US 20180080882A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2018/0080882 A1**

Boyer (43) **Pub. Date: Mar. 22, 2018**

(54) **METHOD AND SYSTEM FOR AUTOMATED DATA COLLECTION AND PART VALIDATION**

(71) Applicant: **The Boeing Company**, Chicago, IL (US)

(72) Inventor: **Mark James Boyer**, Placentia, CA (US)

(21) Appl. No.: **15/269,033**

(22) Filed: **Sep. 19, 2016**

Publication Classification

(51) **Int. Cl.**

G01N 21/95 (2006.01)

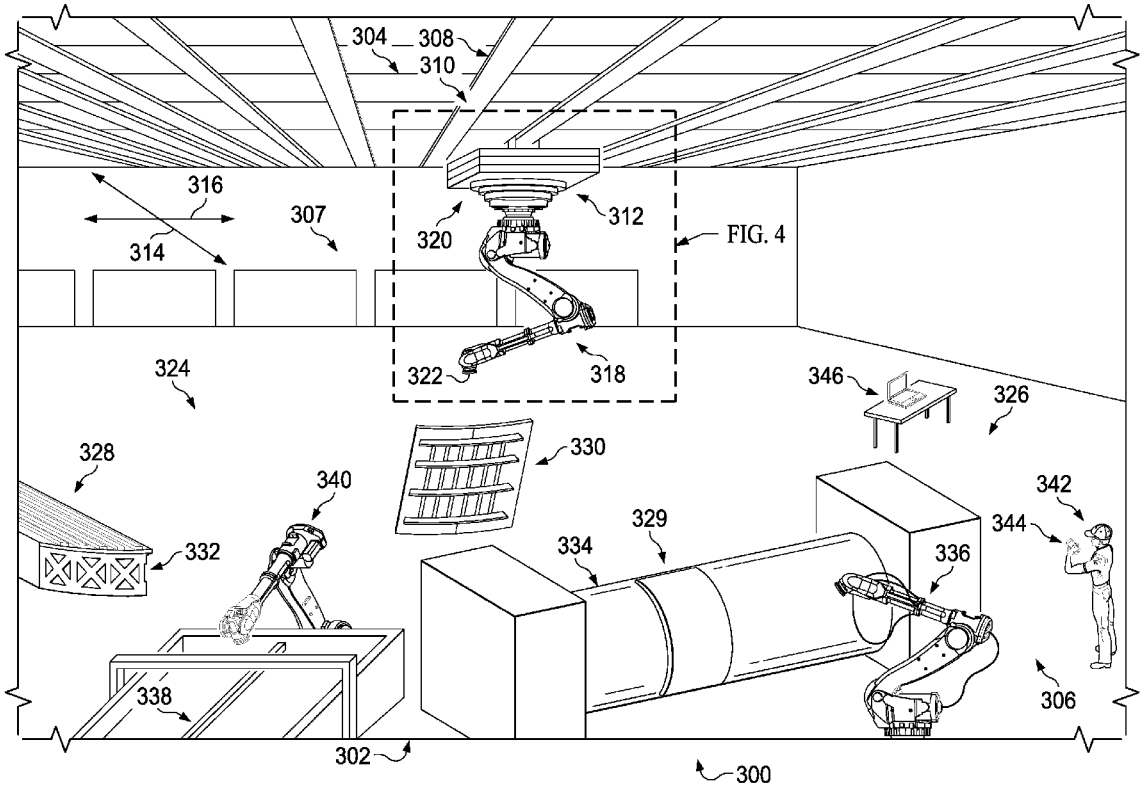
B25J 18/02 (2006.01)

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

CPC ***G01N 21/95*** (2013.01); ***B25J 18/025*** (2013.01); *Y10S 901/47* (2013.01); *G01N 2201/10* (2013.01); *Y10S 901/44* (2013.01); *G01N 2201/06113* (2013.01)

(57) **ABSTRACT**

An inspection system comprises a crane system, a six axis, one hundred and fifty degree articulating robotic arm, a laser inspection system, and a communications system. The robotic arm is connected to a base of the crane system. The laser inspection system is connected to the robotic arm. The communications system is configured to send and receive instructions for the crane system, the robotic arm, and the laser inspection system.



