United States Patent Application Publication	20250264006
Kind Code	A1
Publication Date	August 21, 2025
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Untethered And Autonomous Well Intervention Vehicle

Abstract

A system for automatic well intervention in a wellbore that includes a robotic tool assembly, and a plurality of subassemblies stored at or within the robotic tool assembly, where the robotic tool assembly is configured to assemble a downhole tool from the plurality of subassemblies, and where a subassembly, of the plurality of subassemblies, includes an energy storage subsystem configured to provide power to the downhole tool.

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Appl. No.: **19/189872**

Filed: **April 25, 2025**

Related U.S. Application Data

parent US continuation 18423036 20240125 parent-grant-document US 12312919 child US 19189872
us-provisional-application US 63496338 20230414

Publication Classification

Int. Cl.: **E21B43/013** (20060101); **E21B41/00** (20060101); **E21B47/12** (20120101)

U.S. Cl.:

CPC **E21B43/013** (20130101); **E21B41/0007** (20130101); **E21B47/12** (20130101);

Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] The present application is a nonprovisional application claiming priority to: [0002] i. U.S. Provisional Patent Application 63/496,338 (filed Apr. 14, 2023); and [0003] ii. U.S. Nonprovisional patent application Ser. No. 18/423,036 (filed Jan. 25, 2024). The entirety of each of the above applications is incorporated by reference.

BACKGROUND
[0004] Boreholes drilled into subterranean formations may enable recovery of desirable fluids (e.g., hydrocarbons), or geological storage of other fluids (e.g., carbon dioxide), using a number of different techniques. Boreholes drilled on land and/or the sea-floor may rely on extensive infrastructure. Generally, operations and services are performed while tethered to infrastructure.
[0005] There is a need for un-tethered autonomous robots to execute well intervention services that do not need additional infrastructure like wireline/coil tubing winches, rigging equipment, ships/boats for deep sea wells or shutting off producing wells.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0006] These drawings illustrate certain aspects of some examples of the present disclosure and should not be used to limit or define the disclosure.
[0007] FIG. **1**A illustrates a schematic diagram of an example of a well system in a subsea environment, in accordance with one or more embodiments of the present disclosure.
[0008] FIG. **1**B illustrates a schematic diagram of an example of a well system in a subsea environment, in accordance with one or more embodiments of the present disclosure.
[0009] FIG. **2** illustrates a schematic diagram of an example of a subsea tree and a robotic tool assembly, in accordance with one or more embodiments of the present disclosure.
[0010] FIG. **3**A illustrates a schematic diagram of another example of a subsea tree and a robotic tool assembly in a subsea environment during assembly of a downhole tool, in accordance with one or more embodiments of the present disclosure.
[0011] FIG. **3**B illustrates a schematic diagram of the example subsea tree and robotic tool assembly of FIG. **3**A during deployment of the downhole tool in a wellbore, in accordance with one or more embodiments of the present disclosure.
[0012] FIG. **4**A illustrates a schematic diagram of a semi-transparent view of an example slotted housing configured to receive subassemblies, in accordance with one or more embodiments of the present disclosure.
[0013] FIG. **4**B illustrates a schematic diagram of a partially transparent top-down view of the example slotted housing of FIG. **4**A, in accordance with one or more embodiments of the present disclosure.
[0014] FIG. **4**C illustrates a schematic diagram of a partially transparent perspective view of the example slotted housing of FIGS. **4**A and **4**B, with the downhole tool omitted for clarity, in accordance with one or more embodiments of the present disclosure.
[0015] FIG. **5** illustrates an example of a subsea tree and a robotic tool assembly, in accordance with one or more embodiments of the present disclosure.

[0016] FIG. **6** illustrates an example of an underwater autonomous vehicle for delivering or extracting subassemblies to a robotic tool assembly, in accordance with one or more embodiments of the present disclosure.
[0017] FIG. **7** illustrates an example of a downhole tool deployed in a wellbore from a subsea tree and robotic tool assembly, in accordance with one or more embodiments of the present disclosure.

DETAILED DESCRIPTION

[0018] The present disclosure relates generally to a system and method for autonomous infrastructure that may operate and function apart and untethered from traditional infrastructure. For example, various subassemblies of different downhole tools may be disposed in storage silos that may be assembled and then run into a particular wellbore through an automated assembly. The automated assembly may be a robotic tool assembly that may rotate different subassemblies into an assembly area to assemble different tools, e.g., downhole tool, configured for the desired task. Once assembled, the downhole tool(s) may be run into the wellbore to perform the desired task. Subsequently, downhole tools may be recalled or retrieved (e.g., via wireline or tractor) and disassembled into their respective subassemblies or groups of modules and returned to their respective storage silos in the robotic tool assembly. Modules in need of replacement may be rotated into deployment silos configured to exchange subassemblies. Such autonomous infrastructure may quickly assemble a needed configuration while reducing the amount of infrastructure needed to run the downhole tool into a wellbore. A downhole tool formed by the robotic tool assembly may be, without limitation, a wireline tool, bottomhole assembly, untethered robot, or the like.

FIGS. **1**A and **1**B

[0019] FIGS. **1**A and **1**B illustrate schematic diagrams of an example of a well system **100** that may employ the principles of the present disclosure. M ore particularly, well system **100** may comprise a floating vessel **102** centered over a subterranean hydrocarbon bearing formation **104** located below a sea-floor **106**. A s illustrated, floating vessel **102** is depicted as an offshore, semi-submersible oil and gas drilling platform, but could alternatively comprise any other type of floating vessel such as, but not limited to, a drill ship, a pipe-laying ship, a tension-leg platforms (TLPs), a spar platform, a production platform, a floating production, storage, and offloading (FPSO) vessel, a floating production unit (FPU), and/or the like. Additionally, and without loss of generality, the methods and systems described below may also be utilized for subsea tiebacks to a fixed offshore platform, an onshore facility, or a facility on an artificial island. Moreover, the systems and methods of the present disclosure are applicable to onshore reservoirs and related facilities. A subsea conduit or riser **108** extends from a deck **110** of floating vessel **102** to sea-floor **106** and may connect to a production manifold **112**. As illustrated, static pipe **114** may run from production manifold **112** to a pipeline end termination **116**. Flexible pipe **118** may attach a subsea tree **120** to pipeline end termination **116**. In examples, flexible pipe **118** may traverse from production manifold **112** and connect directly to subsea tree **120**. Additionally, flexible pipe **118** may connect one subsea tree **120** to another subsea tree **120**, effectively tying one or more subsea trees **120** together and allowing for a single flexible pipe **118** to connect one or more subsea trees **120** to a single production manifold **112**.
[0020] Subsea tree **120** may cap a wellbore **122** that has been drilled into formation **104**. Within wellbore may be a completion system comprising of one or more tubulars **124** that are connected to subsea tree **120**. During operations, formation fluids may be produced from formation **104**, and flow through one or more tubulars **124** to subsea tree **120**. As subsea tree **120** is attached to floating vessel **102**, formation fluid may flow from subsea tree **120**, through flexible pipe **118**, pipeline end termination **116**, static pipe **114**, production manifold **112**, and up through riser **108** to floating vessel **102** for processing, storage, and subsequent offloading or export.
[0021] With continued reference to FIGS. **1**A and **1**B, well system **100** may comprise a central controller unit (CCU) **128**. CCU **128** may monitor wellbore **122** in real time. “Real-time” as used

herein refers to a system, apparatus, or method in which a set of input data is processed and available for use within 100 milliseconds (“ms”). In further examples, the input data may be processed and available for use within 90 ms, within 80 ms, within 70 ms, within 60 ms, within 50 ms, within 40 ms, within 30 ms, within 20 ms, or any ranges therebetween. In some examples, real-time may relate to a human's sense of time rather than a machine's sense of time. For example, processing which results in a virtually immediate output, as perceived by a human, may be considered real-time processing. CCU **128** may comprise one or more information handling systems **146**. Information handling system **146** may comprise any instrumentality or aggregate of instrumentalities operable to compute, estimate, classify, process, transmit, receive, retrieve, originate, switch, store, display, manifest, detect, record, reproduce, handle, or utilize any form of information, intelligence, or data for business, scientific, control, or other purposes. For example, an information handling system **146** may be a processing unit **150**, a network storage device, or any other suitable device and may vary in size, shape, performance, functionality, and price. Information handling system **146** may comprise random access memory (RAM), one or more processing resources such as a central processing unit (CPU) or hardware or software control logic, ROM, and/or other types of nonvolatile memory. Additional components of the information handling system **146** may comprise one or more disk drives, one or more network ports for communication with external devices as well as an input device **152** (e.g., keyboard, mouse, etc.) and video display **154**. Information handling system **146** may also comprise one or more buses operable to transmit communications between the various hardware components.

[0022] Alternatively, systems and methods of the present disclosure may be implemented, at least in part, with non-transitory computer-readable media **156**. Non-transitory computer-readable media **156** may comprise any instrumentality or aggregation of instrumentalities that may retain data and/or instructions for a period of time. Non-transitory computer-readable media **156** may comprises, for example, storage media such as a direct access storage device (e.g., a hard disk drive or floppy disk drive), a sequential access storage device (e.g., a tape disk drive), compact disk, CD-ROM, DVD, RAM, ROM, electrically erasable programmable read-only memory (EEPROM), and/or flash memory; as well as communications media such as wires, optical fibers, microwaves, radio waves, and other electromagnetic and/or optical carriers; and/or any combination of the foregoing.

[0023] During monitoring operation, CCU **128** may determine if an intervention operation may be performed. In examples, an intervention operation may be valve shifting, brushing, bailing, milling or routine pressure balancing. In other examples, a user at surface **103**, may send a command to perform the intervention operation to a sea bed server **138** from information handling system **146**. This command may be sent via a telemetry mechanism **134** between surface and sea bed server **138**. Telemetry mechanism **134** may comprise, for example, compression wave telemetry, a fiber optic cable, a radio signal, or any suitable signal, wired, or equivalent form of telemetry known in the art. Sea bed server **138** may request a robotic tool assembly **178**, disposed on subsea tree **120**, to assemble a downhole tool. As used herein, a “robotic tool assembly” refers to a system, disposed at the sea floor, which is capable of forming at least one downhole tool from a plurality of submodules. In general, robotic tool assembly **178** comprises moving parts which are configured to move the submodules during assembly and/or disassembly of the at least one downhole tool.

