

BUOY, BUOY SYSTEM AND ASSEMBLING METHOD THEREOF

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of priority to the Singapore application no. 10202401711W filed 13 June, 2024, the contents of which are hereby incorporated by reference in their entirety for all purposes.

TECHNICAL FIELD

[0002] This application relates generally to the field of marine operations, and more particularly, to a buoy, a buoy system and a method of assembling a buoy system.

BACKGROUND

[0003] Conventional approach towards maintaining a buoy system or a buoy generally involves retrieving the buoy system/buoy from the deployment area and performing maintenance/repair/overhaul of the buoy system/buoy at specific off-site locations, prior to returning the buoy system/buoy back to operation at the deployment area. Similarly, addition and/or replacement of modules on the buoy system/buoy also comprises the various steps of retrieval and redeployment. Such operations are time consuming and costly, and often necessitate the deployment of replacement buoy(s) during the downtime.

SUMMARY

[0004] According to an aspect, disclosed herein a buoy system. The buoy system may be configured to enable lateral coupling or insertion of payload module(s), such as oversized payload modules, which are often deemed unfit (such as being diametrically oversized) for deployment in moonpool of a conventional buoy. Provision of the lateral coupling improves

extensibility and reconfigurability, while concurrently simplifying buoy operations. The buoy system comprises: a buoy, comprising: a frame defining a buoyancy axis; and at least one float module coupled to the frame; and at least one payload module detachably coupleable to a periphery of the buoy along a radial axis, wherein the radial axis is orthogonal to the buoyancy axis.

[0005] According to another aspect, disclosed herein a method of assembling a buoy system. The method comprises: providing a buoy, the buoy comprising a frame defining a buoyancy axis; and at least one float module coupled to the frame; attaching at least one payload module to a periphery of the buoy along a radial axis, wherein the radial axis is orthogonal to the buoyancy axis.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Various embodiments of the present disclosure are described below with reference to the following drawings:

[0007] FIG. 1 is a schematic diagram showing a buoy system according to embodiments of the present disclosure;

[0008] FIGs. 2A and 2B are top views of the buoy system of FIG. 1, prior to and after attaching payload modules;

[0009] FIGs. 3A and 3B show respective buoy dimension of the buoy system of FIGs. 2A and 2B;

[0010] FIG. 4 is a perspective view of a buoy system according to various embodiments;

[0011] FIG. 5 is a partial exploded view of a buoy according to various embodiments;

[0012] FIGs. 6A and 6B show exemplary top mounts of a buoy according to embodiments of the present disclosure;

[0013] FIGs. 7A and 7B are sectional perspective views of a buoy system receiving payload modules on a periphery of the buoy according to embodiments of the present disclosure;

[0014] FIG. 8 is a partial exploded view of a buoy according to various embodiments;

[0015] FIGs. 9A and 9B show exemplary embodiments of peripheral payload modules and peripheral payload mounts;

[0016] FIGs. 10A to 10C show perspective view of exemplary embodiments of peripheral slots and the corresponding exemplary peripheral payload mounts;

[0017] FIGs. 11, 12A and 12B show sectional perspective views of a central conduit and a central conduit payload mount according to various embodiments;

[0018] FIG. 13 is an exploded view of a central conduit payload mount according to various embodiments;

[0019] FIG. 14 is a perspective view of a central conduit payload mount and multiple core payload modules according to various embodiments;

[0020] FIG. 15 shows a plurality of coupling points/coupling spatial quadrants distributed angularly about a cage axis according to various embodiments;

[0021] FIGs. 16A and 16B are perspective views of service doors of the enclosing structure according to various embodiments;

[0022] FIG. 17 is a perspective view of a peripheral conduit payload mount according to various embodiments;

[0023] FIG. 18 is an exploded view of a peripheral conduit payload mount and a peripheral conduit formed on a float module according to various embodiments;

[0024] FIGs. 19A and 19B illustrate the attachment and detachment of a peripheral conduit payload mount from a peripheral conduit formed on a float module according to various embodiments;

[0025] FIG. 20 illustrates a method of assembling a buoy system according to various embodiments;

[0026] FIGs. 21A to 21C illustrate the steps of assembling a float module to a buoy according to various embodiments;

[0027] FIG. 22 is a perspective view of an implementation of a buoy system according to an exemplary embodiment;

[0028] FIG. 23 shows the dimensions of an exemplary central conduit of the buoy system of FIG. 22;

[0029] FIG. 24 shows the dimensions of an exemplary peripheral conduit payload mount of the buoy system of FIG. 22;

[0030] FIG. 25A is a perspective view of an exemplary top mount of the buoy system of FIG. 22;

[0031] FIG. 25B is a sectional view of an exemplary mounting dimension of the top mount of FIG. 25A;

[0032] FIG. 26 shows the dimensions of an exemplary service door of the buoy system of FIG. 22;

[0033] FIGs. 27A and 27B are front view and perspective view of an exemplary frame of the buoy system of FIG. 22;

[0034] FIGs. 28A and 28B are front view and perspective view of an exemplary superstructure of the buoy system of FIG. 22;

[0035] FIGs. 29A and 29B are front view and perspective view of an exemplary ring mast of the buoy system of FIG. 22;

[0036] FIG. 30 illustrates the protective mounting inserts on the float of the buoy system of FIG. 22;

[0037] FIG. 31A illustrates a battery bay formed in the PE/PU float of the buoy system of FIG. 22;

[0038] FIG. 31B is an exploded view of an enclosure of the buoy system of FIG. 22 for waterproofing a standard sealed cuboid battery; and

[0039] FIG. 32 is a system diagram of a renewable energy setup in MESN of the buoy system of FIG. 22.

DETAILED DESCRIPTION

[0040] The following detailed description is made with reference to the accompanying drawings, showing details and embodiments of the present disclosure for the purposes of illustration. Features that are described in the context of an embodiment may correspondingly be applicable to the same or similar features in the other embodiments, even if not explicitly described in these other embodiments. Additions and/or combinations and/or alternatives as described for a feature in the context of an embodiment may correspondingly be applicable to the same or similar feature in the other embodiments.

[0041] In the context of various embodiments, the articles “a”, “an” and “the” as used with regard to a feature or element include a reference to one or more of the features or elements.

[0042] In the context of various embodiments, the term “about” or “approximately” as applied to a numeric value encompasses the exact value and a reasonable variance as generally understood in the relevant technical field, e.g., within 10% of the specified value.

[0043] As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items.

[0044] As used herein, terms “concurrently”, “simultaneously”, “at the same time”, or the like, may refer to events or actions that coincide or overlap within a period of time, regardless of whether the events start at the same time instant, and regardless of whether the events end at the same time instant.

[0045] As used herein, the term “buoyancy axis” may generally be defined as an axis corresponding to the expected buoyant force direction and/or the actual buoyant force direction acting on the buoy during operation. The “buoyancy axis” may be used herein to define a vertical direction of the buoy, in line with the buoyant force.

