UNCREWED OFFSHORE NODE DEPLOYMENT SYSTEMS AND METHODS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims benefit of U.S. provisional patent application Serial No. 63/224,595 filed July 22, 2021, and entitled "Uncrewed Offshore Node Deployment Systems and Methods," which is hereby incorporated herein by reference in its entirety for all purposes.

BACKGROUND

[0003] Sensor arrays may be deployed in offshore subsea environments for a variety of applications. For example, exploration for hydrocarbon bearing subterranean formations may be conducted offshore utilizing the deployment of sensors subsea. In some applications, survey-based seismic exploration may be utilized to estimate properties of the subsurface beneath the sea floor based on reflected seismic waves. For example, a vessel may tow an array of seismic sensors (e.g., hydrophones, geophones, accelerometers etc.) to a desired location above the seabed. At the desired location, an acoustic source supported by the vessel may release one or more frequency-band limited sound waves toward the seabed. The sound waves may reflect off of subsurface formations beneath the seabed, back towards the surface where the reflected sound waves may be captured by the array of seismic sensors. The information captured by the array of seismic sensors, including the amount of time taken for the sound waves to reach the seismic array following their emission from the acoustic source, may be used to estimate or map the geology of the subsurface formations underlying the seabed. In some applications, the seismic array may be deployed directly onto the seabed as an ocean-bottom nodal (OBN) seismic survey in which seismic nodes are freely positioned (i.e., the nodes are not directly connected together) on the seabed.

[0004] In addition to OBN seismic surveys, other sensor arrays may be deployed to the seabed in applications other than hydrocarbon exploration. For example, asset integrity or monitoring sensor arrays comprising, for example, motion sensors, vibration sensors, strain sensors, pressure sensors, leak sensors, etc., may be deployed on the seabed to monitor subsea drilling, completion, and/or production equipment (e.g., wellhead, risers, production manifolds, pipelines, offshore wind substructures, etc.). Additionally, arrays comprising a plurality of communication devices such as subsea internet of things (SIoT) architecture may be deployed to the seabed to enable subsea wireless communication. Other examples may include seabed deployed sensor arrays used for environmental monitoring, metocean applications, and seabed subsidence monitoring.

SUMMARY

[0005] According to a first aspect of the present disclosure, there is provided an offshore node deployment system, including: a control system; a surface vessel comprising a deck, and a propulsion system in signal communication with the control system; a node storage container supported by the deck of the surface vessel, wherein the node storage container is configured to store a plurality of nodes which are physically disconnected from each other at least partially within an interior of the node storage container; and a node deployment system supported by the deck of the surface vessel and controllable by the control system, wherein the node deployment system is configured to retrieve the nodes from the interior of the node storage container, transport the nodes external the interior of the node storage container, and deploy the nodes from the surface vessel to a target subsea location; wherein the control system comprises one or more processors and one or more memory devices containing instructions that, when executed by the one or more processors, cause the one or more processors to: autonomously operate the propulsion system to transport the surface vessel to a target offshore location at which the plurality of nodes are to be deployed based on directions contained in an operational plan stored in the one or more memory devices; autonomously direct the node deployment system to retrieve the nodes from the from the interior of the node storage container, transport the nodes external the interior of the node storage container, and deploy the nodes from the surface vessel to the target subsea location based on the directions contained in the operational plan.

In some embodiments, the surface vessel comprises a seismic source configured to emit an acoustic signal and the nodes comprise sensor nodes each configured to receive the acoustic signal. In some embodiments, the control system comprises a controller configured to control the node deployment system and a wireless communication system configured to receive signals from a remote pilot of the surface vessel for controlling the propulsion system and the node deployment system. In certain embodiments, the control system comprises a controller comprising a memory device that includes instructions for autonomously operating the propulsion system and the node deployment system. In certain embodiments, the node deployment system comprises a node transportation system supported by the deck of the surface vessel and configured to deposit the nodes received from the node storage container into a submersible node deployment container, a container deployment system supported by the deck of the surface vessel and configured to transport the node deployment container from the deck of the surface vessel to the subsea location, and a remotely operated underwater vehicle (ROV) supported by the deck of the surface vessel and configured to retrieve the nodes from the node deployment container. In some embodiments, the node transportation

