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Method and system for inspecting and measuring installed one-sided fasteners in a structure

Abstract

There is provided a method for inspecting and measuring one or more installed one-sided fasteners in a structure. The method includes positioning an X-ray imaging system at a first side of the structure at a location of the one or more installed one-sided fasteners. The method further includes emitting X-rays at the first side of the structure, detecting backscatter from the one or more installed one-sided fasteners, and generating image data from the X-ray imaging system in response to detecting the backscatter. The method further includes measuring and analyzing the image data, with an image processing system, to obtain one or more measurements of one or more dimensions of the one or more installed one-sided fasteners. The method further includes using the image data to inspect the one or more installed one-sided fasteners, and to detect any inconsistencies in the one or more measurements of the one or more dimensions.

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Background/Summary

FIELD

(1) The present disclosure relates generally to X-ray inspection, and more particularly to systems and methods for X-ray inspection and measurement of installed one-sided fasteners in a structure.

BACKGROUND

(2) One-sided fasteners, also referred to as “blind fasteners”, are mechanical fasteners used to typically join two or more structural members together, where the one-sided fastener is only readily accessible at an exterior end on an exterior side of the joined structural members, and is not readily accessible at an interior end protruding from an interior side of the joined structural members, and the interior end is not visible, or is “blind”. One-sided fasteners may be used in the manufacture of aircraft, spacecraft, rotorcraft, watercraft, automobiles, trains, architectural structures, and other vehicles or structures. The one-sided fasteners may be installed in confined spaces, for example, an aircraft fuel tank.

(3) One known system and method used to inspect the installation of one-sided fasteners, or blind fasteners, involves inserting a device, such as a borescope, a camera probe, or a vision system, into an adjacent fastener hole to view an adjacent feature or an adjacent fastener requiring inspection and/or measurement. A borescope is an optical instrument designed to assist visual inspection of difficult to access cavities or areas and comprises a rigid or flexible tube with an eyepiece or display at one end, an objective lens or camera at another end, and linked together by an optical or electrical system therebetween. However, a borescope is used to inspect one-sided fasteners through an adjacent hole and may only be able to view 50% of the one-sided fastener. Moreover, the borescope may be invasive to a part installation, may have focal length limitations, and may have hole size constraints.

(4) Another known system and method used to inspect the installation of one-sided fasteners, or blind fasteners, involves a mechanic or inspector physically entering a confined space to view and/or measure the installation of the one-sided fasteners, to ensure there are no inconsistencies in, for example, formation of a fastener bulb of the one-sided fastener, length of a pin protrusion of the one-sided fastener, or a grip length of the one-sided fastener. However, such confined space entry may be time consuming, labor intensive, and create ergonomic issues. Such increased time and labor may result in increased costs of manufacturing and inspecting structures with the one-sided fasteners.

(5) Accordingly, there is a need in the art for an improved system and method for inspecting and measuring installed one-sided fasteners from the exterior side of a structure with installed one-sided fasteners, that do not require the use of a borescope, a camera probe, or a vision system to insert into an adjacent fastener hole to inspect or measure the installed one-sided fasteners, that reduce or eliminate confined space entry work to inspect and measure installed one-sided fasteners, that save time, labor, and costs in inspection and measurement of installed one-sided fasteners, and that provide advantages over known systems and methods.

SUMMARY

(6) Example implementations of the present disclosure provide for an improved system and method for inspecting and measuring installed one-sided fasteners. As discussed in the below detailed

description, versions of the improved system and method may provide significant advantages over known systems and methods.

(7) In a version of the disclosure, there is provided a method for inspecting and measuring one or more installed one-sided fasteners in a structure. The method comprises the step of positioning an X-ray imaging system directed at a first side of the structure at a location of the one or more installed one-sided fasteners installed through one or more openings in the structure. The one or more installed one-sided fasteners each has a fastener body protruding from a second side of the structure.

(8) The method further comprises the step of emitting X-rays at the first side of the structure at the location of the one or more installed one-sided fasteners. The method further comprises the step of detecting backscatter from the one or more installed one-sided fasteners. The method further comprises the step of generating image data from the X-ray imaging system, in real time, in response to detecting the backscatter. The image data comprises one or more images of the fastener body of the one or more installed one-sided fasteners.

(9) The method further comprises the step of measuring and analyzing the image data, with an image processing system, to obtain one or more measurements of one or more dimensions of the one or more installed one-sided fasteners. The method further comprises the step of using the image data to inspect the one or more installed one-sided fasteners, and to detect any inconsistencies in the one or more measurements of the one or more dimensions of the one or more installed one-sided fasteners.

(10) In another version of the disclosure, there is provided a method for inspecting and measuring one or more installed one-sided fasteners in an aircraft structure. The method comprises the step of positioning an X-ray imaging system directed at a first side of the aircraft structure at a location of the one or more installed one-sided fasteners installed through one or more openings in the aircraft structure. The one or more installed one-sided fasteners each has a fastener body protruding from a second side of the aircraft structure.

(11) The method further comprises the step of emitting X-rays at the first side of the aircraft structure at the location of the one or more installed one-sided fasteners. The method further comprises the step of detecting backscatter from the one or more installed one-sided fasteners. The method further comprises the step of generating image data from the X-ray imaging system, in real time, in response to detecting the backscatter. The image data comprises one or more images of the fastener body of the one or more installed one-sided fasteners.

(12) The method further comprises the step of measuring and analyzing the image data, with an image processing system, to obtain one or more measurements of one or more dimensions of the one or more installed one-sided fasteners. The one or more measurements comprise one or more of, a diameter of a fastener bulb of the one or more installed one-sided fasteners, a length of a pin protrusion of the one or more installed one-sided fasteners, and a grip length of the one or more installed one-sided fasteners. The method further comprises the step of using the image data to inspect the one or more installed one-sided fasteners, and to detect any inconsistencies in the one or more measurements of the one or more dimensions of the one or more installed one-sided fasteners.

(13) In another version of the disclosure, there is provided a system for inspecting and measuring one or more installed one-sided fasteners in a structure. The system comprises the structure having a first side and a second side. The system further comprises one or more one-sided fasteners installed through one or more openings in the structure. The one or more installed one-sided fasteners each has a fastener body protruding from the second side of the structure.

(14) The system further comprises an X-ray imaging system configured to emit X-rays at the first side of the structure at the location of the one or more installed one-sided fasteners, and configured to detect backscatter from the one or more installed one-sided fasteners. The system further comprises image data generated from the X-ray imaging system in response to detecting the backscatter. The image data comprises one or more images of the fastener body of the one or more

installed one-sided fasteners.

(15) The system further comprises an image processing system to measure and analyze the image data, to obtain one or more measurements of one or more dimensions of the one or more installed one-sided fasteners, to inspect the one or more installed one-sided fasteners, and to detect any inconsistencies in the one or more measurements of the one or more dimensions of the one or more installed one-sided fasteners.

(16) The features, functions, and advantages that have been discussed can be achieved independently in various versions of the disclosure or may be combined in yet other versions, further details of which can be seen with reference to the following description and drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) The disclosure can be better understood with reference to the following detailed description taken in conjunction with the accompanying drawings, which illustrate preferred and exemplary versions, but which are not necessarily drawn to scale. The drawings are examples and not meant as limitations on the description or claims.

(2) FIG. 1 is an illustration of a block diagram of an exemplary system of the disclosure;

(3) FIG. 2A is an illustration of a partial sectional top view of an exemplary one-sided fastener that may be used in a version of a system and a method of the disclosure;

(4) FIG. 2B is an illustration of a cross-sectional top view of the one-sided fastener of FIG. 2A installed in a structure;

(5) FIG. 2C is an illustration of a perspective side view of exemplary installed one-sided fasteners installed in a structure;

(6) FIG. 2D is an illustration of a perspective back view of exemplary installed one-sided fasteners installed in a structure;

(7) FIG. 3 is a schematic illustration of a perspective back view of an X-ray image scan of installed one-sided fasteners;

(8) FIG. 4 is an illustration of a front perspective view of an exemplary version of a system disclosed herein used in an inspection environment;

(9) FIG. 5 is an illustration of a front perspective view of another exemplary version of a system disclosed herein used in an inspection environment;

(10) FIG. 6A is an illustration of a cross-sectional top view of an exemplary installed one-sided fastener installed in a structure, and an X-ray imaging system measuring a diameter of a fastener bulb;

(11) FIG. 6B is an illustration of a cross-sectional top view of an exemplary installed one-sided fastener installed in a structure, and an X-ray imaging system measuring a length of a pin protrusion and a grip length;

(12) FIG. 7 is an illustration of a block diagram of an exemplary version of a computer system that may be used with a version of a system and a method of the disclosure;

(13) FIG. 8A is an illustration of a flow diagram of an exemplary version of a method of the disclosure;

(14) FIG. 8B is an illustration of a flow diagram of another exemplary version of a method of the disclosure;

(15) FIG. 9 is an illustration of a perspective view of an aircraft that incorporates aircraft structures having installed one-sided fasteners that may be inspected with a system and a method of the disclosure;

(16) FIG. 10 is an illustration of a flow diagram of an exemplary aircraft manufacturing and service method; and

(17) FIG. 11 is an illustration of an exemplary block diagram of an aircraft.

(18) The figures shown in this disclosure represent various aspects of the versions presented, and only differences will be discussed in detail.

DETAILED DESCRIPTION

(19) Disclosed versions will now be described more fully hereinafter with reference to the accompanying drawings, in which some, but not all of the disclosed versions are shown. Indeed, several different versions may be provided and should not be construed as limited to the versions set forth herein. Rather, these versions are provided so that this disclosure will be thorough and fully convey the scope of the disclosure to those skilled in the art.

(20) This specification includes references to “one version” or “a version”. The instances of the phrases “one version” or “a version” do not necessarily refer to the same version. Particular features, structures, or characteristics may be combined in any suitable manner consistent with this disclosure. All features disclosed in the specification, including the claims, abstract, and drawings, and all the steps in any method or process disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive. Each feature disclosed in the specification, including the claims, abstract, and drawings, can be replaced by alternative features serving the same, equivalent, or similar purpose, unless expressly stated otherwise.