[0046] The term “payload module” may be used interchangeably with the terms “payload”, “sensor payload”, “sensor module”, “instrument module”, “instrument payload”, “payload sensing module”, etc as it may be understood from the context. The term “payload module” may generally refer to a device which is disposed on the buoy to perform a specific function or with a specific purpose, such as for sensing, measurements, energy generation, mechanical actuation, etc.

[0047] The term “buoy dimension” may be used interchangeably with the terms “buoy contour dimension”, “buoy sectional area dimension”, and may generally be defined as a maximum perimeter/contour or maximum area of the buoy when viewed from a vertical/height axis (or buoyancy axis) of the buoy. The term “buoy dimension” may be related to a maximum perimeter of the buoy on a sectional plane orthogonal to the buoyancy axis, and/or related to a maximum sectional area of the buoy on a sectional plane orthogonal to the buoyancy axis. It may be appreciated that the “buoy dimension” may or may not correspond to a sectional plane at the fluid level. Hence, for clarity, the “buoy dimension” may be disposed above the fluid level, at the fluid level or below the fluid level during operation of the buoy.

[0048] Conventional approach towards maintaining a buoy system or buoy generally involves retrieving the buoy system/buoy from the deployment area, and performing maintenance/repair/overhaul of the buoy system/buoy at an off-site location, prior to returning the buoy system/buoy back to operation at the deployment area. Similarly, addition and/or replacement of modules on the buoy system/buoy also comprises the various steps of retrieval

and redeployment. Such operations are time consuming and costly, and often necessitate the deployment of replacement buoy(s) during the downtime.

[0049] The present disclosure comprises a reconfigurable buoy, a reconfigurable buoy system and a method of assembling a buoy system according to various embodiments of the present disclosure. Departing from conventional approaches of maintaining a fixed predetermined payload to preserve or achieve buoy stability, the proposed buoy and buoy system provides reconfigurability thus enabling a variation of payload on the buoy during operation. In addition, replacement or addition of payload modules may be operable by a single user (such as a maintenance crew or an operator) at the buoy deployment area based on “plug and play” detachable couplings provided on the buoy. This alleviates the need for the buoy to be retrieved from the deployment area for reconfiguration or the need for large service vessels for maintenance, thus significantly reducing buoy downtime and operational costs. Further departing from conventional approaches of maintaining an optimized payload and stability configuration, the payload modules may be coupled to a periphery of the buoy, thus allowing oversized payload modules to be coupled and attached to the buoy.

[0050] According to another aspect, addressing the multiple alignment difficulties met during the assembly of a conventional buoy, the present disclosure proposes a method of assembling a buoy by perforating/puncturing coupling holes on float modules during the assembling process in place of preformed holes. This alleviates the common positional error or high tolerance error of coupling holes on conventional float modules due to the fabrication/forming process, thus enabling a more efficient assembling process and a robust buoy structure.

[0051] The proposed buoy system and buoy may comprise one or more payload modules suitable to support marine technology test-bedding and/or marine environmental monitoring. The buoy may be scalable and modular. The buoy may be configured and provided with one or

more open architecture interfaces to allow easy plug-and-play of different types of subsystems (e.g., sensors, actuators and robots) in a variety of shapes/sizes/dimensions. Additionally, subsystems with communication modes may be used with the proposed buoy.

[0052] In various embodiments, the buoy may include modular and swappable peripheral payload modules or peripheral modules. The provision of peripheral payload module(s) may allow the installation or mounting of arbitrary payloads/subsystems that do not fit in standard cylindrical moonpools (e.g., small robots, irregularly shaped sensors). In various embodiments, the buoy may also include modular and swappable float modules or collars.

[0053] In various embodiments, the buoy may include one or more winch module may also be provided to support lifting of payload, such as sensors, above the water or fluid level, for easier access during maintenance (i.e., without the need for SCUBA diving). In various embodiments, a winch module may be provided to support vertical profiling of payload, such as sensor instruments.

[0054] The modular and reconfigurable configuration of the buoy allows adaptation for multiple use cases or applications, such as one being implemented as an environmental monitoring buoy with a wide range of sensor types, as well as a test bedding platform for marine sensors/technologies of various forms, etc. Exemplary applications may include but are not limited to: environmental monitoring, marine research, aquaculture and fisheries, oceanography, maritime buoy, etc.

[0055] According to one aspect, FIGs. 1 to 3B illustrate schematically a buoy system 50 according to various embodiments of the present disclosure. The buoy system 50 may be a reconfigurable buoy system 50 suitable for use with a variety of payload modules. The payload module may be generally defined as one or an ensemble of payloads. The payload modules may include but are not limited to: a sensor payload, a measurement payload, an energy generation payload, a mechanical actuation payload, a combination thereof, etc.

[0056] In various embodiments, the buoy system 100 may comprise a buoy 100 and at least one payload module 410 detachably coupleable to a periphery 102 of the buoy 100. The buoy 100 may include a frame 110 and at least one float module 210 coupled to the frame 110. The at least one float module 210 may be configured to provide buoyancy or a buoyant force to the buoy 100 during operation, such as during a marine survey operation. The frame 110 may define a buoyancy axis 82. The buoyancy axis 82 may be an axis corresponding to an expected buoyant force direction and/or the actual buoyant force direction acting on the buoy during operation. As an example, the buoyancy axis 82 may correspond to a vertical axis or a longitudinal axis of the buoy.

[0057] In various embodiments, the at least one payload module 410 may be detachably coupleable to the periphery 102 of the buoy 100. In various embodiments, the frame 110 may comprise at least one coupling point 115 for attaching or coupling the at least one payload module 410. The at least one payload module 410 may be attached to the buoy 100 along a radial axis 84 which is orthogonal to the buoyancy axis 82. Similarly, the at least one payload module 410 may be detached from the buoy 100 along the radial axis 84. Therefore, it may be understood that the at least one payload module 410 may be coupled to different sides of the buoy 100 in contrast to conventional buoys in which payloads are disposed on the buoy 100. Hence, the buoy 100 may define multiple radial axes 84 corresponding to each of the at least one payload module 410, in which each of the multiple radial axes 84 is orthogonal to the buoyancy axis 82.

[0058] FIGs. 2A and 2B illustrate a top view of the buoy 100 undergoing payload reconfiguration, according to an exemplary embodiment. As shown in FIGs. 2A and 2B, the frame 110 may comprise two coupling points 115 for respectively attaching two payload modules 410A/410B of different sizes, with payload module 410A being a typically sized payload and payload module 410B being an oversized payload. The provision of the coupling

points 115 may allow the oversized payload 410B to be attached to the periphery of the buoy 100, thus overcoming typical payload size limitations for conventional buoys.

[0059] In various embodiments, the payload modules 410 may be held by a respective payload mount (or a payload frame), and the payload mount may be coupled to the respective coupling points 115.

[0060] In various embodiments, the payload modules 410 may be coupled to the coupling points 115 or the buoy 100 submerged or at least partially submerged in the operational environment, such as in the sea water. This is advantageous particularly for oversized payloads, such as payload 410A, as the buoyant force from the sea water may aid to reduce the load on the buoy 100, thus overcoming payload weight limit.

