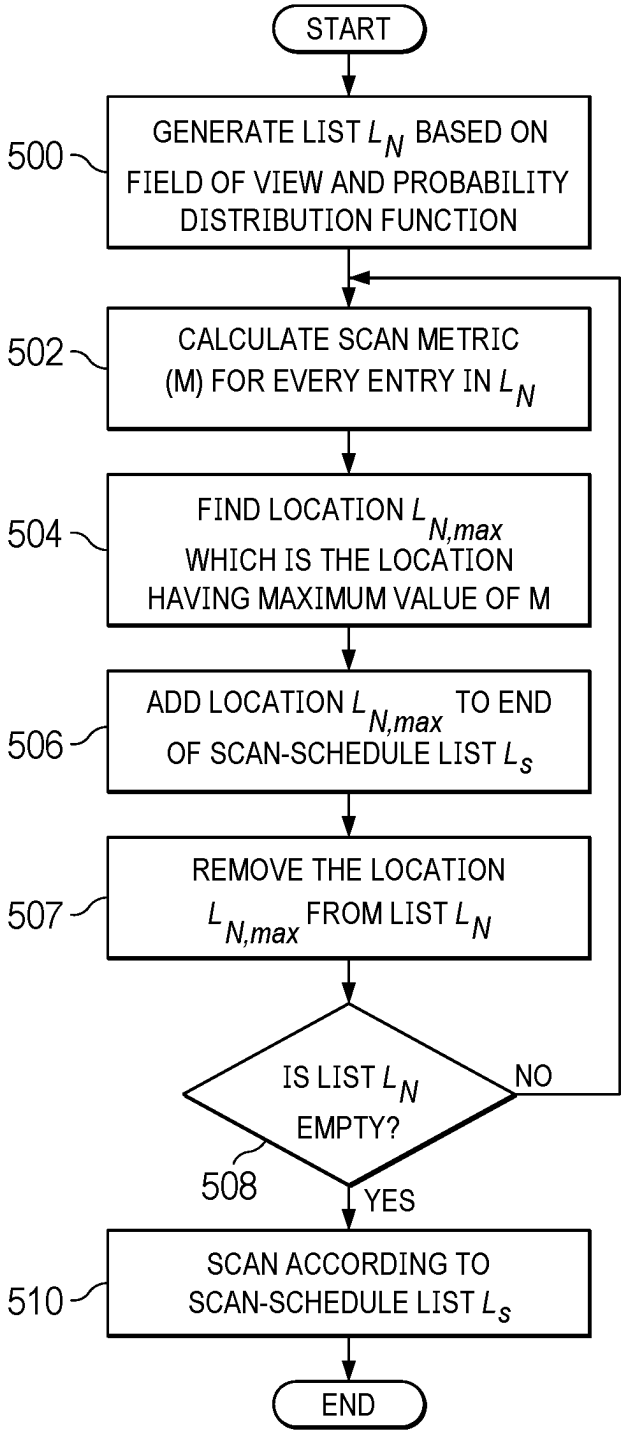

START
500
GENERATE LIST L_N BASED ON FIELD OF VIEW AND PROBABILITY DISTRIBUTION FUNCTION
502
CALCULATE SCAN METRIC (M) FOR EVERY ENTRY IN L_N
504
FIND LOCATION $L_{N,max}$ WHICH IS THE LOCATION HAVING MAXIMUM VALUE OF M
506
ADD LOCATION $L_{N,max}$ TO END OF SCAN-SCHEDULE LIST L_s
507
REMOVE THE LOCATION $L_{N,max}$ FROM LIST L_N
IS LIST L_N EMPTY?
508
NO
YES
510
SCAN ACCORDING TO SCAN-SCHEDULE LIST L_s
END

FIG. 5

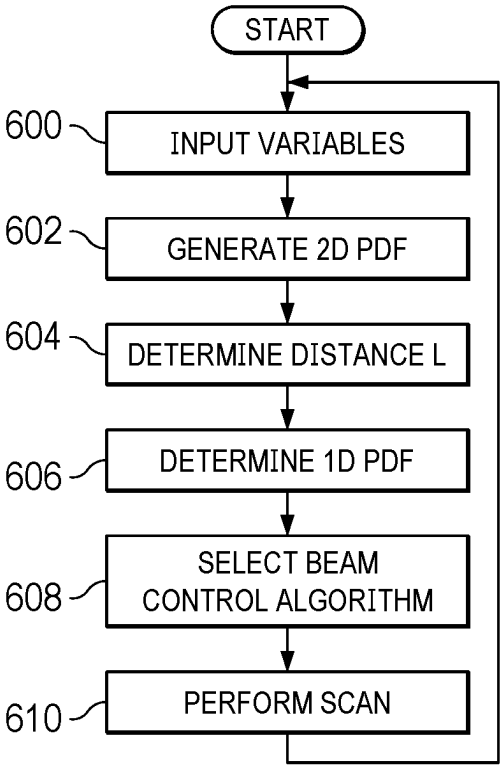

START
600
INPUT VARIABLES
602
GENERATE 2D PDF
604
DETERMINE DISTANCE L
606
DETERMINE 1D PDF
608
SELECT BEAM CONTROL ALGORITHM
610
PERFORM SCAN

FIG. 6

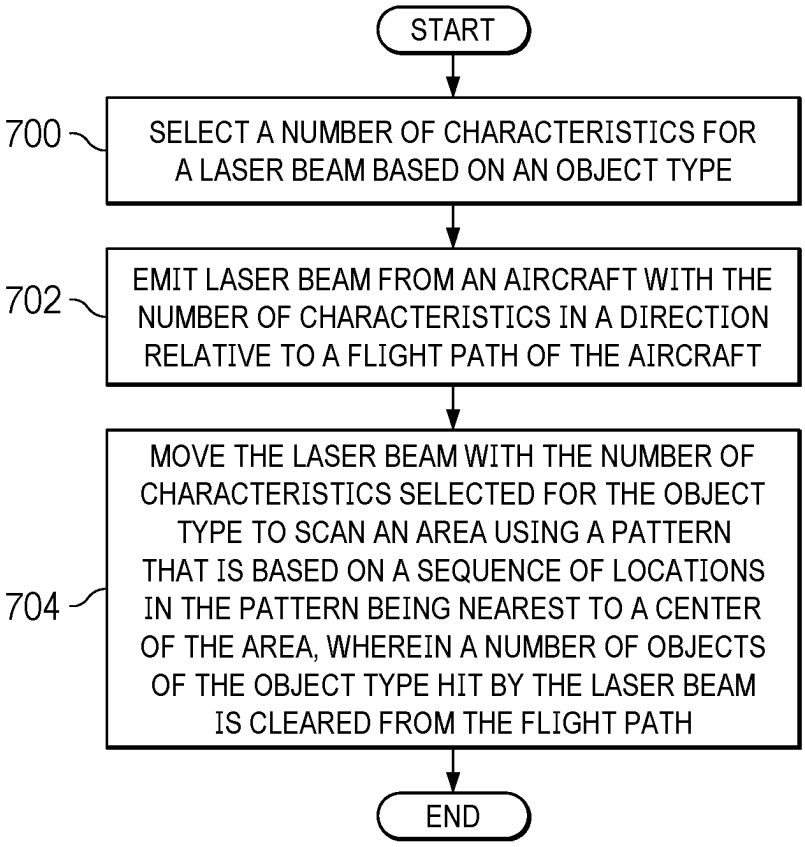

START
700
SELECT A NUMBER OF CHARACTERISTICS FOR A LASER BEAM BASED ON AN OBJECT TYPE
702
EMIT LASER BEAM FROM AN AIRCRAFT WITH THE NUMBER OF CHARACTERISTICS IN A DIRECTION RELATIVE TO A FLIGHT PATH OF THE AIRCRAFT
704
MOVE THE LASER BEAM WITH THE NUMBER OF CHARACTERISTICS SELECTED FOR THE OBJECT TYPE TO SCAN AN AREA USING A PATTERN THAT IS BASED ON A SEQUENCE OF LOCATIONS IN THE PATTERN BEING NEAREST TO A CENTER OF THE AREA, WHEREIN A NUMBER OF OBJECTS OF THE OBJECT TYPE HIT BY THE LASER BEAM IS CLEARED FROM THE FLIGHT PATH
END