(21) As used herein, “comprising” is an open-ended term, and as used in the claims, this term does not foreclose additional structures or steps.

(22) As used herein, “configured to” means various parts or components may be described or claimed as “configured to” perform a task or tasks. In such contexts, “configured to” is used to connote structure by indicating that the parts or components include structure that performs those task or tasks during operation. As such, the parts or components can be said to be configured to perform the task even when the specified part or component is not currently operational (e.g., is not on).

(23) As used herein, the terms “first”, “second”, etc., are used as labels for nouns that they precede, and do not imply any type of ordering (e.g., spatial, temporal, logical, etc.).

(24) As used herein, an element or step recited in the singular and preceded by the word “a” or “an” should be understood as not necessarily excluding the plural of the elements or steps. As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items. As also used herein, the term “combinations thereof” includes combinations having at least one of the associated listed items, wherein the combination can further include additional, like non-listed items.

(25) 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.

(26) Now referring to FIG. 1, FIG. 1 is an illustration of a block diagram of an exemplary system **10**, such as an inspection and measuring system **10a**, for inspecting **12** and measuring **14** one or more installed one-sided fasteners **16a** in a structure **18**. The blocks in FIG. 1 represent elements, and lines connecting the various blocks do not imply any particular dependency of the elements. Furthermore, the connecting lines shown in the various Figures contained herein are intended to represent example functional relationships and/or physical couplings between the various elements, but it is noted that other alternative or additional functional relationships or physical connections may be present in versions disclosed herein. One or more of these blocks may be combined, divided, or combined and divided into different blocks when implemented in an illustrative example. Further, the illustrations of the system **10** in FIG. 1 are 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. As shown in FIG. 1, the system **10** comprises one or more one-sided fasteners **16**, such as one or more installed one-sided fasteners **16a**. As used herein, “one-sided fastener” **16**, also referred to as “blind fastener”, means a mechanical fastener typically joining two or more structural members together, where the mechanical fastener is only readily accessible on a first exterior end of the mechanical fastener on an exterior side of the joined structural members, and a second interior end of the mechanical fastener protruding from an interior side of the joined structural members is not visible, is “blind”, and is not readily accessible from the interior side of the joined structural members.

(27) As shown in FIG. 1, each one-sided fastener **16**, such as each installed one-sided fastener **16a**, has a first end **20**, such as a head end **20a**, a second end **22**, such as a tail end **22a**, and a fastener body **24**, such as a shaft body **24a** (see FIG. 2A), formed between the first end **20** and the second end **22**. As shown in FIG. 1, the one-sided fastener **16** may comprise a bolt **16b**, a rivet **16c**, or another suitable one-sided fastener **16**. An exemplary one-sided fastener **16** is discussed in further detail below with respect to FIG. 2A. An exemplary installed one-sided fastener **16a** is discussed in further detail below with respect to FIG. 2B.

(28) As further shown in FIG. 1, the system **10** is used to obtain one or more measurements **26** of one or more dimensions **28** of the one or more installed one-sided fasteners **16a**. As further shown in FIG. 1, the one or more measurements **26** of the one or more dimensions **28** of the one or more installed one-sided fasteners **16a** comprise one or more of, a dimension **28** of a fastener bulb **30**, such as a diameter **32** of the fastener bulb **30** of the one or more installed one-sided fasteners **16a**, a dimension **28** of a pin protrusion **34**, such as a length **36** of the pin protrusion **34** of the one or more installed one-sided fasteners **16a**, a dimension **28** such as a grip length **38** of the one or more installed one-sided fasteners **16a**, or another suitable measurement of another suitable dimension of the installed one-sided fastener **16a**.

(29) As used herein, “fastener bulb” means when a fastener is installed in a structure, a sleeve of the fastener is compressed, causing it to fold outwards to form a bulb configuration which is formed against an interior side of the structure. As used herein, “pin protrusion” means a length or a height that a fastener protrudes beyond a bearing surface, such as extending beyond an interior side of a structure the fastener is installed through. As used herein “grip length” means a length of an unthreaded portion, or a shank, of a fastener, such as a bolt or rivet.

(30) As shown in FIG. 1, the system **10** further comprises the structure **18**. In one version, the structure **18** comprises two structure portions **18a** (see FIGS. 1, 2B, 4) joined together to form a joined structure **18b** (see FIGS. 2B, 4). In another version, as shown in FIG. 5, the structure **18** comprises one structure portion **18a**. As shown in FIG. 1, the structure **18** has a first side **40**, such as an exterior side **40a**, a second side **42**, such as an interior side **42a**, and a structure body **44** formed between the first side **40** and the second side **42**. As shown in FIGS. 2B, 4, the structure body **44** comprises the two structure portions **18a** forming the joined structure **18b**. The structure **18** has one or more openings **46** (see FIGS. 1, 2B, 4), such as one or more through openings **46a** (see FIGS. 2B, 4), that are drilled, or formed, through the structure **18**. The one or more openings **46** are of a suitable size and dimension to receive the one or more one-sided fasteners **16**. The one or more one-sided fasteners **16** are installed in the one or more openings **46** in the structure **18**. The fastener body **24**, or a portion of the fastener body **24**, and the second end **22** of each one sided-fastener **16**, such as each installed one-sided fastener **16a**, protrude from the second side **42** of the structure **18** when installed in the structure **18**. The one or more installed one-sided fasteners **16a** have one or more locations **48** (see FIG. 1) of installation in the structure **18**.

(31) As shown in FIG. 1, the structure **18** may comprise a workpiece **50** or a coupon **52**. As used herein, “workpiece” means an object, such as a piece of raw material, that is worked on with a tool or machine and that is in the process of being formed into a part or component. As used herein, “coupon”, also referred to as “test coupon”, means an object similar to a part to be manufactured

and subject to the same manufacturing processes as the part and typically used to test qualities for quality assurance, and an example of a coupon may be a laminated composite test coupon.

(32) As shown in FIG. 1, the structure **18** may be a structure **18**, such as a workpiece **50**, of a vehicle **54**, such as an aircraft **56**, for example, an aircraft structure **58** or an aircraft part **60**. As shown in FIG. 1, the structure **18** may also be part of another vehicle **54**, for example, a spacecraft structure **62** of a spacecraft, a rotorcraft structure **64** of a rotorcraft, a watercraft structure (STRUC.) **66** of a watercraft, an automobile structure (STRUC.) **68** of an automobile, a train structure (STRUC.) **70** of a train, or another suitable vehicle structure. As further shown in FIG. 1, the structure **18** may also be an architectural structure **72**.

(33) In these illustrative examples, the system **10** is used to inspect the structure **18**, such as the workpiece **50**, the coupon **52**, the aircraft structure **58**, the aircraft part **60**, or the other suitable structures. The structure **18** may be selected from any number of different types of objects. For example, without limitation, the structure **18** may take the form of a mobile platform, a stationary platform, an air-based structure, a land-based structure, an aquatic-based structure, a space-based structure, or some other suitable type of structure. More specifically, the structure **18** may be the vehicle **54** or the architectural structure **72**. In some cases, the structure **18** may be a part in another object, for example, with the aircraft structure **58** or aircraft part **60** of an aircraft **56**, a section of a fuselage **74** (see FIG. 9) for the aircraft **56**, a wing **76** (see FIG. 9) for the aircraft **56**, or a tail **78** (see FIG. 9) for the aircraft **56**. In other cases, the structure **18** may be a part in another object, for example, with the architectural structure **72**, a building wall, a door, or a panel, a structural support on a bridge, or some other suitable type of part.

(34) As shown in FIG. 1, the system **10** further comprises an X-ray imaging system **80** configured to emit X-rays **82** directed at the first side **40** of the structure **18** at the one or more locations **48** of the one or more installed one-sided fasteners **16a**. The X-ray imaging system **80** is further configured to detect backscatter **84** from the one or more installed one-sided fasteners **16a**. Preferably, the X-ray imaging system **80** comprises a backscatter X-ray imaging system **80a** (see FIG. 1). However, the X-ray imaging system **80** may comprise another suitable X-ray imaging system. The system **10** with the X-ray imaging system **80** comprising the backscatter X-ray imaging system **80a** is an example of a nondestructive inspection (NDI) system **86** (see FIG. 1) that uses X-rays **82** to inspect an object, in this case, the installed one-sided fasteners **16a**, to perform nondestructive inspection (NDI) **88** (see FIG. 1), without causing any undesired effects to the structure **18** or the one or more installed one-sided fasteners **16a**. The backscatter X-ray imaging system **80a** detects radiation or backscatter **84** that reflects from a target, such as the fastener body **24** of the one or more installed one-sided fasteners **16a**.

(35) As shown in FIG. 1, in one illustrative example, the backscatter X-ray imaging system **80a** may include an X-ray tube **90**, a collimator **92**, and a detector **94**. The X-ray tube **90** generates and emits the X-rays **82** (see FIG. 1). The collimator **92** filters the X-rays **82** to form an X-ray beam **96** (see FIG. 1) using a portion of the X-rays **82** that travel substantially parallel to a specified direction. When the X-rays **82**, such as the X-ray beam **96**, encounters the one or more installed one-sided fasteners **16a**, some or all of the X-rays **82** in the X-ray beam **96** are scattered by the one or more installed one-sided fasteners **16a**. In particular, the X-rays **82** may be scattered off of a surface of the one or more installed one-sided fasteners **16a** and/or a subsurface of the one or more installed one-sided fasteners **16a**. The scattered X-rays are referred to as the backscatter **84** (see FIG. 1). The detector **94** detects some or all of the backscatter **84**. The backscatter **84** that is detected may be used to generate image data **98** (see FIG. 1) for the one or more installed one-sided fasteners **16a** that can be used to form one or more images **100** of the one or more installed one-sided fasteners **16a**. For example, the backscatter **84** that is detected when the X-rays **82** in the X-ray beam **96** are directed at the one or more locations **48** of the one or more installed one-sided fasteners **16a** and are directed at one or more portions of the one or more installed one-sided fasteners **16a** may be used to generate an intensity value **102** (see FIG. 1) for a pixel **104** (see FIG.