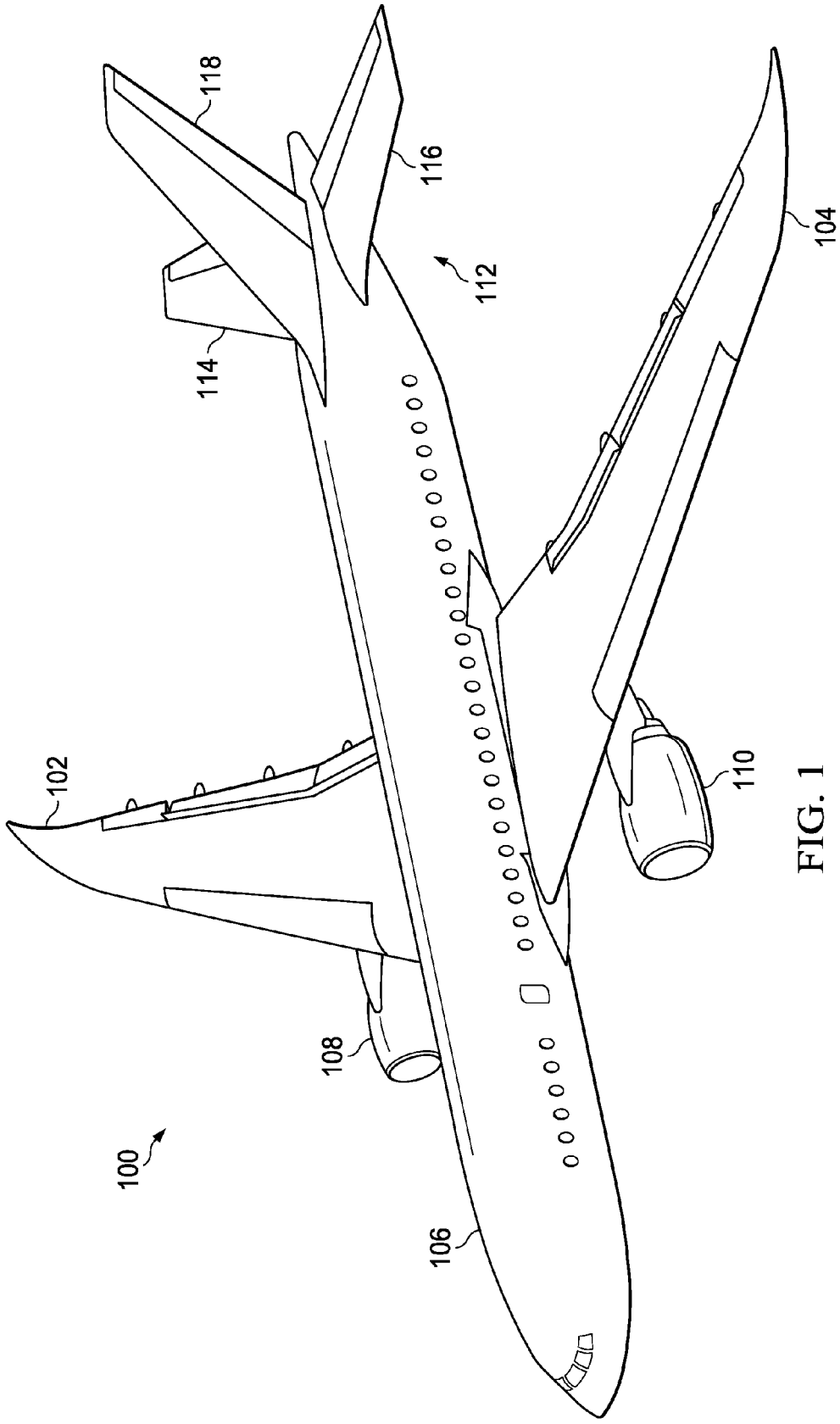


FIG. 1

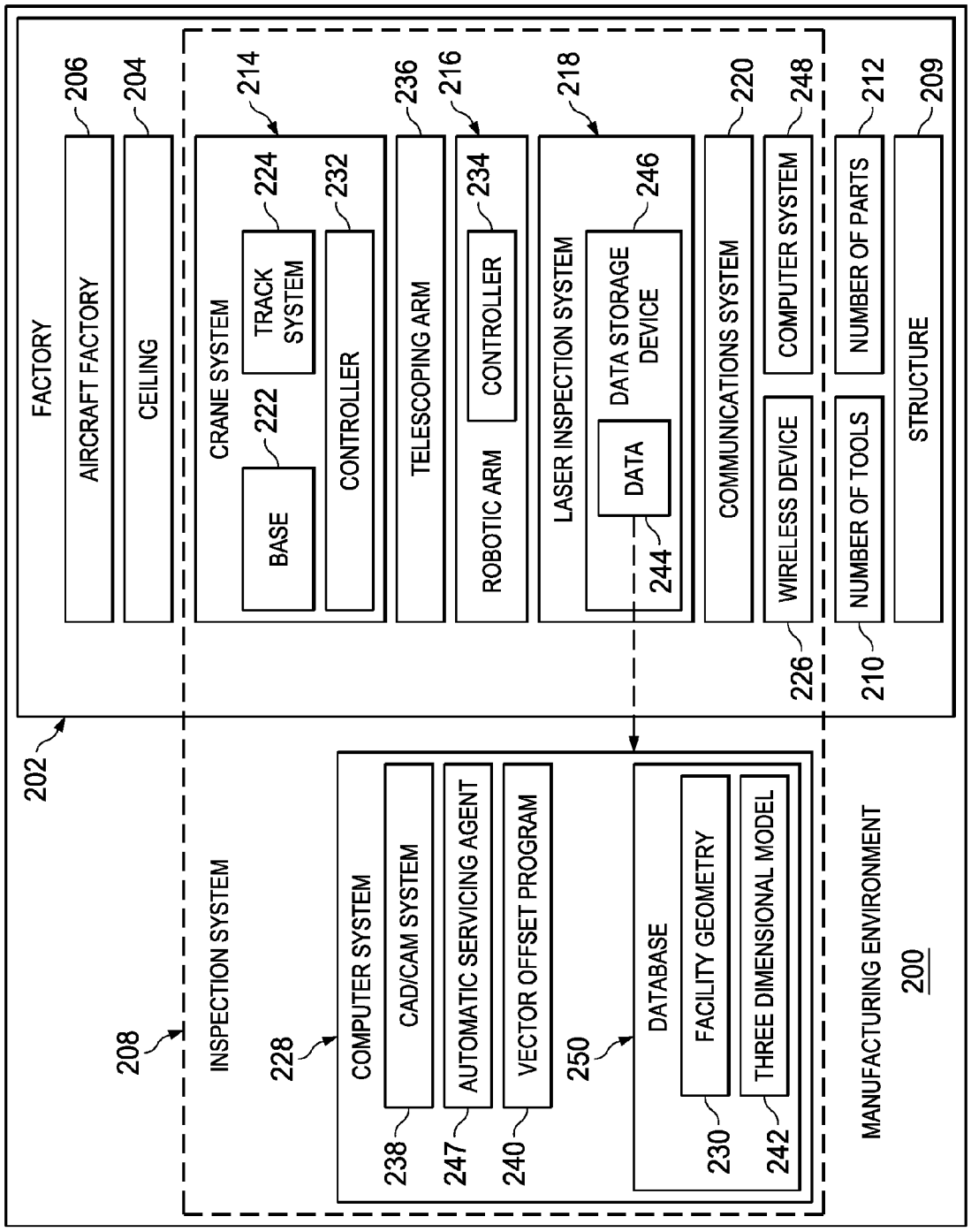

FACTORY
AIRCRAFT FACTORY
206
CEILING
204
CRANE SYSTEM
214
TRACK SYSTEM
224
BASE
222
CONTROLLER
232
TELESCOPING ARM
236
ROBOTIC ARM
CONTROLLER
234
216
LASER INSPECTION SYSTEM
218
DATA STORAGE DEVICE
246
DATA
244
COMMUNICATIONS SYSTEM
220
WIRELESS DEVICE
226
COMPUTER SYSTEM
248
NUMBER OF TOOLS
210
NUMBER OF PARTS
212
STRUCTURE
209
202
208
INSPECTION SYSTEM
228
COMPUTER SYSTEM
CAD/CAM SYSTEM
238
AUTOMATIC SERVICING AGENT
247
VECTOR OFFSET PROGRAM
240
250
DATABASE
FACILITY GEOMETRY
230
THREE DIMENSIONAL MODEL
242
MANUFACTURING ENVIRONMENT
200