FIG. **2**

[0024] FIG. **2** illustrates a schematic diagram of a robotic tool assembly **178**, which may be utilized to form a downhole tool **174**. Robotic tool assembly generally comprises subsea housing **179** disposed on a subsea tree **120** and contains equipment for assembling and disassembling downhole tool **174**. In this figure, such equipment comprises first and second robotic arms **192**, **193**, however may comprise alternative means for assembling or disassembling downhole tool **174** (e.g., pistons, rollers, conveyors, grippers, linear tracks, pulleys, etc.). In general, however, robotic tool assembly **178** is characterized as a “self-contained” system due to its ability to assemble and disassemble downhole tool **174** from a plurality of subassemblies **172** within an assembly space schematically shown at **203** that is disposed within an internal region **197** of a housing **179** of robotic tool assembly **178**. In addition, robotic tool assembly **178** may be characterized as autonomous, in some examples. As used herein, “autonomous” in this context refers to operations for forming a downhole tool based on computer calculation. In other examples, robotic tool assembly **178** may be characterized as directed. As used herein, “directed” in this context refers to operations for forming a downhole tool based on input by a user. In other examples, robotic tool assembly **178** may be characterized as a hybrid, having both autonomous and directed components. Similarly, such may be characterized as automated, or else semi-automated. As used herein, “automated” refers to a process or subpart thereof which is performed entirely without any user input. In examples, robotic tool assembly **178** or one or more subcomponents thereof may be automated such that assembly and/or disassembly of a downhole tool is achieved entirely free, or essentially free, from human input. In some examples, a type or types of procedure common to all downhole tools which may be formed by robotic tool assembly **178** may be performed autonomously, while another type or types of procedure specific to a downhole tool may be directed by user input, in some examples.

[0025] Also visible in this figure are the various subassemblies **172** disposed at their respective storage locations **194**. Subassemblies **172** are modules used to form any given downhole tool **174** of a plurality of types of downhole tools, for example, any of the well intervention, logging, or other downhole tools disclosed herein, which may be tethered or untethered. As used herein, “tethered” refers to a spooled connection between the surface (e.g., seabed or sea level) and a tool, and “untethered” refers to a lack of any spooled connection between the surface and a tool. For example, a tether may be a wireline, slickline, or cabled connection.

[0026] Storage locations **194** are schematically shown as a dotted circle to show their location within housing **179** but may comprise any suitable device or apparatus for compartmentalizing, storing, or otherwise housing subassemblies **172** at locations retrievable by the assembling/disassembling equipment of robotic tool assembly **178**. Optionally, such storage locations **194** may be accessible from subsea environment **232**, such as via slot(s) **173**.

[0027] Slot(s) **173** may be open to subsea environment **232**, or alternatively, may be configured to switch between sealed/unsealed configurations. In examples, this may involve one or more sealing devices, (e.g., sliding doors, hatch, etc.), which may allow robotic tool assembly **178** to seal off internal region **197** from subsea environment **232**, such as in embodiments where it is desirable to pressurize internal region to a wellbore pressure prior to opening or closing well access **230**. The purpose of slot(s) **173** is to allow a UAV (e.g., UAV **160** of FIG. **6**) to resupply robotic tool assembly **178** with subassemblies **172**, replacement batteries, etc., while minimizing the internal region's exposure to the subsea environment **232**. In examples, each slot **173** may be configured to receive a single, or a plurality of, subassemblies **172**. If a slot **173** is adapted to receive more than one subassembly **172**, they may be the same type of subassembly **172**, such as an anchor module, or a bailing module, etc.

[0028] In operation, robotic tool assembly **178** may identify and locate all subassemblies **172** that may form downhole tool **174**. Prior to assembly, the different subassemblies **172** may be housed by robotic tool assembly **178**, as mentioned. In examples, robotic tool assembly **178** may be equipped to retrieve subassemblies **172** from their respective storage locations **194** in order to make up the downhole tool **174** based on pre-determined instructions specific to a type of downhole tool **174**. Storage locations **194** may comprise any suitable type of containment unit (e.g., silo, cubby, plain surface, compartment, dock, etc.) for holding one or more subassemblies **172**. In examples, robotic tool assembly **178** may place all subassemblies **172** for a certain type of downhole tool in a selected order and stack each subassembly on top of each other within an assembly space **203** of robotic tool assembly **178**. The assembly space **203** may comprise a direct well access (e.g., direct well access **202** of FIG. **3**A) or an indirect well access (e.g., indirect well access **200** of FIG. **3**A). As used herein, a “direct well access” refers to a space or region within subsea housing **179** directly above subsea tree **120** for accessing wellbore **122**, whereas an “indirect well access” refers to a space or region within subsea housing **179** which is near or proximate to (e.g., adjacent), a direct well access.

[0029] Identification of subassemblies may involve, to use non-limiting examples, sensing of a magnetic ID tag, RFID tag, bar code, identifier, or the like. In addition, or alternatively, robotic tool assembly **178** may identify subassemblies **172** based on their placement within a storage location **194**, which information may be stored on memory of robotic tool assembly **178**. In essence, identification of subassemblies **172** allows robotic tool assembly **178** to retrieve the appropriate subassembly in order to assemble the correct downhole tool **174** to perform a pre-specified operation within wellbore **122**.

[0030] As alluded to above, equipment for assembling and disassembling downhole tool **174** may include, to use non-limiting examples, robotic arms **192**, **193**, pistons, sprockets, belts, chains, hydraulic flow lines, conveyors, a power source, control electronics, housings, pulleys, fasteners, rotors, motors, connectors, cables, sensors, valves, transmitters, combinations thereof, or the like. The specific mechanisms used to form downhole tool **174** are diverse and should not be limited to the examples shown and described in the figures. However, in general, assembly of downhole tool **174** comprises connecting two or more subassemblies **172** together. The process for connecting subassemblies may be performed iteratively for multiple subassemblies **172** until a complete downhole tool **174** is built. Accordingly, downhole tool **174** may comprise any suitable number of subassemblies **172**, for example, between 2 and 25, or any ranges therebetween.

[0031] Generally, each subassembly **172** may be wet connection compatible and latch into each subassembly **172** or unlatch for disassembly. In other examples, each subassembly **172** may be threaded with an auto make up/break out machine. Connections between subassemblies **172** may comprise, to use non-limiting examples, spun-in (e.g., threaded) connections, pressed-in connections, combinations thereof, or the like. Such connections may be a single universal coupling, which may allow for ergonomic assembly, in some examples. “Universal coupling” in this context refers to identical or substantially identical connections between the various combinations of subassemblies **172**, which streamlines the assembly process despite differences in structure or functions of a particular subassembly **172**. In examples, connecting the two or more subassemblies **172** together may involve pushing subassemblies **172** together by applying opposite force axially and/or differentially to respective tubular bodies of subassemblies **172**.

[0032] In one example, first robotic arm **192** may secure a subassembly **172** within an assembly space **203** and a second robotic arm **193** may secure a different subassembly **172**. The two subassemblies **172** may then be positioned one on top the other within assembly space **203**. One or more members (e.g., grippers **184**) of robotic arms **192**, **193** may then be hydraulically actuated to force, twist, or otherwise compress the two subassemblies **172** together. In this example, robotic arms **192**, **193** may be structurally formed as part of or otherwise securely attached to housing **179**, such as to a base connected to a wall, floor, or other structure disposed within housing **179**, as illustrated. Further, robotic arms **192**, **193** may be configured to retrieve or place batteries **175** to and from charging station **186**, for placement into or removal from ports **177** of individual subassemblies **172**. Only two robotic arms **192**, **193**, are shown in this figure, however, robotic tool assembly **178** may comprise a single robotic arm, more than two (e.g., 3, 4, 5, etc.) robotic arms, or no robotic arms, in some examples.

[0033] As illustrated, a vertical lubricator **170** may be disposed above subsea housing **179**. Vertical lubricator **170** may be utilized to form and build downhole tool **174**. For example, during assembly of downhole tool **174**, which may comprise a tool string, subassemblies may be added from the bottom with a cable head/wireline or other deployment device(s) **182** pulling downhole tool **174** high into vertical lubricator **170** as subassemblies **172** are added to downhole tool **174**.

[0034] While building downhole tool **174**, bottom valve **166** may be closed and top valve **176** may be open. This may allow access to robotic tool assembly **178** while keeping wellbore **122** separate, as will be discussed in greater detail (e.g., with reference to connection well **123** of FIG. **5**). Building downhole tool **174** may comprise robotic tool assembly **178** selecting one or more subassemblies **172** and placing each subassembly **172** in a proper order. Subassemblies **172** that operate at the bottom of downhole tool **174** may be placed first within assembly space **203** of robotic tool assembly **178**. Additional subassemblies may then be stacked and connected to each other until all subassemblies **172** have formed a downhole tool **174** that is created for an intended downhole operation within wellbore **122**. In examples, the top-most subassembly **172** of downhole tool **174** may comprise telemetry for communication while operating as well as rechargeable batteries for downhole power. Downhole tool **174** may be characterized as self-powered, surface-powered, or a combination. A s used herein, "self-powered" refers to electrical power that is delivered without any tethered connection. For example, a downhole tool **174** may be a self-powered tool, e.g., with batteries. A s used herein, "surface-powered" refers to electrical power that is delivered via a tethered connection. For example, a wireline could be surface-powered. A "surface" in this context may refer to either a surface at the sea-floor and/or a surface at sea level. Downhole tool **174**, robotic tool assembly **178**, or both may be characterized, in some examples, as self-powered, surface-powered, or a hybrid thereof. For example, the amount of power used by robotic tool assembly **178** and/or downhole tool **174** may originate directly from a surface in an amount from about 0% to about 30%, about 30% to about 60%, about 60% to about 100%, or any ranges therebetween.

[0035] Thus, downhole tool **174** may be assembled within assembly space **203** of robotic tool assembly **178**. Following assembly, robotic tool assembly **178** may then deploy downhole tool **174** into wellbore **122**. In this example shown, this may involve conveying downhole tool **174** on a wireline or cable through a well access **230**, a passageway **240** extending through subsea tree **120**, and optionally, through another portal (e.g., hatch, door, etc.) to enter wellbore **122**. In examples, valves **166**, **176** may be used to equalize pressure across portals, to be discussed in greater detail in later figures. In this figure, well access **230** is functionally coupled to a servomotor **212** operable to open and close well access **230** when pressure thereacross is equalized. Once downhole tool **174** is ready to be deployed, for example, top valve **176** may close and/or bottom valve **166** may open, and deployment device(s) **182** lowers downhole tool **174** into wellbore **122**. In some examples, deployment device(s) **182** may lower downhole tool **174** to a launching area whereupon downhole tool **174** may be released or reattached to another tether, and then launched to perform a downhole operation in wellbore **122**.

