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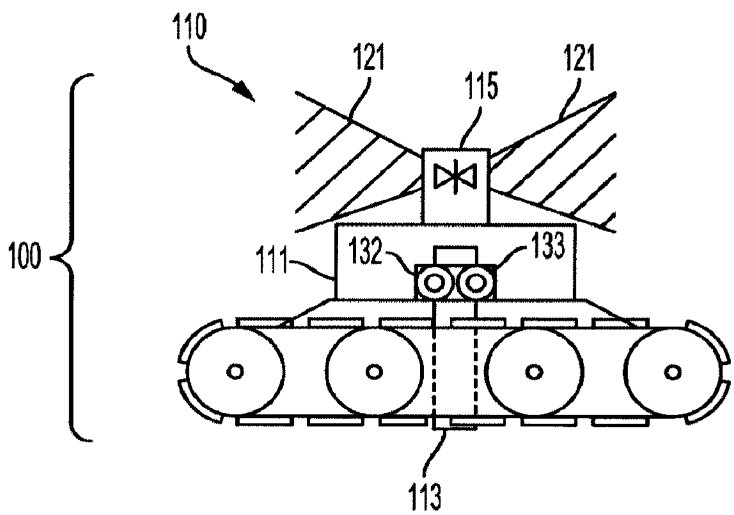

(57) Abrégé/Abstract:
A robotic printing system for an exterior surface of an aircraft includes a robotic printer, the robotic printer having a body and a plurality of vacuum suction cups mounted to the body for attaching the robotic printer to the exterior surface of the aircraft, where the plurality of vacuum suction cups are configured to move the robotic printer along the exterior surface of the aircraft. The robotic printer also includes a printing head mounted to the body, where the printing head is positioned to apply a print medium to the exterior surface of the aircraft. The robotic printer also includes a laser-based positioning device mounted to the body for determining a position of the robotic printer on the exterior surface of the aircraft.

ABSTRACT

A robotic printing system for an exterior surface of an aircraft includes a robotic printer, the robotic printer having a body and a plurality of vacuum suction cups mounted to the body for attaching the robotic printer to the exterior surface of the aircraft, where the plurality of vacuum suction cups are configured to move the robotic printer along the exterior surface of the aircraft. The robotic printer also includes a printing head mounted to the body, where the printing head is positioned to apply a print medium to the exterior surface of the aircraft. The robotic printer also includes a laser-based positioning device mounted to the body for determining a position of the robotic printer on the exterior surface of the aircraft.

ROBOTIC PRINTING SYSTEM FOR AN AIRCRAFT EXTERIOR

FIELD

The present disclosure generally relates to robotic printing systems and methods of operation to print an image on an exterior surface of an aircraft.

BACKGROUND

Application of a decorative livery design to the exterior surface of an aircraft can be a time-consuming process. Current solutions include creation of large-scale design templates (made of, for example, plastic substrates such as MYLAR®, made by DuPont Teijin Films) that are temporarily placed on the aircraft exterior. These large-scale design templates are then used as the basis for masking sections of the aircraft for the application of each color in a livery design, which are applied after the templates are removed. The creation of the design templates can be an iterative process, and the templates eventually must be replaced due to damage or due to changes in the livery design. Further, different templates are required for different models of aircraft and for different airline livery designs, each requiring the storage and maintenance for their intended reuse.

There is a need for improved systems and methods for applying decorative images on the exterior surface of an aircraft.

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SUMMARY

In one embodiment, there is provided a robotic printing system for an exterior surface of an aircraft comprising a robotic printer. The robotic printer comprises: a body; a pair of parallel treads coupled to the body, wherein the pair of parallel treads include multiple connected links arranged around drive wheels; a plurality of vacuum suction cups mounted to the body for attaching the robotic printer to the exterior surface of the aircraft, wherein the plurality of vacuum suction cups are configured to move the robotic printer along the exterior surface of the aircraft, wherein the plurality of vacuum suction cups are arranged on the multiple connected links of the pair of parallel treads that are configured to drive the robotic printer along the exterior surface of the aircraft, wherein the pair of parallel treads rotate around the drive wheels to move the robotic printer along the exterior surface of the aircraft; a printing head mounted to the body, wherein the printing head is positioned to apply a print medium to the exterior surface of the aircraft; and a laser-based positioning device mounted to the body for determining a position of the robotic printer on the exterior surface of the aircraft.

The printing head may be mounted to the robotic printer between the pair of parallel treads.

The printing head may be mounted to the robotic printer outside the pair of parallel treads.

The robotic printer further may include a positioning motor coupled to the printing head. The positioning motor may be configured to adjust a position of the printing head relative to the plurality of vacuum suction cups.

The robotic printing system may further include an umbilical line attached to the body of the robotic printer. The umbilical line may convey one or more of electrical power and vacuum pressure to the robotic printer.

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The laser-based positioning device may include a line of sight. The exterior surface of the aircraft may include a plurality of surface features. The robotic printer may be configured to determine relative position data with respect to the laser-based positioning device for each surface feature within its line of sight. The robotic printer may be configured to determine the position of the robotic printer on the exterior surface of the aircraft based on the relative position data for each surface feature in the plurality of surface features.

The laser-based positioning device may include a line of sight. The robotic printing system may further include a plurality of external positioning devices configured to be positioned at pre-determined locations surrounding the aircraft. The robotic printer may be configured to determine relative position data with respect to the laser-based positioning device for each external positioning device within its line of sight. The robotic printer may be configured to determine the position of the robotic printer on the exterior surface of the aircraft based on the relative position data for each external positioning device in the plurality of external positioning devices.

The robotic printing system may further include a computing device. The computing device includes one or more processors and a non-transitory, computer readable medium having stored thereon instructions, that when executed by the one or more processors, may cause the robotic printing system to perform functions involving: determining, via the laser-based positioning device, relative position data with respect to the laser-based positioning device for each of a plurality of reference points corresponding to the exterior surface of the aircraft; based on the relative position data, determining a position of the robotic printer on the exterior surface of the aircraft; based on the relative position data, mapping the position of the robotic printer to a three-dimensional model of the exterior surface, wherein the three-dimensional model may include a representation of an image on the exterior surface; based on the mapping of the robotic printer to the three-dimensional model, applying, via the printing head, a print medium to a location on the exterior surface of the aircraft corresponding to the representation of the image in the three-dimensional model; and

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moving the robotic printer along the exterior surface of the aircraft via the plurality of vacuum suction cups.

The computing device may be communicatively coupled to the robotic printer via an umbilical line attached to the body of the robotic printer.

There is also described a robotic printing system for an exterior surface of an aircraft comprising a robotic printer. The robotic printer comprises: a body; a pair of parallel treads coupled to the body, wherein the pair of parallel treads include multiple connected links arranged around drive wheels; a plurality of vacuum suction cups mounted to the body for attaching the robotic printer to the exterior surface of the aircraft, wherein the plurality of vacuum suction cups are configured to move the robotic printer along the exterior surface of the aircraft, wherein the plurality of vacuum suction cups are arranged on the multiple connected links of the pair of parallel treads that are configured to drive the robotic printer along the exterior surface of the aircraft, wherein the pair of parallel treads rotate around the drive wheels to move the robotic printer along the exterior surface of the aircraft; a printing head mounted to the body, wherein the printing head is positioned to apply a print medium to the exterior surface of the aircraft; a laser-based positioning device mounted to the body for determining a position of the robotic printer on the exterior surface of the aircraft, wherein the laser-based positioning device comprises a line of sight; and a plurality of external positioning devices configured to be positioned at pre-determined locations surrounding the aircraft, wherein the robotic printer is configured to determine relative position data with respect to the laser-based positioning device for each external positioning device within its line of sight, and wherein the robotic printer is configured to determine the position of the robotic printer on the exterior surface of the aircraft based on the relative position data for each external positioning device in the plurality of external positioning devices.

In another embodiment, there is provided a method of printing an image on an exterior surface of an aircraft. The method comprises providing a robotic printer comprising: a body; a pair of parallel treads coupled to the body, wherein the pair of

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parallel treads include multiple connected links arranged around drive wheels; and a plurality of vacuum suction cups mounted to the body, wherein the plurality of vacuum suction cups are arranged on the multiple connected links of the pair of parallel treads, wherein the pair of parallel treads rotate around the drive wheels to move the robotic printer along the exterior surface of the aircraft. The method further comprises: attaching the robotic printer to the exterior surface of the aircraft via the plurality of vacuum suction cups mounted to the body of the robotic printer, the robotic printer further comprising a laser-based positioning device and a printing head mounted to the body; determining, via the laser-based positioning device, relative position data with respect to the laser-based positioning device for each of a plurality of reference points corresponding to the exterior surface of the aircraft; based on the relative position data, determining a position of the robotic printer on the exterior surface of the aircraft; based on the relative position data, mapping the position of the robotic printer to a three-dimensional model of the exterior surface, wherein the three-dimensional model includes a representation of the image on the exterior surface; based on the mapping of the robotic printer to the three-dimensional model, applying, via the printing head, a print medium to a location on the exterior surface of the aircraft corresponding to the representation of the image in the three-dimensional model; and moving the robotic printer along the exterior surface of the aircraft via the plurality of vacuum suction cups.