FIG. 2

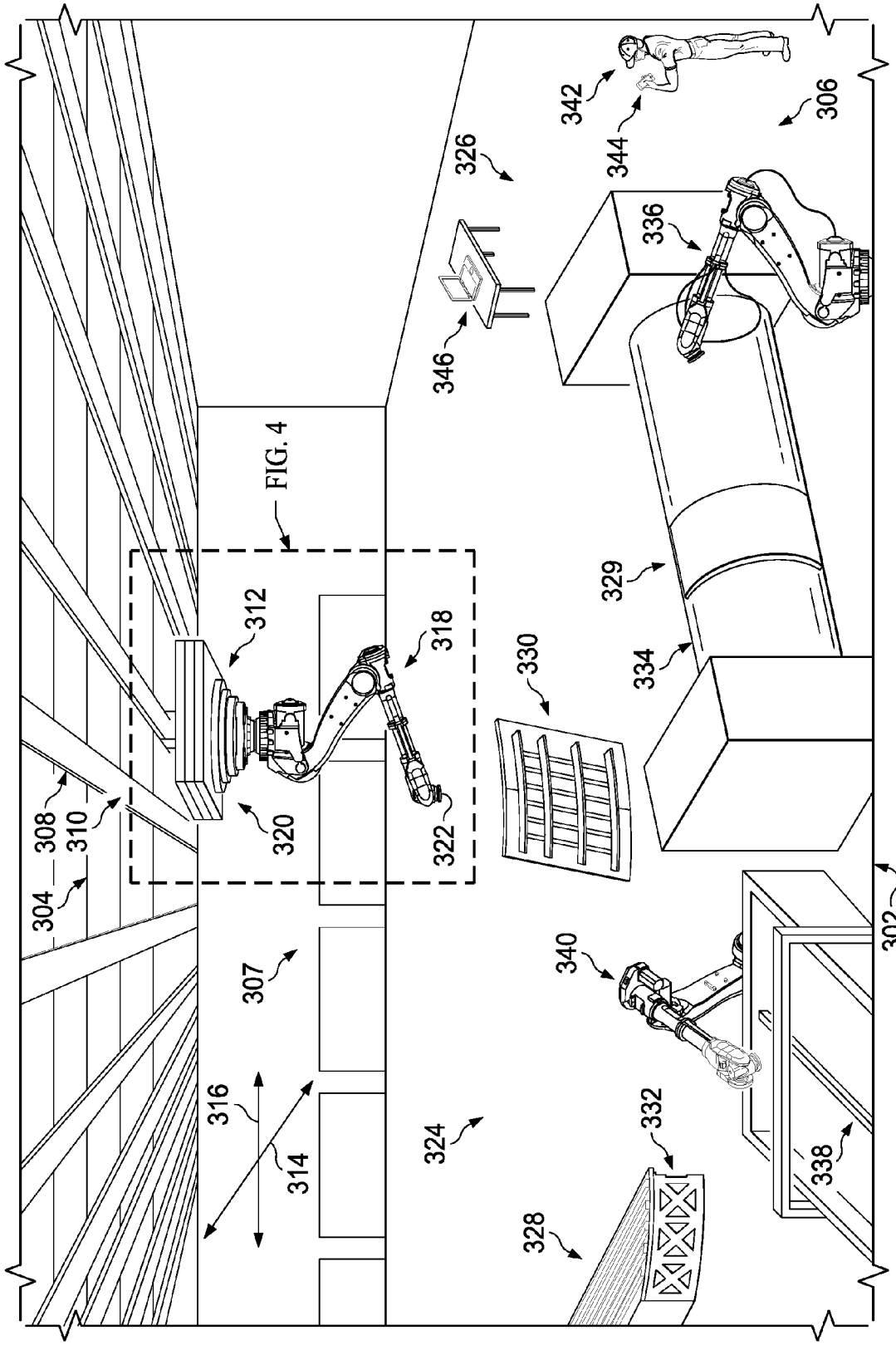


FIG. 4
300
302
304
306
307
308
310
312
314
316
318
320
322
324
326
328
329
330
332
334
336
338
340
342
344
346

FIG. 3

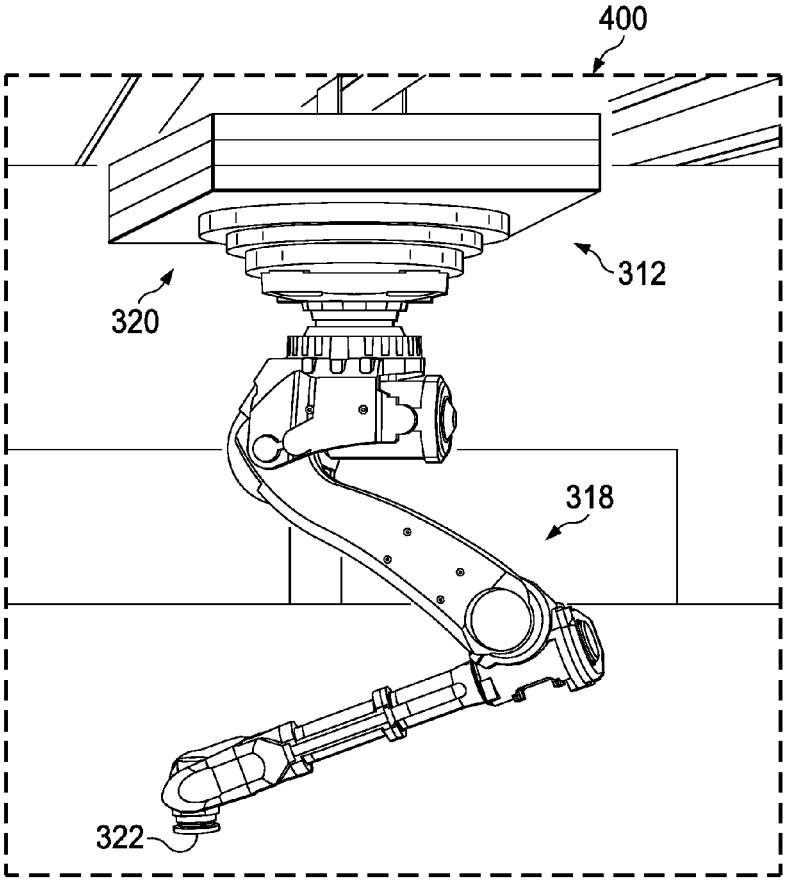

400
312
320
318
322

FIG. 4

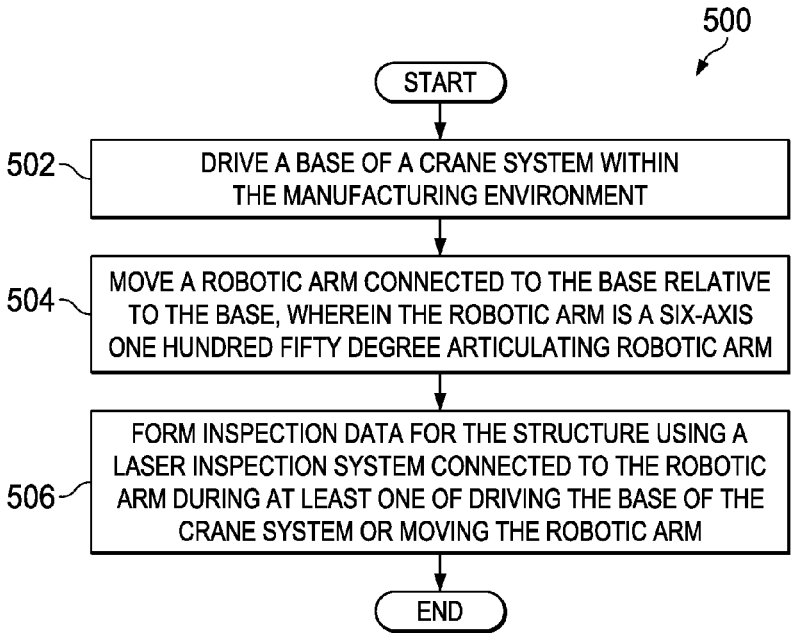

500
START
502
DRIVE A BASE OF A CRANE SYSTEM WITHIN THE MANUFACTURING ENVIRONMENT
504
MOVE A ROBOTIC ARM CONNECTED TO THE BASE RELATIVE TO THE BASE, WHEREIN THE ROBOTIC ARM IS A SIX-AXIS ONE HUNDRED FIFTY DEGREE ARTICULATING ROBOTIC ARM
506
FORM INSPECTION DATA FOR THE STRUCTURE USING A LASER INSPECTION SYSTEM CONNECTED TO THE ROBOTIC ARM DURING AT LEAST ONE OF DRIVING THE BASE OF THE CRANE SYSTEM OR MOVING THE ROBOTIC ARM
END