[0036] Once deployed, downhole tool **174** may traverse wellbore **122** to any depth and perform the desired wellbore operation. As mentioned previously, intervention operations may include, without limitation, milling, valve shifting, brushing, bailing, routine pressure balancing. Others may include casing inspections, logging (e.g., acoustic, electromagnetic, nuclear magnetic resonance, gamma ray, etc.) or other wellbore measurement operations (e.g., fluid sampling). Traversal of wellbore **122** by downhole tool **174** may be performed on a conveyance, such as a wireline, or may be performed autonomously by downhole tool **174**, such as when the downhole tool **174** is an untethered robot. In untethered examples, the downhole tool **174** may navigate wellbore **122** autonomously or semi-autonomously, and thus may be equipped with traction capabilities, propulsion, flow-assisted conveyance systems, buoyancy control systems, intervention equipment, and/or other subsystems for navigating and operating within the wellbore, to be discussed later in greater detail.

[0037] During operations with downhole tool **174** in wellbore **122**, sea bed server **138** (e.g., referring to FIGS. **1**A, **1**B) may monitor operations to determine the effectiveness of an operation and if the operation has concluded. Accordingly, downhole tool **174** may communicate with sea bed server **138** (e.g., referring to FIGS. **1**A, **1**B), for example, via an intermediate communication device housed at robotic tool assembly **178**. In other examples, however, downhole tool **174** does not communicate with sea bed server **138** or robotic tool assembly **178** but stores operational data on memory which is downloaded upon docking (e.g., docking station **186** of FIG. **7**) or after retrieval and/or reuptake of downhole tool **174** into robotic tool assembly **178**. Such data may then be conveyed to sea bed server **138** after download. Once an operation has concluded, sea bed server **138** (e.g., again referring to FIGS. **1**A, **1**B) may instruct robotic tool assembly **178** to retract downhole tool **174** from wellbore **122**. In other examples, downhole tool **174** may operate primarily based on a job plan without needing to wait for instructions from sea bed server **138**. For example, where the downhole tool **174** is untethered, rather than instructing robotic tool assembly **178** to retract downhole tool **174**, a signal may be relayed to downhole tool **174** to cause it to autonomously return to robotic tool assembly **178**, such as by using an internal navigational subsystem. This may involve activating traction devices/mechanisms (e.g., rollers), deploying a sail, opening a chute, using a buoyancy control system to change its buoyancy, activating hydraulic or mechanical propulsion, engaging steering mechanisms, combinations thereof, or the like, of downhole tool **174**, to be discussed in greater detail later.

[0038] As the operation is ongoing or at the end, CCU **128** may use telemetry mechanism **134** (e.g., referring to FIGS. **1**A, **1**B) to communicate and monitor downhole tool **174**. Telemetry mechanism **134** may relay information of operation, well status as well as request any additional assets needed within robotic tool assembly **178** to further and/or complete any operation designated for downhole tool **174**. Such additional assets may include, for example, replacement batteries, replacement subassemblies, replacement cleaner fluid, etc., to be delivered to robotic tool assembly **178**. For example, telemetry mechanism **134** (e.g., referring to FIGS. **1**A, **1**B) may be used to request replacement subassemblies or batteries from the surface. Telemetry mechanism **134** may comprise one or more devices that work together to move information and data from downhole tool **174** to a user on surface **103**. For example, downhole tool **174** may comprise a subassembly **172** that may house communication equipment to communicate with surface computers. This communication equipment may include equipment to interface with a telemetry system based on sonar or telemetry over cable. Information handling system **146** (e.g., also referring to FIGS. **1**A, **1**B) within CCU **128** may send information on the job plan to be executed by one or more robots, tools to be assembled/disassembled, and additional tools and/or subassemblies dispatched from surface **103** to robotic tool assembly **178**. Robotic tool assembly **178** may send information to surface **103** related to a robot location, robot operation log, health, tool storage information, assembly/disassembly status, power delivery system status, tool health, tools needed, completion equipment health and operation logs etc.

[0039] In examples, downhole tool **174** may comprise a subassembly **172** that may further monitor the pressure in wellbore **122** via a pressure sensor. Where used, such a pressure sensor may be utilized to measure modulated pressure pulses that may originate from downhole tool **174**. These pulses, which may be sensed by pressure sensor in these examples, may be digitized by a CCU **128** in telemetry mechanism **134** and then demodulated and sent in real-time from downhole tool **174** to robotic tool assembly **178**. The information sent may comprise information and data as to the operational and health log of downhole tool **174**. In other examples, subassembly **172** may further comprise a flow sensor that may monitor the flow rate of mud within wellbore **122**. Thus, flow sensor may monitor modulated flow pulses originating from downhole tool **174**, in some examples. As before, these pulses may be digitized in a controller and then demodulated to get the information sent in real-time from downhole tool **174** to robotic tool assembly **178**. The information sent may comprise information and data as to the operational and health log of downhole tool **174**.

[0040] Subassembly **172**, which may comprise a telemetry mechanism, may further comprise a house modulator/demodulator unit(s) to communicate with downhole completion equipment via wired-pipe telemetry. This telemetry system will bring information from the sensors embedded with the downhole completion equipment. Along with the sensor data, downhole completion equipment will wirelessly communicate with downhole tool **174** when it is in proximity to the downhole completion equipment. Completion equipment may then transfer data downloaded from downhole tool **174** to CCU **128** on the surface via this wired-pipe telemetry. The data transmitted from downhole tool **174** may further comprise information and data as to the operational and health log of downhole tool **174**.

[0041] Following wellbore operations, robotic tool assembly **178** may disassemble and clean downhole tool **174**. Disassembly of downhole tool **174** may be performed using the same, or different, equipment used to assemble the downhole tool **174**. For example, robotic tool assembly **178** may comprise separate systems, one for assembly and another for disassembly, which may be housed in separate regions of robotic tool assembly **178**.

[0042] Cleaning may involve, for example, treating the downhole tool **174** or one or more subassemblies **172** thereof with cleaning equipment, which may be disposed inside or outside housing **179**. In the illustrated example, cleaning equipment comprises a retrievable tank **204** coupled to a nozzle **169** disposed on robotic arm **192** by a flexible conduit **206**. Alternatively, or additionally, however, cleaning equipment may comprise a series of wipers, cleaners, brushes, sprayers, or any other mechanical or chemical means of removing wellbore fluids from the external surfaces of the downhole tool **174**. Cleaning may be performed before, during, and/or after disassembly within or at robotic tool assembly **178**, and may involve pressurizing cleaning fluid (e.g., seawater, cleaning agents, cleaner fluid, etc.) with a pump. Following disassembly of one type of downhole tool **174** following a wellbore operation, a given subassembly **172** may be reused to assemble the same type, or another type, of downhole tool **174** and used to perform one or more additional operations. In other examples, downhole tool **174** may be reused in a second wellbore operation without disassembly or following partial disassembly/reassembly.

[0043] In examples, robotic tool assembly **178** may also remove batteries **175** from ports **177** of subassemblies **172** or downhole tool **174** and place batteries **175** in a charging station **186**. If, for example, the intervention operation is not completed or a second intervention operation is selected, downhole tool **174** may be connected to a second battery or plurality of batteries that may be fully charged to perform a second operation. As illustrated, batteries **175** be configured to interface, e.g., dock, to a corresponding port **177** of a given subassembly **172**. Removal and/or placement of batteries in port **177** may be performed using the same, or different, equipment used to assemble and/or disassemble downhole tool **174**.

[0044] Other methods of assembling and disassembling downhole tool **174** with robotic tool assembly **178** may involve, without limitation, making connections between subassemblies by utilizing a slotted housing (e.g., slotted housing **210** of FIGS. **3**A, **3**B, **4**A, **4**B, **4**C). In examples, at least a portion of a slotted housing is positioned in robotic tool assembly **178**, which may hold and/or prepare a subassembly **172** to be connected as a part of downhole tool **174**. In further examples, a slotted housing may be rotated by command or controller instructions from an information handling system **146** and/or bed server **138** to select a desired subassembly module slot.

FIGS. **3**A and **3**B

[0045] Accordingly, FIGS. **3**A and **3**B show schematic diagrams of another example of a robotic tool assembly **178** in accordance with some examples of the present disclosure. It should be understood that there may be crossover between the principles taught herein with respect to the examples shown in FIG. **2** and FIGS. **3**A and **3**B. Namely, while not shown in FIG. **2**, certain features of FIGS. **3**A and **3**B may be implemented in FIG. **2**, and vice versa, without departing from the scope and spirit of the disclosure. However, in this example, robotic tool assembly **178** comprises a slotted housing **210**. FIG. **3**A schematically shows one such example of a slotted housing **210** system during assembling of downhole tool **174** within a slotted housing **210** disposed within subsea housing **179**.

[0046] With more specific reference to FIG. **3**A, robotic tool assembly **178** may comprise a slotted housing **210** which may be removably or non-removably attached to a shaft **234** connected to a drive **220** in this example. During assembly of downhole tool **174**, drive **220** may impart rotational and/or vertical movement to the shaft **234**, schematically indicated at lines **222** and **224**, respectively, which may be in turn conveyed to slotted housing **210**. This may involve, for example, conveying hydraulic pressure to the shaft **234**. Other designs are possible to impart rotation and/or vertical movement of slotted housing **210** without a shaft. In this example, however, drive **220** comprises one or more motors **216**, which are disposed within a housing **218** disposed within subsea housing **179** of the robotic tool assembly **178**. A controller **215** may control the drive **220**. In examples, drive **220** may be configured to actuate the shaft **234** rotationally and/or linearly in accordance with instructions, for example, from sea bed server **138** to construct a particular type of downhole tool. Such instructions to construct or disassemble downhole tool **174** may also result in the appropriate subassemblies **172** being transferred to/away from their respective storage locations **194** and conveyed, e.g., via one or more conveyance devices **196**, to and/or from slotted housing **210**. While this example shows shaft **234** as being offset from a central axis of robotic tool assembly **178**, shaft **234** may alternatively be substantially centralized within housing **210** in some examples.

[0047] Prior to assembly within slotted housing **210**, the individual subassemblies **172** may be injected into slot(s) **416** of slotted housing **210**. In examples, conveyance device(s) **196** may move a selected subassembly **172** from storage location **194** to an area proximate slotted housing **210**, at which point the same conveyance device(s) **196**, or additional injection equipment may be used to orient the selected subassembly **172** in an appropriate position such that it is received into the slotted housing **210**. Additional injection equipment may comprise, to use non-limiting examples, a piston, belt, linear track, electronic guidance, and/or other suitable mechanical means for ensuring the selected subassembly **172** is guided into the slot(s) **416** of slotted housing **210**, and which may be disposed in or form part of slotted housing **210**, in some examples. Conveyance device(s) **196** may allow, in some examples, subassemblies **172** stored in one region of slotted housing **210** to be conveyed to another region. In other examples, conveyance device(s) **196** may be configured to move a storage location **194** altogether. Without limitation, this may be achieved by moving (e.g., rotating) one or more internal and/or external structures of robotic tool assembly **178**, such as by rotating the entire housing **179** about a central axis of direct well access **202**, in some examples. In these examples, rotation of housing **179** and/or one or more internal or external structures thereof may be performed with a storage revolver. As used herein, "storage revolver" refers to a system comprising at least a motor and a power source, which transfers at least one subassembly or storage unit containing one or more subassemblies to another location relative to an assembly area such that one or more subassemblies may be retrieved from the new location and conveyed to the assembly area for autonomous make-up of a downhole tool.