The printing head may be mounted to the robotic printer between the pair of parallel treads, and applying a print medium to the exterior surface of the aircraft via the printing head may involve applying a print medium between the pair of parallel treads.

The printing head may be mounted to the robotic printer outside the pair of parallel treads, and applying a print medium to the exterior surface of the aircraft via the printing head may involve applying a print medium outside the pair of parallel treads.

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The plurality of vacuum suction cups may be arranged at respective ends of a plurality of legs.

The robotic printer may further include a positioning motor coupled to the printing head. The method may further involve, based on the position of the robotic printer on the exterior surface of the aircraft and the mapping of the robotic printer to the three-dimensional model, adjusting, via the positioning motor, a position of the printing head relative to the plurality of vacuum suction cups.

The laser-based positioning device may include a line of sight. The exterior surface of the aircraft may include a plurality of surface features. Determining, via the laser-based positioning device, relative position data with respect to the laser-based positioning device for each of a plurality of reference points corresponding to the exterior surface of the aircraft may involve determining relative position data with respect to the laser-based positioning device for each surface feature within its line of sight.

The laser-based positioning device may include a line of sight. A plurality of external positioning devices may be positioned at pre-determined locations surrounding the aircraft. Determining, via the laser-based positioning device, relative position data with respect to the laser-based positioning device for each of a plurality of reference points corresponding to the exterior surface of the aircraft may involve determining relative position data with respect to the laser-based positioning device for each external positioning device within its line of sight.

In another embodiment, there is provided a non-transitory computer readable medium having stored thereon instructions, that when executed by a computing device, cause the computing device to perform functions for printing an image on an exterior surface of an aircraft via a robotic printer comprising: a body; a pair of parallel treads coupled to the body, wherein the pair of parallel treads include multiple connected links arranged around drive wheels; and a plurality of vacuum suction cups

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mounted to the body, wherein the plurality of vacuum suction cups are arranged on the multiple connected links of the pair of parallel treads, wherein the pair of parallel treads rotate around the drive wheels to move the robotic printer along the exterior surface of the aircraft. The robotic printer is attachable to the exterior surface via the plurality of vacuum suction cups mounted to the body of the robotic printer. The functions comprise: determining, via a laser-based positioning device mounted to the body of the robotic printer, relative position data with respect to the laser-based positioning device for each of a plurality of reference points corresponding to the exterior surface of the aircraft; based on the relative position data, determining a position of the robotic printer on the exterior surface of the aircraft; based on the relative position data, mapping the position of the robotic printer to a three-dimensional model of the exterior surface, wherein the three-dimensional model includes a representation of the image on the exterior surface; based on the mapping of the robotic printer to the three-dimensional model, causing a printing head mounted to the body of the robotic printer to apply a print medium to a location on the exterior surface of the aircraft corresponding to the representation of the image in the three-dimensional model; and causing the robotic printer to move along the exterior surface of the aircraft via the plurality of vacuum suction cups.

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

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BRIEF DESCRIPTION OF THE FIGURES

Aspects of embodiments of robotic printing systems and methods of operation in order to print an image on an exterior surface of an aircraft are set out in the following description. The illustrative examples, as well as a preferred mode of use, further objectives and descriptions thereof, will best be understood by reference to the following detailed description of an illustrative example of the present disclosure when read in conjunction with the accompanying Figures.

Figure **1** illustrates a side view of an exterior surface of an aircraft, according to an example implementation.

Figure **2** illustrates a side view of a robotic printing system for an exterior surface of an aircraft, according to an example implementation.

Figure **3** illustrates a top view of a robotic printing system for an exterior surface of an aircraft, according to an example implementation.

Figure **4** illustrates a side view of a robotic printing system for an exterior surface of an aircraft, according to an example implementation.

Figure **5** illustrates an example travel path for a robotic printing system for an exterior surface of an aircraft, according to an example implementation.

Figure **6** illustrates a longitudinal view of a robotic printing system for an exterior surface of an aircraft, according to an example implementation.

Figure **7** illustrates a side view of a plurality of external positioning devices for a robotic printing system for an exterior surface of an aircraft, according to an example implementation.

Figure **8** a longitudinal view of an external positioning device for a robotic printing system for an exterior surface of an aircraft, according to an example implementation.

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Figure **9** illustrates a block diagram of an example computing device, according to an example implementation.

Figure **10** shows a flowchart of an example method of printing an image on an exterior surface of an aircraft, according to an example implementation.

DETAILED DESCRIPTION

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

Examples discussed herein include robotic printing systems and methods of operation to print an image on an exterior surface of an aircraft. The robotic printing system may include a robotic printer having a plurality of vacuum suction cups for attaching the robotic printer to, and moving it along, the exterior surface of the aircraft. The robotic printer may further include a printing head for applying a print medium to the exterior surface, and a laser-based positioning device for determining the position of the robotic printer on the aircraft and mapping that position to a three-dimensional model of the aircraft that includes a representation of the image to be printed. Accordingly, the robotic printer may move along the exterior surface of the aircraft and apply the print medium at locations corresponding to the representation of the image in the three-dimensional model.

By the term "about" or "substantial" and "substantially" or "approximately," with reference to amounts or measurement values, it is meant that the recited characteristic, parameter, or value need not be achieved exactly. Rather, deviations or variations, including, for example, tolerances, measurement error,

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measurement accuracy limitations, and other factors known to those skilled in the art, may occur in amounts that do not preclude the effect that the characteristic was intended to provide.

Referring now to Figure **1**, a side view of an aircraft **101** is shown, according to an example embodiment. The aircraft includes an exterior surface **102**, on which an image **103** can be seen. For example, the image **103** may correspond to color boundaries in a decorative livery design for the aircraft **101**. The decorative livery design may identify the air carrier, or perhaps the manufacturer of the aircraft. Once applied to the aircraft **101**, the image **103** may thus provide a template to facilitate masking portions of the exterior surface **102** (e.g., with tape) in preparation for more large-scale paint application within the color boundaries. The image **103** may be applied with a print medium **114**, which may be paint, ink, or any other medium capable of being applied to the exterior surface **102** of the aircraft **101** to create the image **103**.

The exterior surface **102** of the aircraft **101** also includes a plurality of surface features **104**, several of which are indicated in Figure **1**. The surface features **104** may include, for instance, a door, a window, or a seam where adjacent sections of the fuselage of the aircraft **101** join each other. Other examples of surface features **104** are also possible. As discussed further below, a robotic printing system **100** may utilize the surface features **104** as reference points to index the location of a robotic printer to the exterior surface **102** of the aircraft **101**, allowing the image **103** to be applied according to a three-dimensional model of the aircraft **101** that includes a representation of the image **103**, for example.

Figure **2** shows a side view of a robotic printer **110**, and Figure **3** shows a top view of the robotic printer **110**, according to an example embodiment. The robotic printer **110** includes a body **111** to which other components of the robotic printer **110** may be attached. For example, the robotic printer **110** includes a plurality of vacuum suction cups **112** mounted to the body **111** for attaching the robotic printer **110** to the exterior surface **102** of the aircraft **101**. Each vacuum suction cup **112**

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may be part of an assembly that includes, for example, vacuum tubing that couples a vacuum pressure source to the vacuum suction cup **112**. Further, the plurality of vacuum suction cups **112** are configured to move the robotic printer **110** along the exterior surface **102** of the aircraft **101**, as discussed below.

For instance, as shown in Figures **2** and **3**, the plurality of vacuum suction cups **112** are arranged on a pair of parallel treads **116** that are configured to drive the robotic printer **110** along the exterior surface **102** of the aircraft **101**. This may allow the robotic printer **110** a greater range of movement than some other robotic systems that are used in aircraft assembly. In some implementations, the pair of parallel treads **116** may each include a respective drive motor **130**, which may drive the rotation of the pair of treads **116**, thereby moving the robotic printer **110**.

An alternative example is shown in Figure **4**, in which the plurality of vacuum suction cups **112** are arranged at respective ends **118** of a plurality of legs **117** configured to move the robotic printer **110** along the exterior surface **102** of the aircraft **101**. The example shown in Figure **4** includes four legs, although more or fewer legs are also possible. Otherwise, the robotic printer **110** in Figure **4** may include substantially similar features to those shown in the robotic printer **110** in Figures **2** and **3**.