FIG. 5

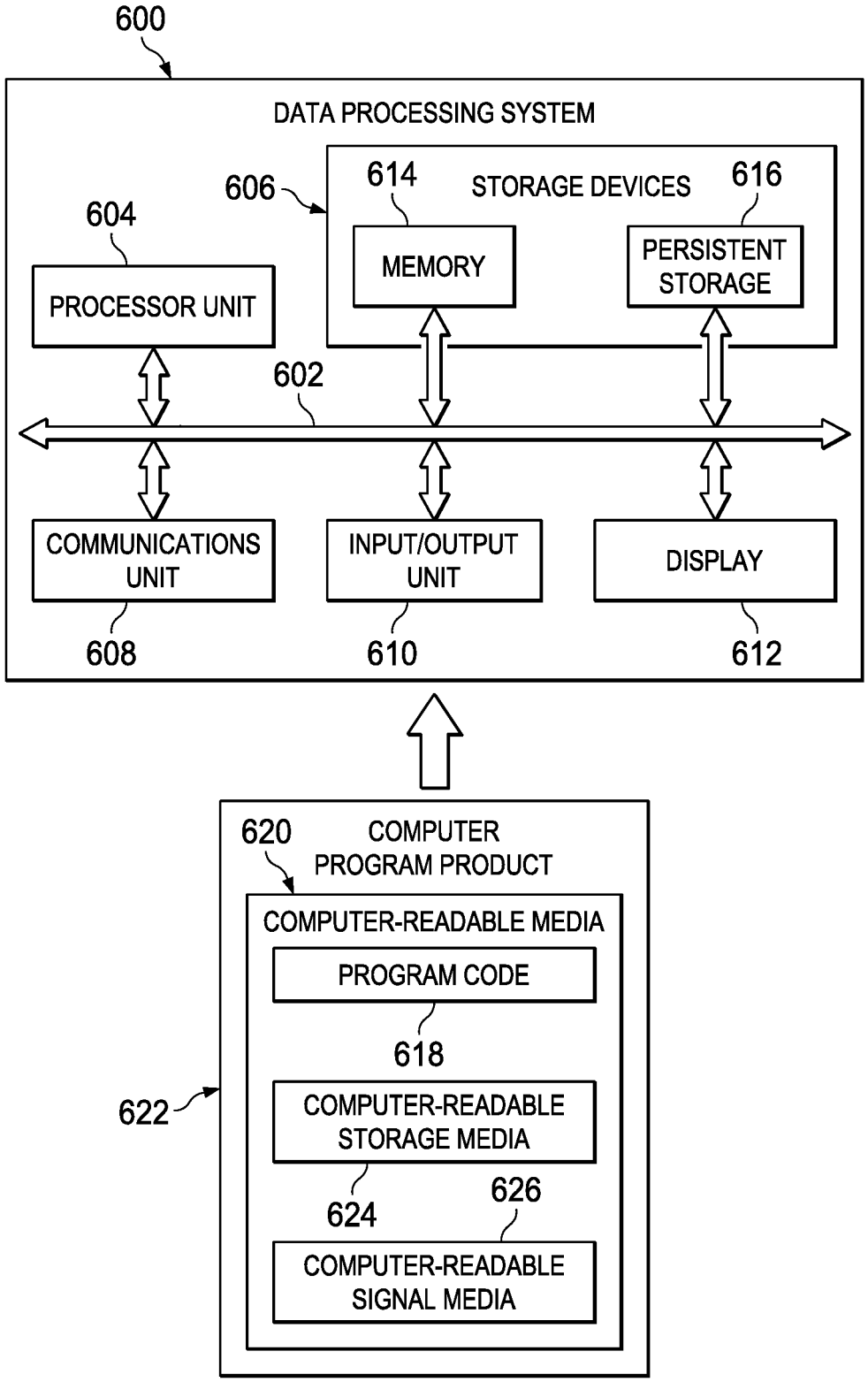

600
DATA PROCESSING SYSTEM
606
614
STORAGE DEVICES
616
604
MEMORY
PERSISTENT STORAGE
PROCESSOR UNIT
602
COMMUNICATIONS UNIT
INPUT/OUTPUT UNIT
DISPLAY
608
610
612
620
COMPUTER PROGRAM PRODUCT
COMPUTER-READABLE MEDIA
PROGRAM CODE
618
622
COMPUTER-READABLE STORAGE MEDIA
624
626
COMPUTER-READABLE SIGNAL MEDIA

FIG. 6

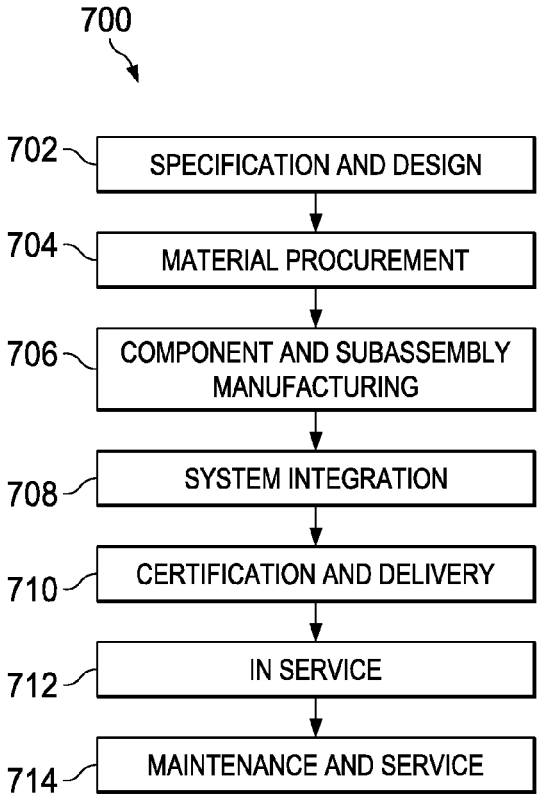

700
702
SPECIFICATION AND DESIGN
704
MATERIAL PROCUREMENT
706
COMPONENT AND SUBASSEMBLY MANUFACTURING
708
SYSTEM INTEGRATION
710
CERTIFICATION AND DELIVERY
712
IN SERVICE
714
MAINTENANCE AND SERVICE

FIG. 7

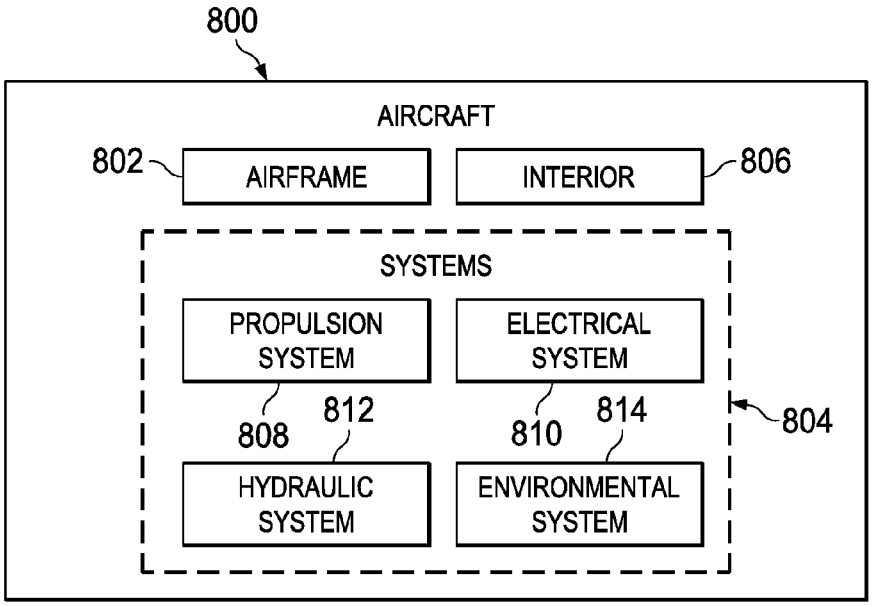

800
AIRCRAFT
802
AIRFRAME
INTERIOR
806
SYSTEMS
PROPULSION SYSTEM
ELECTRICAL SYSTEM
808
812
810
814
804
HYDRAULIC SYSTEM
ENVIRONMENTAL SYSTEM

FIG. 8

METHOD AND SYSTEM FOR AUTOMATED DATA COLLECTION AND PART VALIDATION

BACKGROUND INFORMATION

1. Field

[0001] The present disclosure relates generally to inspecting parts and, more specifically, to inspecting parts using a laser inspection system. Still more particularly, the present disclosure relates to inspecting parts using a laser inspection system connected to a robotic arm connected to a base of a crane system.

2. Background

[0002] Currently, parts are validated for dimensional conformance using computer-aided metrology or physical inspection. Floor space dedicated to conventional computer-aided metrology equipment may be undesirably large.

[0003] Computer-aided metrology equipment has a dedicated location. The parts may be moved to the computer-aided metrology equipment for inspection within a manufacturing environment. Moving the parts to the computer-aided metrology equipment may take an undesirable amount of time or energy. Additionally, moving the parts may cause inconsistencies in the parts.

[0004] Dimensions of computer-aided metrology equipment limit an inspected part size. Some parts may be too large to fit within the conventional computer-aided metrology equipment. When the parts are too large to fit within the computer-aided metrology equipment, the parts may be physically inspected.

[0005] Physical inspection may be undesirably expensive due to a large amount of operator time. Further, the physical inspection may be less accurate than desired. Therefore, it would be desirable to have a method and apparatus that take into account at least some of the issues discussed above, as well as other possible issues.

SUMMARY

[0006] In one illustrative embodiment, an inspection system is presented. The inspection system comprises a crane system, a six axis, one hundred and fifty degree articulating robotic arm, a laser inspection system, and a communications system. The robotic arm is connected to a base of the crane system. The laser inspection system is connected to the robotic arm. The communications system is configured to send and receive instructions for the crane system, the robotic arm, and the laser inspection system.

[0007] In another illustrative embodiment, an inspection system is presented. The inspection system comprises a crane system, a telescoping arm, a six axis, one hundred and fifty degree articulating robotic arm, a laser inspection system, a wireless device, and a communications system. The crane system has a base and a track system. The base of the crane system travels in at least one of an x-direction or a y-direction in a manufacturing environment along the track system. The telescoping arm is connected to the base of the crane system. The six-axis, one hundred and fifty degree articulating robotic arm is connected to the telescoping arm. The laser inspection system is connected to the robotic arm. The wireless device is configured to activate movement at least one of the crane system, the telescoping arm, or the robotic arm for inspection of a structure within the manufacturing environment by the laser inspection system. The communications system is configured to send and receive instructions for the crane system, the robotic arm, and the laser inspection system.

