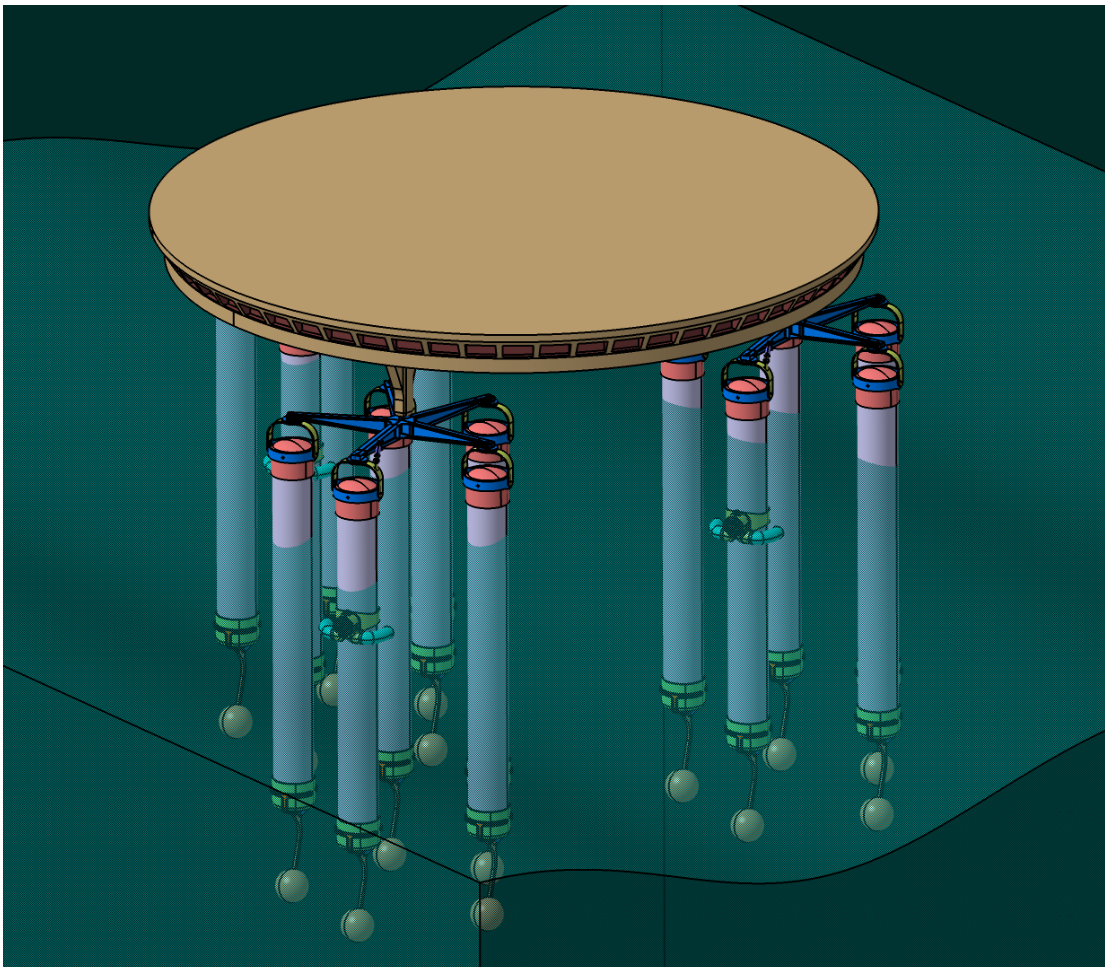
INTRODUCING

THE PILLAR BOAT!



U.S. Patent No. 9,623,935

ABSTRACT

The need to conduct motion sensitive operations at sea is increasing in the fields of space launch and recovery, oil exploration, aquaculture, international business and finance, and travel and leisure. Additionally, motion isolated platforms will open possibilities for individuals to work in, or enjoy, nautical settings without the concern for motion sickness.

Many regions of the world are in need of new living space which will not increase pressure on terrestrial eco systems. The invention of a stable, robust, marine platform capable of handling the most severe wind and waves while providing

occupants a low motion environment will be of tremendous value. Civil, business, research, and military uses of such a platform abound. The arrangement for supporting a stable floating platform upon spar buoy clusters using multiple levels of articulated footings described below could change the world (for the better).

WHAT IS A PILLAR BOAT ANYWAY?

The essential parts of this invention are shown in figures 1 and 2. The platform is separated from the motions of the water surface by at least two layers of articulation. The Pillar Boat platform is supported on clusters of spar buoys. A spar buoy is a long thin cylindrical float weighted at the bottom so it will float upright, the top end of the spar buoy rises above the water like a pillar.

The simplest form of Pillar Boat is shown in figure 1. It consists of a platform with three downward legs, each leg is connected to a footing with three arms, which are in turn connected to three spar buoys. The vertical and lateral distances between the platform and the footings, as well as the vertical and lateral distances between the footings and the spar buoys provide vibration response isolation from surface wave environments. Pillar Boats don't rock, unless you want a smooth ride on any sea, then they really rock (by not rocking). Just look at **Figure 1**.