[0048] In addition, slotted housing **210** may be equipped with sensors disposed proximate the slot(s) **416** to sense when robotic tool assembly **178** has delivered a subassembly **172** thereto, and motors coupled to an intake mechanism (e.g., roller, control arm, mechanical actuator, etc.) to grab the delivered subassembly and ingest it into an assembly space **203** within slotted housing **210**.

[0049] In the illustrated example, storage locations **194** are circumferentially disposed radially outwards from a central axis of direct well access **202**, with multiple subassemblies **172** being disposed in series with each other, each group (e.g., one, two, three, four, five, etc.) of subassemblies **172** being disposed between slotted housing **210** and an outer wall of housing **179** of robotic tool assembly **178**. However, geometries/configurations of subsea housing **179** and storage location(s) **194** alternative to that shown in FIGS. **2**, **3**A, **3**B are possible, to accommodate alternative packing of subassemblies **172** within robotic tool assembly **178**. A plurality of slots **173** may be disposed at the outer wall to allow an external vehicle (e.g., underwater autonomous vehicle of FIG. **5**) to stock, restock, or remove subassemblies **172** to/from storage locations **194**. For example, one or more incoming (e.g., replacement) submodules from subsea environment **232** may be dispensed from an underwater autonomous vehicle (e.g., UAV **160** of FIG. **6**) and injected into robotic tool assembly **178** via, for example, slot(s) **173**. Outgoing (e.g., used, damaged, depleted, etc.) submodules may also be ejected out from robotic tool assembly **178** via slot(s) **173**, to be recollected by the same, or another, vehicle in some examples, to be retrieved and conveyed to vessel **102** at surface **103**. Upon receipt of an incoming submodule, robotic tool assembly **178** may then convey the submodule to the correct storage location **194** within subsea housing **179** using, for example, conveyance device **196**. Conveyance device(s) **196** may comprise, without loss of any generality, a conveyor, conveyor belts, winch, linear track system, tractor arm, or suitable alternative means for transferring the correct subassembly **172** to and from the respective storage locations **194**, slotted housing **210**, and/or slot(s) **173**. Conveyance device **196** may be attached to the subsea tree **120**, subsea housing **179**, or to an internal structure disposed therein.

[0050] Once downhole tool **174** is built, robotic tool assembly **178** may actively move downhole tool **174** from indirect well access **200** to a direct well access **202**. In exemplary embodiments, this may involve removing downhole tool from the slotted housing **210** and then conveying the downhole tool **174** away from the assembly space, such as by lifting and then conveying the downhole tool **174** using, for example, linear track **208**. In the example shown, however, an attachment device **226** affixed to a body of slotted housing **210** is attached to a corresponding attachment device **228** of linear track **208** such that the entire slotted housing **210** is removed from shaft **234** and conveyed to the direct well access **202** while the downhole tool is disposed therein. Thus, one or more pulleys, a grappling mechanism, or other attachment or deployment device, wireline, spool, a robotic arm, a piston, combinations thereof, or the like, may be used to convey slotted housing **210** and/or downhole tool **174** to direct well access **202**. While the indirect well access **200** is shown as being offset from a central axis of robotic tool assembly **178**, it may alternatively be substantially centralized with respect to robotic tool assembly **178**, in some examples, e.g., disposed above direct well access **202**.

[0051] Slotted housing **210** may comprise one or more slots (e.g., slot(s) **416** of FIG. **4**A) in which one or more subassemblies (i.e., of the same type) may be injected/ejected. Such slots may be disposed laterally, e.g., radially, in the side of slotted housing **210**, to allow subassemblies **172** to be inserted from the side. Alternatively, such a slot may be disposed at the bottom of slotted housing **210**, such as in the manner shown in FIGS. **4**A, **4**B, and **4**C, to allow subassemblies **172** to be inserted from below. Y et alternatively, at the top of slotted housing **210** to be inserted from above. As illustrated, slotted housing **210** may provide an assembly space **203** for assembling downhole tool **174**. Slotted housing **210** may also comprise one or more slots in which cryogenic charging may be performed for subassemblies **172** that may utilize cooling protection for downhole operations. In examples, super cooled gas in liquid form may be injected into a cooling subassembly **172**. Such cooling gas may be liquid nitrogen for example. Additionally, subassembly **172** may then use the liquid nitrogen coolant for circulating around control electronics or other systems in downhole tool **174** to keep downhole tool **174** within operational temperature limits underhole conditions that have temperatures much higher than the temperature limits of downhole tool **174**.

[0052] Cleaning area **205** may allow for safe cleaning of well debris and chemicals, such as cuttings, liquids, asphaltenes, wax, and/or the like from subassemblies **172** to make them ready for another run. This functionality may also be integrated into a vertical lubricator (e.g., vertical lubricator **170** of FIGS. **2**, **6**, **7**), or into slotted housing **210** as well. In examples, a retrievable tank **204** where debris, used solvents, and wastes from a cleaning operation is used. This allows cleaning equipment to displace sea water, e.g., through a one-way valve, so that it may be sent to surface when desired, whereupon it may be emptied, cleaned, and then re-deployed. In the example shown, retrievable tank **204** is fluidically coupled via a flexible conduit **206** to first robotic arm **192**, which may be equipped with sprayers and/or nozzles **169** for cleaning a retrieved or disassembled downhole tool with pressurized cleaning fluid (e.g., sea water and/or cleaning agents pressurized with a pump). In some examples, fluids used to clean a retrieved or disassembled downhole tool may be kept apart from some or all of internal region **197** (e.g., direct well access **202**, assembly space **203**, indirect well access **200**, etc.) to disallow contamination of wellbore fluids, debris, etc., therefrom.

[0053] When downhole tool **174** has been assembled and is ready to be run, slotted housing **210** may be conveyed (e.g., pivoted out, moved by linear track **208**, etc.) to direct well access **202** over wellhead **121** and then latched and sealed in place for tool string deployment when well access **230** is opened. In some examples, this may involve lowering a vertical lubricator (e.g., vertical lubricator **170** of FIGS. **2**, **6**, **7**) onto wellhead **121** and/or conveying slotted housing **210** away from direct well access **202**. Conveying slotted housing **210** away from the wellhead **121** allows slotted housing **210** to continue to be accessed even as downhole operations may be occurring.

[0054] Turning now to FIG. **3**B, this figure schematically shows the slotted housing **210** system of FIG. **3**A as the downhole tool **174** is being introduced into wellbore **122** following assembly, in accordance with some examples of the present disclosure. From direct well access **202**, downhole tool **174** may be deployed into wellbore **122**. Deployment may involve, in some examples, opening a well access **230** disposed between direct well access **202** and wellbore **122**, such as by actuating servomotor **212** with electronics **214** to swing open/closed well access **230** after eliminating a pressure differential thereacross using valves **166**, **176**, for example. Opening of valves **166**, **176** may serve to pressurize or depressurize direct well access **202**, such as to match wellbore pressure or an ambient pressure at the sea-floor **106**, depending on if downhole tool **174** is entering or exiting robotic tool assembly **178**.

[0055] In examples, deployment of downhole tool **174** may involve removing downhole tool **174** from slotted housing **210** and then conveying downhole tool **174** to direct well access **202**, and then through well access **230** and passageway **240** through subsea tree **120** and wellhead **121** to access wellbore **122**. Such may involve, without limitation, conveying downhole tool **174** from slotted housing **210** to direct well access **202** using a conveyance device such as linear track **208** and/or attachment device **228**. For example, when slotted housing **210** is non-releasably attached to robotic tool assembly, deployment may be performed without removing slotted housing **210** from shaft **234** but may involve displacing downhole tool **174** from slotted housing **210** following make-up of downhole tool **174**, and then conveying the naked downhole tool **174** to direct well access **202** for deployment into wellbore **122** via a passageway **240** extending thereto.

[0056] In the example shown, however, slotted housing **210** is first removed from shaft **234** and then the entire slotted housing **210** containing downhole tool **174** is lowered to a launch area, whereupon downhole tool **174** is then conveyed away from slotted housing **210** and introduced into wellbore **122** through well access **230**. Thus, as illustrated, wireline cable **236** may extend between slotted housing **210** linear track **208** via attachment devices **226**, **228**.

[0057] In a similar example to that shown, deployment may involve assembling downhole tool **174** within slotted housing **210** at a low pressure (e.g., ambient pressure at the sea-floor **106**), sealing the slotted housing **210**, pressurizing the slotted housing **210** to a high pressure (e.g., to match or approximate a wellbore pressure of wellbore **122**), and moving the sealed, pressurized slotted housing **210** from the direct well access **202** and past well access **230**, e.g., into subsea tree **120**, connection well **123** (e.g., referring to FIG. **5**), or even into wellbore **122**, before opening the slotted housing **210** and launching the downhole tool **174** into the wellbore **122**. Such examples may involve de-attaching downhole tool **174** from slotted housing **210** and re-attaching it to another conveyance device(s) (e.g., wireline) disposed at or below wellhead **121**.

[0058] In other examples altogether, robotic tool assembly **178** may instead comprise a linear track system, which may be utilized in place of, or in addition to, slotted housing **210**. In such examples, subassemblies **172** may be shifted (e.g., with a storage revolver) horizontally under a vertical lubricator in a lubricator chamber disposed between wellhead **121** and a vertical lubricator. Subassemblies **172** may be shifted back and forth on a train to be assembled inside vertical lubricator, or in a connection well, (e.g., connection well **123** of FIG. **5**). Such examples may involve a cable and/or winch when selecting a desired subassembly to form a downhole tool. For example, an opening at the bottom of subsea housing **179** (e.g., at the top **125** of connection well **123**) would open (e.g., via valve **166**), and the deployment device(s) **182** would then lower subassembly **172** down to an assembly area **190** in the lower portion of connection well **123**. Alternately there may be a latching system that holds downhole tool **174** in place, that releases when a subassembly **172** is ready to be lowered into assembly area **190**.