Returning to Figures **2** and **3**, the robotic printer **110** further includes a printing head **113** mounted to the body **111**. The printing head **113** is positioned to apply a print medium, such as the print medium **114** shown in Figure **1** and discussed above, to the exterior surface **102** of the aircraft **101**. For example, the print head **113** may include one or more nozzles or jets to apply the print medium **114**. The printing head **113** may be mounted to approximately the center of the body **111**, between the pair of parallel treads **116**, and on an underside of the robotic printer **110**. In this configuration, the printing head **113** can apply the print medium **114** to the exterior surface **102** of the aircraft **101** as the robotic printer **110** moves along the exterior surface **102**.

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In some embodiments, the robotic printer **110** may include one or more positioning motors **119** coupled to the printing head **113**. The one or more positioning motors **119** may be configured to adjust a position of the printing head **113** relative to the body **111** and the plurality of vacuum suction cups **112**. For example, as the robotic printer **110** moves along the exterior surface **102** via the plurality of vacuum suction cups **112**, it may be possible to position the printing head **113** along a desired travel path within a given tolerance, such as plus or minus two inches. Within this tolerance window, the one or more positioning motors **119** may allow the robotic printer **110** to make finer adjustments to the position of the printing head **113** than may be possible relying only on the movement of the robotic printer **110** via the plurality of vacuum suction cups **112**. For instance, this may allow the robotic printer **110** to more efficiently avoid gaps or overlaps in the application of the print medium **114**. As shown in Figure **3**, the printing head **113** may be coupled to two positioning motors **119**, allowing the printing head **113** to move along two perpendicular axes.

In some implementations, the robotic printing system **100** also includes an umbilical line **120** attached to the body **111**. An example of the umbilical line **120** can be seen in Figures **5** and **6**, and will be discussed further below. In Figure **2**, an electrical port **132** is shown on the body **111** of the robotic printer **110**. The umbilical line **120** may be attached to the electrical port **132** to provide electrical power to the robotic printer **110**. Similarly, a vacuum port **133** is shown on the body **111** adjacent to the electrical port **132**. The umbilical line **120** may be attached to the vacuum port **133** to provide vacuum pressure to the robotic printer **110**, which may be transferred to the plurality of vacuum suction cups **112**. In some implementations, the umbilical line **120** may convey paint or ink from a remote supply to the printing head **113**. Other examples are also possible.

The robotic printer **110** shown in Figures **2** and **3** further includes a laser-based positioning device **115** mounted to the body **111** for determining a position of the robotic printer **110** on the exterior surface **102** of the aircraft **101**. For

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example, the laser-based positioning device **115** may include a light source such as a laser, a rotating mirror, and a sensor for detecting light, such as a photodiode. Other arrangements of the laser-based positioning device **115** are also possible.

The laser-based positioning device **115** includes a line of sight **121**, shown conceptually in Figure **2**. The robotic printer **110** may be configured to determine relative position data with respect to the laser-based positioning device **115** for each surface feature **104** within its line of sight **121**. Additionally, the robotic printer **110** may be configured to determine the position of the robotic printer **110** on the exterior surface of the aircraft **101**, as noted above, based on the relative position data for each surface feature **104** in the plurality of surface features **104**.

For instance, based on the relative position data obtained via the laser-based positioning device **115**, the robotic printing system **100** may map the position of the robotic printer **110** to a three-dimensional model of the exterior surface **102** of the aircraft **101**. For instance, the three-dimensional model of the aircraft **101** may be an engineering drawing used for the design and assembly of the aircraft **101**. Thus, the surface features **104** on the exterior surface **102** may have corresponding features within the three-dimensional model. Accordingly, the relative position of the robotic printer **110** in relation to the surface features **104** in real space can be translated to the three-dimensional model, providing an accurate mapping of the location of the robotic printer **110** within the three-dimensional model.

Further, the three-dimensional model includes a representation of the image **103** that is to be applied to the exterior surface **102**. As noted above, the image **103** may correspond to color boundaries in the decorative livery design of the aircraft. Based on the mapped position of the robotic printer **110** and, by extension, the printing head **113**, the robotic printer **110** may apply the print medium **114** at a location corresponding to the representation of the image **103** in the three-dimensional model. As the robotic printer **110** moves along the exterior surface **102**, the relative position data and the mapped position of the robotic printer **110** will be updated, and the printing head **113** may apply the print medium **114** accordingly.

The robotic printer **110** may be initially attached to the exterior surface **102** of the aircraft **101** at an initial mounting position, which may be on the underside of the aircraft **101**. For example, the robotic printer **110** may be raised, in an inverted position, manually or by a hydraulic or otherwise motorized lift until the plurality of vacuum suction cups **112** are attached to the exterior surface **102**. Once attached, the lift may be lowered and the robotic printer **110** begins moving along the exterior surface **102**. Other initial mounting positions on the exterior surface **102** of the aircraft **101** are also possible.

Figure **5**, shows an example travel path for a robotic printing system **100**, accordingly to an example implementation. The robotic printer **110** is shown on the exterior surface **102** of the aircraft **101**, following an example travel path **122**. In Figure **5**, the robotic printing system **100** includes an umbilical line **120** attached to the body **111** of the robotic printer **110**. As discussed above, the umbilical line **120** may convey electrical power and vacuum pressure to the robotic printer **110**, among other possibilities. For instance, the umbilical line **120** may convey communications between one or more computing devices that are a part of the robotic printing system **100**, or it may supply the print medium **114** to be applied via the printing head **113**. Alternatively, the print medium **114** may be provided in cartridges carried by the robotic printer **110**, which may be changed out when empty.

As seen in Figure **5**, the robotic printer **110** may follow the travel path **122** along the exterior surface **102** of the aircraft **101**. If the print head **113** is located between the plurality of vacuum suction cups **112**, as shown in the examples in Figures **2-4**, the travel path **122** may be designed such that the robot printer **110** does not have to travel back over a section of the exterior surface **102** on which the print medium **113** has just been applied, and thus may still be wet. For example, based on the speed at which the robotic printer **110** travels and the drying time for the print medium **114**, it may be possible for the robotic printer **110** to follow a travel path **122** in which the plurality of vacuum suction cups **112** do not travel over immediately adjacent areas when the robotic printer **110** changes directions. Rather, the plurality of vacuum suction cups **112** travel over already-printed portions of the exterior surface **102** after the print medium **113** has had sufficient time to dry. The example travel path **122** shown in Figure **5** follows such a route.

In an alternative embodiment, the robotic printer **110** may be arranged such that the printing head **113** is mounted outside the pair of parallel treads **116** shown in Figures **2** and **3**, or outside the plurality of legs **117** shown in Figure **4**. For instance, the printing head **113** may be mounted to an arm that extends laterally from the body **111**, such that the print medium **114** is applied along the side of the robotic printer **110** as it moves along the exterior surface **102** of the aircraft **101**, outside the path of the treads **116** or the legs **117**. In this way, rather than the circuitous travel path **122** shown in Figure **5**, the robotic printer **110** may be able to follow a travel path that follows a stepwise progression down the exterior surface **102**, where the printing head **113** applies the print medium **114** just above the travel path in each adjacent pass. Further, depending on the size of the print head **113** and the size and shape of the image **103**, the travel path **122** may require more or fewer passes than what is shown by way of example in Figure **5**. For instance, the pattern shown in Figure **5** may be repeated multiple times along the exterior surface **102**.

As shown in Figure **5**, the umbilical line **120** may hang freely from the robotic printer **110** to the ground during the printing operation, and thus, the self-weight of the umbilical line **120** may be accounted for in the required vacuum pressure needed to maintain attachment to the exterior surface **102** of the aircraft **101**. Because of the wings extending from the aircraft **101**, which may block the umbilical line **120** in such an example, the print medium **114** be applied to a given side of the aircraft **101** in two different sections, forward and aft of the wing.

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In some other implementations, the umbilical line **120** may be suspended from a ceiling or other overhead structure. This may reduce the weight that must be carried by the robotic printer **110**, and thus necessary vacuum pressure to maintain attachment with the exterior surface **102**. In some examples, the umbilical line **120** may be coupled to an overhead track or other support system that allows the suspended umbilical line **120** to move along with the robotic printer **110** as it moves along the exterior surface **102** of the aircraft **101**.

In such an example, the suspended umbilical line **120** may be designed with the tensile strength to also act as a fall arrest system to catch the robotic printer **110** in the event it becomes unattached from the exterior surface **102**, whether due to a loss of vacuum pressure or any other reason. This may increase the safety for the robotic printing system **100**.

Alternatively, in examples where the umbilical line **120** is attached to the robotic printer **110** from the ground, the robotic printing system **100** may further include a lanyard **124** or similar arresting cable attached to the body **111** of the robotic printer **110**. Such an example can be seen in Figure **6**, which shows a view along the longitudinal axis of the aircraft **101**. The lanyard **124** may be coupled to the ceiling or other overhead structure. Thus, the lanyard **124** may increase the safety of the robotic printing system **100**, as discussed above. In some implementations, whether the umbilical line **120**, the lanyard **124**, or another solution is used as a fall arrest system, the robotic printing system **100** may further include a safety fence **140** surrounding the aircraft **101** to further increase safety in the event of a vacuum pressure loss.

