<u>Triton:</u>
outpost in the ocean

by

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Author's Declaration

I herby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by examiners.

I understand that my thesis may be electronically available to the public.

Abstract

The ocean, especially the deep ocean, dominates this world; it is the largest single habitat on the planet, a habitat whose inhabitants constitute the most common forms of life on this planet. By its immense influence on the global climate systems, this vast realm continually shapes life on the land. It is the least understood realm on the planet, home to a system of life that we did not know existed – nor was it one we could even have imagined - only found by accident in the late twentieth century. We are tampering blindly with this vast realm, destroying segments of the intricate and complex systems of life within it. We plunder its riches and only return our waste. We need to know the ocean; it just may control our fate.

Presently, there is a gap in our ability to study this realm: we can no longer only sit on the surface, peering in from time to time; we need to look beneath the ocean's obscuring surface, at any point, for extended periods. Small research submersibles and self-contained diving gear only become available in the later half of the twentieth century, allowing us to venture beneath the ocean's surface. However, these have severe limitations, in their endurance (usually measured in hours) and operational conditions. The heyday for underwater research was the late nineteen-sixties; at that time there were, around the world, over fifty fixed undersea habitats operated by half a dozen countries. Their complexity, and their large on- and off- shore support requirements, eventually lead their sponsors to abandon of most of these habitats. There are only two left operating today, both of which are just off the coast of Florida, with one converted to a dive-access hotel in a coastal lagoon and the other anchored well offshore, the last remaining active undersea research habitat in the world.

We need a new type of ocean-going research vessel that will operate as an observation post on the deep ocean. Scientists need to collect a variety of data, over scales ranging from millimetres to kilometres and time spans ranging from seconds to days, years, and even decades; do this through a continuous, comprehensive, long-term, manned presence on and in the ocean, down to the seafloor, instead of trying to piece together processes by taking intermittent snapshots of a relatively few places and events; and keep this whole endeavour open and accessible to the entire world. A vessel that bridges the surface that isolates the two separate but intricately linked worlds, above and below, would enable researchers to be in both places at once. What such a vessel would be like, how it would function, and what challenges it would deal with; such a vessel is the focus of this thesis.

Acknowledgements

I'd like to thank my supervisor Donald Mckay, my advisors Dr. John Straube, John McMinn, and finally the external reader David Dennis.

And to my fellow officemates and Greg Piccini for their support and for making the long stay enjoyable.

Dedication

For my parents, and grandmother for their unwavering support.

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Preface

The Triton vessel is a built environment, an environment meant to be inhabited. It takes into consideration the comfort of its inhabitants as well as the spaces created for social interaction, privacy, research, and relaxation. It allows for the appreciation of its underwater surroundings even as it supports scientific studies. This Triton vessel embodies the Vitruvian principles of "commodity, firmness, and delight", the very definition of architecture itself.

For me, ships and other large vessels are the ultimate architecture, self-propelled buildings at sea. Where they are not just shelter, they form an architectural world unto themselves, sustaining and inspiring people within a hostile environment. Naval architecture has strayed too far from this responsibility; it has become a practice that focuses on the technical aspects of form and function at the expense of the vessel's community. This is evident in the two most common examples of naval architecture in existence today: the super tanker and the container vessel. These vessels are regarded, for the most part, as technological exercises. Despite their large scale, their function, and their importance to modern western society, they are not considered architecture and are rarely discussed outside of a few specialized circles, communities that focus on the technical and safety aspects of ships. An early example of this technical optimization is the research submarine Ben Franklin - built in the late nineteen-sixties and set to drift in the waters of the gulf stream - where the engineers and designers did not even consider portholes in the hull for the explorers inside to look out into the world they were trying to understand. Only after lengthy debate with the crew and project leaders did the engineers finally relent and provide portholes, even though they interfered with the engineering of the hull. With this specialist tunnel-vision, with neglect for the overall form and meaning of these vessels, they have faded in the public's consciousness.