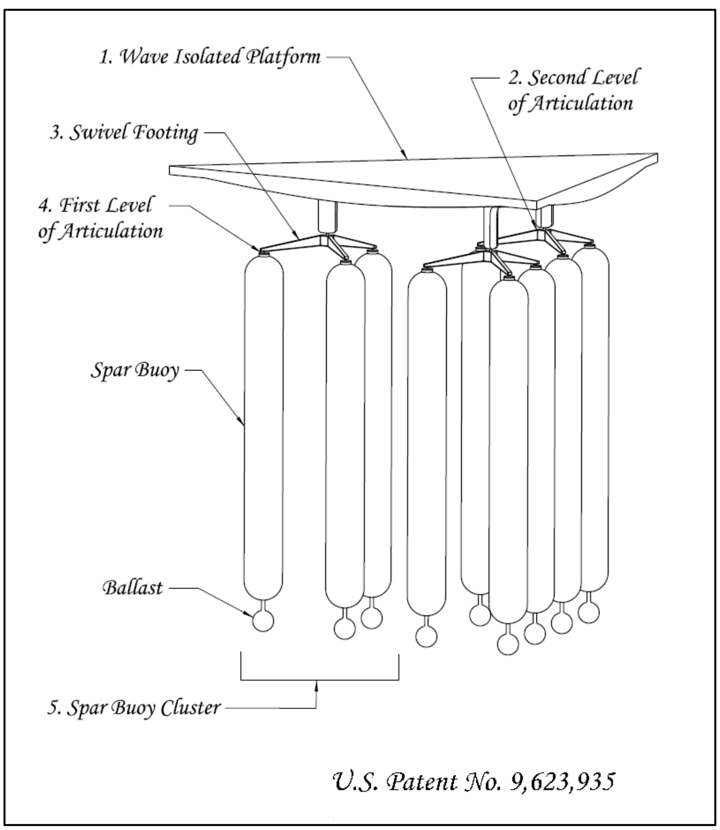


Figure 1.

By their nature, Pillar Boats have a deep draft. The pillars are supported from deep below the waves, so an individual spar buoy will bob only slightly from a passing wave. With the averaging effect provided by the swiveling footing, and also by the footings to the platform, very little wave motion is transmitted to the passenger deck. But three buoys and three clusters is just the start. See **Figure 2**.

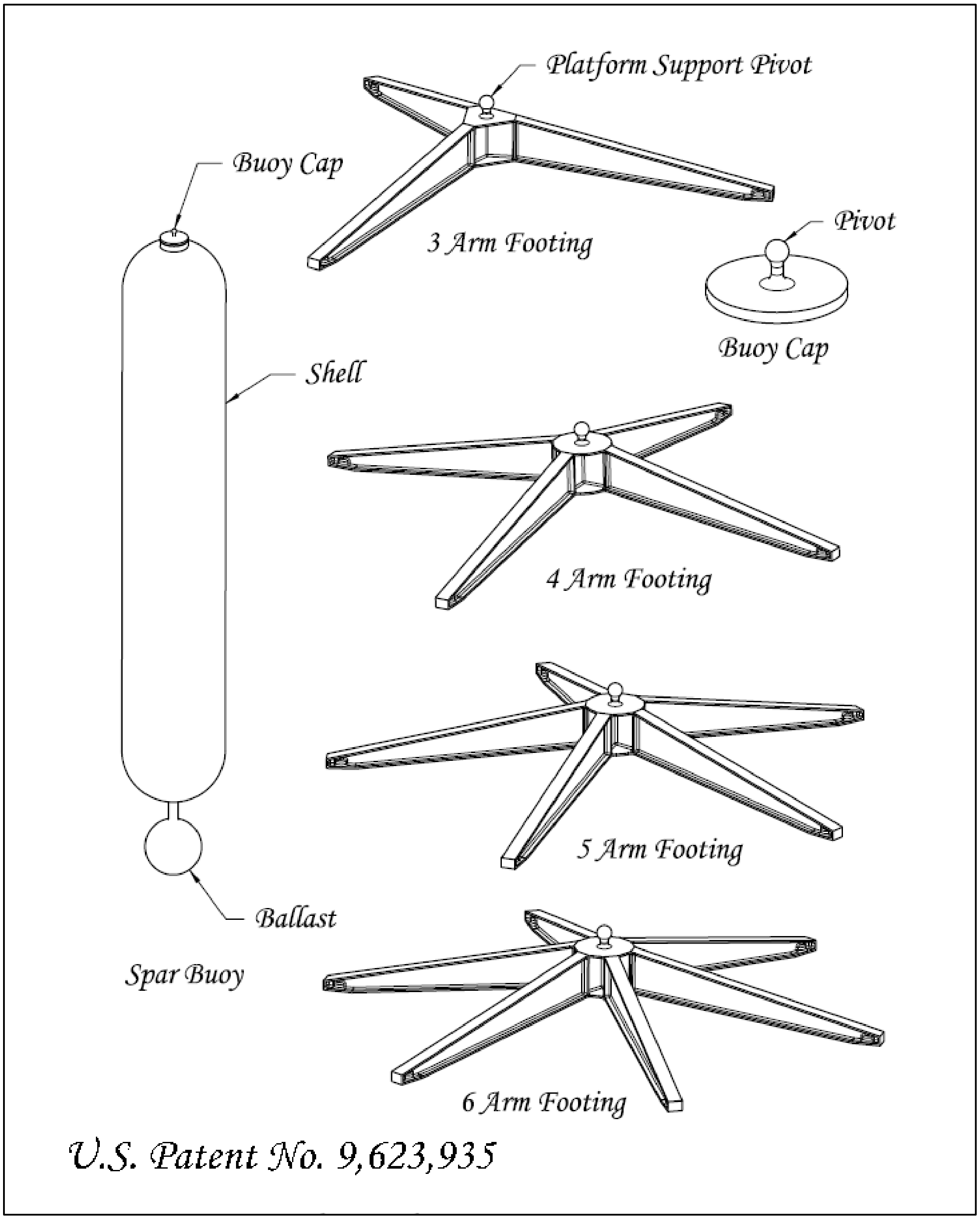
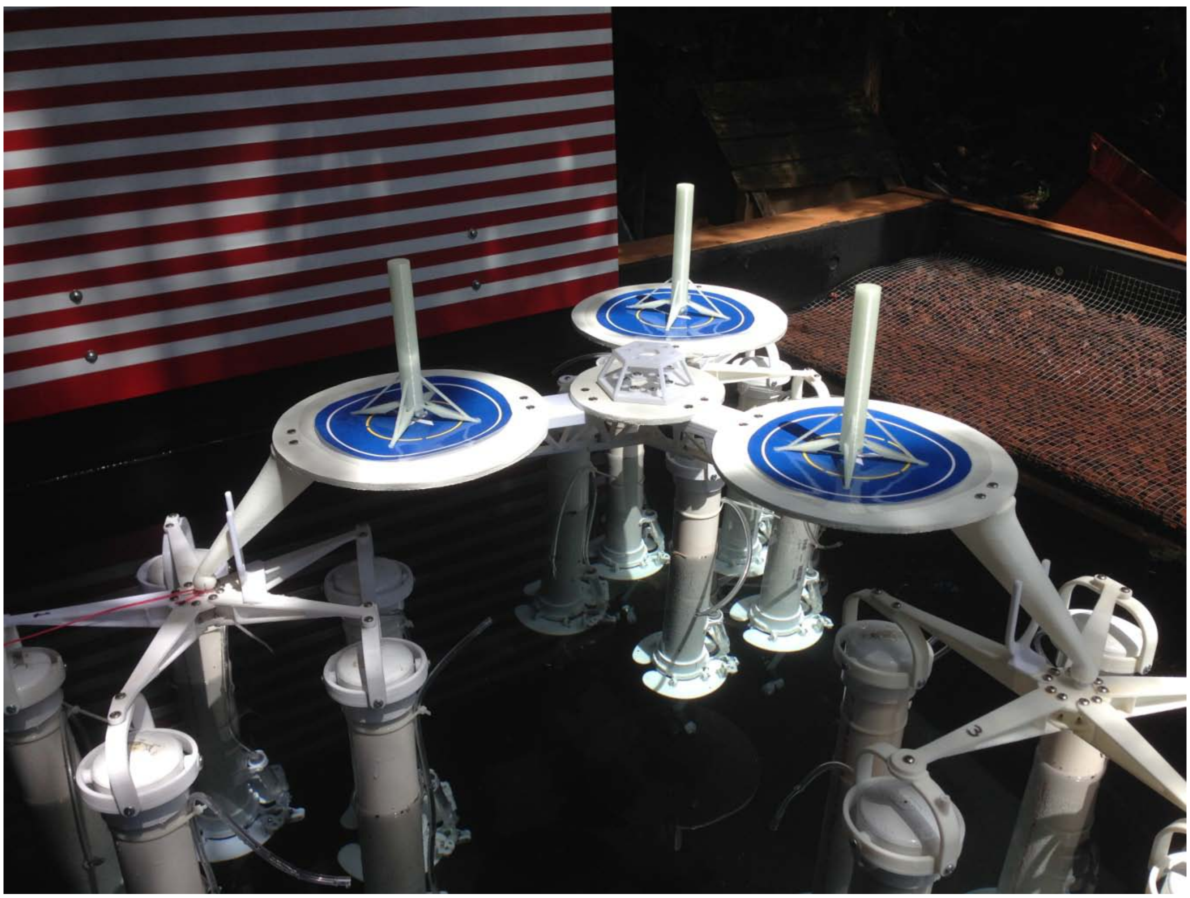