Turning now to Figures **7** and **8**, another example of the robotic printing system **100** is shown, according to an example implementation. In some situations, certain surface features **104** may not be in view of the laser-based positioning device **115** from all locations on the exterior surface **102**. For instance, the windows may not be within the line of sight **121** of the laser-based positioning device **115** when the robotic printer **110** is near the bottom of the aircraft **101**.

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Accordingly, in some implementations it may be desirable to provide additional references for locating the robotic printer **110**. As shown in Figure **7**, the robotic printing system **100** may include a plurality of external positioning devices **105** that are configured to be positioned at predetermined locations **107** surrounding the aircraft **101**.

For example, the plurality of external positioning devices **105** may take the form of a plurality of stands that are positioned around the aircraft **101** and then locked into place. The plurality of external positioning devices **105** may be positioned at predetermined locations based on their location relative to surface features **104** on the exterior surface **102** of the aircraft **101**. For example, a given external positioning device **105** may be equipped with laser-based positioning tools, such as a vertically projecting laser level, that may allow the external positioning device **105** to be aligned with a particular surface feature **104**, such as a vertical join seam in the fuselage of the aircraft **101**. Similar laser-based positioning devices may be used to establish a distance of the external positioning device **105** from the aircraft **101**, and the distance from one external positioning device **105** to the next.

Each external positioning device **105** in the plurality of external positioning devices **105** may include a reference point **106**. Each reference point **106** may be a reflective surface, such as a mirror, that may be detected by the laser-based positioning device **115**. In Figures **7** and **8**, the plurality of reference points **106** are shown at the top of each external positioning device **105**, at approximately the horizontal centerline of the aircraft **101** for increased visibility to the laser-based positioning device **115**. Accordingly, the laser-based positioning device **115** may be configured to determine relative position data with respect to the laser-based positioning device **115** for each external positioning device **105** within its line of sight **121**. The robotic printer **110** is configured to determine the position of the robotic printer **110** on the exterior surface **102** of the aircraft **101** based on the

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relative position data for each external positioning device **105** in the plurality of external positioning devices **105**.

Figure **9** illustrates a block diagram of an example computing device **200** that may form a part of the robotic printing system **100**. In some implementations, the computing device **200** may be an onboard computer housed on or within the body **111** of the robotic printer **110**, or it may be a remote computer that is communicatively coupled to the robotic printer **110** via a communications link **204**. For example, the computing device **200** may be communicatively coupled to the robotic printer **110** via the umbilical line **120** that is attached to the body **111**. Additionally or alternatively, the computing device **200** may communicate wirelessly with the robotic printer **110**. Further, the computing device **200** shown in Figure **11** might not be embodied by a single device, but may represent a combination of computing devices that may or may not be in the same location.

The computing device **200** may include a non-transitory, computer readable medium **202** that includes instructions that are executable by one or more processors **201**. The non-transitory, computer readable medium **202** may include other data storage as well. For example, the instructions may cause the robotic printing system **100** to determine, via the laser-based positioning device **115**, relative position data with respect to the laser-based positioning device **115** for each of a plurality of reference points **106** corresponding to the exterior surface **102** of the aircraft **101**. The relative position data may then be stored on the non-transitory, computer readable medium **202**.

Based on the relative position data, the instructions may then cause the robotic printing system **100** to determine a position of the robotic printer **110** on the exterior surface **102** of the aircraft **101**, and then map the position of the robotic printer **110** to a three-dimensional model of the exterior surface **102**. The three-dimensional model includes a representation of the image **103** on the exterior surface **102**, and may be stored on the non-transitory, computer readable medium.

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Based on the mapping of the robotic printer **110** to the three-dimensional model, the instructions may further cause the robotic printing system to apply, via the printing head **113**, the print medium **114** to a location on the exterior surface **102** of the aircraft **101** corresponding to the representation of the image **103** in the three-dimensional model. In conjunction with applying the print medium **114**, the instructions may further cause the robotic printing system **100** to move the robotic printer **110** along the exterior surface **102** of the aircraft **101** via the plurality of vacuum suction cups **112**.

In some implementations, the computing device **200** also includes a user interface **203** for receiving inputs from a user, and/or for outputting operational data to a user. The user interface **203** might take the form of a control panel located on the robotic printer **110**, or a graphical user interface at a remote location, connected to the robotic printer **110** wirelessly or via the umbilical line **120**, among other examples. For instance, a command for the robotic printer **110** to return to the initial mounting position may be received from a remote user via the user interface **203** of the computing device **200**. The command may be communicated to robotic printer **110** via the umbilical line **120**, or wirelessly as discussed above. In other examples, a return command might be initiated automatically, based on pre-determined parameters stored on the non-transitory, computer readable medium **202**, such as a remaining quantity of the print medium **114** in an onboard cartridge. Other possibilities also exist.

In addition, the non-transitory, computer readable medium **202** may be loaded with one or more software components **205** stored on the computer readable medium **202** and executable by the processor **201** to achieve certain functions.

For example, the robotic printing system **100** may include various systems that contribute to its operation, such as a vacuum suction system, a positioning system for the positioning motor **119**, and a three-dimensional mapping system, among other examples. Each of these systems may be operated in part by

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software components **205** housed on the non-transitory, computer readable medium **202** and executable by the processor **201**.

Turning now to Figure **10**, a flowchart of a method **300** for printing an image on an exterior surface of an aircraft is shown, according to an example implementation. Method **300** shown in Figure **10** presents an example of a method that, for instance, could be used with the robotic printing system **100**, as shown in Figures **1**-**9** and discussed herein. It should be understood that for these and other processes and methods disclosed herein, flowcharts show functionality and operation of one possible implementation of present examples. In this regard, each block in a flowchart may represent a module, a segment, or a portion of program code, which includes one or more instructions executable by a processor for implementing or causing specific logical functions or steps in the process. For example, the method **300** may be implemented by one or more computing devices, such as the computing device **200** as shown in Figure **9** and discussed herein. Alternative implementations are included within the scope of the examples of the present disclosure, in which functions may be executed out of order from that shown or discussed, including substantially concurrently, depending on the functionality involved, as would be understood by those reasonably skilled in the art.

At block **302**, the method **300** includes attaching a robotic printer, such as the robotic printer **110** discussed above, to the exterior surface **102** of the aircraft **101** via a plurality of vacuum suction cups **112** mounted to a body **111** of the robotic printer **110**. The robotic printer **110** further includes a laser-based positioning device **115** and a printing head **113** mounted to the body **111**, as discussed above.

In some implementations, the plurality of vacuum suction cups **112** are arranged on a pair of parallel treads **116**, as shown in Figures **2** and **3**, which rotate to move the robotic printer **110** along the exterior surface **102** of the aircraft **101**. In other implementations, the plurality of vacuum suction cups **112** are arranged at respective ends **118** of a plurality of legs **117**, as shown in Figure **4**.

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At block **304**, the method **300** includes determining, via the laser-based positioning device **115**, relative position data with respect to the laser-based positioning device **115** for each of a plurality of reference points **106** corresponding to the exterior surface **102** of the aircraft **101**. As discussed above, the laser-based positioning device includes a line of sight **121**, and the exterior surface **102** of the aircraft **101** may include a plurality of surface features **104**. In some implementations, the surface features **104** may serve as the reference points **106**, and the method **300** at block **304** may include determining relative position data with respect to the laser-based positioning device **115** for each surface feature **104** within its line of sight **121**.

In some other implementations, a plurality of external positioning devices **105** are positioned at predetermined locations **107** surrounding the aircraft **101**, as shown in Figures **7** and **8** and discussed above. Each external positioning device **105** includes a reference point **106**, such as a mirror, which may be within the line of sight **121** of the laser-based positioning device **115**. Because the plurality of external positioning devices **105** are positioned at known locations around the aircraft **101**, the position of each reference point **106** is known relative to the exterior surface **102** of the aircraft **101**. Accordingly, the method **300** at block **304** may include determining relative position data with respect to the laser-based positioning device **115** for each external positioning device **105** within its line of sight **121**.

At block **306**, the method **300** includes, based on the relative position data, determining a position of the robotic printer **110** on the exterior surface **102** of the aircraft **101**. At block **308**, the method further includes, based on the relative position data, mapping the position of the robotic printer **110** to a three-dimensional model of the exterior surface **102**. The three-dimensional model includes a representation of the image **103** on the exterior surface **102**.