FIG. 7

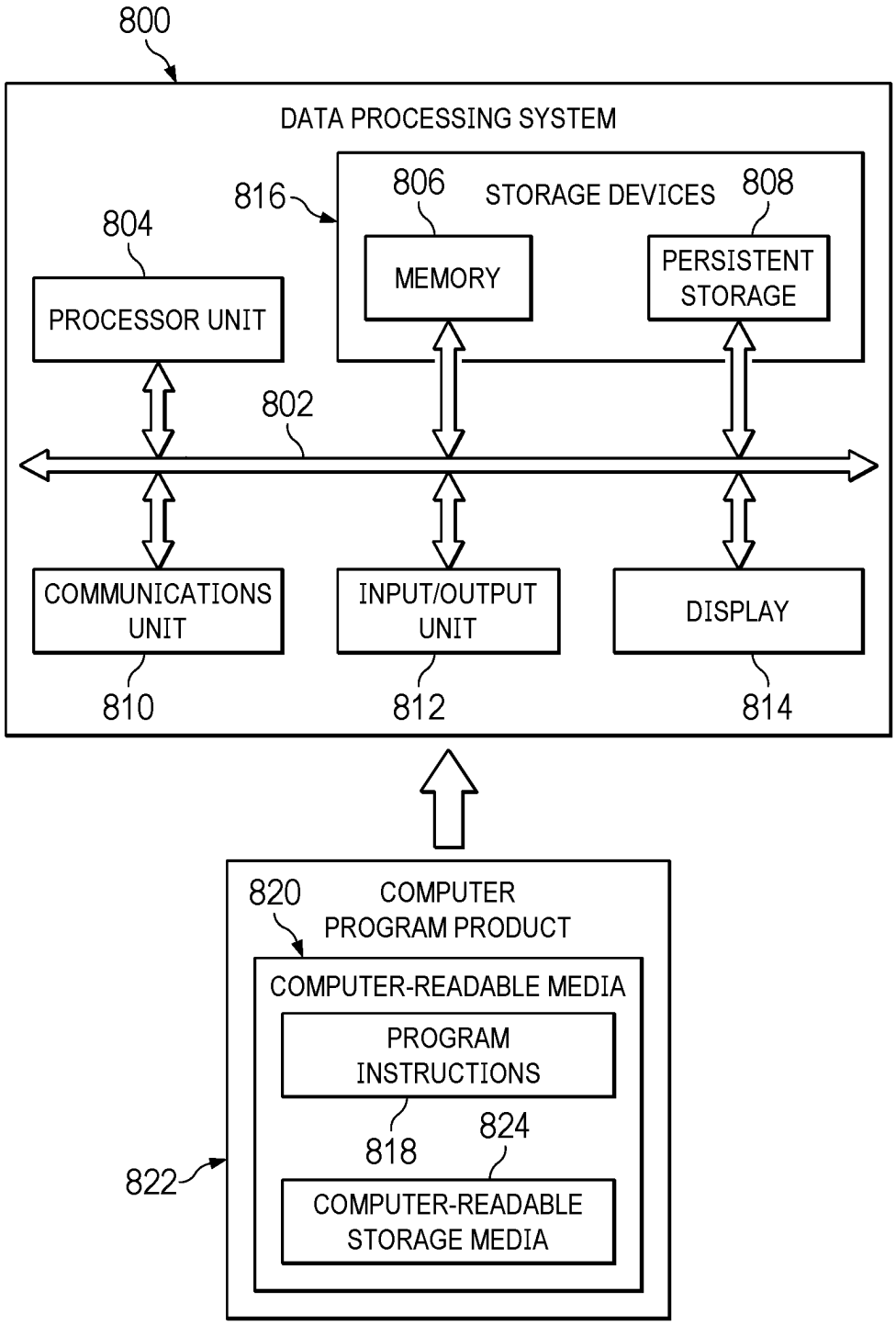

800
DATA PROCESSING SYSTEM
816
806
STORAGE DEVICES
808
804
MEMORY
PERSISTENT STORAGE
PROCESSOR UNIT
802
COMMUNICATIONS UNIT
INPUT/OUTPUT UNIT
DISPLAY
810
812
814
820
COMPUTER PROGRAM PRODUCT
COMPUTER-READABLE MEDIA
PROGRAM INSTRUCTIONS
818
824
822
COMPUTER-READABLE STORAGE MEDIA

FIG. 8

LASER BEAM BASED FLIGHT PATH CLEARING SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is related to U.S. Patent Application entitled "Laser Scanning For Spatial Acquisition Of A Satellite Receiver," Serial No. _____, attorney docket no. 23-1025-US-NP, and U.S. Patent Application entitled "Laser Sensor System With Pattern Scanning," Serial No. _____, attorney docket no. 23-1025-US-NP [2], both of which are filed even date hereof, assigned to the same assignee, and incorporated herein by reference in their entirety.

BACKGROUND INFORMATION

1. Field

[0002] The present disclosure relates generally to aircraft and in particular, to clearing flight paths for aircraft.

2. Background

[0003] In operating commercial airplanes, optimal performance of these airplanes occurs under clean conditions. Having clean aerodynamic surfaces such as wings, fuselage, and other locations are needed to provide a smooth flow of air. Debris, dirt, residue, or other material can disrupt the desired airflow resulting in decreased aerodynamic performance.

[0004] One source of decreased aerodynamic performance results from insect residue that occurs from insects impacting the surfaces of an airplane. The insect residue from impacts with flying insects can increase the surface roughness of an airplane including the leading edges of wings, the nose of the aircraft, and other locations.

[0005] With respect to the aircraft wings, this type of rough surface can promote an earlier transition from laminar to turbulent airflow. This and other types of airflow disruption increases the drag. As a result, the engines of aircraft work harder to maintain the same speed with the increased drag. The situation results in increased fuel use and decreased fuel efficiency.

[0006] Further, this type of insect residue can also interfere with sensors on the exterior of the aircraft. As a result, the accuracy of readings from air speed, angle of attack, and other parameters can be impacted by insect residue.

SUMMARY

[0007] An embodiment of the present disclosure provides a flight path clearing system comprising a laser beam system in an aircraft and a controller. The controller is configured to select a number of characteristics for a laser beam based on an object type. The controller is configured to control the laser beam system to emit the laser beam with the number of characteristics in a direction relative to a flight path of the aircraft. The controller is configured to control the laser beam system to move the laser beam with the number of characteristics selected for the object type to scan an area using a pattern that is based on a sequence of locations in the pattern being nearest to a center of the area, wherein an object of the object type hit by the laser beam is cleared from the flight path.