Figure 2.

Unlike supporting a platform on uneven ground, the buoy tripod is just the first stable arrangement. Additional buoys may be added to support additional load without getting the wobbly table effect. By adding more buoys, safety is also improved by adding redundancy to the support of the vessel. In theory there is no limit to the number of buoys supporting a Pillar Boat.

WHY MAKE A PILLAR BOAT?

What can a pillar boat do that other watercraft can't? Well, check out this application.



This is a test model of a SpaceX falcon 9 landing pad I am proposing. Unlike a barge, the pillar boat is heavily ballasted and has a deep draft, and with the levels of articulated footings, it can provide a stable surface for rocket launches and recoveries. No current vessel design can offer the combined load capacity and stability of a pillar boat.

HOW DOES A PILLAR BOAT WORK?

Figure 2. shows the components of a spar buoy cluster. The spar buoy shell may be made of any suitable rigid material capable of resisting water intrusion, and made to float upright by adding ballast to the base. Large buoys could be constructed economically from marine grade, fiberglass or basaltic rebar reinforced, concrete. The top is closed by a cap with a pivot. The ballast, made of a high density material, is mounted to the base either internally or externally (external ballast is shown). The footings illustrated are of 3, 4, 5, and 6 arms equally spaced around a central pivot. The end of each arm includes a socket which attaches to the pivot cap mounted to the top of the spar buoy. Ball and socket pivots are shown in this figure, alternative pivot arrangements will be shown in later figures.