[0008] In yet another illustrative embodiment, a method of inspecting a structure in a manufacturing environment is presented. A base of a crane system is driven within the manufacturing environment. A robotic arm connected to the base is moved relative to the base. The robotic arm is a six-axis, one hundred and fifty degree articulating robotic arm. Inspection data for the structure is formed using a laser inspection system connected to the robotic arm during at least one of driving the base of the crane system or moving the robotic arm.

[0009] The features and functions can be achieved independently in various embodiments of the present disclosure or may be combined in yet other embodiments in which further details can be seen with reference to the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The novel features believed characteristic of the illustrative embodiments are set forth in the appended claims. The illustrative embodiments, however, as well as a preferred mode of use, further objectives and features thereof, will best be understood by reference to the following detailed description of an illustrative embodiment of the present disclosure when read in conjunction with the accompanying drawings, wherein:

[0011] FIG. **1** is an illustration of an aircraft in which an illustrative embodiment may be implemented;

[0012] FIG. **2** is an illustration of a block diagram of a manufacturing environment in accordance with an illustrative embodiment;

[0013] FIG. **3** is an illustration of a perspective view of a manufacturing environment employing an inspection system, wherein an aircraft is being assembled in accordance with an illustrative embodiment;

[0014] FIG. **4** is an illustration of a robotic arm and a telescoping arm connected to a crane of a manufacturing environment in accordance with an illustrative embodiment;

[0015] FIG. **5** is an illustration of a flowchart of a method for inspecting a structure in a manufacturing environment in accordance with an illustrative embodiment;

[0016] FIG. **6** is an illustration of a block diagram of a data processing system in accordance with an illustrative embodiment;

[0017] FIG. **7** is an illustration of an aircraft manufacturing and service method in the form of a block diagram in accordance with an illustrative embodiment; and

[0018] FIG. **8** is an illustration of an aircraft in the form of a block diagram in which an illustrative embodiment may be implemented.

DETAILED DESCRIPTION

[0019] The different illustrative embodiments recognize and take into account one or more different considerations. For example, the illustrative embodiments recognize and take into account that crane systems are present in aircraft manufacturing facilities. The crane systems in the aircraft manufacturing facilities are used to lift and move large components within the aircraft manufacturing facilities. The

illustrative embodiments recognize and take into account that a crane system may be mounted to a ceiling of an aircraft manufacturing facility.

[0020] The illustrative embodiments recognize and take into account that the crane system is designed to move within the aircraft manufacturing facility without interfering with manufacturing operations. For example, the crane system may be elevated enough to avoid collisions with components in the aircraft manufacturing facility.

[0021] The illustrative embodiments further recognize and take into account that the crane system is designed to access a substantial portion of the aircraft manufacturing facility. In some examples, the crane system may access the majority of the aircraft manufacturing facility.

[0022] Referring now to the figures and, in particular, with reference to FIG. **1**, an illustration of an aircraft is depicted in which an illustrative embodiment may be implemented. In this illustrative example, aircraft **100** has wing **102** and wing **104** connected to body **106**. Aircraft **100** includes engine **108** connected to wing **102** and engine **110** connected to wing **104**.

[0023] Body **106** has tail section **112**. Horizontal stabilizer **114**, horizontal stabilizer **116**, and vertical stabilizer **118** are connected to tail section **112** of body **106**.

[0024] Aircraft **100** is an example of an aircraft having parts that may be inspected using a laser inspection system connected to a robotic arm connected to a base of a crane system. For example, during manufacturing, components of at least one of wing **102**, wing **104**, body **106**, or tail section **112** may be inspected using the described method and system for automated data collection and part validation.

[0025] As used herein, the phrase "at least one of," when used with a list of items, means different combinations of one or more of the listed items may be used, and only one of each item in the list may be needed. 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 may be a particular object, a thing, or a category.

[0026] For example, "at least one of item A, item B, or item C" may include, without limitation, 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 may be present. In other examples, "at least one of" may 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.

[0027] This illustration of aircraft **100** is provided for purposes of illustrating one environment in which the different illustrative embodiments may be implemented. The illustration of aircraft **100** in FIG. **1** is not meant to imply architectural limitations as to the manner in which different illustrative embodiments may be implemented. For example, aircraft **100** is shown as a commercial passenger aircraft. The different illustrative embodiments may be applied to other types of aircraft, such as a private passenger aircraft, a rotorcraft, or other suitable types of aircraft.

[0028] Although the illustrative examples for an illustrative embodiment are described with respect to an aircraft, the illustrative embodiments may be applied to other types of structures. The structure may be, for example, a mobile structure, a stationary structure, a land-based structure, an aquatic-based structure, or a space-based structure. More specifically, the structure may be a surface ship, a tank, a personnel carrier, a train, a spacecraft, a space station, a satellite, a submarine, a manufacturing facility, a building, or other suitable structures.

[0029] Turning now to FIG. **2**, an illustration of a block diagram of a manufacturing environment is depicted in accordance with an illustrative embodiment. Manufacturing environment **200** includes factory **202** having ceiling **204**. In some illustrative examples, factory **202** may be aircraft factory **206**. Components of aircraft **100** of FIG. **1** may be manufactured in aircraft factory **206**.

[0030] Inspection system **208** associated with factory **202** inspects structures, such as structure **209** within factory **202**. Number of tools **210** and number of parts **212** are present within factory **202**. Structure **209** takes the form of one of a tool of number of tools **210** or a part of number of parts **212**. As used herein, "a number of," when used with reference to items, means one or more items. Thus, "number of tools" **210** includes one or more tools. Likewise, "number of parts" **212** includes one or more parts.

[0031] Number of tools **210** is used in the manufacturing and processing of number of parts **212**. Number of tools **210** includes any desirable size or shape of tools. The location of number of tools **210** within factory **202** may change during the manufacturing. For example, a tool of number of tools **210** may be moved within factory **202** to manufacture a part of number of parts **212**. The quantity of tools in number of tools **210** may change during the manufacturing. The tools may be moved into or out of factory **202** as needed.

[0032] Number of parts **212** includes any desirable size or shape of parts. In some illustrative examples, number of parts **212** includes any desirable components of aircraft **100** of FIG. **1**. For example, number of parts **212** may include components of at least one of wing **102**, wing **104**, body **106**, or tail section **112** of aircraft **100** of FIG. **1**.

[0033] As depicted, some components of inspection system **208** are located within factory **202**. Inspection system **208** includes crane system **214**, robotic arm **216**, laser inspection system **218**, and communications system **220**. Robotic arm **216** is a six-axis, one hundred and fifty degree articulating arm. Robotic arm **216** is connected to base **222** of crane system **214**.

[0034] As used herein, a first component "connected to" a second component means that the first component can be connected directly or indirectly to the second component. In other words, additional components may be present between the first component and the second component. The first component is considered to be indirectly connected to the second component when one or more additional components are present between the two components. When the first component is directly connected to the second component, no additional components are present between the two components.

[0035] Laser inspection system **218** is connected to robotic arm **216**. In some illustrative examples, laser inspection system **218** is directly connected to the end of robotic arm **216**. Communications system **220** is configured to send and receive instructions for crane system **214**, robotic arm **216**, and laser inspection system **218**.

[0036] Robotic arm **216** has desirable functional capabilities. The functional capabilities include desirable motion of travel and desirable axis and rotation capabilities.

[0037] The desirable motion of travel may be dependent on the size of factory **202**. In some examples, robotic arm

216 has Z-axis motion of travel of −12 feet to +12 feet; Y-axis motion of travel of +20 feet in both directions; and X-axis motion of travel of +20 feet in both directions.

[0038] The desirable axis and rotation capabilities are independent of size of factory **202**. Robotic arm **216** desirably has an X-Y yaw axis capability of +/−180 degrees; a Y-Z pitch axis capability of +/−115 degrees; and an X-Z rotation capability of at least +/−150 degrees.

[0039] In some examples, crane system **214** includes track system **224**. Track system **224** may be positioned within factory **202** using any desirable method. In some examples, track system **224** is connected to ceiling **204** of factory **202**. Base **222** of crane system **214** travels in at least one of an x-direction or a y-direction within manufacturing environment **200** along track system **224**.

