SUMMARY

The subject matter of the present application has been developed in response to the present state of the art, and in particular, in response to the shortcomings of conventional non-destructive inspection techniques, that have not yet been fully solved by currently available techniques. Accordingly, the subject matter of the present application has been developed to provide an apparatus, system, and associated method that overcome at least some of the above-discussed shortcomings of prior art techniques.

According to an aspect, a non-destructive inspection ("NDI") system includes an unmanned aerial vehicle ("UAV") including a body structure having at least one support arm. The at least one support arm includes a first arm portion having a first end coupled to the body structure and a second end coupled to a second arm portion; the second arm portion having a first end coupled to a NDI scanning device and a second end coupled to the second end of the first arm portion; and a compliant member disposed between the first arm portion and the second arm portion. The NDI scanning device is formed with a housing comprising one or more NDI sensors. The first arm portion is pivotally coupled to the second arm portion. The compliant member biases movement of the second arm portion with respect to the first arm portion.

According to another aspect, a support arm for a non-destructive inspection ("NDI") system includes a first arm portion having a first end coupled to a body structure of an unmanned aerial vehicle ("UAV") and a second end coupled to a second arm portion. The second arm portion has a first end coupled to the second end of the first arm portion and a second end coupled to and NDI scanning device. The support arm also includes a compliant member disposed between the first arm portion and the second arm portion. The first arm portion is pivotally coupled to the second arm portion. The compliant member biases movement of the second arm portion with respect to the first arm portion.

In certain embodiments, the first arm portion is pivotally coupled to the second arm portion, with a rotational joint that allows compliant movement of the second portion of the arm portion with respect to the first arm portion. In other embodiments, the second arm portion is slidably coupled to the first arm portion and telescopes into the first arm portion with a compliant element between them.

Further disclosed is a system for NDI using a UAV and a NDI scanning device coupled to the UAV with the above described support arm. In some embodiments, the system includes a ring mount encircling, and coupled with, the body structure of the UAV. In this example, the at least one support arm is rigidly coupled with ring mount at the first end of the first arm

portion. The system may also include a second support arm coupled with the body structure and having a weight to counterbalance the NDI scanning device.

The NDI scanning device may include a mounting mechanism to couple the NDI scanning device to a surface of a structure, where the mounting mechanism is magnetic-based, vacuum-based, electrostatic-based, gripper-based, or adhesive-based. In certain embodiments, the UAV is operable to move using a predetermined flight path using position and orientation data obtained from a tracking system or controlled using a remote-control system. The one or more NDI sensors of the NDI scanning device include, but are not limited to, eddy current sensors, ultrasonic sensors, acoustic sensors, mechanical impedance sensors, optical sensors, x-ray backscatter sensors, computed tomography sensors, surface roughness sensors, IR

thermography, microwave sensors, and terahertz sensors. In some embodiments, the one or more NDI sensors are moved relative to a structure to be inspected.

In some embodiments, the system also includes one or more maintenance tools including, but not limited to, a sander, a drill, a brush, a paint sprayer, a marker, an ink stamp, a laser, or a target applicator. The system may also include a locomotion mechanism for moving the NDI scanning device around the surface to be inspected.

Also provided is a method that utilizes the above system to perform non-destructive inspection of a surface using an unmanned aerial vehicle.

According to another aspect, a method of non-destructive inspection ("NDI") of an object includes providing an unmanned aerial vehicle ("UAV") comprising a body structure having at least one support arm. The at least one support arm includes a first arm portion having a first end coupled to the body structure and a second end coupled to a second arm portion; the second arm portion having a first end coupled to the second end of the first arm portion and a second end coupled to an NDI scanning device; and a compliant member disposed between the first arm portion and the second arm portion. The first arm portion is pivotally coupled to the second arm portion. The compliant member biases movement of the second arm portion with respect to the first arm portion. The NDI scanning device is formed with a housing comprising one or more NDI sensors. The method also includes directing the UAV to a target location of a structure; placing the NDI scanning device on the surface of the structure at the target location; and performing NDI of the surface using the one or more NDI sensors.

The described features, structures, advantages, and/or characteristics of the subject matter of the present disclosure may be combined in any suitable manner in one or more examples and/or implementations. In the following description, numerous specific details are provided to impart a thorough understanding of examples of the subject matter of the present disclosure. One skilled in the relevant art will recognize that the subject matter of the present disclosure may be practiced without one or more of the specific features, details, components, materials, and/or methods of a particular example or implementation. In other instances, additional features and advantages may be recognized in certain examples and/or implementations that may not be present in all examples or implementations. Further, in some instances, well-known structures, materials, or operations are not shown or described in detail to avoid obscuring aspects of the subject matter of the present disclosure. The features and advantages of the subject matter of the present disclosure will become more fully apparent from the following description and appended claims, or may be learned by the practice of the subject matter as set forth hereinafter.

What is claimed is:

1. A non-destructive inspection (“NDI”) system, the system comprising:

an unmanned aerial vehicle (“UAV”) comprising a body structure having at least one support arm, where the at least one support arm comprises:

a first arm portion having a first end coupled to the body structure and a second end coupled to a second arm portion;

the second arm portion having a first end coupled to a NDI scanning device and a second end coupled to the second end of the first arm portion; and

a compliant member disposed between the first arm portion and the second arm portion; and

where the NDI scanning device is formed with a housing comprising one or more NDI sensors;

where the first arm portion is pivotally coupled to the second arm portion; and

where the compliant member biases movement of the second arm portion with respect to the first arm portion.