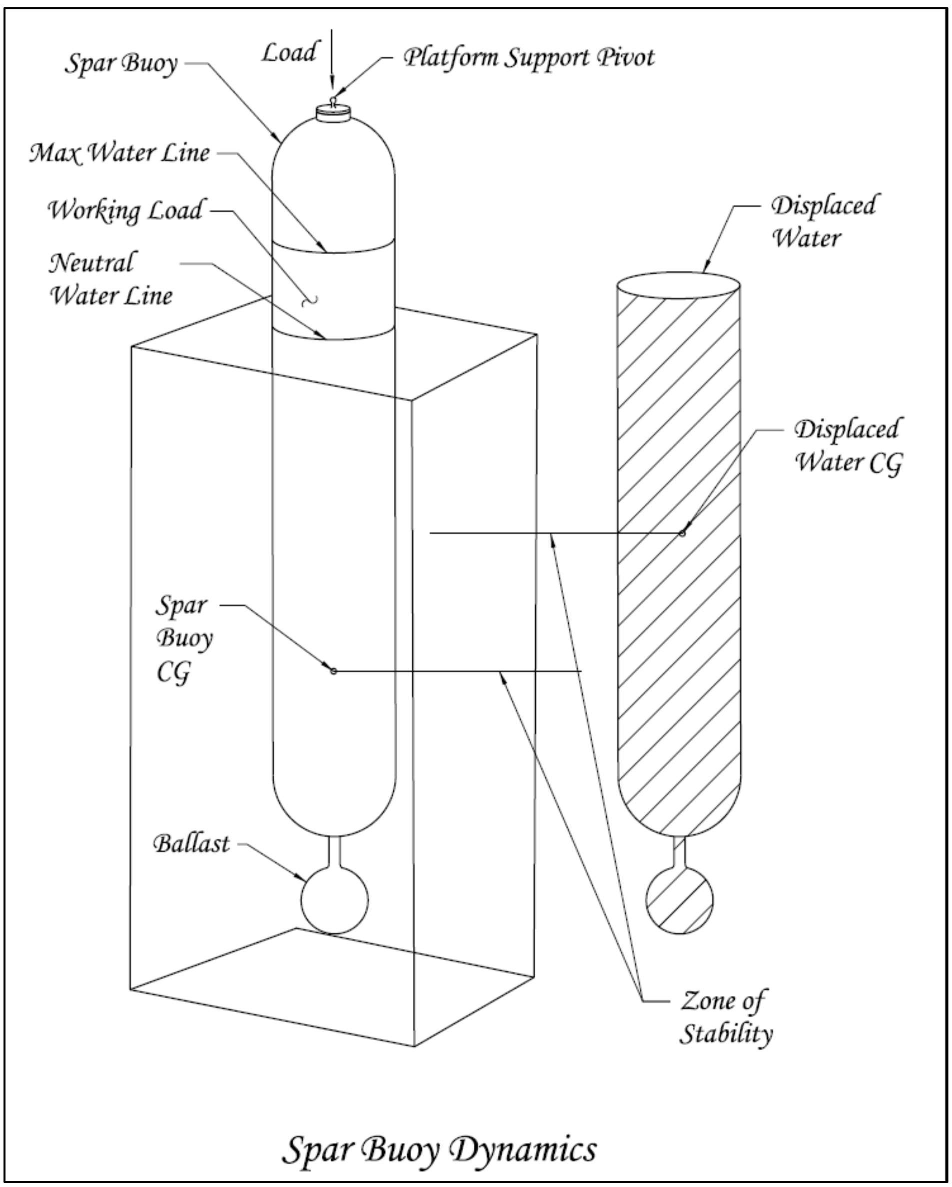


Figure 3.

Figure 3. illustrates the dynamics of the spar buoy arrangement. The buoy is supported by an amount of displaced water equal to its mass. This is the equilibrium point that establishes the natural water line. The buoy will float upright as long as the center of gravity (CG) of the buoy-ballast combination lies below the CG of the displaced water. The distance between the CG of the buoy and the CG of the displaced water defines a zone of stability. Load may be applied to the top of the spar buoy which will cause it to sink further and displace additional water creating a lifting force equal to the load applied. The load applied to the top of the buoy will have the effect of raising the CG of the buoy-ballast-load combination. As long as the CGs are separated by a zone of stability the buoy with an applied load will remain upright. Pillar boat buoys are designed to remain upright even when the top is pushed all the way to the waterline.

Every ballasted buoy arrangement as illustrated will oscillate or bob about the water line at a frequency defined by its mass and cross sectional area. This invention tailors the buoy dimensions to negate response, or respond minimally to inputs of expected water wave frequencies of the body of water for which it is designed. Typically bigger waves require bigger buoys.

HOW DOES A PILLAR BOAT GET OUT TO DEEP WATER?

Figure 4 shows a spar buoy with a movable ballast, able to transition between vertical and horizontal floating positions. The ballast rotates about a pivot point. The motion is created by a lever arm mechanism powered from the vessel platform by hydraulic pressure, a mechanical linkage, or an electric actuator.

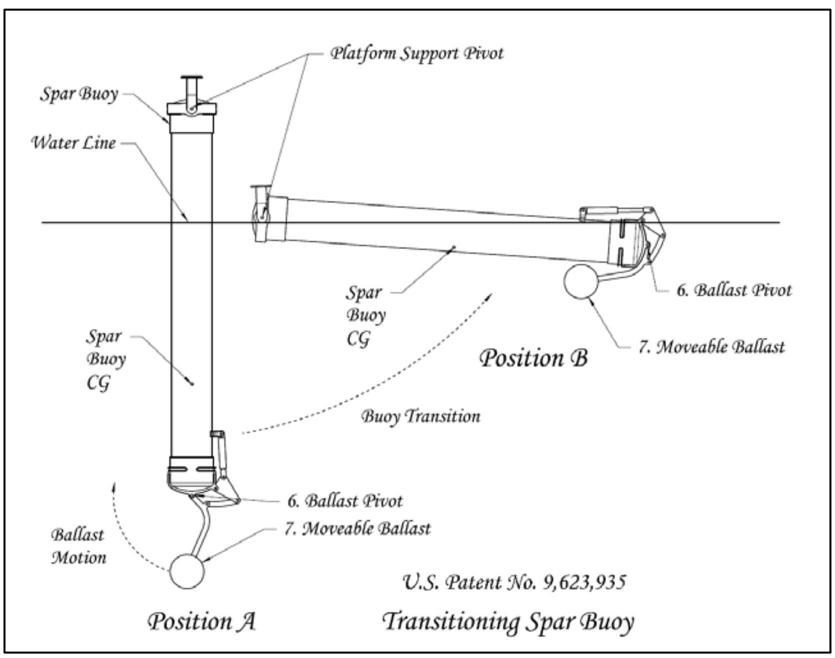


Figure 4.

In the horizontal position, the pillar buoy needs only a fraction of the draft required while upright. The displacement of the ballast in figure 4 may appear insufficient to cause buoy transition, however, this is a non-obvious feature of this invention and depending on the load applied to the top of the buoy even smaller displacements may suffice. The lateral displacement feature of the mechanism provides control of the direction the buoy will rotate while in transition and provides stability in floating orientation after the transition is complete.

Pillar buoys may be towed out to the site of vessel construction, or the entire vessel may be constructed in the horizontal position and then transitioned after reaching water of sufficient depth.

WHAT MAKES A PILLAR BOAT GO?

Figure 6 shows a buoy propulsion system. The ideal propulsion module attaches to the buoy without penetrating the shell, in a wrap around configuration. The intake is positioned on the forward side of the buoy below the waterline so it will remain below the waterline when the buoy transitions from position A to Position B. An impeller is mounted in the main housing and forces water to flow down and out through the nozzles, creating thrust. The nozzles articulate through an angle of 90 degrees so that the thrust may be directed aft in both positions A and B. The impeller may be powered by hydraulic lines similar to large ship thrusters.