1) in the image **100** that corresponds to the one or more locations **48** and the one or more portions of the one or more installed one-sided fasteners **16a**. The intensity values **102** for the pixels **104** in the image **100** may determine the level of contrast in the image **100** and the level of detail in the image **100**. Further, the amount of backscatter **84** detected by the detector **94** determines the intensity value **102** for the pixel **104** of the image **100**.

(36) In one version, the detector **94** may have a shape that may be changed to substantially conform to a shape of a surface of the structure **18** being inspected, for example, a curved surface or a flat surface, of the structure **18**, such as the first side **40** of the structure **18**. For example, in one version, the detector **94** may comprise a plurality of sensor arrays with a plurality of sensors configured to detect the backscatter **84** formed in response to the X-ray beam **96** encountering the one or more installed one-sided fasteners **16a**.

(37) The X-ray imaging system **80** may be supported on various structures and positioned with respect to the structure **18** with the one or more installed one-sided fasteners **16a** in various ways. As shown in FIG. 1, in one version, the X-ray imaging system **80** is attached, or coupled, to a robotic system **106**, and in particular, is attached, or coupled, at an end **108** of a robot arm **110** of the robotic system **106**. The X-ray imaging system **80** may be considered to be an end effector **112** (see FIG. 1).

(38) As shown in FIG. 1, in another version, the X-ray imaging system **80** is attached, or coupled, to a mobile system **114**. The mobile system **114** comprises a movable base **116** (see FIG. 1) configured to move along a track assembly **118** (see FIG. 1), or another suitable structure. In particular, the X-ray imaging system **80** is attached, or coupled, to the movable base **116** of the mobile system **114**.

(39) As shown in FIG. 1, the system **10** further comprises the image data **98** generated from the X-ray imaging system **80** in response to detecting the backscatter **84**. The image data **98** comprises the one or more images **100** (see FIG. 1) of the one or more installed one-sided fasteners **16a**, and in particular, one or more images **100** of the fastener body **24** of the one or more installed one-sided fasteners **16a**.

(40) As shown in FIG. 1, the system **10** further comprises an image processing system **120** to measure and analyze the image data **98**, to obtain the one or more measurements **26** of the one or more dimensions **28** of the one or more installed one-sided fasteners **16a**, to inspect the one or more installed one-sided fasteners **16a**, and to detect any inconsistencies **122** in the one or more measurements **26** of the one or more dimensions **28** of the one or more installed one-sided fasteners **16a**. As shown in FIG. 1, the image processing system **120** comprises one of, an image processing software **124**, an artificial intelligence (AI) neural network **126**, or another suitable image processing system.

(41) As shown in FIG. 1, the image processing system **120** includes a computer system **128** having one or more computers **130** depending on the implementation. Depending on the implementation, the computer system **128** may be configured to control at least one of, the X-ray imaging system **80**, the image processing system **120**, the image processing software **124**, the AI neural network **126**, the robotic system **106**, the mobile system **114**, or other components of the system **10**. For example, computer system **128** may send commands to the X-ray imaging system **80** to control the emission and positioning of the X-rays **82**. The computer system **128**, or a human operator, may use the one or more images **100** to identify any inconsistencies **122** in the measurements **26** of the dimensions **28** of the installed one-sided fasteners **16a**.

(42) As shown in FIG. 1, the system **10** further comprises at least one power supply **132** to provide or supply power to one or more components of the system **10**, such as the X-ray imaging system **80**, the image processing system **120**, the image processing software **124**, the AI neural network **126**, the computer system **128**, the computers **130**, the robotic system **106**, the mobile system **114**, or other components of the system **10**. The at least one power supply **132** may comprise an electrical power supply, a battery power supply, a solar power supply, or another suitable power

supply or power source to provide power to the system **10**.

(43) Thus, an illustrative version of the system **10** provides an X-ray imaging system **80** that directs and emits X-rays **82** at one or more installed one-sided fasteners **16a** installed in one or more openings **46** in the structure **18**, and detects and receives backscatter **84** from the installed one-sided fasteners **16a**. Image data **98** from the X-ray imaging system **80** is generated, in real time, in response to detecting, or receiving, the backscatter **84**, where the image data may comprise one or more images **100** of the one or more installed one-sided fasteners **16a**, for example, the fastener body **24** of each of the one or more installed one-sided fasteners **16a**. The image data **98** is measured and analyzed with the image processing system **120**, to obtain the one or more measurements **26** of the one or more dimensions **28**, of the one or more installed one-sided fasteners **16a**.

(44) The system **10** uses the image data **98** generated from the X-ray imaging system **80** to inspect the one or more installed one-sided fasteners **16a**, to detect any inconsistencies **122** in the one or more measurements **26** of the one or more dimensions **28** of the one or more installed one-sided fasteners **16a**. This results in providing a confined space entry work reduction **134** (see FIG. 1), that is, a reduction in having an operator, a worker, a mechanic, an inspector, a robot, or another user or automated apparatus, perform confined space entry work in a confined space in, for example, an aircraft structure **58**, such as a fuel tank of a wing **76** of an aircraft **56**, by allowing for nondestructive inspection **88** of the one or more installed one-sided fasteners **16a**.

(45) An output **136** (see FIG. 1) of the one or more inconsistencies **122** (see FIG. 1), for example, one or more out-of-specification parameters **122a** (see FIG. 1), in the measurements **26** of the dimensions **28** of the one or more installed one-sided fasteners **16a** is generated if one of the following dimensions **28** is found to be inconsistent with a predetermined measurement (PREDETER. MEAS.) **26a** (see FIG. 1) of a predetermined dimension (PREDETER. DIMEN.) **28a** (see FIG. 1). The one or more measurements **26** of the one or more dimensions **28** being measured and analyzed include the diameter **32** of the fastener bulb **30** of the one or more installed one-sided fasteners **16a**, the length **36** of the pin protrusion **34** of the one or more installed one-sided fasteners **16a**, and the grip length **38** of the one or more installed one-sided fasteners **16a**.

(46) Now referring to FIGS. 2A-2B, FIG. 2A is an illustration of a partial sectional top view of an exemplary one-sided fastener **16** that may be used in a version of the system **10** (see FIG. 1) and the method **250** (see FIG. 8A), and the method **280** (see FIG. 8B), of the disclosure, and FIG. 2B is an illustration of a cross-sectional top view of the one-sided fastener **16** of FIG. 2A, installed in a structure **18**, to form an installed one-sided fastener **16a**.

(47) As shown in FIG. 2A, the one-sided fastener **16** comprises a bolt **16b** having the first end **20**, or head end **20a** with a head portion **21**, the second end **22**, or tail end **22a**, and the fastener body **24**, such as the shaft body **24a**. FIG. 2A further shows a core fastener portion **138** having a shank **140** that is smooth and having a threaded portion **142** with threads **144**. FIG. 2A further shows a sleeve **145** surrounding a first portion **142a** of the threaded portion **142**, and a nut **146** surrounding a second portion **142b** of the threaded portion **142**. FIG. 2A further shows an insert **148** and a thread locking feature **150**. FIG. 2A further shows the grip length **38** of the one-sided fastener **16**, such as the bolt **16b**.

(48) As shown in FIG. 2B, the installed one-sided fastener **16a**, such as the bolt **16b**, is installed in the structure **18** comprising two structure portions **18a** that form a joined structure **18b** with a joint **152**, so that the one-sided fastener **16** of FIG. 2A is now in the form of the installed one-sided fastener **16a**. The installed one-sided fastener **16a** is installed in the opening **46**, such as the through opening **46a**, formed through the structure **18**, such as through the two structure portions **18a**. As shown in FIG. 2B, the installed one-sided fastener **16a**, such as the bolt **16b**, has the first end **20** comprising a break-off end **20b**, where the head portion **21** (see FIG. 2A) of the head end **20a** has been broken off at the first side **40**, such as the exterior side **40a**, of the structure **18**, with the installation process. FIG. 2B further shows the installed one-sided fastener **16a** with the second end

22, or tail end 22a, and the fastener body 24, such as the shaft body 24a. FIG. 2B further shows the core fastener portion 138 having the shank 140 and the threaded portion 142 with threads 144.

(49) FIG. 2B further shows the sleeve 145 now compressed against the second side 42, or interior side 42a, of the structure 18, and surrounding a portion 24b of the fastener body 24, surrounding a portion 140a of the shank 140, and surrounding a first portion 142a of the threaded portion 142. As shown in FIG. 2B, with installation of the one-sided fastener 16 through the structure 18, the sleeve 145 has a first end 154a that compresses and forms the fastener bulb 30 adjacent the second side 42 of the structure 18, and sleeve 145 has a second end 154b adjacent the nut 146. As shown in FIG. 2B, the fastener bulb 30 has a diameter 32, and the sleeve 145 with the fastener bulb 30 has a bell-shaped profile 156. FIG. 2B further shows the nut 146 surrounding the second portion 142b of the threaded portion 142. FIG. 2B further shows a length 158 of the installed one-sided fastener 16a, the grip length 38 of the installed one-sided fastener 16a, and the length 36 of the pin protrusion 34 of the installed one-sided fastener 16a.