FIG. **4**A

[0059] FIG. **4**A illustrates a schematic diagram of a semi-transparent view of an example slotted housing **210** configured to receive subassemblies from below, in accordance with one or more embodiments of the present disclosure. As illustrated, slotted housing **210** may comprise a housing **414** which houses a plurality of subassemblies **172** during assembly and/or disassembly of downhole tool **174**. One or more (e.g., two, three, five, or more, etc.) of slot(s) **416** may be disposed in housing **414** to permit the subassemblies **172** to be injected into and/or ejected out from slotted housing **210**. While only a single slot **416** is shown in this figure, which is shown as disposed at the bottom of the housing **414**, it should be understood that slot(s) **416** may be disposed at any suitable location including, for example, on a cylindrical body of housing **414** to allow subassemblies **172** to be injected/ejected from the side rather than from below.

[0060] As illustrated, slotted housing **210** may contain assembling/disassembling equipment **422**. Assembling equipment/disassembling equipment **422** may include diverse or types of mechanical means for gripping, moving, manipulating, pushing, twisting, conveying, suspending, and/or holding subassemblies **172** during make-up and/or disassembly of downhole tool **174**. In this example, however, equipment/disassembling equipment **422** includes a plurality of gripping members **402***a-f* operationally coupled to motors **408***a-f*, such as via telescoping members **404***a*, **404***b*. Motors **408***a-f* may be disposed on a rotatable tracks **424** vertically disposed within housing **414**, which may impart linear actuation through telescoping members **404***a*, **404***b* to gripping members **402***a-f* to frictionally engage subassemblies **172**. While this example shows three subassemblies **172**, slotted housing **210** may be configured to house any suitable number of subassemblies **172** necessary to form a complete downhole tool **174**, for example, **4**, **5**, **6**, **10**, **12**, etc., depending on the number of modules needed for a particular type of downhole tool **174**. Accordingly, more than the number of motors **408***a-f* and rotatable tracks **424** may be included than what is shown in FIG. **4**A. As illustrated, downhole tool **174** may be suspended by a cable **406** which is attached by a pulley **426** to a motor **405** in this example. Cable **406** may be used to suspend downhole tool **174**, as well as raise or lower downhole tool **174** to an appropriate position within slotted housing **210**. In other examples, assembling/disassembling equipment **422** may alternatively, or additionally, comprise other types of mechanical means for assembling and/or disassembling downhole tool **174**, for example, rollers, troughs, wheels, bearings, belts, pistons, mechanical arms, hinges, actuators, etc., which may assist and/or replace rotatable tracks **424**, cable **406**, gripping members **402***a-f*, etc., in some examples. For example, motors **408***a-f* may be configured in some examples to vertically traverse rotatable tracks **424** which may raise and lower individual subassemblies **172** and/or downhole tool **174**. Thus, motors **408***a-f* may each comprise one or more motors which may have x-axis and/or y-axis functionality, in some examples. A sensor (e.g., infrared sensor, optical sensor, or other suitable sensor, etc.) may be disposed at or near slot(s) **416** to detect if an incoming or outgoing subassembly **172** is being injected into/ejected from slotted housing **210**. Detection of a subassembly **172** at or near slot(s) **416** may trigger an assembly or disassembly process or subprocess.

FIG. **4**B

[0061] FIG. **4**B illustrates a schematic diagram of a top-down view of the example slotted housing **210** of FIG. **4**A, in accordance with one or more embodiments of the present disclosure. As illustrated, downhole tool **174** is held in place by gripping members **402** which are concentrically disposed about subassemblies **172** of which downhole tool **174** is comprised. Motors **410***a-c* are

operationally coupled to each circular track **425** to provide circumferential actuation thereto, effectively providing torque to subassemblies **172** by virtue of the frictional engagement between gripping members **402** and subassemblies **172**. In examples where the connection between subassemblies **172** is spun-in, this allows slotted housing **210** to twist a given subassembly **172** or group thereof in either a clockwise or counter-clockwise direction while exerting a counterforce normal to the rotation to another given subassembly **172** or group thereof. Such rotation may also ensure that the appropriate radial orientation of the various subassemblies **172** is achieved prior to and during makeup of downhole tool **174**. The amount of torque applied may be measured and controlled to ensure the connections between subassemblies **172** are reliable. In other examples, such as when the connections between subassemblies **172** comprises a pressed-in connection, cable **406** which is used in this example to suspend downhole tool **174** may be slackened to allow gravity to push downward on downhole tool **174** while pushing upward on a bottommost subassembly of downhole tool **174** using, for example, an upward-facing piston disposed beneath the bottommost subassembly. In other examples, motors **408***a-f* and gripping member **102***a-f* may be configured to apply the force necessary to push individual subassemblies **172** together to achieve the connection.
FIG. **4**C
[0062] FIG. **4**C illustrates a schematic diagram of a partially transparent perspective view of the example slotted housing of FIGS. **4**A and **4**B, with the downhole tool omitted for clarity, in accordance with one or more embodiments of the present disclosure. Housing **414** is also omitted for clarity, to show upper and lower circular tracks **425***a-c*, **428***a-c* connected together by rotatable tracks **424**. As illustrated, rotatable tracks **424** may extend along a length of slotted housing **210**. Each rotatable track **424** may be connected at its respective upper and lower ends to a corresponding upper circular track **425***a*, **425***b*, **425***c* and lower circular track **428***a*, **428***b*, **428***c*, respectively, as illustrated. In examples, circular tracks and rotatable tracks may be rigidly connected (e.g., welded). In this manner, differential pressure applied by motors **410***a-c* and/or **411***a-c* to upper and lower circular tracks **425***a-c* and **428***a-c*, respectively, may be transferred via rotatable tracks **424** to gripping members **402** (e.g., referring to FIGS. **4**A, **4**B) to grip each subassembly **172** during make-up of downhole tool **174**. This may allow subassemblies **172** to be rotated within slotted housing **210**, such that they may be oriented properly relative to each other before being connected to an adjacent subassembly **172** during assembly of a downhole tool **174**. In examples where the connection between subassemblies **172** is a spun-in connection, rotation of circular tracks **425***a-c* and **428***a-c* may provide the torque needed for the connection. Simultaneous actuation of upper and lower motors **410***a-c*, **411***a-c*, may ensure even rotation of rotatable tracks **424** around a central axis of slotted housing **210**, which may prevent warping due to pressure unevenly applied thereto, in some examples. However, while this example shows two sets of circular tracks disposed at either ends of rotatable tracks **424** with corresponding sets of motors **410***a-c*, **411***a-c*, other configurations are possible, such as by using only a single set of circular tracks and corresponding motors, or greater than two (e.g., **3**, **4**, **5**, **6**, etc.). For example, a single set of circular tracks may be alternatively disposed at or near a midpoint of each rotatable track.
[0063] As alluded to in FIGS. **4**A, **4**B, motors **408** may be configured to apply an inward and/or outward radial force to gripping members **402** (e.g., referring to FIGS. **4**A, **4**B), for example, by expanding or retracting telescoping members **404**. In addition, motors **408** may also provide vertical movement to downhole tool **174** or individual subassemblies thereof by raising/lowering individual subassemblies within slotted housing **210**. Thus, motors **408** may have dual functionality of providing movement in both a radial and an axial direction, in some examples. While FIGS. **4**A-**4**C show one specific type of configuration of assembling or disassembling equipment **422** within housing **414** of slotted housing **210**, it should be understood that other configurations are possible without departing from the spirit and scope of this disclosure. For example, in situations where the connection between subassemblies **172** (e.g., referring to FIGS. **4**A, **4**B) is a pressed-in connection, the force needed to push together adjacent subassemblies may be provided by, for example, a

piston, linear actuator, or the like, disposed above and/or below downhole tool **174**.

FIG. **5**

[0064] With more detailed reference to FIG. **5**, this figure illustrates an example, in which downhole tool **174** may be assembled and disassembled on sea-floor **106** by a robotic tool assembly **178** that is connected to a well access portal. The well access portal may comprise a connection well **123** which may connect to wellbore **122**, as illustrated. Connection well **123** may have open access to robotic tool assembly **178** and valving at the top **125** and bottom **127** (i.e., valve **185**) that may connect and disconnect robotic tool assembly **178** to wellbore **122**, which may be a producing well. In this figure, the valving at the top **125** and bottom **127** may serve to pressurize/depressurize connection well **123** by bringing its pressure in equilibrium with either wellbore **122**, a subsea environment (e.g., subsea environment **232** of FIGS. **2**, **3**A), or an artificial pressure (e.g., internal pressure of subsea tree **120** or robotic tool assembly **178**). In examples, this may eliminate a pressure differential across a well access (e.g., well access **230** of FIGS. **2**, **3**A, **3**B), hatch, sliding door, or other portal connecting connection well **123** to robotic tool assembly **178** and/or subsea tree **120**, or else a portal similarly disposed between connection well **123** and wellbore **122**. While only two valves are referred to herein (e.g., referring to FIGS. **2**, **3**A, **3**B), such pressurization/depressurization may be accomplished using more than two valves (e.g., three, four, five, ten, etc.) to ensure that a downhole tool assembled within robotic tool assembly **178** may traverse a passage between robotic tool assembly **178** and wellbore **122**. In examples, such pressurization/depressurization may comprise bringing the pressure of connection well **123** in equilibrium with a wellbore pressure or a subsea pressure, as mentioned, or alternatively, an artificial pressure. Where used, artificial pressure may be an internal pressure of subsea tree **120** and/or robotic tool assembly **178**, which may differ from both the ambient subsea pressure outside robotic tool assembly in some examples. For example, in embodiments where an assembly space within robotic tool assembly **178** is not in fluidic communication with the ambient subsea environment, the assembly space may be a dry, pressure-sealed environment, or even a wet, pressure-sealed environment. This may involve one or more pumps disposed within subsea housing **179** for expelling fluid (e.g., seawater, wellbore fluid, cleaner fluid, etc.) in some examples. However, the assembly space may be in fluidic and/or pressure communication with the ambient subsea environment, thereby eliminating the need for the assembly space to be pressure-sealed, in some examples. One or more additional pumps may be used to pressurize connection well **123**.

FIG. **6**

[0065] FIG. **6** illustrates a well system **100** with an underwater autonomous vehicle (UAV) **160**. Subassemblies **172** used to assemble a downhole tool **174** in robotic tool assembly **178** may be deployed to and from the surface through UAV **160**. UAVs **160** may be commanded to insert or retrieve subassembly **172** from a position in robotic tool assembly **178**, e.g., through slot(s) **173**, as previously discussed (e.g., referring to FIGS. **2**, **3**A, **3**B). While this figure shows three slots **173**, robotic tool assembly **178** may comprise any number of slots, for example, a single, a pair, or more than three (e.g., 5, 7, 10, etc.) slots. Robotic tool assembly **178** may comprise a slotted housing **210** or equivalent automated equipment to assemble/disassemble downhole tool **174**. In examples, a subassembly **172** is disposed within carrier tube **500** at vessel **102**. Carrier tube **500** is attached to UAV **160**. Carrier tube **500** may then be conveyed down to the sea-floor **106**, where either the carrier tube **500** or only the downhole tool **174** within carrier tube **500** is injected into robotic tool assembly **178**. UAV **160** may be equipped and configured to deliver a single carrier tube **500** carrying a single subassembly, multiple carrier tubes each carrying a single subassembly, a single carrier tube carrying multiple subassemblies, or multiple carrier tubes each carrying multiple subassemblies. Advantageously, this may limit the number of trips needed to supply or resupply a robotic tool assembly **178**.