[0008] Another embodiment of the present disclosure provides a method for clearing a flight path. A number of characteristics is selected for a laser beam based on an object type. The laser beam emitted from an aircraft with the number of characteristics in a direction relative to a flight path of the aircraft. The laser beam with the number of characteristics selected for the object type is moved to scan an area using a pattern that is based on a sequence of locations in the pattern being nearest to a center of the area, wherein an object of the object type hit by the laser beam is cleared from the flight path.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The novel features believed characteristic of the illustrative examples are set forth in the appended claims. The illustrative examples, 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 example of the present disclosure when read in conjunction with the accompanying drawings, wherein:

[0010] FIG. **1** is an illustration of an aircraft in a turbulent environment in accordance with an illustrative example;

[0011] FIG. **2** is an illustration of a block diagram of an aircraft environment in accordance with an illustrative example;

[0012] FIG. **3** is an illustration of a sequence of locations in a pattern in accordance with an illustrative example;

[0013] FIG. **4** is an illustration of locations for beam spots and angles between beam spots in accordance with an illustrative example;

[0014] FIG. **5** is an illustration of a flowchart of a process for identifying locations for scanning an area in accordance with an illustrative example;

[0015] FIG. **6** is an illustration of a flowchart of a process for identifying locations for scanning an area in accordance with an illustrative example;

[0016] FIG. **7** is an illustration of a flowchart of a process for clearing a flight path in accordance with an illustrative example; and

[0017] FIG. **8** is an illustration of a block diagram of a data processing system in accordance with an illustrative example.

DETAILED DESCRIPTION

[0018] The illustrative examples recognize and take into account one or more different considerations as described herein. For example, reduced aerodynamic performance occurs with insect residue on the surface of an aircraft. This insect residue results from flying insects impacting the surface of an aircraft. The illustrative examples also recognize and take into account that unintended impacts with other objects can reduce the performance or cause inconsistencies in the aircraft.

[0019] Currently, sensors such as object detection systems can be used to detect birds and insects. With the detection of objects ahead of the aircraft, pilots can take evasive action as needed. These actions, however, may reduce the passenger experience. In other cases, pilots are trained to take action in response to an action impact with insects or birds. It would be desirable, however, to avoid situations where evasive maneuvers or impacts occur.

[0020] Thus, a method, apparatus, system, and computer program product for clearing a flight path is provided. In one illustrative example, a flight path clearing system comprises

a laser beam system in an aircraft and a controller. The controller is configured to select a number of characteristics for a laser beam based on an object type. The controller is configured to control the laser beam system to emit the laser beam with the number of characteristics in a direction relative to a flight path of the aircraft. The controller is configured to control the laser beam system to move the laser beam with the number of characteristics selected for the object type to scan an area using a pattern that is based on a sequence of locations in the pattern being nearest to a center of the area, wherein an object of the object type hit by the laser beam is cleared from the flight path.

[0021] With reference now to the figures and, in particular, with reference to FIG. **1**, an illustration of an aircraft in a turbulent environment is depicted in accordance with an illustrative example. In this illustrative example, in aircraft environment **133** commercial airplane **100** has wing **102** and wing **104** attached to body **106**. In some examples, body **106** can also be referred to as the fuselage. Engine **108** is attached to wing **102**. In this view of commercial airplane **100**, another engine is attached to wing **104** but not seen in this view.

[0022] Body **106** has tail section **112**. Horizontal stabilizer **114** and vertical stabilizer **118** are attached to tail section **112** of body **106**. Another horizontal stabilizer is present but not shown in this view.

[0023] Commercial airplane **100** is an example of an air vehicle in which flight path clearing system **130** can be implemented in accordance with an illustrative example. In this illustrative example, flight path clearing system **130** scans the environment around commercial airplane **100** to clear objects that may be in the flight path of commercial airplane **100**. Further, with the use of flight path clearing system **130**, the pilot for an aircraft management system can operate commercial airplane **100** without a need to take evasive maneuvers or take action because of impacts with objects such as drone **131**.

[0024] In this illustrative example, flight path clearing system **130** operates to emit laser beam **132** from port **134** of commercial airplane **100**. As depicted, laser beam **132** is emitted in a forward direction **135** relative to flight path **170** of commercial airplane **100**. In this illustrative example, flight path clearing system **130** is operated to move laser beam **132** to scan area **190** ahead of the direction of travel of commercial airplane **100**. In this example, area **190** has the shape of a hexagon. The dimensions of area **190** can be based on the wingspan of commercial airplane **100**. For example, if the wingspan is 60 meters, the diameter of area **190** can be 60 meters.

[0025] By scanning area **190** with laser beam **132**, objects such as drone **131** can be cleared from flight path **170** of commercial airplane **100**. In this example, laser beam **132** as characteristics suitable for clearing drone **131** from flight path **170**. Example, at least one of a wavelength, intensity, power, or other characteristic of laser beam **132** can be selected to cause drone **131** move out of or away from flight path **170**. For example, the characteristics can be selected to affect the navigation system or other components of drone **131** such that is unable to maintain altitude or course that is within flight path **170**.

[0026] In this illustrative example, the scanning of area **190** can be performed by using a pattern based on sequence locations in the pattern being nearest to center **191** of area **190**. In this example, the pattern begins around center **191** and moves outward. The sequence of locations does not need to be the nearest neighbor. At least some locations in the sequence are discontinuous from each other in this example.

[0027] Further, with the use of flight path clearing system **130**, the pilot for an aircraft management system can operate commercial airplane **100** without a need to take evasive maneuvers or take action because of impacts with objects such as drone **131**.

[0028] FIG. **1** is intended as an example and not as an architectural limitation for the different illustrative examples. For example, laser beam **132** can be embedded from other locations other than port **134** in body **106**. In another illustrative example, laser beam **132** can be emitted from a port located in wing **104**, horizontal stabilizer **114**, vertical stabilizer **118**, or other suitable locations.

[0029] A number of objects other than drone **131** may be cleared from flight path **170**. For example, flight path clearing system **130** can be used to clear objects selected from at least one of a bird, an insect, a weather balloon, or drone from flight path **170**.

[0030] As used herein, a "number of" when used with reference to items means one or more items. For example, a number of objects is one or more objects.

[0031] The phrase "at least one of," when used with a list of items, means different combinations of one or more of the listed items can be used, and only one of each item in the list may be needed. In other words, "at least one of" means any combination of items and number of items may be used from the list, but not all of the items in the list are required. The item can be a particular object, a thing, or a category.

[0032] For example, without limitation, "at least one of item A, item B, or item C" may include item A, item A and item B, or item B. This example also may include item A, item B, and item C or item B and item C. Of course, any combination of these items can be present. In some illustrative examples, "at least one of" can be, for example, without limitation, two of item A; one of item B; and ten of item C; four of item B and seven of item C; or other suitable combinations.

[0033] With reference now to FIG. **2**, an illustration of a block diagram of an aircraft environment is depicted in accordance with an illustrative example. In this illustrative example, aircraft environment **200** includes components that can be implemented in hardware in an aircraft such as commercial airplane **100** in FIG. **1**.

[0034] In this illustrative example, flight path clearing system **202** operates to clear objects **249** in atmosphere **210** from flight path **211** on aircraft **201**. In this example, flight path clearing system **202** is located in aircraft **201**.

[0035] Aircraft **201** can take a number of different forms. For example, aircraft **201** can be selected from a group comprising a commercial aircraft, a cargo airplane, a rotorcraft, a fixed wing aircraft, a tilt-rotor aircraft, a tilt wing aircraft, a vertical takeoff and landing aircraft, an electrical vertical takeoff and landing vehicle, a glider, a personal air vehicle, and other types of aircraft that can fly in atmosphere **210**.