(50) Now referring to FIG. 2C, FIG. 2C is an illustration of a perspective side view of three exemplary installed one-sided fasteners 16a installed in, and through, a structure 18 with two structure portions 18a. FIG. 2C shows the first side 40, or exterior side 40a, and the second side 42, or interior side 42a, of the structure 18 comprising a workpiece 50. FIG. 2C shows the installed one-sided fasteners 16a with the fastener body 24 and the second end 22, or tail end 22a, of the installed one-sided fasteners 16a protruding from the second side 42 of the structure 18. FIG. 2C shows two of the installed one-sided fasteners 16a each with the fastener bulb 30 formed by the sleeve 145 compressed against the second side 42 of the structure 18 and each with the threaded portion 142 at the second end 22. As shown in FIG. 2C, each of the fastener bulbs 30 formed has a diameter 32. FIG. 2C further shows one installed one-sided fastener 16a shown in the middle, where the sleeve 145 did not properly compress to form the fastener bulb 30 and the fastener bulb 30 did not form and the threaded portion 142 did not extend past the sleeve 145. As shown in FIG. 2C, the installed one-sided fastener 16a in the middle with no fastener bulb 30 has a diameter 160 that is less than the diameters 32 of the fastener bulbs 30 that are properly formed. The system 10 (see FIG. 1), the method 250 (see FIG. 8A), and the method 280 (see FIG. 8B) are designed to measure the diameter 32 of the fastener bulb 30 of the installed one-sided fasteners 16a, to obtain any inconsistencies 122, of the measurements 26 of the dimension 28 of the installed one-sided fastener 16a, such as shown in FIG. 2C, where the fastener bulb 30 does not form or does not form properly. The system 10 (see FIG. 1), the method 250 (see FIG. 8A), and the method 280 (see FIG. 8B) are designed to detect when the fastener bulb 30 is not properly formed, such as, for example, not formed at all, under formed, or another type of improper formation, by measuring an inconsistency 122, such as an out-of-specification parameter 122a (see FIG. 1), for example, an inconsistent or out-of-specification diameter, or an absence of a diameter.

(51) Now referring to FIG. 2D, FIG. 2D is an illustration of a perspective back view of four exemplary installed one-sided fasteners 16a installed in a structure 18, such as a coupon 52. FIG. 2D shows four installed one-sided fasteners 16a installed in the structure 18. FIG. 2D shows the second side 42, or interior side 42a, of the structure 18 comprising the coupon 52. FIG. 2D shows the installed one-sided fasteners 16a with the fastener body 24 and the second end 22, or tail end 22a, of the installed one-sided fasteners 16a protruding from the second side 42 of the structure 18. FIG. 2D shows each of the four installed one-sided fasteners 16a with the fastener bulb 30 properly formed by the sleeve 145 compressed against the second side 42 of the structure 18 and each with the threaded portion 142 at the second end 22. FIG. 2D further shows the diameter 32 of one of the fastener bulbs 30.

(52) Now referring to FIG. 3, FIG. 3 is a schematic illustration of a perspective back view of an X-ray image scan 162 of the image 100 of installed one-sided fasteners 16a. The X-ray image scan 162 of the image 100 may be formed based on the backscatter 84 (see FIG. 1) received or detected by the X-ray imaging system 80 (see FIG. 1). As shown in FIG. 3, the X-ray image scan 162 of the

image **100** shows the second side **42**, or interior side **42a**, of the structure **18**, and shows locations **48** of the installed one-sided fasteners **16a** installed in the structure **18** through openings **46**. FIG. **3** shows the fastener body **24** and the second end **22**, or tail end **22a**, of the installed one-sided fasteners **16a** protruding from the second side **42** of the structure **18**. FIG. **3** further shows each of the installed one-sided fasteners **16a** with the fastener bulb **30**. FIG. **3** further shows ring portions **164** indicating shadows that may be visible in the X-ray image scan **162** of the image **100** but that do not affect the measurements **26** of the dimensions **28** of the installed one-sided fasteners **16a**, including the diameter **32** of the fastener bulb **30**, the length **36** of the pin protrusion **34**, and the grip length **38**.

(53) Now referring to FIG. **4**, FIG. **4** is an illustration of a front perspective view of an exemplary version of a system **10**, such as an inspection and measuring system **10a**, for example, a system **10b**, used in an inspection environment **166** in accordance with an illustrative example. As shown in FIG. **4**, the system **10** of the inspection environment **166** comprises installed one-sided fasteners **16a** installed in a structure **18**, such as a workpiece **50**, for example, an aircraft structure **58**. As shown in FIG. **4**, the structure **18** comprises the first side **40**, or exterior side **40a**, the second side **42**, or interior side **42a**, and the structure body **44** comprising structure portions **18a** joined together to form the joined structure **18b**. The structure **18** has openings **46** (see FIG. **4**) through which the installed one-sided fasteners **16a** are inserted and fitted in. Although FIG. **4** shows five installed one-sided fasteners **16a**, more than five installed one-sided fasteners **16a** may be installed in the structure **18**.

(54) As further shown in FIG. **4**, the system **10** in the inspection environment **166** comprises a version of the X-ray imaging system **80**, such as a backscatter X-ray imaging system **80a**, positioned on a movable base **116** of a mobile system **114**, where the movable base **116** is coupled to, and moves along, the track assembly **118**. The track assembly **118** may comprise a linear rail system that can be expanded to image different lengths of the structure **18** with the installed one-sided fasteners **16a**. The mobile system **114** may be designed to work in different orientations with respect to the positioning to the structure **18** and the installed one-sided fasteners **16a**.

(55) As shown in FIG. **4**, the X-ray imaging system **80** is directed at the first side **40** of the structure **18** at the location **48** of the installed one-sided fastener **16a** installed through the opening **46** in the structure **18**. As further shown in FIG. **4**, the X-ray imaging system **80** comprises the detector **94**, such as a scintillator detector **94a**, that emits X-rays **82**, such as an X-ray beam **96**, at the first side **40** of the structure **18** and toward the location **48** of the installed one-sided fastener **16a**. The X-rays **82** generated by the X-ray imaging system **80** may travel between the detector **94** and the structure **18**. Backscatter **84** may result from the X-rays **82** reaching the installed one-sided fastener **16a**, and the backscatter **84** is detected from the installed one-sided fastener **16a** installed in the structure **18** and received by the detector **94** of the X-ray imaging system **80**. The X-ray imaging system **80** generates image data **98** (see FIG. **1**), in real time, in response to detecting, or receiving, the backscatter **84**, and the image data **98** generated from the backscatter **84** may be measured and analyzed with the image processing system **120** (see FIG. **1**) to obtain one or more measurements **26** (see FIG. **1**) of one or more dimensions **28** (see FIG. **1**) of the one or more installed one-sided fasteners **16a**. The image data **98** may be used to detect any inconsistencies **122** (see FIG. **1**) in the one or more measurements **26** of the one or more dimensions **28** of the one or more installed one-sided fasteners **16a**.

(56) Now referring to FIG. **5**, FIG. **5** is an illustration of a front perspective view of another exemplary version of a system **10**, such as inspection and measuring system **10a**, for example, a system **10c**, used in an inspection environment **166a** and in a manufacturing environment **167** in accordance with an illustrative example. As shown in FIG. **5**, the system **10** of the inspection environment **166a** comprises installed one-sided fasteners **16a** installed in a structure **18**, such as an aircraft part **60**, for example, a fuselage part. As shown in FIG. **5**, the structure **18** comprises the first side **40**, or exterior side **40a**, the second side **42**, or interior side **42a**, and the structure body **44**

comprising a structure portion **18a**. The structure **18** has openings **46** (see FIG. 5) through which the installed one-sided fasteners **16a** are inserted and fitted in. As further shown in FIG. 5, the structure **18** is supported by a support structure **169**.

(57) As further shown in FIG. 5, the system **10** in the inspection environment **166a** comprises a version of the X-ray imaging system **80** coupled to, and positioned at, the end **108** of a robot arm **110** of a robotic system **106**, that is inspecting multiple exemplary installed one-sided fasteners **16a** installed in the structure **18**. As shown in FIG. 5, the robotic system **106** further comprises an elbow joint **168** connected to the robot arm **110**, a shoulder **170** connected to the elbow joint **168**, a base **172** connected to the shoulder **170**, and a power supply **132** connected to the shoulder **170**, for powering the robotic system **106**. As shown in FIG. 5, the X-ray imaging system **80** acts as an end effector **112** of the robotic system **106**. The robotic system **106** provides customized motion of the X-ray imaging system **80** with respect to the structure **18** and the installed one-sided fasteners **16a**.

(58) As shown in FIG. 5, the X-ray imaging system **80** is directed at the first side **40** of the structure **18** at the location **48** of the installed one-sided fastener **16a** installed through the openings **46** in the structure **18**. As further shown in FIG. 5, the X-ray imaging system **80** comprises the detector **94** that emits X-rays **82**, such as an X-ray beam **96**, at the first side **40** of the structure **18** and toward the location **48** of the installed one-sided fastener **16a**. The X-rays **82** generated by the X-ray imaging system **80** may travel between the detector **94** and the structure **18**. Backscatter **84** (see FIG. 5) results from the X-rays **82** reaching the installed one-sided fastener **16a**, and the backscatter **84** is detected from the installed one-sided fastener **16a** installed in the structure **18** and received by the detector **94** of the X-ray imaging system **80**. The X-ray imaging system **80** generates image data **98** (see FIG. 1), in real time, in response to detecting, or receiving, the backscatter **84**, and the image data **98** generated from the backscatter **84** may be measured and analyzed with the image processing system **120** (see FIG. 1) to obtain one or more measurements **26** (see FIG. 1) of one or more dimensions **28** (see FIG. 1) of the one or more installed one-sided fasteners **16a**. The image data **98** may be used to detect any inconsistencies **122** (see FIG. 1) in the one or more measurements **26** of the one or more dimensions **28** of the one or more installed one-sided fasteners **16a**.