[0040] Inspection system **208** also includes wireless device **226**. Wireless device **226** may take a number of different forms. Depending on the implementation, wireless device **226** may be selected from one of a laptop, a smartphone, a personal digital assistant, a tablet, a portable computer, an external storage device, or some other type of portable device capable of storing a sufficiently large amount of data.

[0041] Wireless device **226** is configured to activate movement of at least one of crane system **214** or robotic arm **216** for inspection of a structure using laser inspection system **218**. Wireless device **226** may activate movement of at least one of crane system **214** or robotic arm **216** directly or indirectly. For example, wireless device **226** may send instructions directly to at least one of crane system **214** or robotic arm **216** to activate movement. As another example, wireless device **226** may activate movement by sending a request to computer system **228**, and computer system **228** sending instructions to at least one of crane system **214** or robotic arm **216**.

[0042] In some examples, wireless device **226** is configured to send movement instructions generated based on operator input. The operator input may be received by using a screen, keypad, tracking device, or any other desirable type of input device.

[0043] In one illustrative example, an operator may "drive" at least one of crane system **214** or robotic arm **216** using wireless device **226**. In this example, the operator may manually control a path of crane system **214** or robotic arm **216** using wireless device **226** as a controller. Wireless device **226** may generate the movement instructions for at least one of crane system **214** or robotic arm **216** as user input is received at wireless device **226**.

[0044] In another illustrative example, wireless device **226** may generate the movement instructions based on the operator's selection. For example, the operator may select a type of part, a type of inspection, or any other desirable type of input from a menu. Wireless device **226** may generate the movement instructions based on this menu input.

[0045] In yet another illustrative example, wireless device **226** is configured to trigger generation of the movement instructions for at least one of crane system **214** or robotic arm **216** by computer system **228** based on facility geometry **230**. Facility geometry **230** includes at least one of positions of number of tools **210** within factory **202**, shapes and sizes of number of tools **210**, positions of number of parts **212** within factory **202**, shapes and sizes of number of parts **212**, or a shape and size of factory **202**. By using facility geometry **230** to generate the movement instructions, crane system **214** and robotic arm **216** avoid undesirable contact with components of factory **202**, number of parts **212**, and number of tools **210**. After generation of the movement instructions by either wireless device **226** or computer system **228**, communications system **220** sends the movement instructions.

[0046] Communications system **220** includes a plurality of communication components configured to communicate with other devices. The plurality of communication components may provide communications using physical communications links, wireless communications links, or both. Communications system **220** includes communication components associated with at least one of crane system **214**, robotic arm **216**, laser inspection system **218**, wireless device **226**, and computer system **228**.

[0047] Components of communications system **220** are configured to send and receive wireless signals in a range of 400-650 mHz to send and receive instructions for crane system **214**. For example, a receiver associated with crane system **214** is configured to receive wireless signals in the range of 400-650 mHz. As another example, at least one of a transmitter associated with computer system **228** or a transmitter associated with wireless device **226** is configured to transmit wireless signals in the range of 400-650 mHz.

[0048] The components of communications system **220** are configured to send and receive wireless signals in a range of 2.4-5.0 Ghz to send and receive instructions for robotic arm **216**. For example, a receiver associated with robotic arm **216** is configured to receive wireless signals in the range of 2.4-5.0 Ghz. As another example, at least one of a transmitter associated with computer system **228** or a transmitter associated with wireless device **226** is configured to transmit the wireless signals in the range of 2.4-5.0 Ghz.

[0049] Controller **232** controls crane system **214** according to instructions received using communications system **220**. Controller **234** controls robotic arm **216** according to instructions received using communications system **220**. Although controller **232** and controller **234** are shown as separate components, in some illustrative examples, crane system **214** and robotic arm **216** may be controlled using the same controller.

[0050] In some examples, inspection system **208** also includes telescoping arm **236**. In these examples, robotic arm **216** is connected to base **222** by telescoping arm **236**. Telescoping arm **236** is connected to base **222** of crane system **214**. In these examples, telescoping arm **236** may be described as directly connected to base **222**. Telescoping arm **236** enables robotic arm **216** to move greater distances away from ceiling **204** of factory **202**.

[0051] Computer system **228** includes computer-aided design/computer-aided manufacturing (CAD/CAM) system **238** configured to generate vector offset program **240** to move robotic arm **216** to inspect structure **209**. Vector offset program **240** is a set of instructions for robotic arm **216**. Computer-aided design/computer-aided manufacturing system **238** uses at least one of facility geometry **230** or three-dimensional model **242** of structure **209** to form vector offset program **240**. In some illustrative examples, vector offset program **240** includes instructions for movement of robotic arm **216** during inspection of structure **209** by laser inspection system **218**. Vector offset program **240** uses location and shape data from facility geometry **230** to avoid

undesirable contact of components of inspection system **208** with components of factory **202**, number of parts **212**, or number of tools **210**.

[0052] During inspection, laser inspection system **218** forms data **244**. Data **244** is stored in data storage device **246** until inspection of structure **209** is completed. When inspection of structure **209** is completed, data **244** is sent to computer system **228** either automatically or by instruction from wireless device **226**.

[0053] Computer-aided design/computer-aided manufacturing system **238** is further configured to compare data **244** generated by laser inspection system **218** for structure **209** to three-dimensional model **242** of structure **209**. Automatic servicing agent **247** starts an internal program within computer-aided design/computer-aided manufacturing system **238** to interrogate data **244** to three-dimensional model **242**. If the results of this interrogation are within tolerance, structure **209** is validated.

[0054] Computer system **228** may be configured to perform other functions. In some examples, computer system **228** is configured to generate a program to drive base **222** of crane system **214** towards structure **209** within manufacturing environment **200** to be inspected based on facility geometry **230**.

[0055] Facility geometry **230** may be referred to as geo-spatial location geometry. The geo-spatial location geometry may be in the form of (deg-min-sec)—latitude and longitude or in the form of ASCII-based X-Y axis geometry. Facility geometry **230** may be used for X-Y axis positioning for crane system **214** and providing association to the robot scanning geometry which provides X,Y,Z, and I,J,K values for robotic arm **216**.

[0056] The X-Y axis positioning geometry for crane system **214** goes through data conversion to XML and is sent to a wireless supervisory control and data acquisition (SCADA) service. Following SCADA, instructions are sent to controller **232**, also referred to as the crane programmable logic controller (PLC). The crane programmable logic controller drives crane system **214** using a numerically based drive program -X-Y axis geometry based file program.

[0057] The robot scanning geometry X,Y,Z, I,J,K+ avoidance geometry for robotic arm **216** goes through data conversion to XML and is sent to controller **234**, also referred to as the robot programmable logic controller. The robot programmable logic controller drives robotic arm **216** using a numerically based drive program with -X-YZ, I-J-K values in an ASCII format.

[0058] The illustration of manufacturing environment **200** in FIG. **2** is not meant to imply physical or architectural limitations to the manner in which an illustrative embodiment 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 embodiment.

[0059] For example, although computer-aided design/computer-aided manufacturing (CAD/CAM) system **238** is depicted as on computer system **228** outside of factory **202**, in some illustrative examples, computer-aided design/computer-aided manufacturing (CAD/CAM) system **238** may instead be associated with computer system **248** within factory **202**. Further, although facility geometry **230** and three-dimensional model **242** are depicted as within database **250**, in some illustrative examples, facility geometry **230** and three-dimensional model **242** may be present in separate databases.

[0060] Turning now to FIG. **3**, an illustration of a perspective view of a manufacturing environment employing an inspection system, wherein an aircraft is being assembled is depicted in accordance with an illustrative embodiment. Manufacturing environment **300** may be a physical implementation of manufacturing environment **200** of FIG. **2**.

[0061] Manufacturing environment **300** includes factory **302** having ceiling **304** and floor **306**. As depicted, factory **302** is an aircraft factory. Inspection system **307** is present within manufacturing environment **300**.