[0036] As depicted, flight path clearing system **202** comprises laser beam system **203**, computer system **212**, and controller **214**. Controller **214** is located in computer system **212**. These components are located within aircraft **201** in this illustrative example.

[0037] Laser beam system **203** is a hardware system and can include software. Laser beam system **203** can be selected from at least one of a gas laser beam system, a carbon dioxide laser beam system, or other suitable type of laser beams system. In other words, laser beam system **203** can be comprised of multiple different types of laser beams systems.

[0038] In this example, laser beam system **203** emits laser beam **220** into atmosphere **210** during flight of aircraft **201**. Laser beam **220** is selected from a group comprising a continuous laser beam and a pulsed laser beam. Laser beam **220** can be a type of laser beam selected from a group comprising a CO2 laser beam, an infrared laser beam, a visible light laser beam, and other suitable types of laser beams. Further, laser beam **220** can be linearly polarized.

[0039] In this illustrative example, laser beam **220** is emitted by laser beam system **203** in a direction relative to flight path **211** of aircraft **201**. In other words, laser beam **220** can be emitted by laser beam system **203** from aircraft **201** in the direction that is relative to flight path **211**. By being relative to flight path **211**, laser beam **220** does not have to be directly on flight path **211**.

[0040] For example, controller **214** can control laser beam system **203** to emit laser beam **220** and move laser beam **220** to locations in area **231**. Area **231** is an area through which flight path **211** of aircraft **201** extends.

[0041] Controller **214** can be implemented in software, hardware, firmware, or a combination thereof. When software is used, the operations performed by controller **214** can be implemented in program instructions configured to run on hardware, such as a processor unit. When firmware is used, the operations performed by controller **214** can be implemented in program instructions and data can be stored in persistent memory to run on a processor unit. When hardware is employed, the hardware can include circuits that operate to perform the operations in controller **214**.

[0042] In the illustrative examples, the hardware can take a form selected from at least one 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 can be configured to perform the number of operations. The device can be reconfigured at a later time or can be permanently configured to perform the number of operations. 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 can be implemented in organic components integrated with inorganic components and can be comprised entirely of organic components excluding a human being. For example, the processes can be implemented as circuits in organic semiconductors.

[0043] Computer system **212** is a physical hardware system and includes one or more data processing systems. When more than one data processing system is present in computer system **212**, those data processing systems are in communication with each other using a communications medium. The communications medium can be a network. The data processing systems can be selected from at least one of a computer, a server computer, a tablet computer, or some other suitable data processing system.

[0044] As depicted, computer system **212** includes a number of processor units **216** that are capable of executing program instructions **218** implementing processes in the illustrative examples. In other words, program instructions **218** are computer-readable program instructions.

[0045] As used herein, a processor unit in the number of processor units **216** is a hardware device and is comprised of hardware circuits such as those on an integrated circuit that respond to and process instructions and program code that operate a computer. When the number of processor units **216** executes program instructions **218** for a process, the number of processor units **216** can be one or more processor units that are in the same computer or in different computers. In other words, the process can be distributed between processor units **216** on the same or different computers in computer system **212**.

[0046] Further, the number of processor units **216** can be of the same type or different types of processor units. For example, the number of processor units **216** can be selected from at least one of a single core processor, a dual-core processor, a multi-processor core, a general-purpose central processing unit (CPU), a graphics processing unit (GPU), a digital signal processor (DSP), or some other type of processor unit.

[0047] In this illustrative example, controller **214**

[0048] In this illustrative example, controller **214** identifies object type **252** for a number of objects **249**. This identification can be made using sensor system **297**. Sensor system **297** is a hardware system and can include software. Sensor system **297** can be located in aircraft **201** or can be in a remote location. This remote location can be, for example, a ground station, another aircraft, a satellite, or some other location. Sensor system **297** can be at least one of a radar system, a lidar, a camera, a visible light camera, a thermal camera, or some other suitable type of sensor system that can be used to detect objects **249** and obtain sensor data **298** that can be used to determine object type **252**.

[0049] Sensor system **297** sends sensor data **298** to controller **214**. This sensor data can be analyzed by controller **214** to identify object type **252** for the number of objects **249**.

[0050] Controller **214** identifies a number of characteristics **209** for laser beam **220** based on object type **252** for the number of objects **249**. In this illustrative example, the number of characteristics **209** is based on characteristics that can be used to clear the number of objects **249** from flight path **211**.

[0051] Object type **252** is for objects **259**. Each object in objects **259** has an object type. Object type **252** can be from a group comprising an insect, a bird, an aerial drone, and other types of objects that may need to be cleared from flight path **211** of aircraft **201**.

[0052] The number of characteristics **209** can include at least one of a wavelength, focal length, a power, a timing, an intensity, or other characteristics. In this example, a focal length of laser beam **220** is selected such that laser beam **220** scans area **231** at a distance from aircraft **201** that enables laser beam **220** to effectively clear flight path **211**. The distance is such that laser beam **220** can scan area **231** with sufficient time to clear an object from flight path **211** without the object hitting aircraft **201**.

[0053] One characteristic in the number of characteristics **209** of laser beam **220** has a wavelength selected for

absorption by at least one of an insect exoskeleton, a bird feather, a plastic, and a metal. As another example, the wavelength selected is eye-safe for birds. In another example, the timing of laser beam **220** is selected from a group comprising pulsed and continuous.

[0054] In this example, controller **214** controls laser beam system **203** to emit laser beam **220** with the number of characteristics **209** in a direction relative to flight path **211** of aircraft **201**.

[0055] Controller **214** also controls laser beam system **203** to move laser beam **220** with the number of characteristics **209** selected for object type **252** to scan area **231** using pattern **232** that is based on a sequence of locations **233** in pattern **232** being nearest to center **235** of area **231**. In one illustrative example, flight path **211** can extend through center **235** of area **231**.

[0056] A number of objects **249** of the object type **252** hit by laser beam **220** is cleared from flight path **211**. The number of objects **249** cleared from flight path **211** may not be directly on flight path **211**. These objects may be sufficiently close to flight path **211** that clearing these objects is performed to avoid the number of objects **249** from entering flight path **211** in a manner that can cause an undesired impact or other effect on aircraft **201**.

[0057] In this illustrative example, pattern **232** can have a number of different shapes. For example, pattern **232** can have a shape selected from a group comprising a hexagon, a honeycomb, a pentagon, an octagon, and other suitable shapes. In this illustrative example, the shapes do not need to be symmetrical and can be irregular.

[0058] In moving, laser beam **220** from location to location in sequence of locations **233**, controller **214** controls laser beam system **203** to move laser beam **220** from location **227** to next location **224** nearest to center **235** of area **231**. In this example, the first location is located at center **235** of area **231**.

[0059] In this example, next location **224** becomes current location **225** for laser beam **220**. This movement of laser beam **220** continues until area **231** has been scanned. The movement from the current location to next location is such that laser beam **220** follows sequence of locations **233** for pattern **232**.

[0060] This movement of laser beam **220** can be performed using nearest to center scan **240**. This type of scan can be faster than moving laser beam **220** between adjacent locations.

[0061] For example, controller **214** can move laser beam **220** from current location **225** to next location **224** nearest to center **235** of area **231** from current location **225**. This type of scan is nearest to center scan **240**. When area **231** has the shape of a hexagon, the scan can be referred to as nearest to center hexagonal scan **241**.