(59) Now referring to FIG. 6A, FIG. 6A is an illustration of a cross-sectional top view of an exemplary installed one-sided fastener **16a**, such as a bolt **16b**, installed in a structure **18**, such as a workpiece **50**, for example, an aircraft structure **58**, and an X-ray device **174** of the X-ray imaging system **80** positioned in a parallel position **176** parallel to, and directly opposite, the installed one-sided fastener **16a** and the first side **40** of the structure **18**, to measure the diameter **32** of the fastener bulb **30** of the installed one-sided fastener **16a**. The parallel position **176** may also be referred to as a top-down position of the X-ray device **174**. As shown in FIG. 6A, in one version, the X-ray device **174** comprises an X-ray backscatter scanning head **175** to detect backscatter **84** (see FIG. 1) of the installed one-sided fastener **16a**. In other versions, the X-ray device **174** may comprise a detector **94** (see FIG. 1), or another suitable device. As shown in FIG. 6A, the X-ray device **174** of the X-ray imaging system **80** is in the form of a portable handheld device **178**. Alternatively, the X-ray device **174** and the X-ray imaging system **80** may be coupled to, and positioned at, the end **108** of a robot arm **110** of a robotic system **106**, as shown in FIG. 5, or may be positioned on a movable base **116** of a mobile system **114**, where the movable base **116** is coupled to, and moves along, the track assembly **118**, as shown in FIG. 4.

(60) As shown in FIG. 6A, the installed one-sided fastener **16a**, such as the bolt **16b**, is installed in the structure **18**, such as the workpiece **50**, for example, the aircraft structure **58**, comprising two structure portions **18a** that form the joined structure **18b** with a joint **152**. The installed one-sided fastener **16a** is installed in the opening **46**, such as the through opening **46a**, formed through the structure **18**, such as through the two structure portions **18a**. As shown in FIG. 6A, the installed one-sided fastener **16a**, such as the bolt **16b**, has the first end **20** comprising the break-off end **20b**, at the first side **40**, such as the exterior side **40a**, of the structure **18**. FIG. 6A further shows the

installed one-sided fastener **16a** with the second end **22**, or tail end **22a**, and the fastener body **24**, such as the shaft body **24a**. FIG. 6A further shows the core fastener portion **138** having the shank **140** and the threaded portion **142** with threads **144**.

(61) FIG. 6A further shows the sleeve **145** compressed against the second side **42**, or interior side **42a**, of the structure **18**, and surrounding the portion **24b** of the fastener body **24**, surrounding the portion **140a** of the shank **140**, and surrounding the first portion **142a** of the threaded portion **142**. FIG. 6A shows the fastener bulb **30** adjacent the second side **42** of the structure **18**, and shows the diameter **32** of the fastener bulb **30** to be measured with the X-ray imaging system **80**.

(62) Now referring to FIG. 6B, FIG. 6B is an illustration of a cross-sectional top view of an exemplary installed one-sided fastener **16a**, such as a bolt **16b**, installed in the structure **18**, such as the workpiece **50**, for example, the aircraft structure **58**, and the X-ray device **174** of the X-ray imaging system **80** positioned at an angled position **180** and an offset configuration **182** and directed at an offset angle **184** to the installed one-sided fastener **16a** and the first side **40** of the structure **18**, to measure the length **36** of the pin protrusion **34** of the installed one-sided fastener **16a**, and to measure the grip length **38** of the installed one-sided fastener **16a**. The offset angle **184** may vary, and in one version, may be a top-down position of the X-ray device **174**. As shown in FIG. 6B, in one version, the X-ray device **174** comprises the X-ray backscatter scanning head **175** to detect backscatter **84** of the installed one-sided fastener **16a**. In other versions, the X-ray device **174** may comprise the detector **94** (see FIG. 1), or another suitable device. As shown in FIG. 6B, the X-ray device **174** of the X-ray imaging system **80** is in the form of a portable handheld device **178a**. Alternatively, the X-ray device **174** and the X-ray imaging system **80** may be coupled to, and positioned at, the end **108** of a robot arm **110** of a robotic system **106**, as shown in FIG. 5, or may be positioned on the movable base **116** of the mobile system **114**, where the movable base **116** is coupled to, and moves along, the track assembly **118**, as shown in FIG. 4.

(63) As shown in FIG. 6B, the installed one-sided fastener **16a**, such as the bolt **16b**, is installed in the structure **18**, such as the workpiece **50**, for example, the aircraft structure **58**, comprising two structure portions **18a** that form the joined structure **18b** with the joint **152**. The installed one-sided fastener **16a** is installed in the opening **46**, such as the through opening **46a**, formed through the structure **18**, such as through the two structure portions **18a**. As shown in FIG. 6B, the installed one-sided fastener **16a**, such as the bolt **16b**, has the first end **20** comprising the break-off end **20b**, at the first side **40**, such as the exterior side **40a**, of the structure **18**. FIG. 6B further shows the installed one-sided fastener **16a** with the second end **22**, or tail end **22a**, and the fastener body **24**, such as the shaft body **24a**. FIG. 6B further shows the core fastener portion **138** having the shank **140** and the threaded portion **142** with threads **144**.

(64) FIG. 6B further shows the sleeve **145** compressed against the second side **42**, or interior side **42a**, of the structure **18**, and surrounding the portion **24b** of the fastener body **24**, surrounding the portion **140a** of the shank **140**, and surrounding the first portion **142a** of the threaded portion **142**. FIG. 6B shows the fastener bulb **30** adjacent the second side **42** of the structure **18**. FIG. 6B further shows the length **158** of the installed one-sided fastener **16a**, the grip length **38** of the installed one-sided fastener **16a**, and the length **36** of the pin protrusion **34** of the installed one-sided fastener **16a**.

(65) Now referring to FIG. 7, FIG. 7 is an illustration of a block diagram of an exemplary version of the computer system **128** that may be used with the system **10** (see FIG. 1), and the method **250** (see FIG. 8A), and the method **280** (see FIG. 8B), of the disclosure. As shown in FIG. 7, the computer system **128** comprises one or more computers **130** with one or more processor devices **186**, and an operating system **188**. The computer system **128** (see FIG. 7) may be used to implement the one or more computers **130** (see FIG. 7).

(66) The one or more computers **130** (see FIG. 7) or one or more processor devices **186** (see FIG. 7) may be configured to control one or more functions of one or more elements of the system **10** (see FIG. 1) through computer program instructions, such as a computer program product **190** (see

FIG. 7) stored on a computer memory **192** (see FIG. 7), accessible to the one or more computers **130** (see FIG. 7), or one or more processor devices **186** (see FIG. 7).

(67) As shown in FIG. 7, the computer system **128** may further comprise one or more computer communications devices **194**, such as networking communications devices **194a**, for linking the system **10** (see FIG. 1), for example, to one or more separate systems. The networking communications devices **194a** (see FIG. 7) may comprise network links between various computers and devices connected together within a network data processing system via wire connections, wireless communication links, fiber optic cables, or other suitable network connections, and that may connect to a network, a server, the Internet, or another system or device.

(68) The one or more computer communications devices **194** (see FIG. 7) may be configured to provide for communications in accordance with any of a number of wired or wireless communication standards. The one or more computers **130** (see FIG. 7) or one or more processor devices **186** (see FIG. 7) may also be configured to facilitate communications via the one or more computer communications devices **194** (see FIG. 7) by, for example, controlling hardware included within the one or more computer communications devices **194** (see FIG. 7). The one or more computer communications devices **194** (see FIG. 7) may include, for example, one or more antennas, a transmitter, a receiver, a transceiver and/or supporting hardware, including, for example, a processor for enabling communications.

(69) As shown in FIG. 7, the computer system **128** further comprises storage devices **196**, such as computer memory **192** and persistent storage **198**. The computer memory **192** (see FIG. 7) may comprise one or more of a random access memory (RAM), including dynamic and/or static RAM, on-chip or off-chip cache memory, or other suitable computer memory. The persistent storage **198** (see FIG. 7) may comprise one or more of a flash memory, a hard drive, Read-Only Memory (ROM), magnetic storage devices such as hard disks, floppy disk drives, and rewritable magnetic tape, rewritable optical disk drives and/or media, non-volatile random access memory (NVRAM), or other suitable persistent storage.

(70) As shown in FIG. 7, the computer system **128** further comprises one or more input/output units **200**, a display **202**, a data bus **204**, and a power supply **132**. The one or more input/output units **200** (see FIG. 7) provide for the input and output of data with other devices connected to the computer system **128** (see FIG. 7), such as, the computer interfaces. The one or more input/output units **200** (see FIG. 7) may comprise such devices as a keyboard, a mouse, a joystick, or other input/output devices. For example, the one or more input/output units **200** (see FIG. 7) may provide a connection for user input through a keyboard and mouse, or may send output to a printer or other device.

(71) The display **202** (see FIG. 7) provides the means to display the image data **98** (see FIG. 1), or other data or information to a user, an analyst, one or more separate automated systems, automated computer programs, automated apparatuses, or automated devices, or another suitable separate system, program, or device. As shown in FIG. 7, the data bus **204** provides communications between the one or more computers **130**, the computer memory **192**, the persistent storage **198**, the computer communications devices **194**, the one or more input/output units **200**, and the display **202**. The power supply **132** (see FIG. 7) of the computer system **128** (see FIG. 7) may comprise batteries, electricity, solar chargers, or other power supply elements.

(72) As shown in FIG. 7, the computer program product **190** is preferably used in the computer system **128**. The computer program product **190** (see FIG. 7) comprises a system logic **206** (see FIG. 7). As shown in FIG. 7, the system logic **206** may comprise a computer software program **208**, such as the image processing software **124**, or an artificial intelligence (AI) based image processing software **210**. The system logic **206** may further comprise an algorithm, program code, computer firmware, or another suitable system logic. As shown in FIG. 7, the computer program product **190** may comprise a computer readable medium **212**. The computer readable medium **212** (see FIG. 7) may comprise computer readable storage media **214** (see FIG. 7), computer readable

signal media **216** (see FIG. 7), or another suitable computer readable medium.

(73) The system logic **206** (see FIG. 7) may be stored in and retrieved from the computer readable storage media **214** (see FIG. 7) and loaded into the one or more computers **130** (see FIG. 7), the one or more processor devices **186**, or other programmable device, to configure and direct the one or more computers **130**, the one or more processor devices **186**, or other programmable device to execute operations to be performed on or by the one or more computers **130**, the one or more processor devices **186**, or other programmable device, and to function in a particular way.