[0061] In various embodiments, the payload modules 410 may be fully submerged and position at below the float modules 210 along the buoyancy axis 82. This allows the oversized payload 410B to take up position under the float modules 210, advantageously overcoming both the payload size limit due to spatial limitation and the payload weight limit due to weight limitation.

[0062] In various embodiments, the buoy 100 may define a buoy dimension 105. FIGs. 3A and 3B illustrate the respective buoy dimension 105A/105B of the buoy 100 of FIGs. 2A and 2B prior to and after attaching the payload modules 410A/410B. The buoy dimension 105 may correspond to a maximum perimeter of the buoy 100 when viewed along the buoyancy axis 82. Hence, the buoy dimension 105 may correspond to a maximum perimeter formed on a plane orthogonal to the buoyancy axis 82. In some embodiments, the buoy dimension 105 may also correspond to a maximum sectional area of the buoy 100, wherein the maximum sectional area is orthogonal to the buoyancy axis 82.

[0063] The buoy dimension 105 may be used to characterize a change in a size of the buoy 100 before and after attaching one or more payload modules 410. It may be seen from FIGs.

3A and 3B that the buoy dimension 105B increases responsive to attaching the payload modules 410A/410B to the buoy 100, and the buoy dimension 105A decreases responsive to detaching the payload modules 410A/410B from the buoy 100. Hence, the buoy 100 is reconfigurable to vary a buoy dimension 105 during operation, thus departing from conventional buoys.

[0064] In addition, to facilitate reconfiguration during operation, attaching the payload module 410 to a respective coupling point 115 on the frame 110 may be manually operable by a single user. In addition, attaching the payload module 410 may also be performed when the buoy 100 is in the water or out of the water. Similarly, detaching the payload module 410 from the respective respective coupling point 115 on the frame 110 may also be manually operable by the single user. This enables payload modules 410 to be swappable by the single user during operation, alleviating the need for retrieval and redeployment of the buoy 100. As an example, the respective coupler between the payload module 410 and the coupling point 115 may be a manually operable coupler, such as a catch and lock mechanism.

[0065] Referring again to FIGs. 2A and 2B, in various embodiments, the buoy 100 may comprise a plurality of float modules 210 detachably coupled to the frame 110, such as four float modules 210A/210B/210C/210D detachably coupled to respective portions of the frame 110 along a respective direction. In various exemplary embodiments, the plurality of float modules 210A/210B/210C/210D may be similarly configured providing a generally uniform shape, such as a quadrant. In various exemplary embodiments, the four float modules 210A/210B/210C/210D may be disposed angularly symmetrical about the buoyancy axis 82. In various exemplary embodiments, the four float modules 210A/210B/210C/210D may provide a similar buoyant force on the buoy 100 during operation. It may be noted that the four float modules 210A/210B/210C/210D may collectively provide a net buoyant force on the buoy 100.

[0066] In various embodiments, with the provision of the plurality of float modules 210A/210B/210C/210D which are detachably coupled to the frame 110, on-site float module replacement may be performed. It may be appreciated that the buoy 100 may remain buoyant responsive to detachment of one of the float modules 210, such as float module 210A. In other words, the buoyant force as provided by the other float modules 210B/210C/210D may be sufficient to keep the buoy 100 afloat during float module replacement. In various embodiments, attaching each of the float modules 210A/210B/210C/210D to the frame 110 may be manually operable by a one or more users. Similarly, detaching each of the float modules 210A/210B/210C/210D from the frame 110 may also be manually operable by the user(s). This enables float modules 210 to be swappable by the user(s) during operation, alleviating the need for retrieval and redeployment of the buoy 100.

[0067] The configuration of multiple float modules 210 aids in improving the seaworthiness of the buoy 100 in the event of damage (for example, from minor vessel collisions) by limiting buoyancy lost to the damaged quadrant. Provision of multiple float modules 210 allows a specific float module to be replaced on-site when damaged, thus reducing operational and repair costs. In addition, due to the reduced size of the float modules 210, transportation costs may be reduced due to more optimized packing when the disassembled buoy 100 is transported.

[0068] FIGs. 4 and 5 illustrate a buoy system 50 according to various embodiments of the present disclosure. The buoy system 50 comprises a buoy 100 and a plurality of payload modules 410 detachably coupleable to the buoy 100. The buoy 100 may comprise a frame 110 and a plurality of float modules 210 coupled to the frame 110. The buoy 100 may also comprise a top mount 310 coupled to a top end of the frame 110. In various embodiments, the frame 110 may further comprise a base frame 112 and an enclosing structure 114 coupled to the base frame 112. In various embodiments, the base frame 112 may be coupled to the enclosing structure 114

along a buoyancy axis 82. In various embodiments, the enclosing structure 114 may define an interior space 116 for housing one or more payload modules 410.

[0069] In various embodiments, the base frame 112 may include one or more peripheral slots 113, for example, four peripheral slots 113 as shown in FIG. 5. Each of the peripheral slots 113 may extend from the base frame 112 (or from the buoyancy axis 82) towards the periphery 102 of the buoy 100 along a respective radial axis 84. As described earlier, the buoy 100 may define multiple radial axes 84, in which each radial axis 84 is orthogonal to the buoyancy axis 82. As shown in FIG. 5, it may be noted that two of the peripheral slots 113 may be aligned on a common radial axis 84. Each of the peripheral slots 113 may be configured as a coupling point 115 for a respective payload module 410. In various embodiments, each of the peripheral slots 113 may be disposed between adjacent pairs float modules 210.

[0070] In various embodiments, one or more battery pack 220 may be disposed or coupled to the float modules 210. Similarly, this facilitates easy swapping of battery pack 220 during maintenance or repair.

[0071] Still referring to FIG. 5, when one or more of the peripheral slots 113 are unoccupied or not in use, a supplementary float module 214 (or smaller float module) may be detachably coupled to the respective peripheral slot 113 to increase the buoyancy of the buoy 100. The supplementary float module 214 may be attached and/or detached manually by a single user. Hence, during buoy reconfiguration, the supplementary float module 214 may be detached from the peripheral slot 113 and replaced with a payload module 410 on-site.

[0072] According to various embodiments, referring to FIGs. 5, 6A and 6B, the buoy 100 may include a top mount 310 coupled to the enclosing structure 114 aligned along the buoyancy axis 82. The top mount 310 may be configured as a ring mast for holding or mounting a plurality of payload modules 410, such as sensors or communication antennas. Further, a plurality of solar panels 320 may be coupled or disposed on the top mount 310 for capturing solar rays.

[0073] In various embodiments, as shown in FIG. 6A, the plurality of solar panels 320 may include top facing solar panels 321 as well as bottom facing solar panels 322. In various embodiments, selected ones of the plurality of solar panels 320 may be bottom top facing solar panels 321 which are disposed facing away from the at float modules 410. In other words, the top facing solar panels 321 faces the sky, configured to receive direct solar rays or sun rays from the sky. In addition, selected others of the plurality of solar panels 320 may be bottom facing solar panels 322 which are disposed facing towards the at float modules 410. In other words, the bottom facing solar panels 322 faces the water or sea surface, configured to receive reflected solar rays or sun rays from the water or sea surface. The provision of both the top facing solar panels 321 and the bottom facing solar panels 322 increases the amount of solar energy harvested, thus increases the electrical output from the solar panels 320. Further, in various embodiments, one or more pairs of top facing solar panel 321 and bottom facing solar panel 322 may be collectively rotatable 325 to vary the respective orientation. This may enable access into the interior space of the buoy 100.