At block **310**, the method **300** includes, based on the mapping of the robotic printer **110** to the three-dimensional model, applying, via the printing head **113**, a print medium **114** to a location on the exterior surface **102** of the aircraft **101** corresponding to the representation of the image **103** in the three-dimensional model. For example, the robotic printer **110** may move along a travel path **122**, as shown in Figure **5**, and continuously map its position to the three-dimensional model of the exterior surface **102**. At appropriate locations corresponding to the representation of the image **103** in the model, the robotic printer **110** may apply the print medium **114**.

In some implementations, where the printing head **113** is mounted to the robotic printer **110** between the pair of parallel treads **116**, applying the print medium **114** to the exterior surface **102** of the aircraft **101** via the printing head **113** includes applying the print medium **114** between the pair of parallel treads **116**. Alternatively, where the printing head **113** is mounted to the robotic printer **110** outside the pair of parallel treads **116**, applying the print medium **114** to the exterior surface **102** of the aircraft **101** via the printing head **113** includes applying the print medium **114** outside the pair of parallel treads **116**.

As discussed above, the robotic printer **110** may include a positioning motor **119** coupled to the printing head **113** to adjust the location of the printing head **113**. Thus, in some implementations, the method **300** may further include, based on the position of the robotic printer **110** on the exterior surface **102** of the aircraft **101** and the mapping of the robotic printer **110** to the three-dimensional model, adjusting, via the positioning motor **119**, the position of the printing head **113** relative to the plurality of vacuum suction cups **112**.

At block **312**, the method **300** includes moving the robotic printer **110** along the exterior surface **102** of the aircraft **101** via the plurality of vacuum suction cups **112**. As noted above, the robotic printer **110** may move via the rotation of the pair of parallel treads **116**, or via the articulation of the plurality of legs **117**.

The description of the different advantageous arrangements has been presented for purposes of illustration and description, and is not intended to be

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exhaustive or limited to the examples in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. Further, different advantageous examples may describe different advantages as compared to other advantageous examples. The example or examples selected are chosen and described in order to explain the principles of the examples, the practical application, and to enable others of ordinary skill in the art to understand the disclosure for various examples with various modifications as are suited to the particular use contemplated

EMBODIMENTS IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A robotic printing system for an exterior surface of an aircraft comprising:

a robotic printer, the robotic printer comprising:

a body;

a pair of parallel treads coupled to the body, wherein the pair of parallel treads include multiple connected links arranged around drive wheels;

a plurality of vacuum suction cups mounted to the body for attaching the robotic printer to the exterior surface of the aircraft, wherein the plurality of vacuum suction cups are configured to move the robotic printer along the exterior surface of the aircraft, wherein the plurality of vacuum suction cups are arranged on the multiple connected links of the pair of parallel treads that are configured to drive the robotic printer along the exterior surface of the aircraft, wherein the pair of parallel treads rotate around the drive wheels to move the robotic printer along the exterior surface of the aircraft;

a printing head mounted to the body, wherein the printing head is positioned to apply a print medium to the exterior surface of the aircraft; and

a laser-based positioning device mounted to the body for determining a position of the robotic printer on the exterior surface of the aircraft.

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2. The robotic printing system of claim **1**, wherein the printing head is mounted to the robotic printer between the pair of parallel treads.

3. The robotic printing system of claim **1**, wherein the printing head is mounted to the robotic printer outside the pair of parallel treads.

4. The robotic printing system of any one of claims **1-3**, wherein the robotic printer further comprises a positioning motor coupled to the printing head, wherein the positioning motor is configured to adjust a position of the printing head relative to the plurality of vacuum suction cups.

5. The robotic printing system of any one of claims **1-4**, further comprising:

an umbilical line attached to the body of the robotic printer, wherein the umbilical line conveys one or more of electrical power and vacuum pressure to the robotic printer.

6. The robotic printing system of any one of claims **1-5**, wherein the laser-based positioning device comprises a line of sight, wherein the exterior surface of the aircraft comprises a plurality of surface features, and wherein the robotic printer is configured to determine relative position data with respect to the laser-based positioning device for each surface feature within its line of sight, and wherein the robotic printer is configured to determine the position of the robotic printer on the exterior surface of the aircraft based on the relative position data for each surface feature in the plurality of surface features.

7. The robotic printing system of any one of claims **1-5**, wherein the laser-based positioning device comprises a line of sight, the robotic printing system further comprising:

a plurality of external positioning devices configured to be positioned at pre-determined locations surrounding the aircraft, wherein the robotic printer is configured to determine relative position data with respect to

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the laser-based positioning device for each external positioning device within its line of sight, and wherein the robotic printer is configured to determine the position of the robotic printer on the exterior surface of the aircraft based on the relative position data for each external positioning device in the plurality of external positioning devices.

8. The robotic printing system of any one of claims **1**-**7**, further comprising a computing device, the computing device comprising:

one or more processors; and

a non-transitory, computer readable medium having stored thereon instructions, that when executed by the one or more processors, cause the robotic printing system to perform functions comprising:

determining, via the laser-based positioning device, relative position data with respect to the laser-based positioning device for each of a plurality of reference points corresponding to the exterior surface of the aircraft;

based on the relative position data, determining a position of the robotic printer on the exterior surface of the aircraft;

based on the relative position data, mapping the position of the robotic printer to a three-dimensional model of the exterior surface, wherein the three-dimensional model includes a representation of an image on the exterior surface;

based on the mapping of the robotic printer to the three-dimensional model, applying, via the printing head, a print medium to a location on the exterior surface of the aircraft corresponding to the representation of the image in the three-dimensional model; and

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moving the robotic printer along the exterior surface of the aircraft via the plurality of vacuum suction cups.

9. The robotic printing system of claim **8**, wherein the computing device is communicatively coupled to the robotic printer via an umbilical line attached to the body of the robotic printer.

10. The robotic printing system of any one of claims **1**-**9**, further comprising a respective drive motor for each of the pair of parallel treads to drive rotation of the pair of parallel treads.

11. A robotic printing system for an exterior surface of an aircraft comprising:

a robotic printer, the robotic printer comprising:

a body;

a pair of parallel treads coupled to the body, wherein the pair of parallel treads include multiple connected links arranged around drive wheels;

a plurality of vacuum suction cups mounted to the body for attaching the robotic printer to the exterior surface of the aircraft, wherein the plurality of vacuum suction cups are configured to move the robotic printer along the exterior surface of the aircraft, wherein the plurality of vacuum suction cups are arranged on the multiple connected links of the pair of parallel treads that are configured to drive the robotic printer along the exterior surface of the aircraft, wherein the pair of parallel treads rotate around the drive wheels to move the robotic printer along the exterior surface of the aircraft;

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a printing head mounted to the body, wherein the printing head is positioned to apply a print medium to the exterior surface of the aircraft;

a laser-based positioning device mounted to the body for determining a position of the robotic printer on the exterior surface of the aircraft, wherein the laser-based positioning device comprises a line of sight; and

a plurality of external positioning devices configured to be positioned at pre-determined locations surrounding the aircraft, wherein the robotic printer is configured to determine relative position data with respect to the laser-based positioning device for each external positioning device within its line of sight, and wherein the robotic printer is configured to determine the position of the robotic printer on the exterior surface of the aircraft based on the relative position data for each external positioning device in the plurality of external positioning devices.

12. The robotic printing system of claim **11**, wherein the plurality of vacuum suction cups are arranged on a pair of parallel treads configured to drive the robotic printer along the exterior surface of the aircraft.

13. The robotic printing system of claim **11**, wherein the printing head is mounted to the robotic printer between the pair of parallel treads.

14. The robotic printing system of claim **11**, wherein the plurality of vacuum suction cups are arranged at respective ends of a plurality of legs configured to move the robotic printer along the exterior surface of the aircraft.

15. The robotic printing system of any one of claims 11-14, wherein the robotic printer further comprises a positioning motor coupled to the printing head,

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wherein the positioning motor is configured to adjust a position of the printing head relative to the plurality of vacuum suction cups.

16. The robotic printing system of any one of claims 11-15, further comprising:

an umbilical line attached to the body of the robotic printer, wherein the umbilical line conveys one or more of electrical power and vacuum pressure to the robotic printer.

17. The robotic printing system of any one of claims **11-16**, wherein the exterior surface of the aircraft comprises a plurality of surface features, and wherein the robotic printer is configured to determine additional relative position data with respect to the laser-based positioning device for each surface feature within its line of sight, and wherein the robotic printer is configured to determine the position of the robotic printer on the exterior surface of the aircraft further based on the additional relative position data for each surface feature in the plurality of surface features.

18. The robotic printing system of any one of claims **11-15**, further comprising a computing device, the computing device comprising:

one or more processors; and

a non-transitory, computer readable medium having stored thereon instructions, that when executed by the one or more processors, cause the robotic printing system to perform functions comprising:

determining, via the laser-based positioning device, additional relative position data with respect to the laser-based positioning device for each of a plurality of reference points corresponding to the exterior surface of the aircraft;

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based on the additional relative position data, further determining the position of the robotic printer on the exterior surface of the aircraft; and

based on the additional relative position data, mapping the position of the robotic printer to a three-dimensional model of the exterior surface, wherein the three-dimensional model includes a representation of an image on the exterior surface.