Execution of the system logic **206** (see FIG. 7) may produce a computer-implemented system, process or method, such that the system logic **206** executed by the one or more computers **130** (see FIG. 7), one or more processor devices **186** (see FIG. 7), or other programmable device provide operations for implementing the functions disclosed herein.

(74) Now referring to FIG. 8A, FIG. 8A is an illustration of a flow diagram of an exemplary version of a method **250** of the disclosure. In another version of the disclosure, there is provided the method **250** for inspecting **12** (see FIG. 1) and measuring **14** (see FIG. 1) one or more installed one-sided fasteners **16a** (see FIGS. 1, 2A-2B) in a structure **18** (see FIG. 1).

(75) The blocks in FIG. 8A represent operations and/or portions thereof, or elements, and lines connecting the various blocks do not imply any particular order or dependency of the operations or portions thereof, or elements. FIG. 8A and the disclosure of the steps of the method **250** set forth herein should not be interpreted as necessarily determining a sequence in which the steps are to be performed. Rather, although one illustrative order is indicated, it is to be understood that the sequence of the steps may be modified when appropriate. Accordingly, certain operations may be performed in a different order or simultaneously.

(76) As shown in FIG. 8A, the method **250** comprises the step **252** of positioning an X-ray imaging system **80** (see FIGS. 1, 4, 5) directed at a first side **40** (see FIGS. 1, 4, 5) of the structure **18** (see FIGS. 1, 4, 5) at a location **48** (see FIGS. 1, 4, 5) of the one or more installed one-sided fasteners **16a** (see FIGS. 1, 4, 5) installed through one or more openings **46** (see FIGS. 1, 4, 5) in the structure **18**. The one or more installed one-sided fasteners **16a** each has a fastener body **24** (see FIGS. 2A-2B) protruding from a second side **42** (see FIG. 2B) of the structure **18** (see FIG. 2B).

(77) The step **252** of positioning the X-ray imaging system **80** further comprises, positioning the X-ray imaging system **80** facing the first side **40** of the structure **18** comprising one of, as shown in FIG. 1, a workpiece **50**, a coupon **52**, an aircraft structure **58**, an aircraft part **60**, a spacecraft structure **62**, a rotorcraft structure **64**, a watercraft structure **66**, an automobile structure **68**, a train structure **70**, an architectural structure **72**, or another suitable structure.

(78) The step **252** of positioning the X-ray imaging system **80** may further comprise, positioning the X-ray imaging system **80** comprising a backscatter X-ray imaging system **80a** (see FIGS. 1, 4).

(79) The step **252** of positioning the X-ray imaging system **80** may further comprise, in one version, as shown in FIG. 5, positioning the X-ray imaging system **80** at an end **108** of a robot arm **110** of a robotic system **106**, so that the X-ray imaging system **80** acts as an end effector **112**. The step **252** of positioning the X-ray imaging system **80** may further comprise, in another version, as shown in FIG. 4, positioning the X-ray imaging system **80** on a movable base **116** of a mobile system **114**, where the movable base **116** is coupled to, and moves along, a track assembly **118**.

(80) The step **252** of positioning the X-ray imaging system **80** may further comprise, in one version, as shown in FIG. 6A, positioning an X-ray device **174** of the X-ray imaging system **80** in a parallel position **176** parallel to, and directly opposite, the one or more installed one-sided fasteners **16a**, to measure a diameter **32** of a fastener bulb **30** of the one or more installed one-sided fasteners **16a**. In another version, the X-ray device **174** of the X-ray imaging system **80** may be positioned in the parallel position **176** parallel to, and directly opposite, the one or more installed one-sided fasteners **16a**, to measure a length **36** of a pin protrusion **34** of the one or more installed one-sided fasteners **16a**, and/or a grip length **38** of the one or more installed one-sided fasteners **16a**. The step **252** of positioning the X-ray imaging system **80** may further comprise, in another version, as

shown in FIG. 6B, positioning the X-ray device **174** of the X-ray imaging system **80** at an angled position **180** directed at the one or more installed one-sided fasteners **16a**, to measure the length **36** of the pin protrusion **34** of the one or more installed one-sided fasteners **16a**, and/or the grip length **38** of the one or more installed one-sided fasteners **16a**. In another version, the X-ray device **174** of the X-ray imaging system **80** is positioned in the angled position **180** directed at the one or more installed one-sided fasteners **16a** to measure the diameter **32** of the fastener bulb **30** of the one or more installed one-sided fasteners **16a**.

(81) As shown in FIG. 8A, the method **250** further comprises the step **254** of emitting X-rays **82** (see FIGS. **1**, **4**) at the first side **40** of the structure **18** at the location **48** of the one or more installed one-sided fasteners **16a**. As shown in FIG. 8A, the method **250** further comprises the step **256** of detecting backscatter **84** (see FIGS. **1**, **4**) from the one or more installed one-sided fasteners **16a**.

(82) As shown in FIG. 8A, the method **250** further comprises the step **258** of generating image data **98** (see FIG. **1**) from the X-ray imaging system **80**, in real time, in response to detecting the backscatter **84**. The image data **98** comprises one or more images **100** (see FIG. **1**) of the fastener body **24** (see FIGS. **1**, **6A-6B**) of the one or more installed one-sided fasteners **16a**.

(83) As shown in FIG. 8A, the method **250** further comprises the step **260** of measuring **14** (see FIG. **1**) and analyzing **15** (see FIG. **1**) the image data **98**, with an image processing system **120** (see FIG. **1**), to obtain one or more measurements **26** (see FIG. **1**) of one or more dimensions **28** (see FIG. **1**) of the one or more installed one-sided fasteners **16a**. The step **260** of measuring **14** and analyzing **15** the image data **98** with the image processing system **120** may further comprise, measuring **14** and analyzing **15** the image data **98** with the image processing system **120** comprising one of, an image processing software **124** (see FIG. **1**), an artificial intelligence neural network **126** (see FIG. **1**), or another suitable image processing system. The step **260** of measuring **14** and analyzing **15** the image data **98** may further comprise, measuring **14** and analyzing **15** the image data **98** to obtain the one or more measurements **26** of one or more dimensions **28** comprising one or more of, the diameter **32** (see FIG. **1**) of the fastener bulb **30** (see FIG. **1**) of the one or more installed one-sided fasteners **16a**, the length **36** (see FIG. **1**) of the pin protrusion **34** (see FIG. **1**) of the one or more installed one-sided fasteners **16a**, and the grip length **38** (see FIG. **1**) of the one or more installed one-sided fasteners **16a**.

(84) As shown in FIG. 8A, the method **250** further comprises the step **262** of using the image data **98** to inspect the one or more installed one-sided fasteners **16a**, and to detect any inconsistencies **122** (see FIG. **1**), such as out-of-specification parameters **122a** (see FIG. **1**), in the one or more measurements **26** of the one or more dimensions **28** of the one or more installed one-sided fasteners **16a**. The step **262** of using the image data **98** to inspect the one or more installed one-sided fasteners **16a** may further comprise, using the image data **98** to provide a confined space entry work reduction **134** (see FIG. **1**), by allowing for nondestructive inspection **88** (see FIG. **1**) of the one or more installed one-sided fasteners **16a**. Thus, performance of confined space entry work by an operator, a worker, a mechanic, an inspector, a robot, or another user or automated apparatus, to measure and inspect the one or more installed one-sided fasteners **16a** is reduced or minimized with the method **250**.

(85) Now referring to FIG. 8B, FIG. 8B is an illustration of a flow diagram of an exemplary version of a method **280** of the disclosure. In another version of the disclosure, there is provided the method **280** for inspecting **12** (see FIG. **1**) and measuring **14** (see FIG. **1**) one or more installed one-sided fasteners **16a** in an aircraft structure **58** (see FIGS. **1**, **9**) for an aircraft **56** (see FIGS. **1**, **9**).

(86) The blocks in FIG. 8B represent operations and/or portions thereof, or elements, and lines connecting the various blocks do not imply any particular order or dependency of the operations or portions thereof, or elements. FIG. 8B and the disclosure of the steps of the method **280** set forth herein should not be interpreted as necessarily determining a sequence in which the steps are to be performed. Rather, although one illustrative order is indicated, it is to be understood that the

sequence of the steps may be modified when appropriate. Accordingly, certain operations may be performed in a different order or simultaneously.

(87) As shown in FIG. 8B, the method **280** comprises the step **282** of positioning the X-ray imaging system **80** (see FIGS. 1, 5) directed at the first side **40** (see FIGS. 1, 5) of the aircraft structure **58** (see FIGS. 1, 5) at a location **48** (see FIGS. 1, 5) of the one or more installed one-sided fasteners **16a** (see FIGS. 1, 5) installed through one or more openings **46** (see FIGS. 1, 5) in the aircraft structure **58**. The one or more installed one-sided fasteners **16a** each has the fastener body **24** (see FIGS. 1, 2A) protruding from the second side **42** (see FIGS. 1, 5) of the aircraft structure **58**.

(88) The step **282** of positioning the X-ray imaging system **80** may further comprise, in one version, as shown in FIG. 6A, positioning the X-ray device **174** of the X-ray imaging system **80** in a parallel position **176** parallel to, and directly opposite, the one or more installed one-sided fasteners **16a**, to measure the diameter **32** of the fastener bulb **30** of the one or more installed one-sided fasteners **16a**. Alternatively, the diameter **32** of the fastener bulb **30** of the one or more installed one-sided fasteners **16a** may be measured by positioning the X-ray device **174** of the X-ray imaging system **80** at an angled position **180** directed at the one or more installed one-sided fasteners **16a**. The step **282** of positioning the X-ray imaging system **80** may further comprise, in another version, as shown in FIG. 6B, positioning the X-ray device **174** of the X-ray imaging system **80** at the angled position **180** directed at the one or more installed one-sided fasteners **16a**, to measure one or more of, the length **36** of the pin protrusion **34** of the one or more installed one-sided fasteners **16a**, and the grip length **38** of the one or more installed one-sided fasteners **16a**.