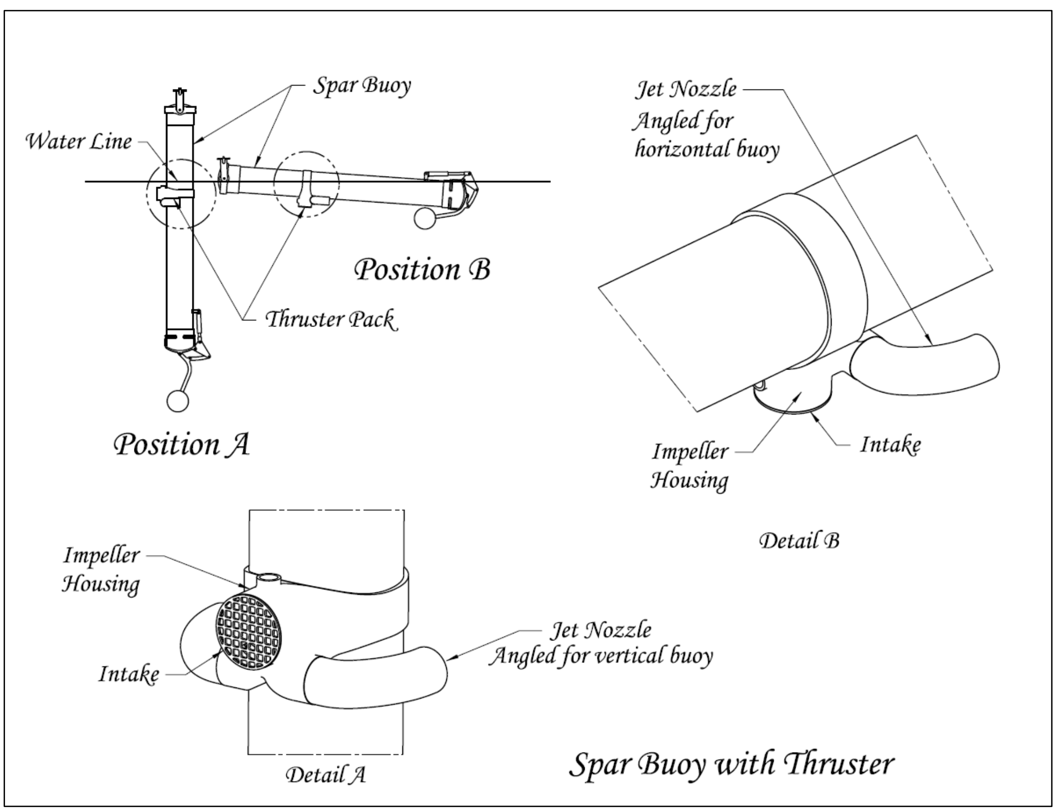


Figure 6.

HOW DO YOU STEER A PILLAR BOAT?

Figure 7 shows the various steering mechanisms. Directional control is achieved by means of an actuator or push rod that causes the buoy equipped with the thruster pack to rotate about its longitudinal axis. This in turn will cause the buoy cluster to rotate about its central axis. When the cluster is aligned in the direction of desired motion, the actuator returns the thrust buoy to the neutral position. When all clusters are aligned in the same direction, the vessel will move in a straight line. This system allows the vessel to move in any direction without the need to rotate the main platform. Aligning the clusters to thrust in different directions will cause the upper platform to rotate. If all thrusting clusters are aligned in a tangential pattern, the vessel may be made to rotate in place without any lateral motion. Combinations of alignments in between those listed above may be used to create rotational and forward motion simultaneously. Such motions may be useful for sightseeing tours.