[0062] As depicted, track system **308** of crane system **310** is connected to ceiling **304**. Base **312** of crane system **310** may move along track system **308** in at least one of x-direction **314** or y-direction **316**.

[0063] Robotic arm **318** is connected to base **312** by telescoping arm **320**. Laser inspection system **322** for inspecting at least one of number of parts **324** and number of tools **326** within manufacturing environment **300** is connected to robotic arm **318**. Laser inspection system **322** generates data while at least one of robotic arm **318** or base **312** of crane system **310** moves within factory **302**.

[0064] As depicted, number of parts **324** includes stringers **328**, composite panel **329**, and assembled panels **330**. Number of parts **324** present in factory **302** may change during manufacturing of an aircraft. Further, the location of each part of number of parts **324** present in factory **302** may change during manufacturing of the aircraft. As depicted, stringers **328** are resting on table **332**. However, stringers **328** may be used to form a panel similar to assembled panels **330**. Any of number of parts **324** may be inspected using inspection system **307**.

[0065] As depicted, number of tools **326** includes jig **334**, tape laying robot **336**, jig **338**, and tape laying robot **340**. Tape laying robot **336** applies composite tape to jig **334** to form composite panel **329**. Tape laying robot **340** applies composite tape to jig **338** to form a stringer, such as stringers **328**. Number of tools **326** present in factory **302** may change during manufacturing of the aircraft. Further, the location of each tool of number of tools **326** present in factory **302** may change during manufacturing of the aircraft. Any of number of tools **326** may be inspected using inspection system **307**. For example, jig **334** or jig **338** may be inspected for appropriate shape, size, or location within factory **302**.

[0066] Operator **342** triggers inspection of a structure using wireless device **344**. The structure may be at least one of a part of number of parts **324** or a tool of number of tools **326**. In some illustrative examples, operator **342** may indicate a structure to be inspected using input on wireless device **344**. One of wireless device **344** or computer system **346** sends movement instructions to at least one of crane system **310** or robotic arm **318**. In some illustrative examples, computer system **346** creates movement instructions based on input of operator **342** and known facility geometry. In other illustrative examples, operator **342** may manually drive inspection system **307** using wireless device **344**.

[0067] After inspection, laser inspection system **322** sends data to computer system **346** for analysis. Computer system **346** compares the data to a three-dimensional model of the

structure. Afterwards, results are provided in a desirable format. If the results are within tolerance, the inspected structure is validated.

[0068] Turning now to FIG. **4**, an illustration of a robotic arm and a telescoping arm connected to a crane of a manufacturing environment is depicted in accordance with an illustrative embodiment. View **400** is a view of manufacturing environment **300** of FIG. **3** within box **4-4**. View **400** provides a closer look at components of inspection system **307** of FIG. **3**.

[0069] Turning now to FIG. **5**, an illustration of a flowchart of a method for inspecting a structure in a manufacturing environment is depicted in accordance with an illustrative embodiment. Method **500** may be used to inspect structure **209** in manufacturing environment **200** of FIG. **2**. Method **500** may be used to inspect a part of number of parts **324** or a tool of number of tools **326** in manufacturing environment **300** of FIG. **3**.

[0070] Method **500** drives a base of a crane system within the manufacturing environment (operation **502**). Method **500** moves a robotic arm connected to the base relative to the base, wherein the robotic arm is a six-axis, one hundred and fifty degree articulating robotic arm (operation **504**). Method **500** forms inspection data for the structure using a laser inspection system connected to the robotic arm during at least one of driving the base of the crane system or moving the robotic arm (operation **506**). Afterwards the process terminates.

[0071] The flowcharts and block diagrams in the different depicted embodiments illustrate the architecture, functionality, and operation of some possible implementations of apparatus and methods in an illustrative embodiment. In this regard, each block in the flowcharts or block diagrams may represent a module, a segment, a function, and/or a portion of an operation or step.

[0072] In some alternative implementations of an illustrative embodiment, 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 executed 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.

[0073] In some illustrative examples, method **500** further generates instructions for at least one of driving the base of the crane system or moving the robotic arm based on facility geometry stored on a computer system. In other illustrative examples, method **500** further generates instructions for at least one of driving the base of the crane system or moving the robotic arm based on user input received on a wireless device. In some illustrative examples, method **500** compares inspection data for the structure to a three-dimensional model of the structure to form results. In other illustrative examples, method **500** changes a length of a telescoping arm positioned between the robotic arm and the base of the crane system. In some examples, method **500** disables manual crane controls prior to driving the base of the crane or moving the robotic arm.

[0074] Turning now to FIG. **6**, an illustration of a block diagram of a data processing system is depicted in accordance with an illustrative embodiment. Data processing system **600** may be used to implement portions of inspection system **208** of FIG. **2**, such as computer system **228** or computer system **248**. As depicted, data processing system **600** includes communications framework **602**, which provides communications between processor unit **604**, storage devices **606**, communications unit **608**, input/output unit **610**, and display **612**. In some cases, communications framework **602** may be implemented as a bus system.

[0075] Processor unit **604** is configured to execute instructions for software to perform a number of operations. Processor unit **604** may comprise a number of processors, a multi-processor core, and/or some other type of processor, depending on the implementation. In some cases, processor unit **604** may take the form of a hardware unit, such as a circuit system, an application specific integrated circuit (ASIC), a programmable logic device, or some other suitable type of hardware unit.

[0076] Instructions for the operating system, applications, and/or programs run by processor unit **604** may be located in storage devices **606**. Storage devices **606** may be in communication with processor unit **604** through communications framework **602**. As used herein, a storage device, also referred to as a computer-readable storage device, is any piece of hardware capable of storing information on a temporary and/or permanent basis. This information may include, but is not limited to, data, program code, and/or other information.

[0077] Memory **614** and persistent storage **616** are examples of storage devices **606**. Memory **614** may take the form of, for example, a random access memory or some type of volatile or non-volatile storage device. Persistent storage **616** may comprise any number of components or devices. For example, persistent storage **616** may comprise a hard drive, a flash memory, a rewritable optical disk, a rewritable magnetic tape, or some combination of the above. The media used by persistent storage **616** may or may not be removable.

[0078] Communications unit **608** allows data processing system **600** to communicate with other data processing systems and/or devices. Communications unit **608** may provide communications using physical and/or wireless communications links.

[0079] Input/output unit **610** allows input to be received from and output to be sent to other devices connected to data processing system **600**. For example, input/output unit **610** may allow user input to be received through a keyboard, a mouse, and/or some other type of input device. As another example, input/output unit **610** may allow output to be sent to a printer connected to data processing system **600**.

[0080] Display **612** is configured to display information to a user. Display **612** may comprise, for example, without limitation, a monitor, a touch screen, a laser display, a holographic display, a virtual display device, and/or some other type of display device.

[0081] In this illustrative example, the processes of the different illustrative embodiments may be performed by processor unit **604** using computer-implemented instructions. These instructions may be referred to as program code, computer usable program code, or computer-readable program code and may be read and executed by one or more processors in processor unit **604**.

[0082] In these examples, program code **618** is located in a functional form on computer-readable media **620**, which is selectively removable, and may be loaded onto or transferred to data processing system **600** for execution by processor unit **604**. Program code **618** and computer-read-

able media **620** together form computer program product **622**. In this illustrative example, computer-readable media **620** may be computer-readable storage media **624** or computer-readable signal media **626**.

[0083] Computer-readable storage media **624** is a physical or tangible storage device used to store program code **618**, rather than a medium that propagates or transmits program code **618**. Computer-readable storage media **624** may be, for example, without limitation, an optical or magnetic disk or a persistent storage device that is connected to data processing system **600**.

[0084] Alternatively, program code **618** may be transferred to data processing system **600** using computer-readable signal media **626**. Computer-readable signal media **626** may be, for example, a propagated data signal containing program code **618**. This data signal may be an electromagnetic signal, an optical signal, and/or some other type of signal that can be transmitted over physical and/or wireless communications links.