system comprises a robotic arm configured to retrieve the nodes from the node storage container and a conveyor configured to transport the nodes retrieved by the robotic arm. In some embodiments, the container deployment system comprises a lifting crane configured to lift the node deployment container from the deck of the surface vessel. In certain embodiments, the node deployment system is configured to retrieve an individual node from the node storage container and deploy the individual node to a subsea location. In certain embodiments, the control system comprises an artificial intelligence (AI) module configured to operate the node deployment system to retrieve the nodes from the node storage container and deploy the nodes to the subsea location. In some embodiments, at least a portion of the control system is not positioned on the surface vessel. In some embodiments, the node storage container comprises a node transporter configured to transport at least one of the plurality of nodes from a storage position within the node storage container to an exit position. In certain embodiments, the exit position is located at a position beyond an outer periphery of the deck of the surface vessel. In certain embodiments, the node transporter comprises a conveyor having a ramp extendable below a waterline.

[0007] According to a second aspect of the present disclosure, there is provided an offshore node deployment system, including: a control system; a surface vessel comprising a deck, and a propulsion system in signal communication with the control system; a node storage container supported by the deck of the surface vessel, wherein the node storage container is configured to store a plurality of nodes at least partially within an interior of the node storage container; and a node deployment system supported by the deck of the surface vessel and controllable by the control system, wherein the node deployment system is configured to retrieve an individual node from the interior of the node storage container, transport the node external the interior of the node storage container, and deploy the node from the surface vessel to a target subsea location; wherein the control system comprises one or more processors and one or more memory devices containing instructions that, when executed by the one or more processors, cause the one or more processors to: autonomously operate the propulsion system to transport the surface vessel to a target offshore location at which the node is to be deployed based on directions contained in an operational plan stored in the one or more memory devices; autonomously direct the node deployment system to retrieve the node from the interior of the node storage container, transport the node external the interior of the node storage container, and deploy the node from the surface vessel to the target subsea location based on the directions contained in the operational plan.

In some embodiments, the surface vessel comprises a seismic source configured to emit an acoustic signal and the plurality of nodes comprise sensor nodes each

configured to receive the acoustic signal. In some embodiments, the surface vessel comprises a modular surface vessel comprising a plurality of separable and releasably coupled modules including a propulsion module comprising the propulsion system, and a first node deployment module comprising the node deployment system. In certain embodiments, the surface vessel comprises a second node deployment module comprising another node deployment system. In certain embodiments, the node deployment system comprises a node transportation system supported by the deck of the surface vessel and configured to deposit the node received from the node storage container into a submersible node deployment container, a container deployment system supported by the deck of the surface vessel and configured to transport the node deployment container from the deck of the surface vessel to the subsea location, and a remotely operated underwater vehicle (ROV) system supported by the deck of the surface vessel and configured to retrieve the node from the node deployment container. In some embodiments, the node transportation system comprises a robotic arm configured to retrieve the node from the node storage container and a conveyor configured to transport the node retrieved by the robotic arm. In some embodiments, the container deployment system comprises a lifting crane configured to lift the node deployment container from the deck of the surface vessel. In certain embodiments, the node storage container is configured to store the plurality of nodes such that the plurality of nodes are free to move independently relative each other. In certain embodiments, the control system comprises an artificial intelligence (AI) module configured to operate the node deployment system to retrieve the node from the node storage container and deploy the node to the subsea location. In some embodiments, at least a portion of the control system is not positioned on the surface vessel. In some embodiments, the node storage container comprises a node transporter configured to transport the node from a storage position within the node storage container to an exit position. In certain embodiments, the exit position is located at a position beyond an outer periphery of the deck of the surface vessel. In certain embodiments, the node transporter comprises a conveyor having a ramp extendable below a waterline.

[0008] According to a third aspect of the present disclosure, there is provided a method for deploying a plurality of nodes offshore, including: (a) autonomously transporting by a control system a surface vessel to a target offshore location at which the plurality of nodes are to be deployed based on directions contained in an operational plan stored in one or more memory devices of the control system, wherein a node storage container is supported by a deck of the surface vessel, the node storage container comprises the plurality of nodes which are physically disconnected from each other and at least partially received within an interior of the node storage container; (b) autonomously retrieving by

the control system and, based on the directions contained in the operational plan, the nodes from the interior of the node storage container and transporting the nodes external the interior of the node storage container using a node deployment system supported by the deck of the surface vessel; and (c) autonomously deploying by the control system and, based on the directions contained in the operational plan, the nodes from the surface vessel to a subsea location using the node deployment system.