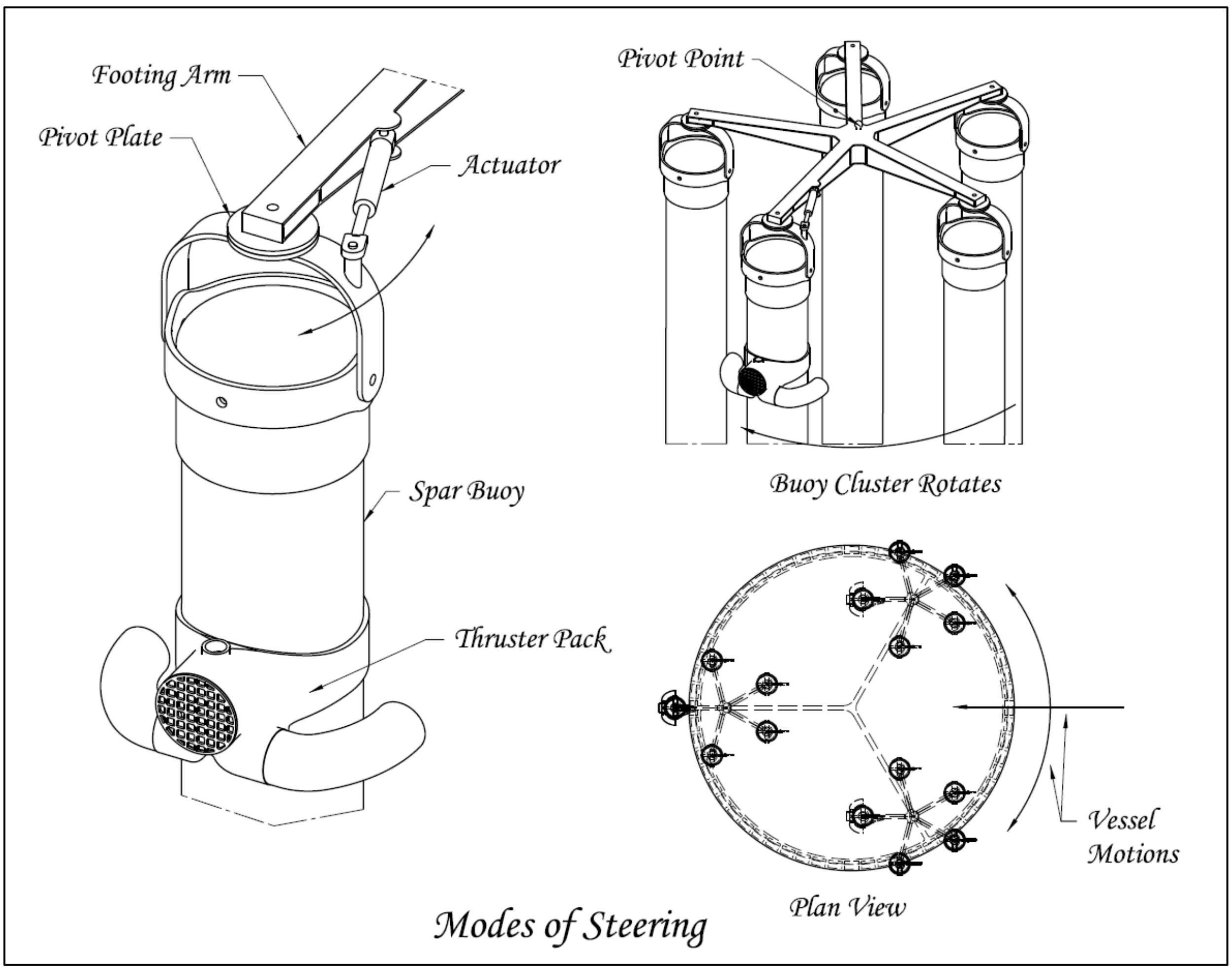


Figure 7.

Figure 8 shows an upright vessel configured with three buoy clusters having five buoys per cluster. Such a vessel could receive and launch aircraft, or spacecraft from the upper deck. The upper structure of the vessel could be made of materials used in high rise commercial buildings, or similar to cruise ship superstructures. Such a vessel would provide occupants with a low motion environment for conduct of onboard activities. This vessel could be useful for touring in comfort, or to host a variety of activities such as, medical facilities, manufacturing or maintenance, military surveillance, oil exploration, nautical research, search and rescue basing, and many more.

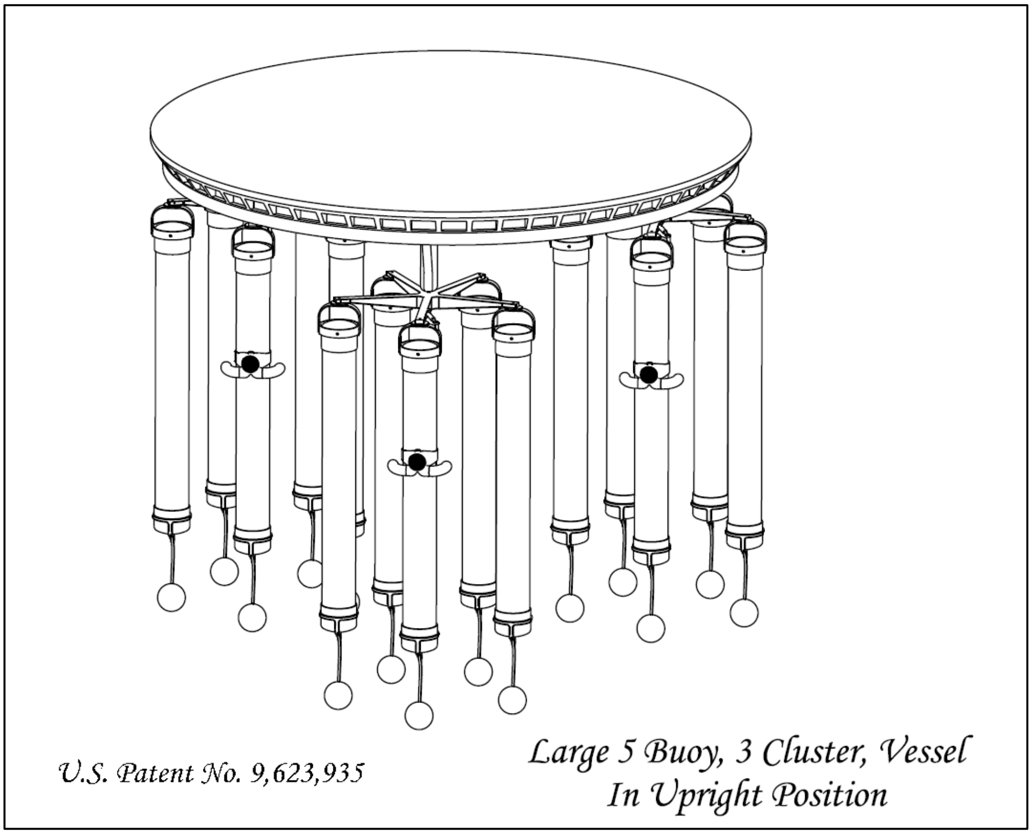
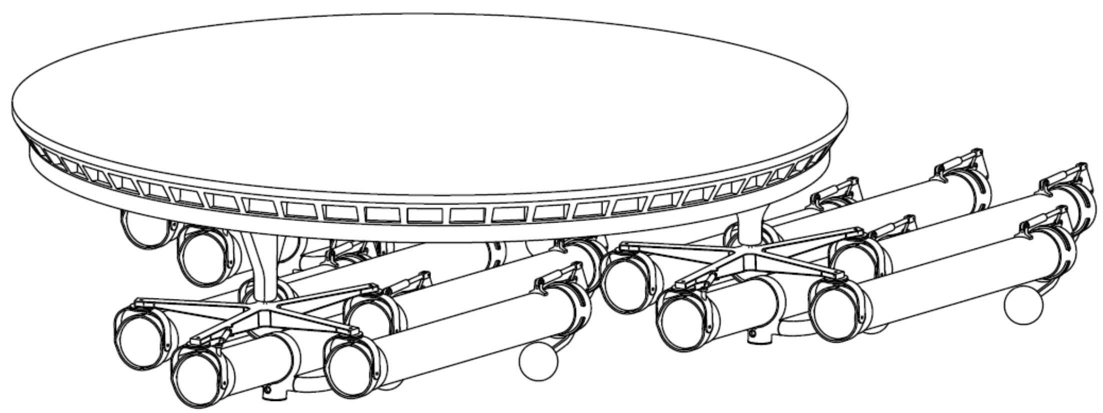


Figure 8.

In order to provide a sense of scale the following table lists the properties of the vessel in Figure 8 based on the diameter of the buoys. All features of the vessel are kept to scale. (A buoy with twice the diameter will be twice as long).