[0074] In other embodiments, referring to FIG. 6B, in consideration of weight saving, the plurality of solar panels 320 may only include top facing solar panels 321. The top facing solar panels 321 may also be rotatable 325 to vary the respective orientation.

[0075] In various embodiments, the plurality of payload modules 410 may be configured with different function and/or comprises different purposes, or in other words, are different types of payload modules 410. As such, it may be worth noting that due to the different operational requirements, the plurality of payload modules 410 may be detachably attached or detachably coupled to various locations on the buoy 100, or various locations on the frame 110.

[0076] Referring back to FIG. 4, in various embodiments, the payload modules 410 may include one or more peripheral payload modules 412. The peripheral payload modules 412 may generally be detachably coupleable to a periphery 102 of the buoy 100. As examples, the

peripheral payload modules 412 may be submersible or semi-submersible devices or instruments for use in the operational environment, such as the sea. As another example, the peripheral payload modules 142 may also include oversize payload modules 410 which are otherwise unsuitable to be disposed in the limited space available on the buoy 100. As another example, the peripheral payload modules 142 may also include overweight payload modules 410 which are otherwise too heavy to be held by the buoy 100.

[0077] In various embodiments, the oversized payload modules 410 may be disposed submerged in the water at a fluid level (water level) lower than the buoy 100 or the float modules 210. As such, the oversized payload module 410 may not be limited by space otherwise taken up by the float modules 210 of the buoy 100. This allows oversized payload modules 410 which are diametrically larger than conventional payload modules to be carried by the buoy 100.

[0078] Similar to previous embodiments, the buoy 100 may define a buoy dimension. The buoy dimension may be orthogonal to the buoyancy axis 82. Therefore, similarly, the buoy dimension may increase responsive to attaching the peripheral payload modules 412 to the frame 110/buoy 100, and the buoy dimension may decrease responsive to detaching the peripheral payload modules 412 from the frame 110/buoy 100. In various embodiments, attaching the peripheral payload modules 412 to the frame 110/buoy 100 and detaching the peripheral payload modules 412 from the frame 110/buoy 100 may both be manually operable by a single user.

[0079] In various embodiments, each of the peripheral payload module 412 may be coupleable to a respective peripheral slot 113. FIGs. 7A, 7B and 8 illustrate the attaching of peripheral payload modules 412 to the respective peripheral slot 113. In various embodiments, each of the peripheral payload module 412 may be coupled to a peripheral payload mount 420. The peripheral payload mount 420 may be a supporting structure for holding the peripheral

payload module 412. In various embodiments, each of the peripheral slot 113 may comprise a rail 117 moveably coupleable to the peripheral payload mount 420. A coupling provided between rail 117 and the peripheral payload mount 420 may enable a displacement of the peripheral payload module 412 along the respective radial axis 84, thus enabling positional adjustment of the peripheral payload module 412 along the radial axis 84 by the single user. Further, the rail 117 may also aid in the attaching and/or detaching of the peripheral payload module 412 (or the peripheral payload mount 420) to the respective peripheral slot 113, by supporting the weight of the peripheral payload module 412.

[0080] FIGs. 9A and 9B illustrate exemplary peripheral payload modules 412 and the respective peripheral payload mounts 420. The peripheral payload modules 412 may include oversized payloads (FIGs. 8 and 9A) as well as odd shaped/elongated payloads (FIG. 9B). In exemplary embodiments, electronics and/or miniature float modules may be attached to the peripheral payload mounts 420. FIGs. 10A, 10B and 10C further illustrate another exemplary peripheral slot 113 as well as the corresponding exemplary peripheral payload mounts 420.

[0081] Referring back to FIG. 4, in various embodiments, the payload modules 410 may include one or more core payload modules 414. The core payload modules 414 may be coupled to and be held by the frame 110 coupled within the periphery 102 of the buoy 100. In contrast to peripheral payload modules 412, the buoy dimension may remain unchanged responsive to attaching the core payload modules 414 to the buoy 100, and responsive to detaching the core payload modules 414 from the buoy 100. In various embodiments, attaching the core payload modules 414 to the frame 110/buoy 100 and detaching the core payload modules 414 from the frame 110/buoy 100 may both be manually operable by a single user.

[0082] Referring to FIGs. 5, 11 to 15, the buoy 100 may define at least one conduit 117 extending through the base frame 112 along or parallel to the buoyancy axis 82. One or more of the core payload modules 414 may be movably coupled to the at least one conduit 117.

[0083] In various embodiments, the at least one conduit 117 may be a central conduit 117 which extends coaxially with the buoyancy axis 82. In other words, the central conduit 117 is in-line or in alignment with the buoyancy axis 82. Further, the buoy 100 may further comprise a central conduit payload mount 430 for holding or disposing one or more core payload modules 414. The central conduit payload mount 430 may be movable or slidable relative to the central conduit 117 along the buoyancy axis 82. Further, the buoy 100 may also include a winch module coupled to the frame 110 or the top mount 310. The winch module may be configured for lifting the at least one payload module 410 along the buoyancy axis 82. For example, the winch module may be configured to lift 435 the central conduit payload mount 430 along the buoyancy axis 82 and/or release 435 the payload mount 430 along the buoyancy axis 82.

[0084] In various embodiments, the central conduit 117 may extend from the interior space 116 of the enclosing structure 114 through a buoyancy plane of the buoy 100 to terminate at a flange 118 formed on the base frame 112. The buoyancy plane may correspond to a fluid level or expected fluid level relative to the buoy 100 in an operational environment, such as in the sea. In other words, the buoyancy plane may be substantially coplanar with the fluid level of the operational environment. This beneficially allows the central conduit payload mount 430 or core payload modules 414 to access to the sea via the central conduit 117. In addition, the configuration reduces the material required without compromising the structural integrity/strength of the buoy 100 during operation.

[0085] According to various embodiments, referring to FIG. 13, the central conduit payload mount 430 may comprise an elongated support boom 432 coupled to a cage 434. The cage 434 may be configured to hold one or more core payload modules 414, such as sensors. In an example, the cage 434 may be configured to hold the core payload modules 414 via a socket and coupling mechanism, to facilitate installing and removing the core payload modules 414 (such as sensors), reducing the time required for the maintenance process.

[0086] According to various embodiments as shown in FIGs. 14 and 15, the cage 434 may define a plurality of coupling points (and coupling spatial quadrants) distributed angularly about a cage axis 435. Each of the plurality of coupling points/coupling spatial quadrants may be coupleable to one or more core payload modules 414. In other examples, the coupling spatial quadrants may also be spaced apart along a height of the cage 434, i.e. along the buoyancy axis 82.