19. The robotic printing system of claim **18**, wherein the computing device is communicatively coupled to the robotic printer via an umbilical line attached to the body of the robotic printer.

20. The robotic printing system of claim **18**, wherein the functions further comprise:

based on the mapping of the robotic printer to the three-dimensional model, applying, via the printing head, a print medium to a location on the exterior surface of the aircraft corresponding to the representation of the image in the three-dimensional model; and

moving the robotic printer along the exterior surface of the aircraft via the plurality of vacuum suction cups.

21. A method of printing an image on an exterior surface of an aircraft comprising:

providing a robotic printer comprising:

a body;

a pair of parallel treads coupled to the body, wherein the pair of parallel treads include multiple connected links arranged around drive wheels; and

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a plurality of vacuum suction cups mounted to the body, wherein the plurality of vacuum suction cups are arranged on the multiple connected links of the pair of parallel treads, wherein the pair of parallel treads rotate around the drive wheels to move the robotic printer along the exterior surface of the aircraft;

attaching the robotic printer to the exterior surface of the aircraft via the plurality of vacuum suction cups mounted to the body of the robotic printer, the robotic printer further comprising a laser-based positioning device and a printing head mounted to the body;

determining, via the laser-based positioning device, relative position data with respect to the laser-based positioning device for each of a plurality of reference points corresponding to the exterior surface of the aircraft;

based on the relative position data, determining a position of the robotic printer on the exterior surface of the aircraft;

based on the relative position data, mapping the position of the robotic printer to a three-dimensional model of the exterior surface, wherein the three-dimensional model includes a representation of the image on the exterior surface;

based on the mapping of the robotic printer to the three-dimensional model, applying, via the printing head, a print medium to a location on the exterior surface of the aircraft corresponding to the representation of the image in the three-dimensional model; and

moving the robotic printer along the exterior surface of the aircraft via the plurality of vacuum suction cups.

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22. The method of claim **21**, wherein the printing head is mounted to the robotic printer between the pair of parallel treads, and wherein applying a print medium to the exterior surface of the aircraft via the printing head comprises applying a print medium between the pair of parallel treads.

23. The method of claim **21**, wherein the printing head is mounted to the robotic printer outside the pair of parallel treads, and wherein applying a print medium to the exterior surface of the aircraft via the printing head comprises applying a print medium outside the pair of parallel treads.

24. The method of any one of claims **21**-**23**, wherein the plurality of vacuum suction cups are arranged at respective ends of a plurality of legs.

25. The method of any one of claims **21**-**24**, wherein the robotic printer further comprises a positioning motor coupled to the printing head, the method further comprising:

based on the position of the robotic printer on the exterior surface of the aircraft and the mapping of the robotic printer to the three-dimensional model, adjusting, via the positioning motor, a position of the printing head relative to the plurality of vacuum suction cups.

26. The method of any one of claims **21**-**24**, wherein the laser-based positioning device comprises a line of sight, wherein the exterior surface of the aircraft comprises a plurality of surface features, and wherein determining, via the laser-based positioning device, relative position data with respect to the laser-based positioning device for each of a plurality of reference points corresponding to the exterior surface of the aircraft comprises determining relative position data with respect to the laser-based positioning device for each surface feature within its line of sight.

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27. The method of any one of claims **21**-**24**, wherein the laser-based positioning device comprises a line of sight, wherein a plurality of external positioning devices are positioned at pre-determined locations surrounding the aircraft, and

wherein determining, via the laser-based positioning device, relative position data with respect to the laser-based positioning device for each of a plurality of reference points corresponding to the exterior surface of the aircraft comprises determining relative position data with respect to the laser-based positioning device for each external positioning device within its line of sight.

28. A non-transitory computer readable medium having stored thereon instructions, that when executed by a computing device, cause the computing device to perform functions for printing an image on an exterior surface of an aircraft via a robotic printer comprising:

a body;

a pair of parallel treads coupled to the body, wherein the pair of parallel treads include multiple connected links arranged around drive wheels; and

a plurality of vacuum suction cups mounted to the body, wherein the plurality of vacuum suction cups are arranged on the multiple connected links of the pair of parallel treads, wherein the pair of parallel treads rotate around the drive wheels to move the robotic printer along the exterior surface of the aircraft;

wherein the robotic printer is attachable to the exterior surface via the plurality of vacuum suction cups mounted to the body of the robotic printer,

the functions comprising:

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determining, via a laser-based positioning device mounted to the body of the robotic printer, relative position data with respect to the laser-based positioning device for each of a plurality of reference points corresponding to the exterior surface of the aircraft;

based on the relative position data, determining a position of the robotic printer on the exterior surface of the aircraft;

based on the relative position data, mapping the position of the robotic printer to a three-dimensional model of the exterior surface, wherein the three-dimensional model includes a representation of the image on the exterior surface;

based on the mapping of the robotic printer to the three-dimensional model, causing a printing head mounted to the body of the robotic printer to apply a print medium to a location on the exterior surface of the aircraft corresponding to the representation of the image in the three-dimensional model; and

causing the robotic printer to move along the exterior surface of the aircraft via the plurality of vacuum suction cups.

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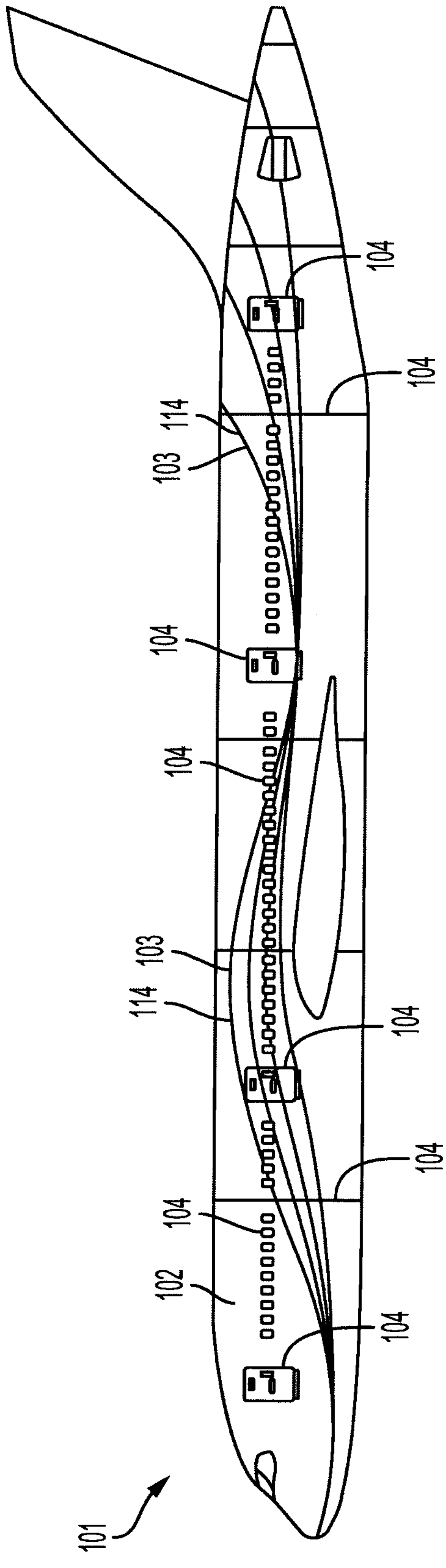