[0085] Illustrative embodiments of the present disclosure may be described in the context of aircraft manufacturing and service method **700** as shown in FIG. **7** and aircraft **800** as shown in FIG. **8**. Turning first to FIG. **7**, an illustration of an aircraft manufacturing and service method is depicted in accordance with an illustrative embodiment. During pre-production, aircraft manufacturing and service method **700** may include specification and design **702** of aircraft **800** in FIG. **8** and material procurement **704**.

[0086] During production, component and subassembly manufacturing **706** and system integration **708** of aircraft **800** takes place. Thereafter, aircraft **800** may go through certification and delivery **710** in order to be placed in service **712**. While in service **712** by a customer, aircraft **800** is scheduled for routine maintenance and service **714**, which may include modification, reconfiguration, refurbishment, and other maintenance or service.

[0087] Each of the processes of aircraft manufacturing and service method **700** may be performed or carried out by a system integrator, a third party, and/or an operator. In these examples, the operator may be a customer. For the purposes of this description, a system integrator may include, without limitation, any number of aircraft manufacturers and major-system subcontractors; a third party may include, without limitation, any number of vendors, subcontractors, and suppliers; and an operator may be an airline, a leasing company, a military entity, a service organization, and so on.

[0088] With reference now to FIG. **8**, an illustration of an aircraft is depicted in which an illustrative embodiment may be implemented. In this example, aircraft **800** is produced by aircraft manufacturing and service method **700** in FIG. **7** and may include airframe **802** with plurality of systems **804** and interior **806**. Examples of systems **804** include one or more of propulsion system **808**, electrical system **810**, hydraulic system **812**, and environmental system **814**. Any number of other systems may be included. Although an aerospace example is shown, different illustrative embodiments may be applied to other industries, such as the automotive industry.

[0089] Apparatuses and methods embodied herein may be employed during at least one of the stages of aircraft manufacturing and service method **700**. One or more illustrative embodiments may be used during component and subassembly manufacturing **706** of FIG. **7**. For example, inspection system **208** of FIG. **2** may be used to inspect parts during component and subassembly manufacturing **706**. Further, inspection system **208** of FIG. **2** may be used to inspect replacement parts during maintenance and service **714** of FIG. **7**.

[0090] An operational concept of the inspection system is that facilities will permanently bolt the robotic arm and the telescoping arm to the base plate of the crane system on the factory ceiling. Facilities will then attach the control cabling from the robotic arm to the crane control system. An operator will then download a numeric control (NC) offset measurement tracking program and run the robot with a handheld wireless device. Once the process is complete, the robotic arm and the telescoping arm may then rotate back into a protective box. After the storage process is complete, data will be transmitted either to the product data manager via a handheld wireless device for an automated interrogation process to occur or through a persistent gateway for data analytics processing. The results of the data analytics processing will automatically be posted to an internally based website for review by the customer.

[0091] The systems concept of the inspection system is that a six-axis, one hundred and fifty degree articulating robotic arm will be numerically driven through large tooling structures by an NC vector offset program developed on the computer-aided design/computer-aided manufacturing (CAD/CAM) system. This robot will have a digital laser scanner on the end effector of the robotic arm. The laser scanner will record and cache all of the identified point and vector details onto an external hard drive. The operator may then use a specific handheld device to perform a wireless data transfer from the laser tracker external hard drive to a specific folder within the PDM database where an automatic servicing agent (ASA) will start an internal program within the CAD/CAM system to interrogate the data file to the computer-aided design (CAD) geometry.

[0092] In some examples, the wireless data transfer may be performed automatically without the operator. The results of the interrogation will be written to a database into a web-based hypertext mark-up language (HTML) formatted flat file and then automatically sent to an internally secure website. Users can then log into this website and type in a part number to review the results of the measurement on the associated tooling or the data analytics.

[0093] The inspection system will automate the conventionally manual tooling inspection certification process on thousands of large, out-sized aircraft assembly tools and jigs in large manufacturing factories and provide web-based data interrogation results and visibility to the users with desirable accuracy and efficiency.

[0094] The description of the different illustrative embodiments has been presented for purposes of illustration and description, and is not intended to be exhaustive or limited to the embodiments in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. Further, different illustrative embodiments may provide different features as compared to other illustrative embodiments. The embodiment or embodiments selected are chosen and described in order to best explain the principles of the embodiments, the practical application, and to enable others of ordinary skill in the art to understand the disclosure for various embodiments with various modifications as are suited to the particular use contemplated.

What is claimed is:

1. An inspection system comprising:

a crane system;

a six-axis, one hundred and fifty degree articulating robotic arm, wherein the robotic arm is connected to a base of the crane system;

a laser inspection system connected to the robotic arm; and

a communications system configured to send and receive instructions for the crane system, the robotic arm, and the laser inspection system.

2. The inspection system of claim **1**, wherein the crane system comprises a track system, wherein the base of the crane system travels in at least one of an x-direction or a y-direction within a manufacturing environment along the track system.

3. The inspection system of claim **1** further comprising:

a wireless device configured to activate movement of at least one of the crane system or the robotic arm for inspection of a structure using the laser inspection system.

4. The inspection system of claim **3**, wherein the wireless device is configured to send movement instructions generated based on operator input.

5. The inspection system of claim **3**, wherein the wireless device is configured to trigger generation of movement instructions for at least one of the crane system or the robotic arm by a computer system based on facility geometry.

6. The inspection system of claim **1**, wherein the robotic arm is connected to the base by a telescoping arm.

7. The inspection system of claim **1**, wherein components of the communications system are configured to send and receive wireless signals in a range of 400-650 mHz to send and receive instructions for the crane system.

8. The inspection system of claim **1**, wherein components of the communications system are configured to send and receive wireless signals in a range of 2.4-5.0 Ghz to send and receive instructions for the robotic arm.

9. An inspection system comprising:

a crane system having a base and a track system, wherein the base of the crane system travels in at least one of an x-direction or a y-direction in a manufacturing environment along the track system;

a telescoping arm connected to the base of the crane system;

a six-axis, one hundred and fifty degree articulating robotic arm connected to the telescoping arm;

a laser inspection system connected to the robotic arm;

a wireless device configured to activate movement of at least one of the crane system, the telescoping arm, or the robotic arm for inspection of a structure within the manufacturing environment by the laser inspection system; and

a communications system configured to send and receive instructions for the crane system, the robotic arm, and the laser inspection system.

10. The inspection system of claim **9** further comprising:

a computer-aided design/computer-aided manufacturing system configured to generate a vector offset program to move the robotic arm to inspect a structure.

11. The inspection system of claim **10**, wherein the computer-aided design/computer aided manufacturing system is further configured to compare data generated by the laser inspection system for the structure to a three-dimensional model of the structure.

12. The inspection system of claim **9**, wherein a computer system is configured to generate a program to drive the base of the crane system towards a structure within the manufacturing environment to be inspected based on facility geometry.

13. The inspection system of claim **9**, wherein the wireless device is configured to send movement instructions generated based on operator input.

14. The inspection system of claim **9**, wherein the wireless device is configured to trigger generation of movement instructions for at least one of the crane system or the robotic arm by a computer system based on facility geometry.

15. A method of inspecting a structure in a manufacturing environment, the method comprising:

driving a base of a crane system within the manufacturing environment;

moving a robotic arm connected to the base relative to the base, wherein the robotic arm is a six-axis one hundred and fifty degree articulating robotic arm; and

forming inspection data for the structure using a laser inspection system connected to the robotic arm during at least one of driving the base of the crane system or moving the robotic arm.

16. The method of claim **15** further comprising:

generating instructions for at least one of driving the base of the crane system or moving the robotic arm based on facility geometry stored on a computer system.

17. The method of claim **15** further comprising:

generating instructions for at least one of driving the base of the crane system or moving the robotic arm based on user input received on a wireless device.

18. The method of claim **15** further comprising:

comparing inspection data for the structure to a three-dimensional model of the structure to form results.

19. The method of claim **15** further comprising:

changing a length of a telescoping arm positioned between the robotic arm and the base of the crane system.

20. The method of claim **15** further comprising:

disabling manual crane controls prior to driving the base of the crane system or moving the robotic arm.

* * * * *