In some embodiments, (a) comprises remotely piloting the surface vessel via a control system of the surface vessel from a remote location. In some embodiments, (b) comprises retrieving the nodes individually from the node storage container and (c) comprises deploying the nodes individually to the subsea location. In certain embodiments, (b) comprises (b1) retrieving the nodes individually from the node storage container using a robotic arm supported by the deck of the surface vessel, and (b2) transporting the nodes retrieved from the node storage container using a conveyor whereby the nodes are deposited into a node deployment container, and (c) comprises (c1) lifting the node deployment container from the deck of the surface vessel using a lifting crane and lowering the node deployment container towards a seabed using a tether, and (c2) retrieving the nodes individually from the node deployment container using a remotely operated underwater vehicle (ROV). In certain embodiments, (c) comprises transporting the nodes from the node storage container to an exit position that is spaced from the node storage container.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] For a detailed description of exemplary embodiments of the disclosure, reference will now be made to the accompanying drawings in which:

[0010] Figures 1-8 are schematic views of an uncrewed node deployment system deploying nodes according to a first node deployment method according to some embodiments;

[0011] Figure 9 is a schematic view of the uncrewed node deployment system of Figures 1-9 deploying nodes according to a second node deployment method according to some embodiments;

[0012] Figure 10 is a schematic views of another uncrewed node deployment system according to some embodiments;

[0013] Figure 11 is a schematic view of another uncrewed node deployment system according to some embodiments;

CLAIMS

1. An offshore node deployment system, comprising:

a control system;

a surface vessel comprising a deck, and a propulsion system in signal communication with the control system;

a node storage container supported by the deck of the surface vessel, wherein the node storage container is configured to store a plurality of nodes which are physically disconnected from each other at least partially within an interior of the node storage container; and

a node deployment system supported by the deck of the surface vessel and controllable by the control system, wherein the node deployment system is configured to retrieve the nodes from the interior of the node storage container, transport the nodes external the interior of the node storage container, and deploy the nodes from the surface vessel to a target subsea location;

wherein the control system comprises one or more processors and one or more memory devices containing instructions that, when executed by the one or more processors, cause the one or more processors to:

autonomously operate the propulsion system to transport the surface vessel to a target offshore location at which the plurality of nodes are to be deployed based on directions contained in an operational plan stored in the one or more memory devices;

autonomously direct the node deployment system to retrieve the nodes from the from the interior of the node storage container, transport the nodes external the interior of the node storage container, and deploy the nodes from the surface vessel to the target subsea location based on the directions contained in the operational plan.

2. The system of claim 1, wherein the surface vessel comprises a seismic source configured to emit an acoustic signal and the nodes comprise sensor nodes each configured to receive the acoustic signal.

3. The system of claim 1, wherein the control system comprises a controller configured to control the node deployment system and a wireless communication system configured to receive signals from a remote pilot of the surface vessel for controlling the propulsion system and the node deployment system.

4. The system of claim 1, wherein the node deployment system comprises:

a node transportation system supported by the deck of the surface vessel and configured to deposit the nodes received from the node storage container into a submersible node deployment container;

a container deployment system supported by the deck of the surface vessel and configured to transport the node deployment container from the deck of the surface vessel to the target subsea location; and

a remotely operated underwater vehicle (ROV) supported by the deck of the surface vessel and configured to retrieve the nodes from the node deployment container.

5. The system of claim 4, wherein:

the node transportation system comprises a robotic arm configured to retrieve the nodes from the node storage container and a conveyor configured to transport the nodes retrieved by the robotic arm.

6. The system of claim 5, wherein the container deployment system comprises a lifting crane configured to lift the node deployment container from the deck of the surface vessel.

7. The system of claim 1, wherein the node deployment system is configured to retrieve an individual node from the node storage container and deploy the individual node to the target subsea location.

8. The system of claim 1, wherein at least a portion of the control system is not positioned on the surface vessel.

9. The system of claim 1, wherein the node storage container comprises a node transporter configured to transport at least one of the plurality of nodes from a storage position within the node storage container to an exit position.

10. The system of claim 9, wherein the exit position is located at a position beyond an outer periphery of the deck of the surface vessel.