[0066] As discussed, robotic tool assembly **178** may comprise slot(s) **173**. Slot(s) **173** may be external slots of a housing **179** of robotic tool assembly **178** or else may be slot(s) **416** of a slotted housing **210** (e.g., referring to FIGS. **4**A, **4**B), in some examples. For example, in one or more embodiments, housing **179** may itself be or comprise part of the body (e.g., housing **414** of FIG. **4**A) of slotted housing **210**. Essentially, slot(s) **173** allows UAV **160** to deliver one or more (e.g., a plurality) of modules (e.g., subassemblies **172** batteries, etc.) to one or more internal regions (e.g., storage locations **194** of FIGS. **2**, **3**A, **3**B) of robotic tool assembly **178**. In examples where slot(s) **173** are the same as slot(s) **416**, robotic tool assembly **178** may be simplified so that it essentially consists of a slotted housing **210** (e.g., referring to FIGS. **4**A, **4**B), or else a slotted housing **210** coupled to a vertical lubricator **170** (e.g., referring to FIG. **2**). However, any suitable robotic tool assembly **178** may be used, such as those shown and described in FIGS. **2**, **3**A, **3**B. In one or more examples, slot(s) **173** may cause one or more internal region(s) of robotic tool assembly **178** to be in fluidic and/or pressure equilibrium with a subsea environment **232** (e.g., referring to FIGS. **2**, **3**A, **3**B). It should be understood, however, that slot(s) **173** may be designed to allow exchange between UAV **160** and robotic tool assembly **178** while preventing fluidic and/or pressure communication between the subsea environment and the internal region(s).

[0067] In examples, UAV **160** may have an on-board navigation system to propel subassembly **172** to and from vessel **102**. To control precision navigation in the vicinity of well system **100**, acoustic transmitters at various locations on well system **100** may be used to help guide UAV **160** to a location. Selective acoustic transmitters may be used to help steer UAV **160** to the correct slot **173** for example. One or more acoustic transmitters may be localized next to slot **173** which may be open for final alignment for the delivery or retrieval of subassembly **172**. If the ocean currents are within acceptable limits a subsurface buoyed cable **502** with acoustic and light transmitters may be deployed to help UAV **160** follow it down to well system **100** disposed on sea-floor **106**. Acoustic and optical transmitters **506** may be located at intervals along cable **502**. Cable **502** may also contain autonomous propulsion units **504** that are used in unison to maintain cable **502** in a relatively vertical position against currents, in addition to a high load buoy lifting force to keep the line tight against the currents. Cable **502** may also be utilized for UAV **160** to attach to and slide up and down at least a portion of cable **502** to aid in guiding it to well system **100**. In other examples, however, UAV **160** may be function without any cable **502**, such as in some fully autonomous examples where UAV **160** is untethered.

[0068] UAV **160** may have sensors & navigation which may include one or more inertial measurement unit (IMU) sensors which may be a combination of precision mems gyroscopes, accelerometers, and magnetometers. Sensor measurements may be used to determine depth of UAV **160** in real time. In some examples, this information may be relayed to surface **103** in real time to inform an operator about the progress of a delivery or extraction operation, for example.

[0069] Operations performed by UAV **160** may be controlled by an internal controller (IC) subsystem. IC may comprise microcontrollers, memory, I/O processing, communication bus, etc. In examples, IC may use algorithms for autonomous operation of UAV **160**. Inputs for this algorithm may include a job plan, as well as real time feedback. Based on these inputs, an algorithm may provide commands which may allow for UAV **160** to operate and function. In examples, IC may also log runtime operational parameters in its memory.

FIG. **7**

[0070] FIG. **7** illustrates a downhole tool **174** deployed in wellbore **122**. Following deployment from robotic tool assembly, downhole tool **174** may traverse wellbore **122**. Downhole tool **174** may be deployed on a conveyance (e.g., wireline) or may navigate wellbore **122** autonomously. For example, downhole tool **174** may have treads or tires for frictionless centralization, roving, and positioning capability. As mentioned, downhole tool **174** may perform a variety of wellbore operations including, without limitation, logging, sampling, as well as various wellbore intervention operations.

[0071] In some embodiments, downhole tool **174** may utilize wired well systems for telemetry and for power. However, downhole power generation devices and wireless telemetry may allow downhole tool **174** to operate independently, without needing wired wells in some examples. As mentioned, downhole tool **174** may be deployed and utilized within wellbore **122**. To perform all necessary tasks within wellbore **122**, downhole tool **174** and its respective subassemblies **172** (e.g., referring to FIGS. **2**, **3**A, **3**B, **4**A, **4**B) may comprise of a plurality of subsystems that may be utilized to perform a plurality of operations. As discussed in greater detail below, subsystems may comprise, without limitation, a buoyancy controller, flow assisted conveyance, energy storage, untethered mode communication, docking & release, sensors & navigation, central controller unit, traction system, intervention tools, and combinations thereof.

[0072] Buoyancy of downhole tool **174** may be manipulated in a manner similar to the example described for UAV **160** (e.g., referring to FIG. **6**), except that buoyancy is controlled in a wellbore environment rather than an oceanic environment, and is therefore adapted to sink or float relative to density of wellbore fluids instead of seawater. In these examples, one or more modules of downhole tool **174** (e.g., subassembly **172**) may include a controller subsystem which may be used primarily for depth control of downhole tool **174**. In examples, one or more subassemblies of downhole tool **174** may be filled with buoyancy increasing materials such as air-filled ceramic balls or syntactic foam. During operation, buoyancy controller may intake fluid from wellbore **122**, if decent into wellbore **122** is selected and may expel fluid if ascent is selected. In one embodiment, active buoyancy control may intake/expel continuously, so floating at a depth within wellbore **122** is achieved. In another embodiment, a buoyancy controller is used to augment the motive force delivered by traction system, discussed below. Active buoyancy control may make use of a linear actuated piston, driven by motor and ball screw, for example.

[0073] During operations, a reference depth is similarly provided to the buoyancy controller, for example by CCU **128** (e.g., referring to FIGS. **1**A, **1**B), which may also be based on a pre-loaded job profile for downhole tool **174**. Actual measured depth may also be likewise provided to a buoyancy controller by a navigation subsystem of downhole tool **174**, with a buoyancy controller computing error between the reference depth and actual depth and using a PID controller to adjust a piston position, for example. Thus, the controller intakes/expels controlled amount of well fluid out of downhole tool **174** to adjust its buoyancy. In another embodiment, CCU **128** determines the desired direction of travel. Travelling deeper into wellbore **122** may result in an increase in the amount of force applied to the air chamber while traveling towards the surface results in CCU **128** may result in a decrease in the amount of force applied to the air chamber. In one or more examples, the air in the air chamber may be created downhole. For example, the air in the air chamber may be created through electrical action, or a chemical reaction, as discussed in the foregoing. When batteries in the energy storage system go below a pre-determined threshold, then all the fluid is expelled to aid with retrieval of downhole tool **174**. In one embodiment, the pressure in the air chamber is greater than the hydrostatic pressure of wellbore **122**. A motor may compress fluid housed by downhole tool **174** to increase its density for entry into and/or descent further down wellbore **122**. As with a UAV, downhole tool **174** may have a fail-safe feature such that in the event of system failure, battery loss, on-set inability to compress buoyancy fluid, or other event, expanding gas causes the buoyancy of the downhole tool **174** to increase and floats towards the sea-floor **106**. Thus, an air chamber within a subassembly of downhole tool **174** may act as a fail-safe of downhole tool **174** that automatically induces a return to robotic tool assembly **178** in the event of a failure on downhole tool **174**.

[0074] Materials used for downhole tool **174** to assist with the buoyancy may comprise light weight composites, thermoplastic composite, a filament wound assembly, dead weights, demagnetizing magnets, etc. Also, a subassembly of downhole tool **174** may have an umbrella, may be configured to deploy wipers, or may be configured to change the downhole tool's **174** diameter or else its fluid dynamic profile, for example, to a venturi shape. When batteries in the energy storage system go below a pre-determined threshold or when CCU **128** (e.g., referring to FIGS. **1**A, **1**B) identifies that downhole tool **174** is incapacitated, an umbrella may be opened to convey downhole tool **174** back to the sea-floor **106**. In one embodiment, an umbrella acts as a fail-safe mechanism so that it automatically deploys in the event of failure or the sudden loss of battery energy downhole tool **174**.

[0075] In downhole tools whose subassemblies include an energy storage subsystem, the media of energy storage may be battery (electro-chemical), fuel cell, or capacitor. For battery-powered downhole tools, the energy storage subsystem may comprise rechargeable batteries for powering the functions of downhole tool **174**. Such batteries may be high temperature high pressure (HTHP) compatible to accommodate a variety of downhole environments, such as when wellbore **122** is deeper than conventional wells. For fuel cell-powered downhole tools, energy may be stored as hydrogen/oxygen in a closed system for which water is produced. Electrolysis may produce hydrogen and oxygen which may be stored in separate containers or absorbed to substrates such as but not limited to metal hydrides or stored as a chemical form such as but not limited to acid and oxidizers. Depending on the amount of time a downhole tool is expected to remain in a wellbore before being disassembled by robotic tool assembly **178**, energy re-storage may take place over weeks at regular intervals or on demand as triggered.

[0076] Where used, an energy storage subsystem may also have connections to a battery charging infrastructure of a wellbore **122**, for example, when downhole tool **174** is docked to a docking station **186**. As illustrated, docking station **186** may be disposed within a wellbore such as at or near wellhead **121**, as well as at one or more downhole locations. In other examples, an energy storage subsystem may be recharged following disassembly within robotic tool assembly **178**. In some embodiments, downhole tool **174** (or a subassembly thereof) has a combination of rechargeable battery, ultra-capacitors, primary batteries, and a turbine-based power generator that converts some of the production flow energy of the wellbore **122** into electrical energy. Various charging mechanisms are possible, but may include for example, non-contact induction charging, non-contact capacitive-charging, or a wet-mate connector connection, to use non-limiting examples. The state of charge of a battery may be continuously monitored and reported to the CCU **128**. The state of charge of the battery may be monitored by noting the open-circuit voltage of the battery, the closed-circuit voltage of the battery, the internal resistance of the battery, or the amount of charge delivered by the battery. The internal resistance of the battery may be estimated by comparing how the voltage of the battery changes with the current draw. Energy storage subsystem may optionally have a cooling system to keep batteries at lower temperatures, during extended operations in wellbore **122**. Alternatively, the battery and/or the electronics may be housed in a flask to slow down temperature increase. Batteries may be mounted within one or more subassemblies **172** (e.g., referring to FIGS. **2**, **3**A, **3**B, **4**A, **4**B) of downhole tool **174**. These batteries may be replaced at the sea-floor **106** by robotic tool assembly **178** and, if the batteries are deemed end of life or non-rechargeable, a request for battery retrieval/replacement may be triggered to be delivered by UAV **160** (e.g., referring to FIG. **6**).