[0087] The cage 434 and hence the core payload modules 414 may be movable relative to the central conduit 117 along the buoyancy axis 82 by pulling or releasing on the support boom 432. In various embodiments, the support boom 432 may be telescopically extendable and retractable along the buoyancy axis 82. This permits a relatively shorter central conduit payload mount 430 when the support boom 432 is in a retracted state, thus alleviating the need for a tall enclosing structure 114. In various embodiments, the interior space 116 of the enclosing structure 116 may house the core payload modules 414 / central conduit payload mount 430 when the support boom 432 is in the retracted state. Optionally, the enclosing structure 116 may be provided with a limiter or a hard support for holding and/or supporting the core payload modules 414 in the retracted state. This allows the core payload modules 414 / central conduit payload mount 430 to be locked or held in position relative to the frame 110/base frame 112 during servicing or maintenance. In an example, extending or retracting the support boom 432 may be performed using the winch module.

[0088] In various embodiments, the oversized payload modules 410 may be defined as one diametrically larger than the central conduit 117, or may be larger than the cage 434. In an example, the oversized payload modules 410 may have a larger sectional area than the central conduit 117. In another example, the oversized payload module 410 may include a diametrical side which is longer than a diameter of the central conduit 117.

[0089] In various embodiments, referring to FIGs. 16A and 16B, the enclosing structure 116 may further include one or more service doors 119 installable by a single user. The service door 119 may allow or restrict access to the interior space 116 of the enclosing structure 116. The service doors 119 may also be configured with one or more junction boxes for housing electronics. In various embodiments, the junction boxes may be movable relative to the service door 119, for example by use of a mounting rail.

[0090] Provision of the telescopic support boom 432 enables an ensemble of core payload modules 414 to be disposed in water as the sensors are held and protected by the cage 434, while concurrently allowing collective lifting of the core payload modules 414 for easy maintenance. This beneficially improves the performance of core payload modules 414, such as sensors, to produce more stable and robust measurements, and alleviates the need for costly diving operations and/or heavy lifting crane during repair or maintenance, thus reducing operational costs for payload modules which require frequent maintenance. In addition, the telescopic support boom 432 configuration when coupled to a support, also improves operator safety and reduces risk to core payload modules 414 or sensors during lifting operations. The provision of winch modules and a limiter enables the cage 434 to be held at the retracted position, thus reducing the loading time and minimizes load on the winch module and the lifting cables. Risk of potential vandalism, sabotages or unauthorized modifications may also be mitigated, as lifting the cage 434 is difficult without external tool support.

[0091] Referring to FIGs. 17 to 19B, in various embodiments, at least one peripheral conduit 217 may be formed through the float module 210. The peripheral conduit 217 may extend through the float module 210 parallel to and spaced apart from the buoyancy axis 82 along the radial axis 84. In other words, the peripheral conduit 217 may be spaced apart from the radial axis 84, such that the peripheral conduit 217 and the central conduit 117 are spaced apart along

the radial axis. One or more of the core payload modules 414 may be movably coupled to the peripheral conduit 117.

[0092] In various embodiments, the peripheral conduit 217 may extend from a top side of the float module 210 through a buoyancy plane of the buoy 100 to terminate at a bottom side of the float module 210. The buoyancy plane may correspond to a fluid level or expected fluid level relative to the buoy 100 in an operational environment, such as in the sea.

[0093] According to various embodiments, referring to FIG. 17, the buoy 100 may further comprise a peripheral conduit payload mount 440 for holding or disposing one or more core payload modules 414. The peripheral conduit payload mount 440 may be movable or slidable relative to the peripheral conduit 217 parallel to the buoyancy axis 82. Further, the peripheral conduit payload mount 440 may comprise an elongated support boom 442 coupled to a cage 444. The cage 444 may be configured to hold one or more core payload modules 414, such as sensors. As shown in FIG. 19A and 19B, the support boom 442 may be provided with a handle for easy lifting by a single user, such as a maintenance crew.

[0094] Referring again to FIG. 10B, in various embodiments, the float modules 210 may include intermediate frames 213 for the peripheral conduit 217 and battery tray. The intermediate frames 213 may correspond to locations where contact is frequent. The intermediate frames 213 may be configured as replaceable protection frames, which may be swapped with a replacement piece by a user upon sustaining wear and tear during operation.

[0095] According to another aspect of the disclosure, disclosed herein a method of assembling a buoy system 50. The method comprises: providing a buoy, the buoy comprising a frame defining a buoyancy axis; and at least one float module coupled to the frame; and attaching at least one payload module to a periphery of the buoy along a radial axis, wherein the radial axis is orthogonal to the buoyancy axis.

[0096] Referring to FIGs. 20 to 21C, according to another aspect, in order to enable the float modules 410 to be manually swappable, the method of assembling a buoy system 50 may also address and overcome the large manufacturing tolerance in typical float module fabrication process. FIG. 20 shows multiple potential puncture sites 215 or perforation sites on a coupling wall 212 of the float module 210. The multiple potential puncture sites 215 may be large puncture area corresponding to or matching the mounting hole 111 on the frame. This enables the tolerance of the float to be accounted for during assembly. According to various embodiments, the method of assembling the buoy system may further comprise: in FIGs. 21A and 21B, puncturing, perforating or drilling a coupling wall 212 on the float module 210 using a drill 218 to form a coupling hole 215 on the coupling wall 212; and in FIG. 21C, attaching a fastener 216 to a preformed mounting hole 111 on the frame 112 through the coupling hole 215. By perforating or puncturing coupling holes on a coupling interface of the float modules during the assembling process in place of using holes that are formed previously or during the fabrication process (such as during the molding process), this alleviates the common positional error or high tolerance error between the coupling holes on the float module and the frame 110. Hence, forming the coupling hole during the assembly process of the float module allows damaged float modules to be swapped with ones from different production batches modularly. This reduces maintenance cost for the buoy as well as facilitating maintenance of the buoy and/or swapping of float modules on-site.

[0097] **Exemplary implementation**

[0098] FIG. 22 illustrates an implementation of the proposed buoy system and buoy. The buoy system or buoy platform is configured to address the limitations of existing data buoys in the market, namely on-site or in-water payload changes and extensibility and the maintenance cost of sensors that need frequent human attention. The proposed buoy system and buoy provide an open-architecture mechanical interface to accept diverse payloads from third-party users.

One prominent feature of the buoy system/buoy is the ability to accept unconventional payloads that cannot fit into standard moonpools using a unique side-insertion payload bay.

[0099] The proposed buoy system/buoy comprises an open-architecture lightweight frame that accepts multiple small sensors to stabilize and maximize the utilization of each central or peripheral moonpool. Further, a telescopic boom for the central moonpool is provided which allows retracting a 590 mm rosette-like sensor cage to the surface for easy maintenance. The proposed buoy system/buoy comprises various features, such as a rapid sensor coupling mechanism, flexible railing systems for electronics boxes, reconfigurability of sections, replaceable floats, and a mechanism to lift sensors to the surface for maintenance without divers, which reduces operational costs and improves service turnaround time.