FIG. 1

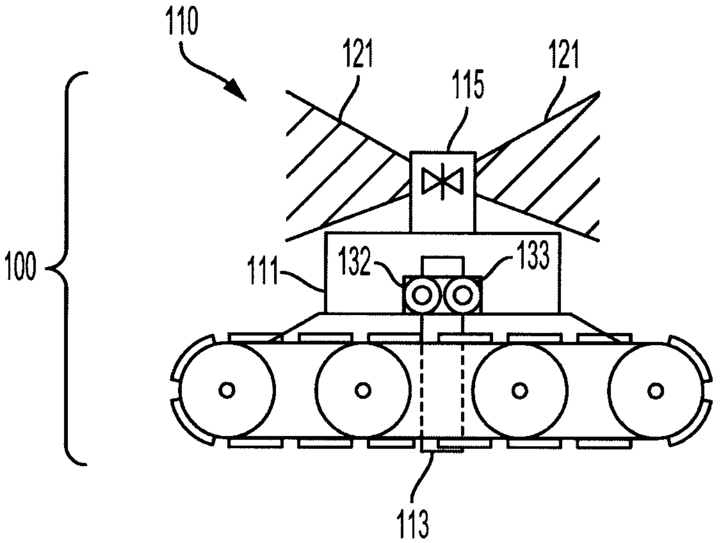

110
121
115
121
100
132
133
111
113

FIG. 2

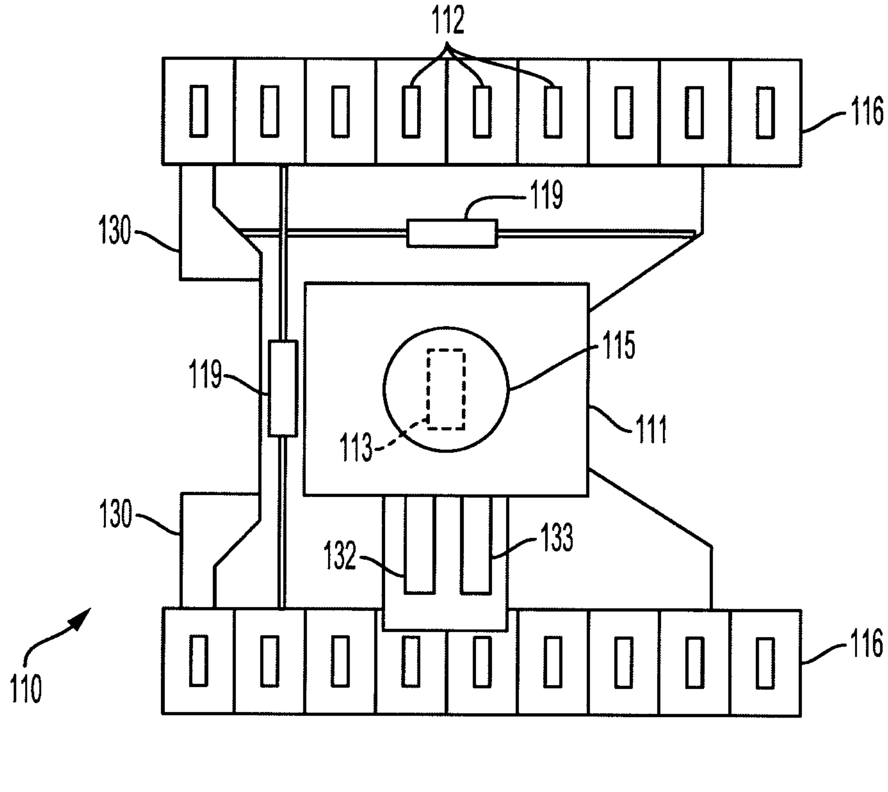

112
116
119
130
115
119
111
113
130
132
133
110
116

FIG. 3

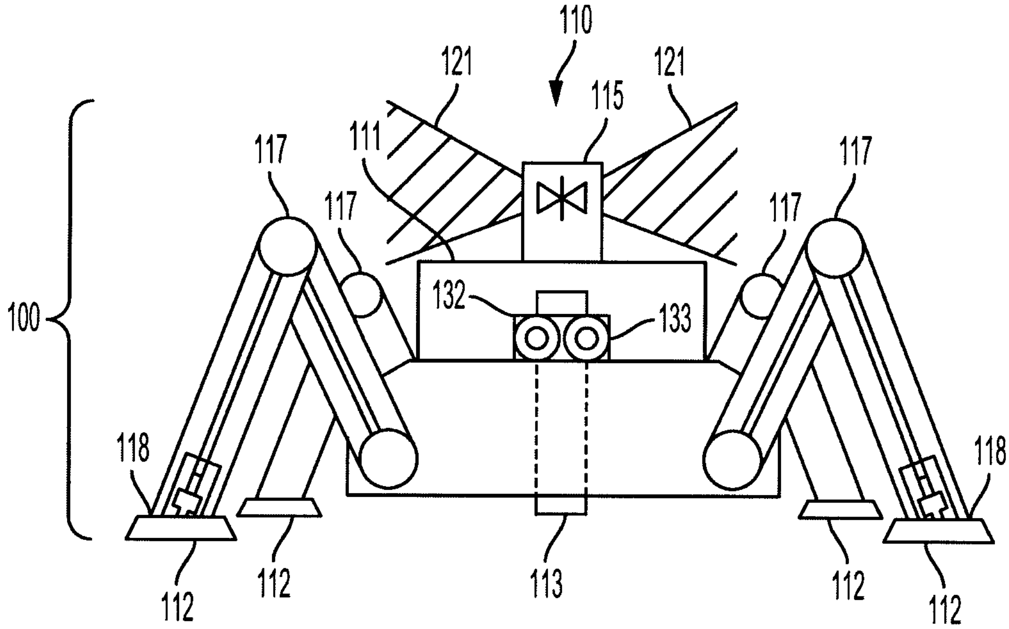

110
121
115
121
111
117
117
117
117
100
132
133
118
118
112
112
113
112
112

FIG. 4

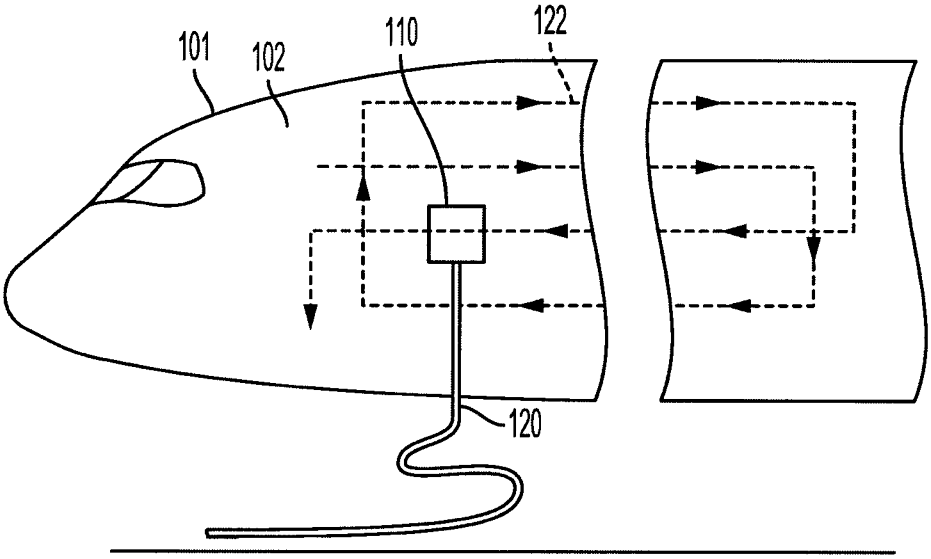


FIG. 5

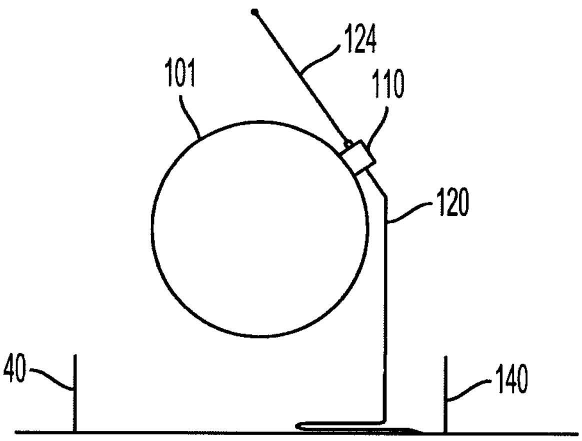


FIG. 6

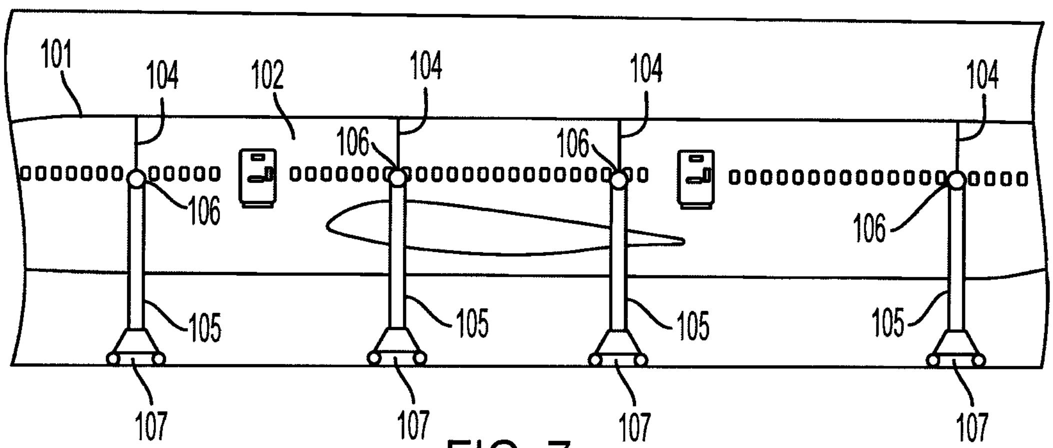

101
104
102
104
104
104
106
106
106
106
105
105
105
105
107
107
107
107

FIG. 7

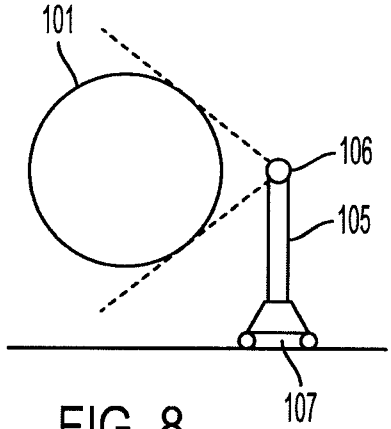

101
106
105
107

FIG. 8

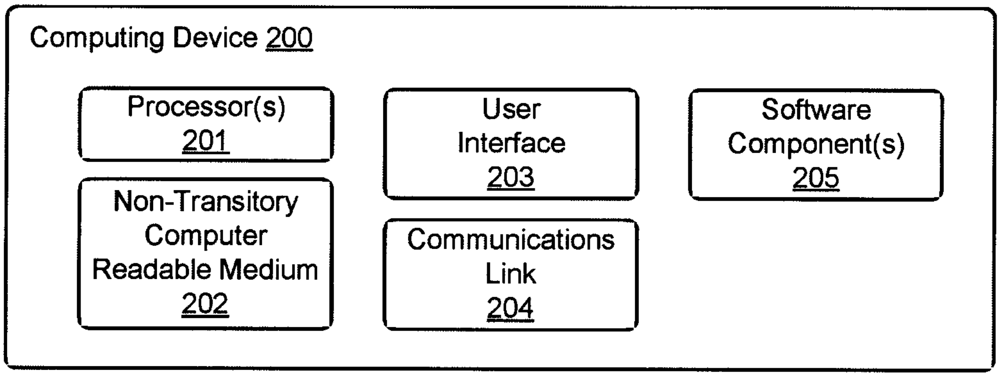

Computing Device 200
Processor(s) 201
Non-Transitory Computer Readable Medium 202
User Interface 203
Communications Link 204
Software Component(s) 205

FIG. 9

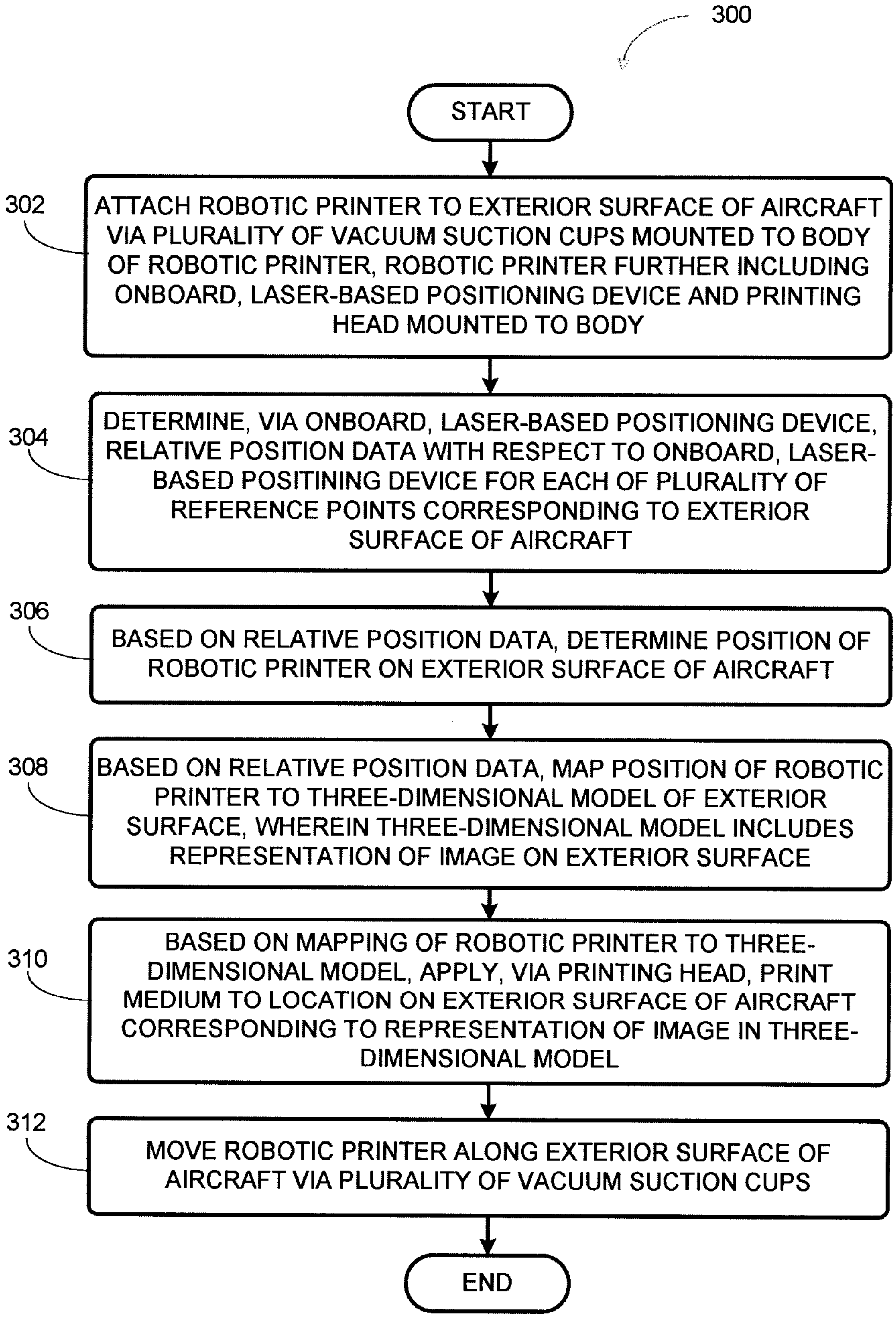
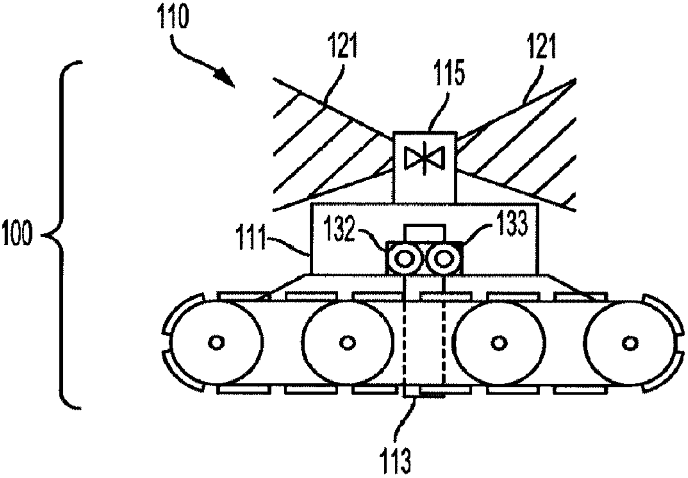

300
START
302