[0077] With continued reference to FIG. **7**, one or more subassemblies of downhole tool **174** may further comprise a packer that may be inflatable around at least a portion of the body of downhole tool **174**. Downhole tool **174** may have capability to inflate and deflate the packer in a pattern, which may be based on the information downhole tool **174** is transmitting. This inflation/deflation may obstruct/free the flow of production fluid passing by downhole tool **174** at a given region of wellbore **122**, thereby creating a telemetric pressure pulse. Essentially, this mechanism may modulate information on the pressure pulses. Alternatively, the modulated information may be carried on the variations in the flow velocity as measured at the surface. These pressure pulses may be sensed, for example at or by docking station **186**, and then demodulated to interpret the information sent by downhole tool **174**. The key to this concept is that downhole tool **174** adjusts the flow restriction around downhole tool **174** in order to digitally encode a downhole measurement. Suitable mechanisms for obstruction for obstructing production fluid may be, to use non-limiting examples, a variable seal (like an inflatable packer element), a variable drag component (like the umbrella, wiper, etc.), or a variable restriction (like a flow siren). Data may be encoded through pulse position encoding, amplitude modulation, frequency modulation, as well as differential versions of these encoding schemes. Variable restriction may result in a variable flowrate (as measured by the generator frequency) and a variable tubing pressure. The bits of the differential pulse position encoding are visible for the header, address, command, and checksum.

[0078] In wellbores which include a docking station **186**, downhole tool **174** may dock to docking station **186** following deployment, such as when it enters wellbore **122** and/or after it performs a wellbore operation. During docking, batteries utilized by downhole tool **174** may be charged. Battery charger circuit may be part of docking station **186**. Docking station **186** may be powered by either a power pack at sea-floor **106** or from a wireline connected to the surface power supply. While docked, a job plan may be downloaded from CCU **128** in docking station **186** to downhole tool **174**. This job plan may define a wellbore operation to be performed, well depth to initiate the wellbore operation, well depth to stop the wellbore operation, quality check criteria, references for various control systems, parameters to log in the memory, combinations thereof, etc. In addition to a job plan, well survey and casing tally information may also be downloaded from CCU **128** in docking station **186** to downhole tool **174**. Downhole tool **174** may provide this information to the navigation system to determine the real time depth during operations.

[0079] Command to release (i.e., undock) downhole tool **174** from docking station **186** may either come from a user command from surface to docking station **186** or based on a pre-programmed condition. To execute the release command, docking station **186** may unlock downhole tool **174** and let downhole tool **174** separate from docking station **186** and start its descent into wellbore **122**. For docking, downhole tool **174** may move to docking station **186**, with either its own power or with flow assisted conveyance. Downhole tool **174** may have sensors to align itself with docking station **186** and then push itself to dock to docking station **186**. After downhole tool **174** has completed a downhole operation and has docked to docking station **186**, the mission log from downhole tool **174** memory may be uploaded to docking station **186**. A log file may then be sent to surface from docking station **186**. Docking station **186** may be, without limitation, in a side pocket, dead-end section, section with a larger flow area, etc., of wellbore **122**.

[0080] One or more subassemblies of a downhole tool **174** may comprise sensors and a navigation subsystem which may have inertial measurement unit (IM U) sensors which may be a combination of precision mems gyroscopes, accelerometers, and magnetometers. In addition, downhole tool **174** may also include casing collar locator (CCL) sensors. Well survey and casing tally information (downloaded from the docking system) along with the sensor information may be used to determine the depth of downhole tool **174** in real time. More precise location information may be included at the valves that may be actuated and at the sensors that may need replacing or measuring. While profiles may be used for this more precise axial and circumferential location, profiles in one or more tubulars **124** (i.e., casing, production tubing, etc.) may be eroded with time and may be filled by scale and debris. Markers may be provided through an electromagnetic source (such as a permanent magnet, an RFID tag, or an NFC tag) or by a nuclear source. A plurality of magnets may be arranged such that they form a unique magnetic pattern for the specific location. The RFID and NFC tags may have a unique identifier for a specific location. Additional sensors may comprise bore hole pressure and temperature sensors. Downhole tool **174** may also have sensors to detect and establish communication with permanently mounted completion electronics in the well. Once communication is established, downhole tool **174** may download operational & health logs from these completion electronics.

[0081] As with a UAV **160**, one or more operations performed by downhole tool **174** may be controlled by an internal controller (IC) subsystem. An IC may also control the inflation/deflation of the packers for untethered mode communication with the docking station **186**, in some examples. In examples, commands issued by an IC may be determined from algorithms for autonomous operation of downhole tool **174**. Inputs for this algorithm will be the job plan and may also include real time feedback from any subsystem herein described in this disclosure. Based on these inputs IC may provide commands to the same subsystem that transmitted the input or to any other subsystem of downhole tool **174**. This may allow for downhole tool **174** to operate and function in accordance with the job plan, as well as to adapt to changing conditions or unanticipated events that arise during the operation without the need for human intervention, in some examples. In examples, IC may also log runtime operational parameters in its memory. After the mission is completed and downhole tool **174** has either docked to docking station **186**, been disassembled by robotic tool assembly **178**, or else interfaced with well system **100** (e.g., referring to FIG. **1**A, **1**B) in some manner following the operation, IC may download the log to either or both robotic tool assembly **178** and docking station **186** which may then convey it to surface **103**, e.g., via telemetry mechanism **134**.

[0082] During operations, a traction subsystem may provide propulsion to downhole tool **174** when downhole tool **174** is in, for example, a horizontal or deviated section of wellbore **122**. Traction subsystem may also provide power for docking downhole tool **174** to docking station **186**. In examples, traction subsystem may comprise motors, speed/position sensors, transmission, wheels, contact force adjustment system, drive electronics, and/or motor & traction controller. Where used, motor & traction controllers may communicate with an IC of downhole tool **174** and download run time commands. Based on these commands, motor & traction controller may provide the commutation signals for the drive electronics to run the motors at the desired operating conditions-torque/speed/power. Traction control subsystem may comprise wheel slip/slide detection & correction and contact force adjustment to achieve needed adhesion between wheel(s) and the casing. In some cases, the drive motors may be regenerative. If the fluid drag is pushing downhole tool **174** or if the gravitational forces are pulling downhole tool **174**, then the drive motors may serve as generators and produce electrical power. This produced electrical power may be used to augment the stored energy on downhole tool **174**, to recharge the secondary batteries, or may be used to estimate the health of downhole tool **174**.

[0083] During operations, downhole tool **174** may utilize one or more intervention tools. The intervention tool may comprise an anchor to anchor the downhole tool **174** in wellbore **122**, a linear or rotary actuator, a linear or rotary actuated accessory/accessories, and/or sensors for operation of the intervention tool. Intervention tools may comprise drive electronics and/or motors to drive the actuators. Each intervention tool may be chosen based on the kind of intervention operation to be conducted in wellbore **122**. Non-liming examples of intervention tools comprise a shifter, a miller, a bailer, a hone, and a rush. In some examples, intervention tools connected to downhole tool **174** may be able to carry parts, as may be needed, to replace worn out parts on completion equipment disposed within wellbore **122**. Examples of such parts may be a power pack, pressure gages, etc. In another example, an intervention tool may utilize pyrotechnic compositions such as Thermite to perform controlled ignition to melt down paraffin wax in the production flow path, for example. In other examples, downhole tool **174** may carry production logging tools to log pressure/temperature/flow rate etc. Downhole tool **174** may be deployed without intervention tools for collecting information from completion sensors or for pressure/temperature surveys of wellbore **122**. In some examples, production logging tools may be connectable to downhole tool **174**. In some examples, downhole tool **174** may comprise a permanent or a semi-permanent downhole tool to be disposed within wellbore **122**. For example, downhole tool **174** may be disposed in wellbore **122** for a period of least 1 hour, at least 1 day, at least 2 days, at least 1 week, at least 2 weeks, at least 1 month, and at least 3 months, in some examples, before retrieval, such as when the operation is an ongoing logging operation. Thus, the various subassemblies of downhole tool **174** may comprise a plurality of wellbore operational equipment including, for example and without limitation, logging sensors such as electromagnetic sensors, pulsed neutron, or passive gamma ray sensors, acoustic sensors, fluid measurement devices and sampling capability. In some examples, surface conditions may provide triggers for logging or sampling with downhole tool **174**.

[0084] Downhole tool **174** may be tethered or untethered. Where used, a tether may extend along a substantial length of wellbore **122**, such as between a docking station **186** to a most distal portion to be logged or an intervention operation performed. In such examples, a tether may provide a retractable force to be applied to downhole tool **174** should gravity not be adequate to retract a downhole tool to a desired location. A tether may also supply power or telemetry directly to downhole tool **174**. Docking station **186** may pass energy from a wired means or from downhole power generation or stored energy from either downhole power generation or wired means. For instance, a larger battery bank, capacitor bank or electrochemical cell may be located in docking station **186**. Thereby, low power from wiring may be stored for larger power boosts to downhole tool **174** via a tether. A tether may be released and retracted in order to keep the tether taut and may further provide means of measuring position within wellbore **122**.
[0085] Accordingly, the present disclosure may provide methods and systems for building and deploying a downhole tool at the sea-floor. The methods and systems may include any of the various features disclosed herein, including one or more of the following statements.
STATEMENTS
[0086] Statement 1: A method comprising: assembling a downhole tool from a plurality of subassemblies with a robotic tool assembly disposed on a subsea tree at a sea-floor in a subsea environment; introducing the downhole tool into a wellbore; traversing the wellbore with the downhole tool to reach one or more target depths; and performing at least a wellbore operation with the downhole tool at the one or more target depths.
[0087] Statement 2: The method of statement 1, further comprising: retrieving the downhole tool from the wellbore after performing the wellbore operation; and disassembling the downhole tool with the robotic tool assembly after retrieving the downhole tool from the wellbore.
[0088] Statement 3: The method of statement 2, wherein the assembling and the disassembling is performed autonomously by the robotic tool assembly based on instructions specific for a type of the downhole tool.
[0089] Statement 4: The method of any of statements 1-3, wherein traversing the wellbore with the downhole tool comprises lowering the downhole tool to the one or more target depths using a wireline, wherein at least a portion of the wireline is initially housed within the robotic tool assembly or the subsea tree.
[0090] Statement 5: The method of any of statements 1-4, wherein the downhole tool is an untethered robot.
[0091] Statement 6: The method of any of statements 1-5, wherein the assembling is performed using one or more robotic arms disposed within the robotic tool assembly.
[0092] Statement 7: The method of any of statements 1-6, wherein the assembling comprises stacking two or more of the subassemblies together and raising the stacked subassemblies into a vertical lubricator.
[0093] Statement 8: The method of any of statements 1-7, wherein the assembling comprises: identifying and locating subassemblies of the robotic tool assembly; picking the identified subassemblies from respective storage locations of the robotic tool assembly; moving the picked subassemblies into an assembly space; and connecting the picked subassemblies together within the assembly space to form the downhole tool.
[0094] Statement 9: The method of any of statements 1-8, wherein two or more connections between different combinations of subassemblies of the downhole tool comprise a single connection-type.
[0095] Statement 10: The method of statement 9, wherein the single connection-type is a pressed-in or a spun-in connection.
[0096] Statement 11: The method of any of statements 1-10, further comprising transporting one or more carrier tubes containing one or more of the plurality of subassemblies using an underwater autonomous vehicle.