[00100] Components of the buoy system

[00101] 1. PE/PU buoy floatation for operation safety

[00102] 2. Compartmentalised floats to minimise loss of buoyancy and replacement cost.

[00103] 3. Accept diverse payloads

[00104] a. 1 nos. central moonpool ID 590 mm

[00105] b. 4 nos. peripheral moonpool ID 280 mm

[00106] c. 2 nos. peripheral module slots rectangular 300 x 1000 mm

[00107] d. 2 nos. top sensor pole with clamps

[00108] e. 3 nos. electronics mounting space (D)280 x (W)500 x (H)1700 mm

[00109] 4. Minimise sensor maintenance cost with retractable sensor frame

[00110] 5. Lockable superstructure 1200 mm width, 3100 mm tall

[00111] Central moonpool with retractable boom

[00112] The central moonpool (or central conduit) includes a retractable boom (or central payload mount) that carries an underwater sensor cluster. The boom's telescopic design stabilizes the underwater sensors in strong currents and lifts them to the surface for

maintenance. The boom helps produce more stable measurements and avoids costly diving or lifting crane operations during maintenance, reducing operational costs for sensors that require frequent maintenance.

[00113] The boom is provided with coupling mechanism facilitating installation and removal of sensors, allowing an easy and brief attachment/detachment of sensors inside a rosette-like protection cage, and reducing the time required for the maintenance process.

[00114] The telescopic boom comprises two to three collapsible sections, holding a 590 mm diameter quick-installable rosette package in the water. A single user may retract or lift the sensors to the surface quickly, allowing an easy removal, maintenance and reconfiguration of the sensor composition.

[00115] Lifting of the boom is supported by a 12/24V DC winch operating from a small battery. The lifting process is a multi-stage process designed for safe operations. Removable inserts (or limiters) are introduced to help shift the weight loading from the winch wires to the structure support to improve operation safety. The inserts help support the booms in the lifting process and improve safety during long maintenance hours. The battery pack and inserts are removed between maintenance trips to prevent unwanted access to the expensive sensors. Central boom operations. FIGs. 11 to 12B illustrate the boom extended during normal operation (left) when lifted to maintain sensors (middle) and the inserts that provide safety support during prolonged maintenance operations (right).

[00116] The buoy provides a mounting interface and dimension to mount the boom (FIGs. 13 and 23). The mounting dimension is made available to general users as part of the open architecture interface documentation, allowing the development of customized boom according to requirements. Mixed-material welding was used to install SS316 boom mountings on the mild steel core. The welding improves the robustness of the mounting points while keeping the cost low.

[00117] Further, the boom provides a rosette-like sensor cage with a quick installation and removal mechanism to host diverse sensors in the central moonpool. The mechanism comprises a central socket system and standardized fixtures that may be inserted into the socket. To install new sensors, the users may use or provide clamps specific to the respective sensors and attach the clamps to the adapter (see FIG. 14). In the implementation, the sensor cage is provided with eight installation slots that are angularly distributed within a 155 mm toroidal space of 650 mm height (see FIG. 15).

[00118] For cylindrical sensors, which are a good approximation of most underwater sensors, the cage may host or house eight sensors with a 130 mm diameter. The single user may also install sensors up to 150 mm in diameter by taking up space for adjacent slots. Maximising the number of sensors to be carried by interlacing big and small sensors in the setup is possible.

[00119] Peripheral moonpool

[00120] The buoy provides four peripheral moonpools (or peripheral conduits) each with an internal diameter of 280 mm to support smaller sensors. A lightweight aluminium mounting frame with mounting rails is provided to hold multiple sensors rigidly in the peripheral moonpool. However, the number of sensors to be fitted in the mounting frame (or peripheral conduit payload mount) is constrained by the inner diameter of the cage of 110 mm and the exposed and in-water vertical space of about 750 mm. FIGs. 19A and 19B illustrate the standard moonpool operations and the lightweight aluminium frame (see FIG. 17).

[00121] The mounting dimensions (as shown in FIG. 24) of the mounting frame may be included as part of the open architecture interfaces of the proposed buoy system, thus allowing the single user to configure the relevant payloads as needed. When using the standard frame, the single user may produce suitable C-clamps that fit the sensors to the mounting rail.

[00122] Peripheral module bay

[00123] One of the features that sets the proposed buoy system/buoy apart from conventional buoys is the ability to accept payloads with non-conventional shapes and sizes. The peripheral module bay provides a novel way to install and remove payloads that do not fit into a standard moonpool, differentiating the buoy from standard data buoys. The peripheral module bay significantly reduces operation costs by enabling onsite, in-water payload changes, eliminating the need for a large vessel to lift the buoy out of the water or involve diver operations. The buoy body may naturally protect the payloads installed in the bay from surface vessels. The rail and frame system may include self-righting buoyancy, an insertion mechanism, and a locking mechanism.

[00124] Peripheral module bay (PM bay) refers to the slotted space the buoy provides. Peripheral module rail (PM rail) is the rail mechanism installed in the PM bay to support easy insertion of payloads. The peripheral module frame (PM frame) is a structural support frame that holds the payload and its electronics. It has a matching design that slots into the PM rail. Payloads that are too large or complex to fit into peripheral or central moonpool may be installed into the PM bay. FIGs. 7A and 7B show two PM bays, each about 300 mm wide, to support the complex payloads.

[00125] The PM bay may provide a standardized mounting interface that would, in turn, accept peripheral module rails, as shown in FIGs. 10A to 10C. This provides the flexibility to change the peripheral module rail according to different demands. FIG. 10A shows the mounting interface in PM bay, FIG. 10B shows the default peripheral module rails that make use of part of the PM bay mounting interface, and FIG. 10C shows the matching PM frame that slots into the PM rail.

[00126] During normal operations, the top frame is slotted into the PM rail until it reaches the desired position and bolted in place from the surface. The lower frame is then locked in place by lowering the central bar, which pushes two lateral stoppers sideways towards the PM

bay. This provides a friction-fit holding point against the walls of the PM bay and minimizes motions

[00127] Based on the PM rail, the PM bay may accept multiple payloads within its available space (see FIG. 8). With the lateral insertion method, the PM bay is not limited by the size of moonpools or the footprint of the bay. This enables oversized payloads of arbitrary shapes to be accommodated, as shown in the examples in FIG. 7B. This freedom from size constraints sets the buoy apart from conventional data buoys. In addition to serving as an anchoring structure for the peripheral module rail and peripheral frame fittings, the bay area is also useful for housing watertight electronics and other payloads that do not require access to free-flowing waters but could benefit from heat dissipation. The space available is up to 1m x 30 cm x 1.4 m, depending on how many PM frames are used. The PM frame installed from the bay would then serve as structural support for the oversized payloads extended below the buoy.

[00128] If the peripheral module payload (PM payload) is on the same plane, the payload may share the available underwater space with sensors from the peripheral moonpool. However, if the PM payload clears the sensors' depth from the peripheral moonpool, the PM payload may use all the space available apart from the mooring swings. A small gated door is provided to maintain the hydrodynamics of the buoy and to minimize changes to the drag.