[0062] Further, controller **214** can control the movement of laser beam **220** to change from nearest to center scan **240** to nearest neighbor scan **242**. This type of scan in which the scanning changes from nearest to center scan **240** to nearest neighbor scan **242** is referred to as hybrid scan **263**. This change can be made when moving from one location to another location that is adjacent to each other using nearest neighbor scan **242** is faster than moving to a nonadjacent location using nearest to center scan **240**.

[0063] For example, controller **214** moves laser beam **220** to neighbor location **243** of nearest neighbor **244** in response to the time for moving laser beam **220** from current location **225** to next location **224** using location **227** nearest to center **235** of area **231** being greater than a threshold. These locations are adjacent to each other when using nearest neighbor scan **242**.

[0064] In this illustrative example, controller **214** can control the movement of laser beam **220** to have at least one of continuous movement **261** or dwell time **262** at each location in sequence of locations **233**.

[0065] In another example, clearing an aerial drone as the number of objects from flight path **211** comprises causing, at least one of, interference with the navigation system of the aerial drone the aerial drone to fly outside of the flight path of the aircraft, damage to the aerial drone, or destruction of the aerial drone such that the aerial drone moves away from flight path **211** of aircraft **201**. In yet another example, objects **249** in the form of birds and inspections can be cleared from flight path **211**.

[0066] In another example, a controller controls a laser beam system to move a laser beam to scan area **400** using a pattern that comprises a sequence of locations in the pattern that are selected based on a scan metric. The movement does not need to be based on being nearest to center **235** of area **231**.

[0067] The illustration of aircraft environment **200** in FIG. **2** is not meant to imply physical or architectural limitations to the manner in which an illustrative example may be implemented. Other components in addition to 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 example.

[0068] For example, the scan of area **231** can be performed using a scan other than nearest to center scan **240**. For example, controller **214** controls laser beam system **203** to move laser beam **220** to scan area **231** using a pattern **232** that comprises sequence of locations **233** in pattern **232** that is selected based on a scan metric. The controller **214** moves laser beam **220** from location **227** to next location **224** in sequence of locations **233** using the scan metric. Next location **224** becomes current location **225** for laser beam **220**. The movement of laser beam **220** from current location **225** to next location **224** continues until area **231** has been scanned.

[0069] Controller **214** selects next location **224** in area **231** from a set of candidate locations that has a highest value for the scan metric. The scan metric is as follows:

$$M=\mathrm{PDF}_{int}/t_{tot}$$

where PDF_{int} is a probability density function integrated over an area of interest for a next potential location and t_{tot} is a total time $t_{tot}=t_{slew}+t_{dwell}$, t_{slew} is a time to slew a line-of-sight from the current location to the next potential location, and t_{dwell} is a time the line-of-sight dwells at the next potential location. This process can be repeated to select the sequence of locations for the pattern.

[0070] With reference now to FIG. **3**, an illustration of a sequence of locations in a pattern is depicted in accordance with an illustrative example. In this example, sequence of locations **304** for a pattern are depicted within area **300**. This area is an example of area **190** in FIG. **1** and area **231** in FIG.

2. As depicted, area **300** has a hexagonal shape. Sequence of locations **304** is an example of sequence of locations **233** in FIG. **2**.

[0071] In this example, locations in this sequence can be selected to be the nearest to center **302** of area **300**. For example, the first location can be the location for center **302**. The next locations closest to center **302** are locations A.

[0072] Locations selected that are closest to center **302** after locations A are locations B. The next locations used for pointing laser beams are locations C. The next locations closest to center **302** are locations Ds with locations E being the next locations closest to the center after locations D. The next locations closest to center **302** are locations F followed by locations G.

[0073] Turning to FIG. **4**, an illustration of locations for beam spots and angles between beam spots is depicted in accordance with an illustrative example. In this example, a scan for directing a laser beam at beam spots in a pattern in area **400** can be performed using a nearest to center scan. The pattern includes the location of beam spots as well as an order in which a laser beam is directed to the different beam spots. This order can be sequence of locations **233** in FIG. **2** for pattern **232**. This pattern can also be referred to as a beam spot pattern. In this example, the locations of these beam spots can be selected as being nearest to center **401** of area **400**.

[0074] In this example, a scan for directing a laser beam at beam spots in a pattern can be performed using a nearest to center scan. A beam spot is the region that the laser beam hits in area **400**. In this example, a beam spot can be the same or about the same size and dimensions as a location. The pattern includes the location of beam spots as well as an order in which the laser beam is directed to the different beam spots. This pattern can also be referred to as a beam spot pattern.

[0075] As depicted, angle θ_{cc} is between beam spot E and beam spot G, and angle θ_{nn} is between beam spot E and beam spot F. Also shown is angle φ_{cc} between the center and beam spot G and angle φ_{nn} is between the center and beam spot F. These angles can be used in determining a pattern of beam spots for pointing a laser beam.

[0076] In this example, the beam spot pattern can be determined using a nearest to center scan. For a given beam spot pattern, the following equation can be used:

$$t_{net\ savings} \approx \frac{t_{scan}}{N}[PDF(\varphi_{cc}) - PDF(\varphi_{nn})] - \frac{\theta_{cc} - \theta_{nn}}{\text{slew rate}} \qquad \text{Equation A}$$

where $t_{net\ savings}$ is the time saved for a single jump from beam spot to beam spot using the nearest to center scan relative to the nearest neighbor scan. In other words, this variable is the time it takes for a single jump from one beam spot to another beam spot using the nearest to center scan approach minus the time it takes for a single jump from beam spot to beam spot using the nearest neighbor scan to determine the beam spot pattern.

[0077] t_{scan} is the total scan time to use the nearest neighbor scan.

[0078] N is the total number of beam spots in the scan pattern.

[0079] PDF(φ_{cc}) is a unitless value of the probability density function for the beam spot that was moved to for the nearest to center scan. This value is a function of distance from the beam spot to the center of the probability density function, which is equivalent to an angle defined as "φ".

[0080] PDF(φ_{nn}) is the unitless value of the probability density function for the beam spot that was moved to for the nearest neighbor scan.

[0081] θ_{cc} is the angular separation between two beam spots when jumping from beam spot to beam spot using the nearest to center scan. The units can be degrees or radians.

[0082] θ_{nn} is the angular separation between two beam spots when jumping from beam spot to beam spot using the nearest neighbor scan.

[0083] slew rate is the speed at which the gimble moves. The units are angular change over time I (e.g., degree/s or rad/s).

Example 1

[0084] In this example, the slew rate is infinite. This infinite slew rate means the laser beam instantly jumps from beam spot to beam spot. In this case Equation A becomes:

$$t_{net\ savings} \approx \frac{t_{scan}}{N}[PDF(\varphi_{cc}) - PDF(\varphi_{nn})] - \frac{\theta_{cc} - \theta_{nn}}{\infty} = \frac{t_{scan}}{N}[PDF(\varphi_{cc}) - PDF(\varphi_{nn})]$$

[0085] Since PDF(φ_{cc})cc)≥PDF(φ_{nn}), $t_{net\ savings}$≥0, there is never a need to switch from the closest to center scan to the nearest neighbor scan for determining the beam spot pattern.

Example 2

[0086] In this example, the slew rate can be considered zero resulting in the following:

$$t_{net\ savings} \approx \frac{t_{scan}}{N}[PDF(\varphi_{cc}) - PDF(\varphi_{nn})] - \frac{\theta_{cc} - \theta_{nn}}{0} = -\infty$$

[0087] In this case, the nearest to center scan is not needed because the $t_{net\ savings}$<0.

Example 3

[0088] Example 1 showed that if the slew rate is sufficiently fast, it always saves time to use the nearest to center scan to determine a beam spot pattern. Example 2 shows that if the slew rate is sufficiently slow, no time savings is present. In this example, the nearest neighbor scan is used.