Buoy Diameter	Useful Load (Structure and Payload)	Draft in Meters Upright/Horizontal	Natural Period Of Spar Buoys
1 meter	22 metric tons	8.5 / 1.8	5.2 seconds
2 meters	174 metric tons	17 / 3.6	7.3 seconds
5 meters	2,700 metric tons	43 / 9	11.5 seconds
10 meters	21,700 metric tons	85 / 18	16.4 seconds
20 meters	174,000 metric tons	170 / 36	23 seconds

Vessels of all sizes and load capacity may be created to any speciation. A vessel as in figure 8, with buoys between 2 and 5 meters in diameter could safely be deployed in the Gulf of Mexico, the Mediterranean, or any of Earth's large lakes. A vessel with buoys 20 meters in diameter would be able to withstand any condition seen in the Atlantic Ocean.



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Large, 5 Buoy, 3 Cluster, Vessel
In Retracted Position

Figure 9.

Figure 9 shows a retracted vessel configured with three buoy clusters having five buoys per cluster. The retracted configuration is the configuration the vessel may take when entering or departing shallow water ports, or when traveling through shallows between deep water bodies. My favorite thing about this configuration is how it resembles the Starship Enterprise.

PRIMARY MODES FOR CARRYING OUT THE INVENTION

This invention may be expressed in three basic modes. The first mode is that of a passive wave isolation platform which must be towed into position and anchored. This mode is the simplest form and is shown in figure 1. A spar buoy tailored for a specific wave frequency will have a fixed load bearing capacity. To increase the total load capacity that may be supported by the platform, additional buoys may be added to each cluster and additional clusters may be added to support the top platform. This is true for all further modes described.

The second mode, is a self propelled wave isolation platform which includes a propulsion mechanism added to one or more of the individual spar buoys in one or more of the spar buoy clusters. This mode is capable of navigating and avoiding obstacles in water of sufficient depth to remain floating. The frequency and size of the waves expected to be encountered for application on a particular body of water, will dictate the spar buoy dimensions requiring water of a particular depth to float the buoys in the vertical orientation. Large, long period waves will dictate large buoy dimensions. This could limit the vessel to deep water, and could restrict access to all but the deepest water ports. It could even limit such a vessel to remain continuously at sea if no port of sufficient depth is available.

The third mode is a self propelled wave isolation platform with the ability to transition all of the spar buoys simultaneously from vertical axis alignment to horizontal axis alignment and vise versa. In this mode, a mechanism to relocate a portion, or all of the ballast is added to each spar buoy. The vessel is equipped with a central control able to coordinate the positions of the movable ballast on every individual buoy at the same time. In addition, the pivot connecting the buoy to the first level footing must be configured to accommodate both vertical and horizontal alignment of the buoy. Furthermore the propulsion mechanism attached to any such buoy must be configured to provide useful thrust in either vertical or horizontal alignment.

If the vessel is underway at a low speed when initiating transition, the drag of the motion through the water will help keep the buoys aligned in the same direction as they swing from vertical to horizontal or vise versa. This is in addition to the natural tendency of the buoys to tilt in the direction of the displacement of the ballast from the buoy's central axis. By keeping the buoys within a cluster oriented so that the ballasts all swing in the same direction and maintaining a small amount of velocity through the water, a gentle transition may be managed.

A vessel of this mode will have access to a greater number of ports when returning from sea or seeking safe harbor. However, with the buoys in horizontal alignment, much of the wave isolation capability will be lost. Such a vessel should only be used in the horizontal buoy alignment configuration while navigating through shallows in fair conditions.

UNIQUE FEATURES AND ADVANTAGES

1. This invention tailors the natural frequency of the spar buoys to provide minimal response to the actions of waves on the body of water for which it is intended.

2. This invention employs a novel arrangement of multiple levels of articulation for the purpose of motion isolation of the upper platform for the conduct of motion sensitive operations while afloat.

3. This invention is unique in clustering spar buoys under articulated footings in groups of three or more to allow for a high load capacity while maintaining a tuned frequency response to the action of waves.

4. The buoy transition mechanism involving the lateral and upward displacement of ballast is novel and useful in controlling the direction the buoys will swing up and down while in transition.

5. The thruster arrangement of this invention provides individual control of each buoy cluster and endows the vessel with unique modes of locomotion not seen in traditional surface ships.

6. The upright vessel may travel in any direction without reorienting the upper platform. The retracted horizontal configuration navigates more like traditional surface vessels but has a unique appearance resembling something from science fiction.

TECHNICAL DETAILS

A spar buoy's natural oscillation period may be calculated using equation 1.

$$T = 2\pi\sqrt{M/A\rho G} \tag{1}$$

Where T is the time period of one oscillation, M is the mass of the buoy/load combination, A is the cross sectional area of the buoy, ρ is the density of the fluid medium (sea water) and G is the gravitational attraction of the Earth at sea level.

The study of vibration response is a well documented and complex science. In simple terms, if the natural oscillation period of a system is more than 1.7 times the period of the forcing function (sea waves) the system will not resonate and will respond marginally to the forcing function. So for waves with five seconds between crests such as found in the Gulf of Mexico, a buoy should have a natural period of 8.5 seconds or higher. For wave sets with 10 seconds between crests, the buoy should have a natural period of 17 seconds or higher. The period T in equation 1 may be increased by either increasing the mass M or decreasing the area A or may be decreased by doing the opposite.

Response to waves may also be decreased by spreading the buoys and buoy clusters so that they will each ride a different part of the wave. The displacement of the center pivot of a footing will be the average of the individual buoy displacements, thus if some buoys, or clusters are riding up a wave while other are riding down, the average will tend toward being neutral.

The velocity of sea waves is given by equation 2.

$$v = 1.25\sqrt{L} \quad or \quad v = L/T \tag{2}$$

A little algebra yields equation 3.

$$L = (1.25T)^2 \tag{3}$$

Knowing the wave length allows the buoys to be positioned so that they will be out of phase with the other buoys. The angle of phase may be computed by equation 4.

$$Phase\ Angle\ \ \theta = 360\left(\frac{D}{L}\right) \tag{4}$$

Values of D/L of .333 or higher will ensure that the inputs from individual buoy response do not interfere constructively.