ATTACH ROBOTIC PRINTER TO EXTERIOR SURFACE OF AIRCRAFT VIA PLURALITY OF VACUUM SUCTION CUPS MOUNTED TO BODY OF ROBOTIC PRINTER, ROBOTIC PRINTER FURTHER INCLUDING ONBOARD, LASER-BASED POSITIONING DEVICE AND PRINTING HEAD MOUNTED TO BODY
304
DETERMINE, VIA ONBOARD, LASER-BASED POSITIONING DEVICE, RELATIVE POSITION DATA WITH RESPECT TO ONBOARD, LASER-BASED POSITINING DEVICE FOR EACH OF PLURALITY OF REFERENCE POINTS CORRESPONDING TO EXTERIOR SURFACE OF AIRCRAFT
306
BASED ON RELATIVE POSITION DATA, DETERMINE POSITION OF ROBOTIC PRINTER ON EXTERIOR SURFACE OF AIRCRAFT
308
BASED ON RELATIVE POSITION DATA, MAP POSITION OF ROBOTIC PRINTER TO THREE-DIMENSIONAL MODEL OF EXTERIOR SURFACE, WHEREIN THREE-DIMENSIONAL MODEL INCLUDES REPRESENTATION OF IMAGE ON EXTERIOR SURFACE
310
BASED ON MAPPING OF ROBOTIC PRINTER TO THREE-DIMENSIONAL MODEL, APPLY, VIA PRINTING HEAD, PRINT MEDIUM TO LOCATION ON EXTERIOR SURFACE OF AIRCRAFT CORRESPONDING TO REPRESENTATION OF IMAGE IN THREE-DIMENSIONAL MODEL
312
MOVE ROBOTIC PRINTER ALONG EXTERIOR SURFACE OF AIRCRAFT VIA PLURALITY OF VACUUM SUCTION CUPS
END

FIG. 10


110
121
121
115
100
111
132
133
113