[0089] If the slew rate is something in-between these extremes, initially, time savings are present using the nearest to center scan.

[0090] With reference next to FIG. **5**, an illustration of a flowchart of a process for identifying locations for scanning an area in accordance with an illustrative example is depicted. The process in FIG. **5** can be implemented in hardware, software, or both. When implemented in software, the process can take the form of program instructions that are run by one or more processor units located in one or more hardware devices in one or more computer systems. This process can be implemented to identify locations in a sequence of locations in a pattern for scanning an area. For example, the process can be implemented in controller **214** in computer system **212** in FIG. **2**.

[0091] The process begins by generating a list L_N of all possible locations for the next scan step (operation **500**). In operation **500**, the possible locations are potential next locations for scanning. The process calculates a scan metric (M) for every entry in the list (L_N) (operation **502**).

[0092] In operation **502**, the scan metric is as follows:

$$M=\mathrm{PDF}_{int}/t_{tot}$$

where PDF_{int} is the probability density function (PDF) integrated over an area of interest (AOI) for the next potential dwell location. The probability density function shows probability that an object is in a particular location in the area being scanned. In this example, the probability density function can be based on the estimated location of an object when the actual location of the object is unknown. So, probability density function can also take into account uncertainty in errors in estimating the position of the object.

[0093] The probability density function can be, for example, a Gaussian function, analytical distribution, a skewed distribution, or other type of probability density function. In this example, the center is the peak of the probability density function when the probability density function has a single peak. In another example, the maximum probability density function can be used when the maximum is not the center of the probability density function.

[0094] The area of interest for pointing a laser beam is the region over which the laser beam exceeds a threshold. For example, the area of interest is for a region over which the laser beam has characteristics at a level that clears an object from the flight path. The characteristics can be, for example, power, intensity, wavelength, and other suitable characteristics.

[0095] In this example, the total time, t_{tot}, is given by $t_{tot}=t_{slew}+t_{dwell}$, where t_{slew} is the time it takes to slew the line-of-sight (LOS) from the current dwell location to the next potential location, and t_{dwell} is the time the line-of-sight dwells at the next potential location. After the dwell at the current location, that dwell location is removed from the list of next possible dwell locations, and the process is repeated until there are no remaining possible dwell locations. The line-of-sight can be the center of spot for the laser beam is moved to point the laser beam at different locations.

[0096] The process finds location $L_{N,max}$, which is the location having maximum value of M (operation **504**). In operation **504**, the location $L_{N,max}$ is the location in the list L_N with the maximum value for M. The system adds the location $L_{N,max}$ to the end of scan-schedule list L_s (operation **506**). In operation **506**, the scan-schedule list L_s is a scan-schedule list that saves an optimal order of scan steps to use in moving the laser beam to different locations.

[0097] The process then removes the location $L_{N,max}$, from list L_N (operation **507**). The process determines whether the list L_N is empty (operation **508**). In operation **508**, if list L_N is not empty, the process returns to operation **502**. Otherwise, the process proceeds to scan according to the scan-schedule list L_S (operation **510**) with the process terminating thereafter. Thus, this process generates a sequence of locations for a pattern to scan the area.

[0098] With reference next to FIG. **6**, an illustration of a flowchart of a process for identifying locations for scanning an area is depicted in accordance with an illustrative example. The process in FIG. **6** can be implemented in hardware, software, or both. When implemented in software, the process can take the form of program instructions that are run by one or more processor units located in one or more hardware devices in one or more computer systems. This process can be implemented to a probability density function for use in determining a sequence of locations in a pattern for scanning an area. This process can be implemented in controller **214** in computer system **212** in FIG. **2**.

[0099] Insects, birds, aerial drones and other objects present a hazard for commercial aircraft. An aircraft can clear a flight path for the aircraft by emitting a laser beam into the flight path. The process in this flowchart can be used to perform the scan for clearing the flight path.

[0100] With respect to aerial drones, clearing a flight path of an aerial drone can involve the laser beam heating or melting one or more components of the aerial drone reducing the ability of the aerial drone to fly or navigate, and therefore causing the aerial drone to fly or fall away from the flight path of aircraft.

[0101] The process begins by inputting variables (operation **600**). In operation **600**, these variables are used to generate a probability density function. In this example, with respect to acquiring a flight path, the conditions include aircraft speed, estimated object speed, and crosswind.

[0102] The process then generates a two-dimensional probability density function (2D PDF) (operation **602**). In this example, the two-dimensional probability density function is comprised of multiple one-dimensional problem density functions. A one-dimensional probability density function is for an area in a plane. Additional one-dimensional probability density functions are generated for additional areas on other planes parallel to the first plane.

[0103] The process determines a distance from the aircraft (operation **604**). In operation **604**, effective distance is the distance at which a laser beam is focused to scan an area in a sequence of locations in a pattern. In these examples, the distance for focusing a laser beam to scan an area is selected as an effective distance that enables the laser beam to effectively clear an object from the flight path of an aircraft.

[0104] The effective distance can be selected based on factors such as the ability to scan the area and the effectiveness of the laser beam in clearing an object. As the distance decreases, the amount of time to scan the area before encountering an object decreases and the effectiveness of the laser beam increases. The power or intensity of the laser beam at shorter distances is greater than at longer distances. Thus, the effective distance to effectively clear an object from the flight path of an aircraft is a distance that provides the ability to clear an object from the flight path of the aircraft while having sufficient time to scan an area for the object without the aircraft encountering the object. In these examples, more than one distance can be considered an effective distance for scanning in an area.

[0105] The process then determines the one-dimensional probability density function (1D PDF) (operation **606**). In operation **606**, a single probability density function is selected from the multiple problems involving density functions determined in operation **602**. In this example, the probability density function is selected as the one closest to the distance determined in operation **604**.

[0106] The process then selects a beam control algorithm (operation **608**). This beam control algorithm can be, for example, a nearest to center scan, a hybrid scan, a scan based on a scan metric, and other types of scans. The process then performs the scan using the selected algorithm (operation

610). The process then returns to operation **600** and repeats the process. These operations can be performed any number of times to during the flight of aircraft to scan the area ahead of the aircraft.

[0107] Several variables can be used in the process for clearing the flight path of an aircraft. The first variable is the probability that the object will collide with the aircraft. If the object is far from the aircraft's flight path, but close to the aircraft, there may not be enough time for the aerial drone to collide with the aircraft. As a result, a low probability of collision is present in this example. If the object is far from the aircraft's flight path, and far from the aircraft, there may be enough time for the aerial drone to collide with the aircraft. In this situation a moderate probability of collision is present. If the object is close to the aircraft's flight path, and close to the aircraft, the time for the aerial drone to move out of the flight path of the aircraft may not be sufficient. In this example, a high probability of collision is present.

[0108] Since the location of the object is unknown, the probability of collision is described as a two-dimensional Gaussian shaped probability density function (PDF), where one axis represents the radial distance perpendicular to the flight path (R), and the other axis represents the distance parallel to the flight path and forward from the aircraft (L). Mathematically, this equates to $PDF_{2D}=f(R, L)$. If a crosswind is not present for the aircraft, the peak of this probability density function is the center of the flight path (i.e., $R_{effetive}=0$). Thus, in these examples, the center of the probability density function can shift to take into account a crosswind.

[0109] As for the distance at which to focus the laser beam, two approaches can be used in this illustrative example. In a first approach, physical limitations are considered. The amount of time to scan a laser beam to hit an object that is located very close to the aircraft may be insufficient. Also, the beam power or irradiance may be too low to heat an object far from the aircraft.