[00129] The PM payload may be configured to be slightly buoyant (such as by adding a small float module or buoyancy support) in order to facilitate the insertion of the PM payloads onsite and in-water from the surface without diver support. The buoyancy support may be located within the PM frame region, which provides a self-righting moment stabilizing the buoy during installation. The buoyancy support may be permanent or removed after the installation process. FIGs. 9A and 9B show examples of the PM payloads mounted. FIG. 9A shows an example of a small payload that clamps a pole to the PM frame and uses a float to trim the buoyancy. FIG.

9B shows an example of two PM frames (and occupies the entire PM bay) to support a larger payload.

[00130] The buoy provides two mounting options to mount dry-end sensors, such as meteorological, dynamic wave, etc.

[00131] Top sensor pole and rail

[00132] The first option is to use the top-side sensor ring or top mount provided by the buoy with the mounting definition as shown in FIGs. 25A and 25B. The mounting interfaces may be part of the open architecture interface documentation to facilitate the adoption of the buoy. The single user may choose to mount sensors directly onto the ring mast or add sensor poles on the rings using the same interface to increase the height and number of sensors (see FIG. 25A).

[00133] Junction box mounting rail

[00134] The second option is to mount the sensor within the superstructure using junction box mounting rail provided. Given that the buoy is configured to hold a substantial number of sensors, space is added to support multiple electronics boxes inside the superstructure. The electronic boxes are configured to allow installation by a single service crew member, i.e., the box is within lifting weight. This is important due to limited working space on small buoys and the instability when multiple service crew members are on the buoy.

[00135] A railing system is provided which enables flexible installation and removal of electronics boxes/sensors. The railing system comprises a supporting bar and a locking slider. The supporting bar is first adjusted to match the mounting points of the box. It is then bolted on the rail at an appropriate height that matches the mounting point below the box. A sliding bar would then be installed on the rail as a locking mechanism to keep the box in place. During installation, the service crew member may insert and rest the junction box on the supporting bar, thereafter, slide the locking slider to restrain the top of the box before bolting/tightening the junction box at the bottom supporting bar.

[00136] These rails may also support sensors that do not specifically require atmospheric exposure (such as dynamic-based wave sensors, etc.). FIGs. 16A and 16B show the mounting rails in the superstructure, and FIG. 26 shows the dimensions of the interfaces.

[00137] Buoy structure reconfigurability

[00138] The proposed buoy is configured for modularity and reconfigurability, allowing the swapping of payload modules/sections based on specific use case or requirements.

[00139] Core Frame

[00140] Referring to FIGs. 27A and 28B, the core frame (or frame) is the key supporting structure that holds the core components together, such as floats, superstructure, mooring, etc. and serves as a strengthening member that provides rigidity to the buoy. The lifting and mooring eyes are integral parts of the core and are rated for a safe working load of 10MT aggregate. It is manufactured from grade BSEN 10025 2004 S275 mild steel and treated with a ZINGA coating for long-term service.

[00141] Floats

[00142] The floats (float modules) comprise cylindrical quadrant sections and rectangular rotor-moulded from UV-stabilized virgin Polyethylene with colour fastness. The floats are filled with marine-grade closed-cell PU foam, which has an absorption rate of less than 10% and a filling rate of 92%. Hence, a crack in the float collar would reduce buoyancy by up to 18%. Therefore, the operational design should ensure reserve buoyancy is larger than this to keep the buoy always afloat. The floatation unit is purposefully divided into six independent units to further limit the loss of buoyancy during accidental events.

[00143] The float or float module from the rotor molding process typically exhibits about 10% tolerance. To allow an on-site swapping of damaged floats with replacement from different production batches, the mounting surface is not provided with prefabricated mounting holes. Instead, the coupling holes are formed on-site during assembly/replacement.

[00144] Superstructure

[00145] Referring to FIGs. 28A and 28B, the superstructure (or enclosing structure) is coupled to the steel core, with both including a common mounting interface. The common mounting interface gives the single user the flexibility to change the structure design and swap out damaged units if needed. The superstructure is built from marine-grade aluminium to improve buoy stability and includes features to enhance operations efficiency and safety. The superstructure includes an integrated ladder to access the top, safety handrail and safety harness anchor points for operators to move around the buoy, safety support for the retractable boom to minimize the risk of snapping the lifting cables, door stopper to prevent swinging of open door should the sea/environment become choppy, and electrical cabling routing trays for housekeeping.

[00146] Ring-mast support

[00147] Referring to FIGs. 29A and 29B, the buoy further comprises a ring-mast support (or top mount) which decouples the top-side configuration from the superstructure to provide flexibility in reconfiguring power systems and sensors without affecting the core electronics housed in the superstructure. The ring-mast support module interfaces with the superstructure, and may support dry-end sensor mounts and solar panels. A common interface mounting is defined between the superstructure and the ring-mast support.

[00148] As the next broadest structure following the floatation unit, the top mount has a higher risk of damage from mechanical impacts. Hence, a swappable top mount reduces downtime and the cost of repair should unwanted events occur. FIGs. 6A and 6B show examples of two types of top mount. FIG. 6A shows a top mount with upward facing PV panels (solar panels) as well as downward facing PV panels, for harnessing additional energy from the reflective sunlight. The top mount uses six nos. of smaller 75W panels instead of four larger

100W panels of FIG. 6B. As the PV panels are mounted to all six sides of the superstructure, a special flippable solar panel was created to allow maintenance access to the top.

[00149] Protecting PE/PU float from mounting wear and tear

[00150] It is known that various marine environmental sensors or payload modules often require frequent cleaning and maintenance. The maintenance process often involves frequent removal and re-installation of payload modules or sensors through the moonpools. Hence, the mounting inserts on the PE/PU float moonpools (peripheral moonpools) which are frequently accessed, is often subjected to high wear and tear. As the mounting inserts are typically molded in place, the mounting inserts are irreparable. The proposed buoy system/buoy comprises intermediate frames for enduring wear and tear typically sustained by the float during repair or maintenance. FIG. 30 shows the intermediate frames used for peripheral moonpools and battery tray. The intermediate frames may be replaceable protection frames which may be swapped with a replacement piece upon sustaining wear and tear during operation.

[00151] Waterproofing of standard batteries

[00152] FIG. 31A illustrates a battery bay formed in the PE/PU float (or float module). Disposing the battery in the float enables the centre of gravity to be lowered, enhancing stability. However, this puts a requirement on the batteries to be waterproofed. FIG. 31B shows a low-cost and flexible enclosure solution to waterproof a standard sealed cuboid battery with minimal size increment. The solution comprises a custom-designing a tray system and a potting process to irreversibly seal the battery within an enclosure.

[00153] Renewable energy system

[00154] The proposed buoy system/buoy is configured with a renewable energy generation system using solar panels as a primary power source. FIG. 32 shows a system diagram of a renewable energy setup in MESN of the proposed buoy system/buoy. The energy generation

and consumption can be monitored through Modbus RTU and streamed to the cloud if required.

A diversion controller is added to protect overcharging from future turbine systems.