Alternatively, the length **36** of the pin protrusion **34** of the one or more installed one-sided fasteners **16a**, and/or the grip length **38** of the one or more installed one-sided fasteners **16a**, may be measured by positioning the X-ray device **174** of the X-ray imaging system **80** in the parallel position **176** parallel to, and directly opposite, the one or more installed one-sided fasteners **16a**.

(89) The step **282** of positioning the X-ray imaging system **80** may further comprise, positioning the X-ray imaging system **80** comprising the backscatter X-ray imaging system **80a** (see FIG. 1). The step **282** of positioning the X-ray imaging system **80** may further comprise, in one version, as shown in FIG. 5, positioning the X-ray imaging system **80** at the end **108** of the robot arm **110** of the robotic system **106**. The step **252** of positioning the X-ray imaging system **80** may further comprise, in another version, as shown in FIG. 4, positioning the X-ray imaging system **80** on the movable base **116** of the mobile system **114**, where the movable base **116** is coupled to, and moves along, the track assembly **118**.

(90) As shown in FIG. 8B, the method **280** further comprises the step **284** of emitting X-rays **82** at the first side **40** of the aircraft structure **58** at the location **48** of the one or more installed one-sided fasteners **16a**. As shown in FIG. 8B, the method **280** further comprises the step **286** of detecting backscatter **84** (see FIGS. 1, 4) from the one or more installed one-sided fasteners **16a**.

(91) As shown in FIG. 8B, the method **280** further comprises the step **288** of generating image data **98** (see FIG. 1) from the X-ray imaging system **80**, in real time, in response to detecting the backscatter **84**. The image data **98** comprises one or more images **100** (see FIG. 1) of the fastener body **24** of the one or more installed one-sided fasteners **16a**.

(92) As shown in FIG. 8B, the method **280** further comprises the step **290** of measuring **14** (see FIG. 1) and analyzing **15** (see FIG. 1) the image data **98**, with an image processing system **120** (see FIG. 1), to obtain one or more measurements **26** (see FIG. 1) of one or more dimensions **28** (see FIG. 1) of the one or more installed one-sided fasteners **16a**. The one or more measurements **26** comprise one or more of, the diameter **32** (see FIG. 1) of the fastener bulb **30** (see FIG. 1) of the one or more installed one-sided fasteners **16a**, the length **36** of the pin protrusion **34** (see FIG. 1) of the one or more installed one-sided fasteners **16a**, and the grip length **38** (see FIG. 1) of the one or more installed one-sided fasteners **16a**.

(93) As shown in FIG. 8B, the method **280** further comprises the step **292** of using the image data **98** to inspect the one or more installed one-sided fasteners **16a**, and to detect any inconsistencies

122 (see FIG. 1), such as any out-of-specification parameters **122a** (see FIG. 1), in the one or more measurements **26** of the one or more dimensions **28** of the one or more installed one-sided fasteners **16a**. The step **292** of using the image data **98** to inspect the one or more installed one-sided fasteners **16a** may further comprise, using the image data **98** to provide the confined space entry work reduction **134** (see FIG. 1), by allowing for the nondestructive inspection **88** (see FIG. 1) of the one or more installed one-sided fasteners **16a**. Thus, performance of confined space entry work by an operator, a worker, a mechanic, an inspector, a robot, or another user or automated apparatus, to measure and inspect the one or more installed one-sided fasteners **16a** is reduced or minimized with the method **280**.

(94) Now referring to FIG. 9, FIG. 9 is an illustration of a perspective view of a vehicle **54**, such as an aircraft **56**, that may incorporate one or more aircraft structures **58**, and aircraft parts **60** (see FIG. 1), having one-sided fasteners **16** (see FIGS. 1, 2A) that may be inspected with the system **10** (see FIG. 1) and the method **250** (see FIG. 8A) or the method **280** (see FIG. 8B) of the disclosure. As shown in FIG. 9, the aircraft **56** comprises the fuselage **74**, wings **76**, tail **78**, and engines **218**. The one or more aircraft structures **58** may comprise composite structures, such as carbon fiber reinforced plastic (CFRP) structures or another type of composite structure, may comprise metal structures, such as aluminum, steel, or another type of metal structure, or may comprise a combination of composite and metal structures.

(95) Although the aircraft **56** shown in FIG. 9 is generally representative of a commercial passenger aircraft having one or more aircraft structures **58**, the teachings of the disclosed versions may be applied to other passenger aircraft. For example, the teachings of the disclosed versions may be applied to cargo aircraft, military aircraft, rotorcraft, and other types of aircraft or aerial vehicles, as well as aerospace vehicles, spacecraft, satellites, space launch vehicles, rockets, and other aerospace vehicles. Further, the teachings of the disclosed versions may be applied to watercraft, automobiles, trains, or architectural structures **72** (see FIG. 1).

(96) Now referring to FIGS. 10 and 11, FIG. 10 is an illustration of a flow diagram of an exemplary aircraft manufacturing and service method **300**, and FIG. 11 is an illustration of an exemplary block diagram of an aircraft **316**. Referring to FIGS. 10 and 11, versions of the disclosure may be described in the context of the aircraft manufacturing and service method **300** as shown in FIG. 10, and the aircraft **316** as shown in FIG. 11.

(97) During pre-production, exemplary aircraft manufacturing and service method **300** may include specification and design **302** of the aircraft **316** and material procurement **304**. During manufacturing, component and subassembly manufacturing **306** and system integration **308** of the aircraft **316** takes place. Thereafter, the aircraft **316** may go through certification and delivery **310** in order to be placed in service **312**. While in service **312** by a customer, the aircraft **316** may be scheduled for routine maintenance and service **314** (which may also include modification, reconfiguration, refurbishment, and other suitable services).

(98) Each of the processes of the aircraft manufacturing and service method **300** may be performed or carried out by a system integrator, a third party, and/or an operator (e.g., 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. An operator may include an airline, leasing company, military entity, service organization, and other suitable operators.

(99) As shown in FIG. 11, the aircraft **316** produced by the exemplary aircraft manufacturing and service method **300** may include an airframe **318** with a plurality of systems **320** and an interior **322**. Examples of the plurality of systems **320** may include one or more of a propulsion system **324**, an electrical system **326**, a hydraulic system **328**, and an environmental system **330**. Any number of other systems may be included. Although an aerospace example is shown, the principles of the disclosure may be applied to other industries, such automotive.

(100) Methods and systems embodied herein may be employed during any one or more of the

stages of the aircraft manufacturing and service method **300**. For example, components or subassemblies corresponding to component and subassembly manufacturing **306** may be fabricated or manufactured in a manner similar to components or subassemblies produced while the aircraft **316** is in service **312**. Also, one or more apparatus embodiments, method embodiments, or a combination thereof, may be utilized during component and subassembly manufacturing **306** and system integration **308**, for example, by substantially expediting assembly of or reducing the cost of the aircraft **316**. Similarly, one or more of apparatus embodiments, method embodiments, or a combination thereof, may be utilized while the aircraft **316** is in service **312**, for example and without limitation, to maintenance and service **314**.

(101) Disclosed versions of the system **10** (see FIG. 1), the method **250** (see FIG. 8A), and the method **280** (see FIG. 8B) provide an improved system and method for inspecting **12** (see FIG. 1) and measuring **14** (see FIG. 1) installed one-sided fasteners **16a** (see FIGS. 1, 2B) from the first side **40** (see FIGS. 1, 2B), such as the exterior side **40a** (see FIGS. 1, 2B), of a structure **18** (see FIGS. 1, 2B), that do not require the use of a borescope, a camera probe, or a vision system to insert into an adjacent fastener hole to inspect or measure the installed one-sided fasteners **16a**, that reduce or eliminate confined space entry work to inspect and measure installed one-sided fasteners **16a**, thus resulting in a confined space entry work reduction **134** (see FIG. 1), and that save time, labor, and costs in inspection and measurement of installed one-sided fasteners **16a** installed in a structure **18**, as compared to known systems and methods.

(102) In addition, disclosed versions of the system **10** (see FIG. 1), the method **250** (see FIG. 8A), and the method **280** (see FIG. 8B) provide a nondestructive inspection **88** (see FIG. 1) to measure the diameter **32** (see FIG. 1) of the fastener bulb **30** (see FIG. 1) of the installed one-sided fasteners **16a**, to measure the length **36** (see FIG. 1) of the pin protrusion **34** (see FIG. 1) of the installed one-sided fasteners **16a**, and to measure the grip length **38** (see FIG. 1) of the installed one-sided fasteners **16a**. The system **10**, method **250**, and method **280** disclosed herein solve the inspection of installed one-sided fasteners **16a** through one-sided examination of the installation area of the installed one-sided fasteners **16a**. The system **10**, method **250**, and method **280** disclosed herein also provide a full verification method that reduces or eliminates the need for an operator, a worker, a mechanic, an inspector, a robot, or another user or automated apparatus, to maneuver within a confined space and measure the installed one-sided fasteners **16a**, such as the diameter **32** of the fastener bulb **30**, the length **36** of the pin protrusion **34**, and the grip length **38**. Further, the system **10** (see FIG. 1), the method **250** (see FIG. 8A), and the method **280** (see FIG. 8B) provide for using an X-ray imaging system **80** (see FIG. 1) to measure the backscatter **84** (see FIG. 1), such as radiation, that is reflected from the target, such as the installed one-sided fasteners **16a**. The X-rays **82** (see FIG. 1) are backscattered off the installed one-sided fasteners **16a** to capture one or more images **100** (see FIG. 1) of the fastener bulb **30** on the interior side **42a** (see FIG. 1) of the structure **18**.