[0110] An effective distance at which the beam should be focused is indicated by L_{eff}.

[0111] Atmospheric conditions can also play a role in determining this distance. Atmospheric conditions may affect laser beam attenuation. These conditions include, for example, clouds, fog, rain, dust, and other conditions that may change the attenuation of a laser beam traveling through the atmosphere.

[0112] In the second approach, the probability of collision (PC) is determined at every distance in front of the aircraft by integrating the PDF_{2D} at each of these locations, then taking the derivative of the result, setting it to zero, and solving for L to find the plane with the highest probability of collision. The probability of collision in a plane located at a distance L can be expressed as follows:

$$PC(L)=\int_0^{\infty}\mathrm{PDF}_{2D}(r,L)dr$$

and the location of plane having the greatest probability of collision (i.e., L_{max}) and the plane's probability of collision can be found by:

$$0=\frac{d}{dL}[PC(L)]\rightarrow L_{max}\rightarrow PD_{1D}(r, L_{max})$$

[0113] If L_{max} is a distance given the laser beam characteristics and atmospheric conditions that enables the laser beam to effectively clear objects in the area from the flight path, the beam is focused to L_{max}.

[0114] Regardless of the location $L_{effective}$ and the shape of the probability density function, the aircraft emits a laser beam that moves the spot from location to location in a sequence of locations in a hexagonal pattern in this example. Also in this example, the laser beam dwells at each location.

[0115] In this example, the first location is located at the center of the probability density function. The location of following spots in the hexagonal pattern is determined by an algorithm that takes into account the probability that the object is located at a particular spot and the time it takes the beam to shift to that particular spot (i.e., slew time).

[0116] Once the scan pattern is complete, the path is likely clear. However, the path could soon be reoccupied a short time later (e.g., minutes). Thus, the process in FIG. **6** can be repeated.

[0117] With reference next to FIG. **7**, an illustration of a flowchart of a process for clearing a flight path is depicted in accordance with an illustrative example.

[0118] The process in FIG. **7** can be implemented in hardware, software, or both. When implemented in software, the process can take the form of program instructions that are run by one of more processor units located in one or more hardware devices in one or more computer systems. This process can be implemented to identify locations in a sequence of locations in a pattern for scanning an area. For example, the process can be implemented in controller **214** in computer system **212** in FIG. **2**.

[0119] The process begins by selecting a number of characteristics for a laser beam based on an object type (operation **700**). The process emits a laser beam from an aircraft with the number of characteristics in a direction relative to a flight path of the aircraft (operation **702**).

[0120] The process moves the laser beam with the number of characteristics selected for the object type to scan an area using a pattern that is based on a sequence of locations in the pattern being nearest to a center of the area, wherein a number of objects of the object type hit by the laser beam is cleared from the flight path (operation **704**). The process terminates thereafter.

[0121] The flowcharts and block diagrams in the different depicted embodiments illustrate the architecture, functionality, and operation of some possible implementations of apparatuses and methods in an illustrative example. In this regard, each block in the flowcharts or block diagrams can represent at least one of a module, a segment, a function, or a portion of an operation or step. For example, one or more of the blocks can be implemented as program instructions, hardware, or a combination of the program instructions and hardware. When implemented in hardware, the hardware can, for example, take the form of integrated circuits that are manufactured or configured to perform one or more operations in the flowcharts or block diagrams. When implemented as a combination of program instructions and hardware, the implementation may take the form of firmware. Each block in the flowcharts or the block diagrams can be implemented using special purpose hardware systems that perform the different operations or combinations of special purpose hardware and program instructions run by the special purpose hardware.

[0122] In some alternative implementations of an illustrative example, the function or functions noted in the blocks may occur out of the order noted in the figures. For example,

in some cases, two blocks shown in succession may be performed substantially concurrently, or the blocks may sometimes be performed in the reverse order, depending upon the functionality involved. Also, other blocks may be added in addition to the illustrated blocks in a flowchart or block diagram.

[0123] Turning now to FIG. **8**, an illustration of a block diagram of a data processing system is depicted in accordance with an illustrative example. Data processing system **800** can be used to implement computer system **212** in FIG. **2**. In this illustrative example, data processing system **800** includes communications framework **802**, which provides communications between processor unit **804**, memory **806**, persistent storage **808**, communications unit **810**, input/output (I/O) unit **812**, and display **814**. In this example, communications framework **802** takes the form of a bus system.

[0124] Processor unit **804** serves to execute instructions for software that can be loaded into memory **806**. Processor unit **804** includes one or more processors. For example, processor unit **804** can be selected from at least one of a multicore processor, a central processing unit (CPU), a graphics processing unit (GPU), a physics processing unit (PPU), a digital signal processor (DSP), a network processor, or some other suitable type of processor. Further, processor unit **804** can be implemented using one or more heterogeneous processor systems in which a main processor is present with secondary processors on a single chip. As another illustrative example, processor unit **804** can be a symmetric multi-processor system containing multiple processors of the same type on a single chip.

[0125] Memory **806** and persistent storage **808** are examples of storage devices **816**. A storage device is any piece of hardware that is capable of storing information, such as, for example, without limitation, at least one of data, program instructions in functional form, or other suitable information either on a temporary basis, a permanent basis, or both on a temporary basis and a permanent basis. Storage devices **816** may also be referred to as computer-readable storage devices in these illustrative examples. Memory **806**, in these examples, can be, for example, a random-access memory or any other suitable volatile or non-volatile storage device. Persistent storage **808** may take various forms, depending on the particular implementation.

[0126] For example, persistent storage **808** may contain one or more components or devices. For example, persistent storage **808** can be a hard drive, a solid-state drive (SSD), a flash memory, a rewritable optical disk, a rewritable magnetic tape, or some combination of the above. The media used by persistent storage **808** also can be removable. For example, a removable hard drive can be used for persistent storage **808**.

[0127] Communications unit **810**, in these illustrative examples, provides for communications with other data processing systems or devices. In these illustrative examples, communications unit **810** is a network interface card.

[0128] Input/output unit **812** allows for input and output of data with other devices that can be connected to data processing system **800**. For example, input/output unit **812** may provide a connection for user input through at least one of a keyboard, a mouse, or some other suitable input device. Further, input/output unit **812** may send output to a printer. Display **814** provides a mechanism to display information to a user.

[0129] Instructions for at least one of the operating system, applications, or programs can be located in storage devices **816**, which are in communication with processor unit **804** through communications framework **802**. The processes of the different embodiments can be performed by processor unit **804** using computer-implemented instructions, which may be located in a memory, such as memory **806**.

[0130] These instructions are referred to as program instructions, computer usable program instructions, or computer-readable program instructions that can be read and executed by a processor in processor unit **804**. The program instructions in the different embodiments can be embodied on different physical or computer-readable storage media, such as memory **806** or persistent storage **808**.

[0131] Program instructions **818** are located in a functional form on computer-readable media **820** that is selectively removable and can be loaded onto or transferred to data processing system **800** for execution by processor unit **804**. Program instructions **818** and computer-readable media **820** form computer program product **822** in these illustrative examples. In the illustrative example, computer-readable media **820** is computer-readable storage media **824**.