[00155] The baseline PV system consists of an array of six 75W upward-facing PV panels and six 75W downward-facing panels. Both arrays are fed into separate solar chargers that connect to the same pool of battery banks.

[00156] The battery bays can accept banks of four 110Ah 25.6V LiFePO4 or eight 65Ah 25.6V LiFePO4 batteries depend on operational requirements. The advantage of using smaller batteries is the ease of swapping them, an important feature of one's plans to push the limit of one's power budget. However, the larger batteries have the advantage of being a well-tested industry solution.

[00157] Table 1 shows the various parameters of the implementation of the proposed buoy system.

Table 1. Specification of the implementation of the proposed buoy system

Description	Parameter	Remarks
Physical specification		
Focal Height of Lantern	5240 mm	
Super structure height	3190 mm	
Buoy Diameter	2650 mm	
Float height	1400 mm	
Overall Length	7400 mm	To the tip of the sensor pole
Total buoyancy	6100 kg	
kg/mm submersion	~4.35	
Rated payload	500 kg	Distributed among moonpools & towers
Buoy weight without payload & operator	3350 kg	Including batt, PV & ballast
Adjustable ballast included	1000 kg	Three layers of independent semi-circle ballasts
Draft without payload	1860 mm	Without chain
Freeboard without payload	630 mm	Without chain
Mooring type	two point mooring	Can modified to single point using V-link.
Max 2pt-mooring depth @20mm, 24mm chain	50 m,30 m	full load, 600 kg reserve buoyancy

Max 1pt-mooring depth @20mm, 24mm chain	100 m,50 m	full load, 600 kg reserve buoyancy
Material		
Float	PE shell, PU foam	PE UV stabilised 10 year
Superstructure	Marine grade aluminium	
Core frame	Mild steel with antifouling layer over ZINGA coating	
Visibility		
Lantern	M860 equivalent	Programmable, range up to 7 nm
Topmark	Special mark cross, yellow	
Radar reflector, range	EM325	RCSmax=62.15 m2, RCSavg=7.92 m2
Appearance	IALA special buoy, yellow	
Renewable energy		
PV array	40W continuous load in Singapore	
Battery	LiFePo4 26.7V, 8 x 65Ah or 4 x 110Ah	7 days of reserve or more
Diversion controller included	Optional protection for turbine system integration	
Stability		Current 3 knots, wind 20 m/s
Natural frequency with load without chain	2.5s (heave), 4.6s (longitudinal), 5.2s (traversal)	Analytic estimation
Tilt with load & mooring	6.5 deg	Simulated, mooring along current, wind & wave orthogonal

[00158] All examples described herein, whether of apparatus, methods, materials, or products, are presented for the purpose of illustration and to aid understanding, and are not intended to be limiting or exhaustive. Modifications may be made by one of ordinary skill in the art without departing from the scope of the invention as claimed.

CLAIMS

1. A buoy system, comprising:
 - a buoy, comprising:
 - a frame defining a buoyancy axis; and
 - at least one float module coupled to the frame; and
 - at least one payload module detachably coupleable to a periphery of the buoy along a radial axis, wherein the radial axis is orthogonal to the buoyancy axis.
2. The buoy system as recited in claim 1, wherein the buoy defines a buoy dimension orthogonal to the buoyancy axis, wherein the buoy dimension increases responsive to attaching the at least one payload module to the buoy, and wherein the buoy dimension decreases responsive to detaching the at least one payload module from the buoy.
3. The buoy system as recited in claim 2, wherein attaching the at least one payload module to the frame and detaching the at least one payload module from the frame are both manually operable by a single user.
4. The buoy system as recited in any one of the above claims, wherein the at least one float module is detachably coupled to the frame, wherein attaching the at least one float module to the frame and detaching the at least one float module from the frame are both manually operable by a single user.
5. The buoy system as recited in any one of the above claims, wherein the frame comprises at least one peripheral slot, the at least one peripheral slot disposed between adjacent

pairs of the plurality of float modules, wherein the at least one peripheral slot extends from the frame towards the periphery of the buoy along the radial axis.

6. The buoy system as recited in claim 5, wherein the at least one payload module comprises at least one peripheral payload module, each of the at least one peripheral payload module being coupleable to a respective one of the at least one peripheral slot.

7. The buoy system as recited in claim 6, wherein each of the at least one peripheral slot comprises a rail for displacing a respective one of the at least one peripheral payload module along the radial axis.

8. The buoy system as recited in any one of the above claims, further comprising a plurality of float modules coupled to the frame, the plurality of float modules disposed angularly symmetrical about the buoyancy axis.

9. The buoy system as recited in any one of the above claims, wherein the buoy defines at least one conduit, wherein the at least one payload module comprises at least one core payload module, each of the at least one core payload module being movably coupled to the at least one conduit.

10. The buoy system as recited in claim 9, wherein the at least one conduit extends parallelly to the buoyancy axis through a buoyancy plane of the buoy, the buoyancy plane corresponding to a fluid level relative to the buoy in an operational environment.

11. The buoy system as recited in any one of claims 9 and 10, wherein the buoy further comprises a cage movable relative to the at least one conduit along the buoyancy axis, the cage being configured to hold the at least one core payload module.

12. The buoy system as recited in claim 11, wherein the cage further comprises a support boom telescopically extendable and retractable along the buoyancy axis, wherein the support boom is operable by a single user.

13. The buoy system as recited in any one of claims 11 and 12, wherein the cage defines a plurality of coupling points distributed angularly about a cage axis, wherein each of the plurality of coupling points is coupleable to the at least one core payload module.

14. The buoy system as recited in any one of claims 9 to 12, wherein the at least one conduit extends coaxially in relative to the buoyancy axis.

15. The buoy system as recited in any one of claims 9 to 14, wherein the at least one conduit is formed through the at least one float module, wherein the at least one conduit is spaced apart from the buoyancy axis along the radial axis.

16. The buoy system as recited in any one of claims 9 to 15, wherein the frame comprises an enclosing structure, the enclosing structure defining an interior space for housing the at least one core payload module in a retracted state.

17. The buoy system as recited in claim 16, wherein the support structure further comprises a limiter for supporting the at least one core payload module in the retracted state.

18. The buoy system as recited in any one of the above claims, further comprising a plurality of solar panels coupled to the frame, wherein selected ones of the plurality of solar panels are disposed facing towards the at least one float module, and wherein selected others of the plurality of solar panels are disposed facing away from the at least one float module.

19. The buoy system as recited in any one of the above claims, further comprising a winch module coupled to the frame for lifting the at least one payload module along the buoyancy axis.

20. A method of assembling a buoy system, the method comprising:

providing a buoy, the buoy comprising a frame defining a buoyancy axis; and

at least one float module coupled to the frame;

attaching at least one payload module to a periphery of the buoy along a radial axis,

wherein the radial axis is orthogonal to the buoyancy axis.

21. The method of assembling the buoy system as recited in claim 20, further comprising:

puncturing a coupling wall on the at least one float module to form a coupling hole

on the coupling wall; and

attaching a fastener to a preformed mounting hole on the frame through the coupling

hole.