[0097] Statement 12: The method of any of statements 1-11, further comprising monitoring the downhole tool during the performing of the wellbore operation, wherein the method further comprises relaying instructions to the robotic tool assembly from a sea bed server to retract or recall the downhole tool.
[0098] Statement 13: The method of any of statements 1-12, further comprising removing one or more batteries from one or more of the subassemblies and placing the batteries in a charging station disposed at or within a housing of the robotic tool assembly.
[0099] Statement 14: The method of any of statements 1-13, wherein retrieving the downhole tool after performing the wellbore operation comprises modifying a buoyancy of the downhole tool by expelling fluid out from the downhole tool and/or deploying a sail or opening a chute of the downhole tool.
[0100] Statement 15: The method of any of statements 1-14, wherein the wellbore operation comprises at least one intervention operation selected from the group consisting of: valve shifting, brushing, bailing, milling, routine pressure balancing, logging, and any combination thereof.
[0101] Statement 16: The method of any of statements 1-15, further comprising: downloading wellbore operation data gathered by the downhole tool during the wellbore operation to a memory device stored at the sea-floor; and conveying the downloaded data to a surface location.
[0102] Statement 17: A system comprising: a subsea tree disposed on a wellhead of a wellbore; a robotic tool assembly disposed at or on the subsea tree; and a plurality of storage locations for holding a plurality of subassemblies, wherein the robotic tool assembly is configured to assemble a downhole tool comprising the plurality of subassemblies.
[0103] Statement 18: The system of statement 17, further comprising: a well access; a vertical lubricator disposed above the wellhead; one or more valves for eliminating a pressure difference across the well access.
[0104] Statement 19: The system of statements 17 or 18, wherein at least one of the plurality of subassemblies comprises a buoyancy controller, a flow assisted conveyance module, energy storage, a telemetry module, a docking and release module, a sensors and navigation module, a central controller unit, a traction system module, an intervention tool module, and any combination thereof.
[0105] Statement 20: The system of any of statements 17-19, wherein the robotic tool assembly comprises a storage revolver configured to revolve the plurality of storage locations, the plurality of subassemblies, or both, about an assembly area of the robotic tool assembly.
[0106] Statement 21: A method comprising assembling a downhole tool from a plurality of subassemblies with a robotic tool assembly disposed on a subsea tree at a sea-floor in a subsea environment.
[0107] Statement 22: The method of statement 22, further comprising introducing the downhole tool into a wellbore.
[0108] Statement 23: The method of statement 22 or 23, further comprising traversing the wellbore with the downhole tool to reach one or more target depths.
[0109] Statement 24: The method of any of statements 21-23, further comprising performing at least a wellbore operation with the downhole tool at the one or more target depths.
[0110] Statement 25: The method of any of statements 21-24, further comprising retrieving the downhole tool from the wellbore after performing the wellbore operation.

Solutions and Improvements

[0111] Advantages of the present disclosure are various and may include, in some examples, the ability to autonomously perform wellbore interventions using downhole tools assembled at or near the sea-floor. This may simplify the ergonomics of wellbore operations by reducing or eliminating the need for extensive planning and personnel.

General Notes

[0112] Although the present disclosure and its advantages have been described in detail, it should

be understood that various changes, substitutions, and alterations may be made herein without departing from the spirit and scope of the disclosure as defined by the appended claims. The preceding description provides various embodiments of the systems and methods of use disclosed herein which may contain different method steps and alternative combinations of components. It should be understood that, although individual embodiments may be discussed herein, the present disclosure covers all combinations of the disclosed embodiments, including, without limitation, the different component combinations, method step combinations, and properties of the system. The term “include,” and derivations thereof, mean “including, but not limited to.” However, it should be understood that the systems and methods are described in terms of “including,” “containing,” or “including” various components or steps, the systems and methods can also “consist essentially of” or “consist of” the various components and steps. Moreover, the indefinite articles “a” or “an,” as used in the claims, are defined herein to mean one or more than one of the element that it introduces. Furthermore, the word “may” is used throughout this application in a permissive sense (i.e., having the potential to, being able to), not in a mandatory sense (i.e., must). The term “coupled” means directly or indirectly connected. If there is any conflict in the usages of a word or term in this specification and one or more patent or other documents that may be incorporated herein by reference, the definitions that are consistent with this specification should be adopted for the purposes of understanding this invention.
[0113] For the sake of brevity, only certain ranges are explicitly disclosed herein. However, ranges from any lower limit may be combined with any upper limit to recite a range not explicitly recited, as well as, ranges from any lower limit may be combined with any other lower limit to recite a range not explicitly recited, in the same way, ranges from any upper limit may be combined with any other upper limit to recite a range not explicitly recited. Additionally, whenever a numerical range with a lower limit and an upper limit is disclosed, any number and any comprised range falling within the range are specifically disclosed. In particular, every range of values (of the form, “from about a to about b,” or, equivalently, “from approximately a to b,” or, equivalently, “from approximately a-b”) disclosed herein is to be understood to set forth every number and range encompassed within the broader range of values even if not explicitly recited. Thus, every point or individual value may serve as its own lower or upper limit combined with any other point or individual value or any other lower or upper limit, to recite a range not explicitly recited.
[0114] Therefore, the present embodiments are well adapted to attain the ends and advantages mentioned as well as those that are inherent therein. The particular embodiments disclosed above are illustrative only and may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. Although individual embodiments are discussed, the disclosure covers all combinations of all of the embodiments. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. Also, the terms in the claims have their plain, ordinary meaning unless otherwise explicitly and clearly defined by the patentee. It is therefore evident that the particular illustrative embodiments disclosed above may be altered or modified and all such variations are considered within the scope and spirit of those embodiments. If there is any conflict in the usages of a word or term in this specification and one or more patent(s) or other documents that may be incorporated herein by reference, the definitions that are consistent with this specification should be adopted.

Claims

1. A system for automatic well intervention in a wellbore, comprising: a robotic tool assembly; and a plurality of subassemblies stored at or within the robotic tool assembly, wherein the robotic tool assembly is configured to assemble a downhole tool from the plurality of subassemblies, and wherein a subassembly, of the plurality of subassemblies, comprises an energy storage subsystem

configured to provide power to the downhole tool.
2. The system of claim 1, wherein the energy storage subsystem comprises a fuel cell.
3. The system of claim 2, wherein the fuel cell is configured to operate using hydrogen and oxygen stored within the subassembly.
4. The system of claim 3, wherein the hydrogen and the oxygen are stored in separate containers, absorbed to substrates, or stored in a chemical form.
5. The system of claim 3, wherein the hydrogen and the oxygen are generated via electrolysis.
6. The system of claim 1, wherein the energy storage subsystem comprises a turbine-based power generator configured to convert production flow energy of the wellbore into electrical energy.
7. The system of claim 1, wherein the energy storage subsystem further comprises an ultra-capacitor.
8. The system of claim 1, wherein the energy storage subsystem may be charged at a charging station.
9. The system of claim 8, wherein the charging station uses contact charging to charge the energy storage subsystem.
10. The system of claim 8, wherein the charging station uses non-contact charging to charge the energy storage subsystem.
11. A method for automatic well intervention in a wellbore, comprising: assembling, with a robotic tool assembly, a downhole tool from a plurality of subassemblies, wherein a subassembly, of the plurality of subassemblies, comprises: an energy storage subsystem with a fuel cell or a turbine-based power generator; introducing the downhole tool into the wellbore; powering at least a portion of the downhole tool during operation using the energy storage subsystem; and performing a wellbore operation with the downhole tool.
12. The method of claim 11, wherein powering the downhole tool comprises utilizing the fuel cell within the energy storage subsystem.
13. The method of claim 12, further comprising operating the fuel cell using stored hydrogen and oxygen.
14. The method of claim 13, prior to or during assembling the downhole tool, the method further comprises: generating the hydrogen and the oxygen via electrolysis.
15. The method of claim 11, wherein powering the downhole tool comprises utilizing the turbine-based power generator within the energy storage subsystem to convert production flow energy into electrical energy.
16. The method of claim 11, further comprising retrieving the downhole tool from the wellbore and disassembling the downhole tool with the robotic tool assembly.
17. A system for subsea well intervention, the system comprising: a plurality of subassemblies, wherein each subassembly is configured to perform a specific function related to a wellbore operation; a plurality of storage locations disposed at a sea-floor, wherein each storage location is configured to hold a subassembly; and a robotic tool assembly disposed at the sea-floor and operatively coupled to the plurality of storage locations, wherein the robotic tool assembly is configured to: select a subset of subassemblies, of the plurality of subassemblies, from the plurality of storage locations based on a desired wellbore operation; and assemble a downhole tool from the subset of subassemblies.
18. The system of claim 17, wherein the robotic tool assembly is further configured to: retrieve the downhole tool from a wellbore after the desired wellbore operation is performed; disassemble the downhole tool into the subset of subassemblies; and return the subset of subassemblies to the plurality of storage locations after disassembly.
19. The system of claim 17, wherein the desired wellbore operation is a logging operation, and wherein the downhole tool is tethered during the logging operation.
20. The system of claim 17, wherein the robotic tool assembly further comprises: an assembly space configured to receive the subset of subassemblies for assembly of the downhole tool.