[0132] Computer-readable storage media **824** is a physical or tangible storage device used to store program instructions **818** rather than a medium that propagates or transmits program instructions **818**. Computer-readable storage media **824** may be at least one of an electronic storage medium, a magnetic storage medium, an optical storage medium, an electromagnetic storage medium, a semiconductor storage medium, a mechanical storage medium, or other physical storage medium. Some known types of storage devices that include these mediums include: a diskette, a hard disk, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), a static random access memory (SRAM), a compact disc read-only memory (CD-ROM), a digital versatile disk (DVD), a memory stick, a floppy disk, a mechanically encoded device, such as punch cards or pits/lands formed in a major surface of a disc, or any suitable combination thereof.

[0133] Computer-readable storage media **824**, as that term is used in the present disclosure, is not to be construed as storage in the form of transitory signals per se, such as at least one of radio waves or other freely propagating electromagnetic waves, electromagnetic waves propagating through a waveguide, light pulses passing through a fiber optic cable, electrical signals communicated through a wire, or other transmission media.

[0134] Further, data can be moved at some occasional points in time during normal operations of a storage device. These normal operations include access, de-fragmentation or garbage collection. However, these operations do not render the storage device as transitory because the data is not transitory while the data is stored in the storage device.

[0135] Alternatively, program instructions **818** can be transferred to data processing system **800** using a computer-readable signal media. The computer-readable signal media are signals and can be, for example, a propagated data signal containing program instructions **818**. For example, the computer-readable signal media can be at least one of an

electromagnetic signal, an optical signal, or any other suitable type of signal. These signals can be transmitted over connections, such as wireless connections, optical fiber cable, coaxial cable, a wire, or any other suitable type of connection.

[0136] Further, as used herein, "computer-readable media **820**" can be singular or plural. For example, program instructions **818** can be located in computer-readable media **820** in the form of a single storage device or system. In another example, program instructions **818** can be located in computer-readable media **820** that is distributed in multiple data processing systems. In other words, some instructions in program instructions **818** can be located in one data processing system while other instructions in program instructions **818** can be located in one data processing system. For example, a portion of program instructions **818** can be located in computer-readable media **820** in a server computer while another portion of program instructions **818** can be located in computer-readable media **820** located in a set of client computers.

[0137] The different components illustrated for data processing system **800** are not meant to provide architectural limitations to the manner in which different embodiments can be implemented. In some illustrative examples, one or more of the components may be incorporated in or otherwise form a portion of, another component. For example, memory **806**, or portions thereof, may be incorporated in processor unit **804** in some illustrative examples. The different illustrative examples can be implemented in a data processing system including components in addition to or in place of those illustrated for data processing system **800**. Other components shown in FIG. **8** can be varied from the illustrative examples shown. The different embodiments can be implemented using any hardware device or system capable of running program instructions **818**.

[0138] The description of the different illustrative examples 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. The different illustrative examples describe components that perform actions or operations. In an illustrative example, a component can be configured to perform the action or operation described. For example, the component can have a configuration or design for a structure that provides the component an ability to perform the action or operation that is described in the illustrative examples as being performed by the component. Further, to the extent that terms "includes", "including", "has", "contains", and variants thereof are used herein, such terms are intended to be inclusive in a manner similar to the term "comprises" as an open transition word without precluding any additional or other elements.

[0139] Many modifications and variations will be apparent to those of ordinary skill in the art. Further, different illustrative examples may provide different features as compared to other desirable 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.

What is claimed is:

1. A flight path clearing system comprising:

a laser beam system in an aircraft; and

a controller configured to:

select a number of characteristics for a laser beam based on an object type; and

control the laser beam system to:

emit the laser beam with the number of characteristics in a direction relative to a flight path of the aircraft; and

move the laser beam with the number of characteristics selected for the object type to scan an area using a pattern that is based on a sequence of locations in the pattern being nearest to a center of the area, wherein a number of objects of the object type hit by the laser beam is cleared from the flight path.

2. The flight path clearing system of claim **1**, wherein the number of characteristics of the laser beam comprises at least one of a wavelength, focal length, a power, a timing, or an intensity.

3. The flight path clearing system of claim **2**, wherein the focal length is selected such that the laser beam scans the area at a distance from the aircraft that enables the laser beam to effectively clear the flight path.

4. The flight path clearing system of claim **2**, wherein the timing is selected from a group comprising pulsed and continuous.

5. The flight path clearing system of claim **1**, wherein the laser beam system is selected from at least one of a gas laser beam system or a carbon dioxide laser beam system.

6. The flight path clearing system of claim **1**, wherein the object type is an aerial drone.

7. The flight path clearing system of claim **1**, wherein the pattern is selected from a group comprising a hexagon, a honeycomb, a pentagon, and an octagon.

8. The flight path clearing system of claim **1**, wherein clearing an aerial drone as the number of objects from the flight path comprises causing at least one of interference with a navigation system of the aerial drone, the aerial drone to fly outside of the flight path of the aircraft, damage to the aerial drone, or destruction of the aerial drone such that the aerial drone moves away from the flight path of the aircraft.

9. The flight path clearing system of claim **1**, wherein the pattern has a shape selected from a group comprising a hexagon, a honeycomb, a pentagon, and an octagon.

10. A flight path clearing system comprising:

a laser beam system in an aircraft; and

a controller configured to:

select a number of characteristics for a laser beam based on an object type; and

control the laser beam system to:

emit the laser beam with the number of characteristics in a direction relative to a flight path of the aircraft; and

move the laser beam with the number of characteristics selected for the object type to scan an area using a pattern that is based on a sequence of locations in the pattern that are selected based on a scan metric, wherein a number of objects of the object type hit by the laser beam is cleared from the flight path.

11. The flight path clearing system of claim **10**, wherein the controller selects the next location in the area from a set

of candidate locations that has a highest value for the scan metric, wherein the scan metric is as follows:

$$M = PDF_{int}/t_{tot}$$

where PDF_{int} is a probability density function integrated over an area of interest for a next potential location and t_{tot} is a total time $t_{tot}=t_{slew}+t_{dwell}$, t_{slew} is a time to slew a line-of-sight from a current location to the next potential location, and t_{dwell} is a time line-of-sight dwells at the next potential location.

12. A method for clearing a flight path, the method comprising:

selecting a number of characteristics for a laser beam based on an object type, and

emitting the laser beam from an aircraft with the number of characteristics in a direction relative to the flight path of the aircraft; and

moving the laser beam with the number of characteristics selected for the object type to scan an area using a pattern that is based on a sequence of locations in the pattern being nearest to a center of the area, wherein a number of objects of the object type hit by the laser beam is cleared from the flight path.

13. The method of claim **12**, wherein the number of characteristics of the laser beam comprises at least one of a wavelength, focal length, a power, a timing, or an intensity.

14. The method of claim **13**, wherein the focal length is selected such that the laser beam scans the area at a distance from the aircraft that enables the laser beam to effectively clear the flight path.

15. The method of claim **13** wherein the timing is selected from a group comprising pulsed and continuous.

16. The method of claim **12**, wherein the laser beam is emitted from a laser beam system selected from at least one of a gas laser beam system or a carbon dioxide laser beam system.

17. The method of claim **12**, wherein the object type is an aerial drone.

18. The method of claim **12**, wherein the pattern is selected from a group comprising a hexagon, a honeycomb, a pentagon, and an octagon.

19. The method of claim **12**, wherein clearing an aerial drone as the number of objects from the flight path comprises causing at least one of interference with a navigation system of the aerial drone, the aerial drone to fly outside of the flight path of the aircraft, damage to the aerial drone, or destruction of the aerial drone such that the aerial drone moves away from the flight path of the aircraft.

20. The method of claim **12**, wherein the pattern has a shape selected from a group comprising a hexagon, a honeycomb, a pentagon, and an octagon.

* * * * *