Additional layers articulation may be added by the insertion of footings between the platform and the first level footings for increased wave isolation. The top platform in figure 1. would be replaced by a larger footing supported by the lower spar buoy clusters. The top platform is then supported by a minimum of three second level footings. The minimum such arrangement requires a top platform, three second level footings, nine first level footings, and twenty-seven individual spar buoys. Theoretically any number of layers of articulation is possible, however economics and logistics will restrict the number of such layers in actual applications. Furthermore, each cluster may have four, five, six, or more spar buoys to provide additional support to the footing. Footings with up to six arms are shown in figure 2. The spar buoys may be of equal dimensions, equally spaced around the center of rotation of the footing, or may be of differing dimensions, unequally spaced on arms of differing lengths in order to tailor the footing vibration response to the wave motion of the water surface. In such an arrangement it is desirable to have the combined center of buoyancy of the buoys supporting a footing aligned beneath the center of rotation of that footing.

Figure 5 shows various types of articulated joints for use between buoys and footings or between footings and higher footings or the upper platform stiff legs. These joints transmit limited rotational forces, allowing free movement between the buoy and the footing or the footing and higher platforms. The amount of rotation allowed varies for each type, however each may be modified to allow buoy transition between vertical and horizontal orientation. The universal joint and the spherical bearing may require an additional rotation joint similar to the swivel plate shown on the gimbal joint to allow the buoy to rotate about its longitudinal axis.

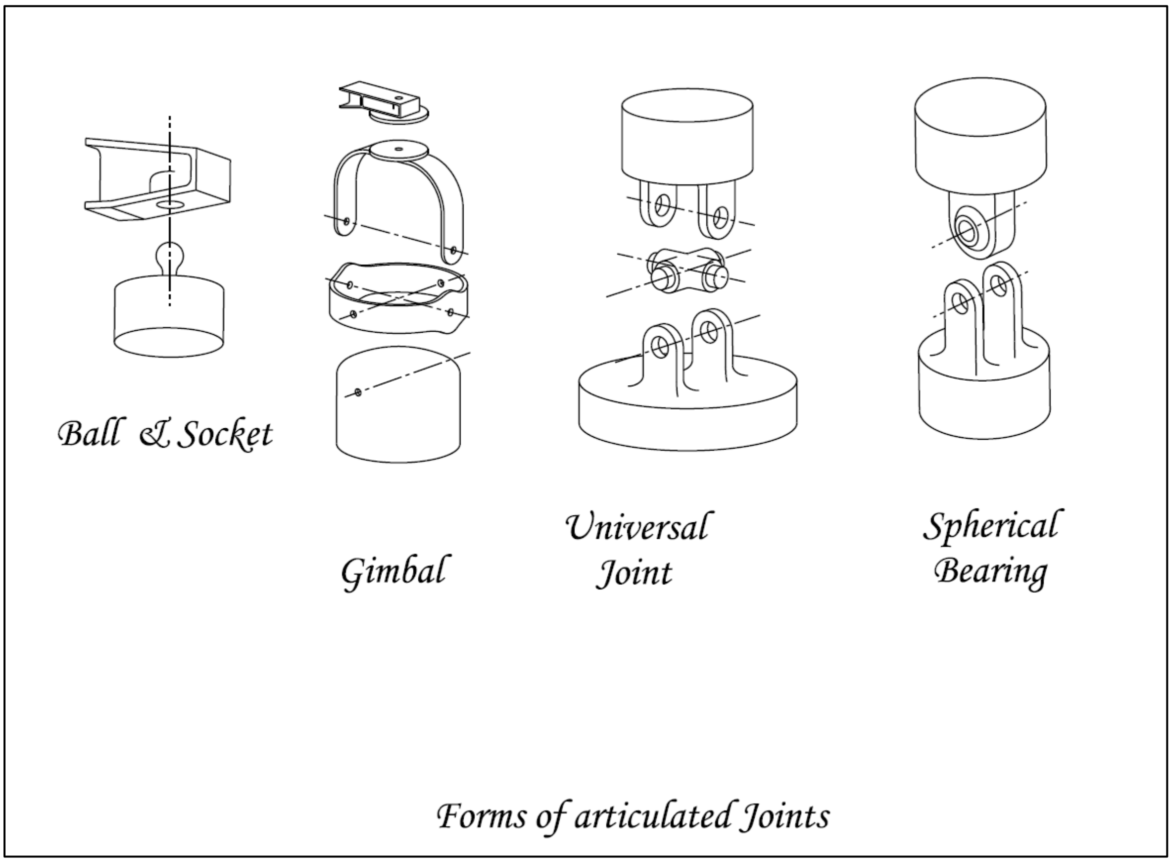

Figure 5.

ALTERNATIVE EMBODIMENTS

Spar buoys illustrated are of circular cross section but they may be of any closed shape projected along an axis. Ballast has been illustrated as a spherical mass but may be sculpted to a hydrodynamic form which may assist in reducing drag while the vessel is underway in either the upright or retracted configuration. The mechanism for relocating the ballast has been illustrated as a simple swinging lever, however, a track mounted system, or a cable drawn system, or other means of creating the required displacement may be employed.

Footings have been illustrated as star-like shapes with arms radiating from a central hub, however, they could easily be circular discs, rectangular blocks, or any other shape having multiple pivot attach points for support from three or more buoys and a single main pivot point for support of a higher platform. When equipped with a thruster buoy, the footing may include a mechanism for the directional control of the thrust not shown in the figures.

The upper decks or platforms shown in the figures are of simple geometric shapes but by no means should this imply a restriction of the possible shapes and functions of the upper platform. The platform must have at least three pivot attachments to the footings and be of sufficient size and strength to survive the marine environment. After this has been achieved any shape imaginable is possible. Very tall structures may lead to decreased stability and increased sensitivity to wind.

The pivot attachments between the buoys and footings and the footings and the platform may be of any configuration that transmits limited rotational force and allows free movement of the buoys, footings, and platform.

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