~~2. The NDI system of claim 1, where the first arm portion is pivotally coupled to the second arm portion.~~

~~3. The NDI system of any of claims 1 to 2, where the biasing compliant member biases movement of the second arm portion with respect to the first arm portion.~~

~~4. The NDI system of any of claims 1 to 3, where the second arm portion is slidably coupled to the first arm portion and telescopes into the first arm portion.~~

~~5. The NDI system of any of claims 1 to 4, where the compliant member biases movement of the second arm portion with respect to the first arm portion.~~

~~6~~2. The NDI system of ~~any of claims 1 to 5~~claim 1, further comprising a ring mount encircling, and coupled with, the body structure, the ring mount comprising an inner ring element and an outer ring element that rotates with respect to the inner ring element.

~~7~~3. The NDI system of ~~any of claims 1 to 6~~claim 2, where the at least one support arm is rigidly coupled with the outer ring element of the ring mount at the first end of the first arm portion.

~~8~~4. The NDI system of any of claims 1 to ~~7~~3, where the at least one support arm comprises a first support arm, and further comprising a second support arm coupled with the body structure and having a weight to counterbalance the at least one support arm and the NDI scanning device.

~~9~~5. The NDI system of any of claims 1 to ~~8~~4, where the NDI scanning device further comprises a mounting mechanism to couple the NDI scanning device to a surface of a structure, where the mounting mechanism is magnetic-based, vacuum-based, electrostatic-based, gripper-based, or adhesive-based.

6. The NDI system of claim 5, wherein the mounting mechanism is electrostatic-based, and the at least one support arm or the NDI scanning device comprises an electroadhesive surface.

7. The NDI system of claim 6, wherein the electroadhesive surface comprises conductive electrodes that are deposited on the surface of a polymer.

8. The NDI system of any one of claims 5 to 7, wherein the NDI scanning device is movably secured to the surface of the structure.

~~10~~9. The NDI system of any of claims 1 to ~~9~~8, where the UAV is operable to move using a predetermined flight path using position and orientation data obtained from a tracking system or controlled using a remote-control system.

~~11~~10. The NDI system of any of claims 1 to ~~10~~9, where the one or more NDI sensors comprises at least one of: eddy current sensors, ultrasonic sensors, acoustic sensors, mechanical impedance sensors, optical sensors, x-ray backscatter sensors, computed tomography sensors, surface roughness sensors, IR thermography, microwave sensors, and terahertz sensors.

~~12~~11. The NDI system of any of claims 1 to ~~11~~10, where the one or more NDI sensors are configured to be moved relative to a structure to be inspected.

~~13~~12. The NDI system of any of claims 1 to ~~12~~11, where the at least one ~~or more~~ support arm~~s~~ is configured to support one or more maintenance tools, where the one or more maintenance tools comprise one of a sander, a drill, a brush, a paint sprayer, a marker, an ink stamp, a laser, or a target applicator.

~~14~~13. The NDI system of any of claims 1 to ~~13~~12, where the NDI scanning device further comprises a locomotion mechanism for moving the NDI scanning device around a surface to be inspected.

14. The NDI system of any one of claims 1 to 13, wherein the compliant member comprises one or more compression springs.

15. The NDI system of any one of claims 1 to 14, wherein the UAV is configured to measure a pressure applied to the NDI scanning device, and to modify a distance between the UAV and a structure to be inspected in order to maintain a desired pressure.

~~15~~16. A support arm for a non-destructive inspection ("NDI") system, the support arm comprising:

a first arm portion having a first end coupled to a body structure of an unmanned aerial vehicle ("UAV") and a second end coupled to a second arm portion;

the second arm portion having a first end coupled to the second end of the first arm portion and a second end coupled to an NDI scanning device; and

a compliant member disposed between the first arm portion and the second arm portion, where the first arm portion is pivotally coupled to the second arm portion; and

where the compliant member biases movement of the second arm portion with respect to the first arm portion.

~~16. The support arm of claim 15, where the first arm portion is pivotally coupled to the second arm portion.~~

~~17. The support arm of any of claims 15 to 16, where the compliant member biases movement of the second arm portion with respect to the first arm portion.~~

~~18. The support arm of any of claims 15 to 17, where the second arm portion is slidably coupled to the first arm portion and telescopes into the first arm portion.~~

~~19. The support arm of any of claims 15 to 18, where the compliant member biases movement of the second arm portion with respect to the first arm portion.~~

~~20~~17. A method of non-destructive inspection ("NDI") of an object, comprising:

providing an unmanned aerial vehicle ("UAV") comprising a body structure having at least one support arm, where the at least one support arm comprises:

a first arm portion having a first end coupled to the body structure and a second end coupled to a second arm portion;

the second arm portion having a first end coupled to the second end of the first arm portion and a second end coupled to an NDI scanning device;

a compliant member disposed between the first arm portion and the second arm portion; and

where the NDI scanning device is formed with a housing comprising one or more NDI sensors;

where the first arm portion is pivotally coupled to the second arm portion; and

where the compliant member biases movement of the second arm portion with respect to the first arm portion;

directing the UAV to a target location of a structure;

placing the NDI scanning device on the surface of the structure at the target location; and

performing NDI of the surface using the one or more NDI sensors.