(103) As shown in FIG. 5, the X-ray imaging system **80**, in one version, is coupled to the end **108** of a robot arm **110** of a robotic system **106**, and is positioned at the first side **40**, such as the exterior side **40a**, of the structure **18**. As shown in FIG. 4, the X-ray imaging system **80**, in another version, is coupled to a movable base **116** of a mobile system **114**, and the movable base **116** is coupled to a track assembly **118**. As shown in FIG. 6A, in another version, the X-ray imaging system **80** is a portable handheld device **178**. The X-ray imaging system **80** emits X-rays **82** (see FIG. 1) directed to the first side **40**, such as the exterior side **40a**, of the structure **18**, which are backscattered off the installed one-sided fasteners **16a**, to capture one or more images **100** of the fastener bulb **30** installed on the interior side **42a** of the structure **18**. The X-ray imaging system **80** measures the diameter **32** (see FIG. 1) of the fastener bulb **30** of the installed one-sided fasteners **16a**, and conducts analysis through the artificial intelligence (AI) neural network **126** (see FIG. 1) or through the image processing software **124** (see FIG. 1), to determine if the diameter **32** of the fastener bulb **30** meets installation requirements and is in specification.

(104) Moreover, disclosed versions of the system **10** (see FIG. 1), the method **250** (see FIG. 8A), and the method **280** (see FIG. 8B) provide potential applications where less destructive examination is required, and can operate even if only one side of the target, such as the installed one-sided fasteners **16a**, is available for examination. The image processing system **120** (see FIG. 1) uses image processing software **124** and/or the artificial intelligence (AI) neural network **126** to process the one or more images **100** (see FIG. 1) and to measure the diameter **32** (see FIG. 1) of the fastener bulb **30** (see FIG. 1) of the installed one-sided fasteners **16a**, to measure the length **36** (see FIG. 1) of the pin protrusion **34** (see FIG. 1) of the installed one-sided fasteners **16a**, and to measure the grip length **38** (see FIG. 1) of the installed one-sided fasteners **16a**. The post image processing has artificial intelligence capabilities to identify an installed one-sided fastener **16a**, to measure the diameter **32** of the fastener bulb **30**, and the length **36** of the pin protrusion **34**, and to provide an accept or reject for a technician verification. Further, disclosed versions of the system **10** (see FIG. 1), the method **250** (see FIG. 8A), and the method **280** (see FIG. 8B) may be used to measure parts, such as aircraft parts **60** (see FIG. 1), and may be used to measure locations of parts in relation to each other, and all capable through post image processing.

(105) Many modifications and other versions of the disclosure will come to mind to one skilled in the art to which this disclosure pertains having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. The versions described herein are meant to be illustrative and are not intended to be limiting or exhaustive. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation. Functionally equivalent methods and apparatuses within the scope of the disclosure, in addition to those enumerated herein, are possible from the foregoing descriptions. Such modifications and variations are intended to fall within the scope of the appended claims. The present disclosure is to be limited only by the terms of the appended claims, along with the full scope of equivalents to which such claims are entitled.

Claims

1. A method for inspecting and measuring one or more installed one-sided fasteners in a structure, the method comprising the steps of: positioning an X-ray imaging system directed at a first side of the structure at a location of the one or more installed one-sided fasteners installed through one or more openings in the structure, the one or more installed one-sided fasteners each having a fastener body protruding from a second side of the structure; emitting X-rays at the first side of the structure at the location of the one or more installed one-sided fasteners; detecting backscatter from the one or more installed one-sided fasteners; generating image data from the X-ray imaging system, in real time, in response to detecting the backscatter, the image data comprising one or more images of the fastener body of the one or more installed one-sided fasteners; measuring and analyzing the image data, with an image processing system, to obtain one or more measurements of one or more dimensions of the one or more installed one-sided fasteners, the one or more measurements comprising one or more of: a diameter of a fastener bulb of the one or more installed one-sided fasteners, wherein the fastener bulb is formed against an interior side of the structure when the fastener is installed in the structure; a length of a pin protrusion of the one or more installed one-sided fasteners; and a grip length of the one or more installed one-sided fasteners; and using the image data to inspect the one or more installed one-sided fasteners, and to detect any out-of-specification parameters of the one or more measurements of the one or more dimensions of the one or more installed one-sided fasteners.

2. The method of claim 1, wherein the step of positioning the X-ray imaging system further comprises, positioning the X-ray imaging system facing the first side of the structure comprising one of, a workpiece, a coupon, an aircraft structure, an aircraft part, a spacecraft structure, a rotorcraft structure, a watercraft structure, an automobile structure, a train structure, or an

architectural structure.

3. The method of claim 1, wherein the step of positioning the X-ray imaging system further comprises, positioning the X-ray imaging system comprising a backscatter X-ray imaging system.

4. The method of claim 1, wherein the step of positioning the X-ray imaging system further comprises, positioning the X-ray imaging system at an end of a robot arm of a robotic system.

5. The method of claim 1, wherein the step of positioning the X-ray imaging system further comprises, positioning the X-ray imaging system on a movable base of a mobile system.

6. The method of claim 1, wherein the step of positioning the X-ray imaging system further comprises, positioning an X-ray device of the X-ray imaging system in a parallel position parallel to, and directly opposite, the one or more installed one-sided fasteners.

7. The method of claim 1, wherein the step of positioning the X-ray imaging system further comprises, positioning an X-ray device of the X-ray imaging system at an angled position directed at the one or more installed one-sided fasteners.

8. The method of claim 1, wherein the step of measuring and analyzing the image data with the image processing system further comprises, measuring and analyzing the image data with the image processing system comprising one of, an image processing software, or an artificial intelligence neural network.

9. The method of claim 1, wherein the step of measuring and analyzing the image data further comprises, measuring and analyzing the image data to obtain the diameter of the fastener bulb to detect any out-of-specification diameter, and to detect when the fastener bulb is not properly formed.

10. The method of claim 1, wherein the step of using the image data to inspect the one or more installed one-sided fasteners further comprises, using the image data to provide a confined space entry work reduction, by allowing for a nondestructive inspection of the one or more installed one-sided fasteners.

11. A method for inspecting and measuring one or more installed one-sided fasteners in an aircraft structure, the method comprising the steps of: positioning an X-ray imaging system directed at a first side of the aircraft structure at a location of the one or more installed one-sided fasteners installed through one or more openings in the aircraft structure, the one or more installed one-sided fasteners each having a fastener body protruding from a second side of the aircraft structure; emitting X-rays at the first side of the aircraft structure at the location of the one or more installed one-sided fasteners; detecting backscatter from the one or more installed one-sided fasteners; generating image data from the X-ray imaging system, in real time, in response to detecting the backscatter, the image data comprising one or more images of the fastener body of the one or more installed one-sided fasteners; measuring and analyzing the image data, with an image processing system, to obtain one or more measurements of one or more dimensions of the one or more installed one-sided fasteners, wherein the one or more measurements comprise one or more of: a diameter of a fastener bulb of the one or more installed one-sided fasteners, wherein the fastener bulb is formed against an interior side of the aircraft structure when the fastener is installed in the aircraft structure; a length of a pin protrusion of the one or more installed one-sided fasteners; and a grip length of the one or more installed one-sided fasteners; and using the image data to inspect the one or more installed one-sided fasteners, and to detect any out-of-specification parameters of the one or more measurements of the one or more dimensions of the one or more installed one-sided fasteners.

12. The method of claim 11, wherein the step of positioning the X-ray imaging system further comprises, positioning an X-ray device of the X-ray imaging system in a parallel position parallel to, and directly opposite, the one or more installed one-sided fasteners, to measure the diameter of the fastener bulb of the one or more installed one-sided fasteners.

13. The method of claim 11, wherein the step of positioning the X-ray imaging system further comprises, positioning an X-ray device of the X-ray imaging system at an angled position directed

at the one or more installed one-sided fasteners, to measure one or more of, the length of the pin protrusion of the one or more installed one-sided fasteners, and the grip length of the one or more installed one-sided fasteners.

14. The method of claim 11, wherein the step of using the image data to inspect the one or more installed one-sided fasteners further comprises, using the image data to provide a confined space entry work reduction, by allowing for a nondestructive inspection of the one or more installed one-sided fasteners.

15. A system for inspecting and measuring one or more installed one-sided fasteners in a structure, the system comprising: the structure having a first side and a second side; the one or more installed one-sided fasteners installed through one or more openings in the structure, the one or more installed one-sided fasteners each having a fastener body protruding from the second side of the structure; an X-ray imaging system configured to emit X-rays at the first side of the structure at a location of the one or more installed one-sided fasteners, and configured to detect backscatter from the one or more installed one-sided fasteners; image data generated from the X-ray imaging system in response to detecting the backscatter, the image data comprising one or more images of the fastener body of the one or more installed one-sided fasteners; and an image processing system to measure and analyze the image data, to obtain one or more measurements of one or more dimensions of the one or more installed one-sided fasteners, to inspect the one or more installed one-sided fasteners, and to detect any out-of-specification parameters of the one or more measurements of the one or more dimensions of the one or more installed one-sided fasteners, the one or more measurements comprising one or more of: a diameter of a fastener bulb of the one or more installed one-sided fasteners, wherein the fastener bulb is formed against an interior side of the structure when the fastener is installed in the structure; a length of a pin protrusion of the one or more installed one-sided fasteners; and a grip length of the one or more installed one-sided fasteners.

16. The system of claim 15, wherein the structure comprises one of, a workpiece, a coupon, an aircraft structure, an aircraft part, a spacecraft structure, a rotorcraft structure, a watercraft structure, an automobile structure, a train structure, or an architectural structure.

17. The system of claim 15, wherein the X-ray imaging system is attached at an end of a robot arm of a robotic system.

18. The system of claim 15, wherein the X-ray imaging system is attached to a movable base of a mobile system.

19. The system of claim 15, wherein the image processing system comprises one of, an image processing software, or an artificial intelligence neural network.

20. The system of claim 15, wherein one of the out-of-specification parameters comprises an out-of-specification diameter of the fastener bulb, when the fastener bulb is not properly formed.