11. The system of claim 9, wherein the node transporter comprises a conveyor having a ramp extendable below a waterline.

12. An offshore node deployment system, comprising:

a control system;

a surface vessel comprising a deck, and a propulsion system in signal communication with the control system;

a node storage container supported by the deck of the surface vessel, wherein the node storage container is configured to store a plurality of nodes at least partially within an interior of the node storage container; and

a node deployment system supported by the deck of the surface vessel and controllable by the control system, wherein the node deployment system is configured to retrieve an individual node from the interior of the node storage container, transport the node external the interior of the node storage container, and deploy the node from the surface vessel to a target subsea location;

wherein the control system comprises one or more processors and one or more memory devices containing instructions that, when executed by the one or more processors, cause the one or more processors to:

autonomously operate the propulsion system to transport the surface vessel to a target offshore location at which the node is to be deployed based on directions contained in an operational plan stored in the one or more memory devices;

autonomously direct the node deployment system to retrieve the node from the interior of the node storage container, transport the node external the

interior of the node storage container, and deploy the node from the surface vessel to the target subsea location based on the directions contained in the operational plan.

13. The system of claim 12, wherein the surface vessel comprises a seismic source configured to emit an acoustic signal and the plurality of nodes comprise sensor nodes each configured to receive the acoustic signal.

14. The system of claim 12, wherein the surface vessel comprises a modular surface vessel comprising a plurality of separable and releasably coupled modules including a propulsion module comprising the propulsion system, and a first node deployment module comprising the node deployment system.

15. The system of claim 14, wherein the surface vessel comprises a second node deployment module comprising another node deployment system.

16. The system of claim 12, wherein the node deployment system comprises:

a node transportation system supported by the deck of the surface vessel and configured to deposit the node received from the node storage container into a submersible node deployment container;

a container deployment system supported by the deck of the surface vessel and configured to transport the node deployment container from the deck of the surface vessel to the target subsea location; and

a remotely operated underwater vehicle (ROV) system supported by the deck of the surface vessel and configured to retrieve the node from the node deployment container.

17. The system of claim 16, wherein the node transportation system comprises a robotic arm configured to retrieve the node from the node storage container and a conveyor configured to transport the node retrieved by the robotic arm.

18. The system of claim 17, wherein the container deployment system comprises a lifting crane configured to lift the node deployment container from the deck of the surface vessel.

19. The system of claim 12, wherein the node storage container is configured to store the plurality of nodes such that the plurality of nodes are free to move independently relative each other.

20. The system of claim 12, wherein at least a portion of the control system is not positioned on the surface vessel.

21. The system of claim 12, wherein the node storage container comprises a node transporter configured to transport the node from a storage position within the node storage container to an exit position.

22. The system of claim 21, wherein the exit position is located at a position beyond an outer periphery of the deck of the surface vessel.

23. The system of claim 21, wherein the node transporter comprises a conveyor having a ramp extendable below a waterline.

24. A method for deploying a plurality of nodes offshore, comprising:

(a) autonomously transporting by a control system a surface vessel to a target offshore location at which the plurality of nodes are to be deployed based on directions contained in an operational plan stored in one or more memory devices of the control system, wherein a node storage container is supported by a deck of the surface vessel, the node storage container comprises the plurality of nodes which are physically disconnected from each other and at least partially received within an interior of the node storage container;

(b) autonomously retrieving by the control system and, based on the directions contained in the operational plan, the nodes from the interior of the node

storage container and transporting the nodes external the interior of the node storage container using a node deployment system supported by the deck of the surface vessel; and

(c) autonomously deploying by the control system and, based on the directions contained in the operational plan, the nodes from the surface vessel to a subsea location using the node deployment system.

25. The method of claim 24, wherein (a) comprises remotely piloting the surface vessel via a control system of the surface vessel from a remote location.

26. The method of claim 24, wherein (b) comprises retrieving the nodes individually from the node storage container and (c) comprises deploying the nodes individually to the target subsea location.

27. The method of claim 26 wherein:

(b) comprises:

(b1) retrieving the nodes individually from the node storage container using a robotic arm supported by the deck of the surface vessel; and

(b2) transporting the nodes retrieved from the node storage container using a conveyor whereby the nodes are deposited into a node deployment container;

(c) comprises:

(c1) lifting the node deployment container from the deck of the surface vessel using a lifting crane and lowering the node deployment container towards a seabed using a tether; and

(c2) retrieving the nodes individually from the node deployment container using a remotely operated underwater vehicle (ROV).

28. The method of claim 24, wherein (c) comprises transporting the nodes from the node storage container to an exit position that is spaced from the node storage container.