This project is more than just a technical response to a particular set of criteria; it is meant to inspire not just those people who occupy it, but as importantly, if not more so, those who remaining onshore.

This thesis is laid out in several sections. The first is a brief account of the importance of the ocean and of humanity's relationship to it. The second section considers some of the unique physical properties of the oceanic realm this vessel will inhabit. The third section is the mission parameters for this vessel, and the design criteria that these parameters would generate. Finally, the fourth section is a design developed from the examination of the preceding parameters.

1.0 Background

Seen from the utter blackness of outer space, Earth our home is clearly misnamed. With the vast majority of its surface covered by water, our planet takes on a distinctive sapphire-blue colour when viewed from afar.

Oceanus

The Earth is a marine world. Not until the middle of the nineteenth century did, we even begin to understand this simple fact. It was only after a number of bold expeditions into the Arctic and Antarctic regions that we were able to fill in the last gaps in our knowledge about the global distribution of land and sea. Those expeditions signalled the end of the phase of surface mapping that constituted a necessary first step toward a scientific understanding of the global ocean. A global ocean that covers seventy-one percent of our planet, thirty seven hundred metres deep on average, resists our immediate grasp. Humanity only really started to begin to understand the enormity of the ocean forty years ago when we first left our planet and looked back at it from another world. In fact, we now know more about the surfaces and processes on other worlds than what is going on under the surface of the oceans of our home. Humankind has walked on the moon flown great distances into space, but no one has yet set foot on the deep ocean floor, and only a few have seen far beneath the ocean's obscuring surface. From above, the Earths dry contours stand out, rocky mountains, rolling plains, thick forests - but the sea, a flat sheet of opaque water, discloses very little.

For thousands of years humankind has looked out to sea with wonder. It is only within the past one hundred and thirty years that humanity has actively gone to sea for the sole purpose of trying to understand it. Throughout human history, the sea has been a highway for trade, free from the political boundaries imposed on the land. The ocean, with its enormity and mystery, has forever been part of the human consciousness. As mystery gave way to mastery, whole

Map showing the major oceanic regions.

Thor Heyerdahl

The renowned Norwegian explorer and archaeologist Thor Heyerdahl forever remembered as the Kon-Tiki man. In 1947, he skippered the tiny balsawood raft on a 6,000-kilometre journey from Peru to Polynesia. The Kon-Tiki expedition caught the imagination of a world enduring post-war austerity. The film of the expedition won Thor Heyerdahl an Oscar for best documentary; the book sold 60 million copies worldwide.

In 1970, he crossed the Atlantic in a papyrus craft; Ra II after the original Ra had disintegrated shortly after it set out. The journey, which ended in triumph in the West Indies, turned the idea that Columbus was the first transatlantic navigator on its head. Eight years later he skippered another ship, the Tigris, on a journey from the Euphrates and Tigris rivers, down the Persian Gulf to Oman, Pakistan and, then, across the Indian Ocean to Djibouti on the Horn of Africa. The five-month journey meant to show how the ancient Sumerians could have travelled widely. When, in Djibouti, the Tigris was prevented from entering the Red Sea by local conflicts, Heyerdahl burned it in a poignant protest against war. A committed internationalist, he always travelled with a multinational crew and always flew the flag of the United Nations.

Thor Heyerdahl's expeditions fostered a close understanding of the global environment and he voiced his concern at the increasing problem of pollution, which he had encountered even in the middle of the world's oceans. "We seem to believe the ocean is endless," he said, "but we use it like a sewer."

He said the world's oceans should be treated as one vast highway. That was how, he claimed, that ancient civilisations saw them. Modern people, he said, should be more ready to think in ancient terms. Thor Heyerdahl's controversial beliefs on human migration may have cut across the conventional wisdom of his time, but his pioneering spirit and continuing quest for understanding endeared him to millions.

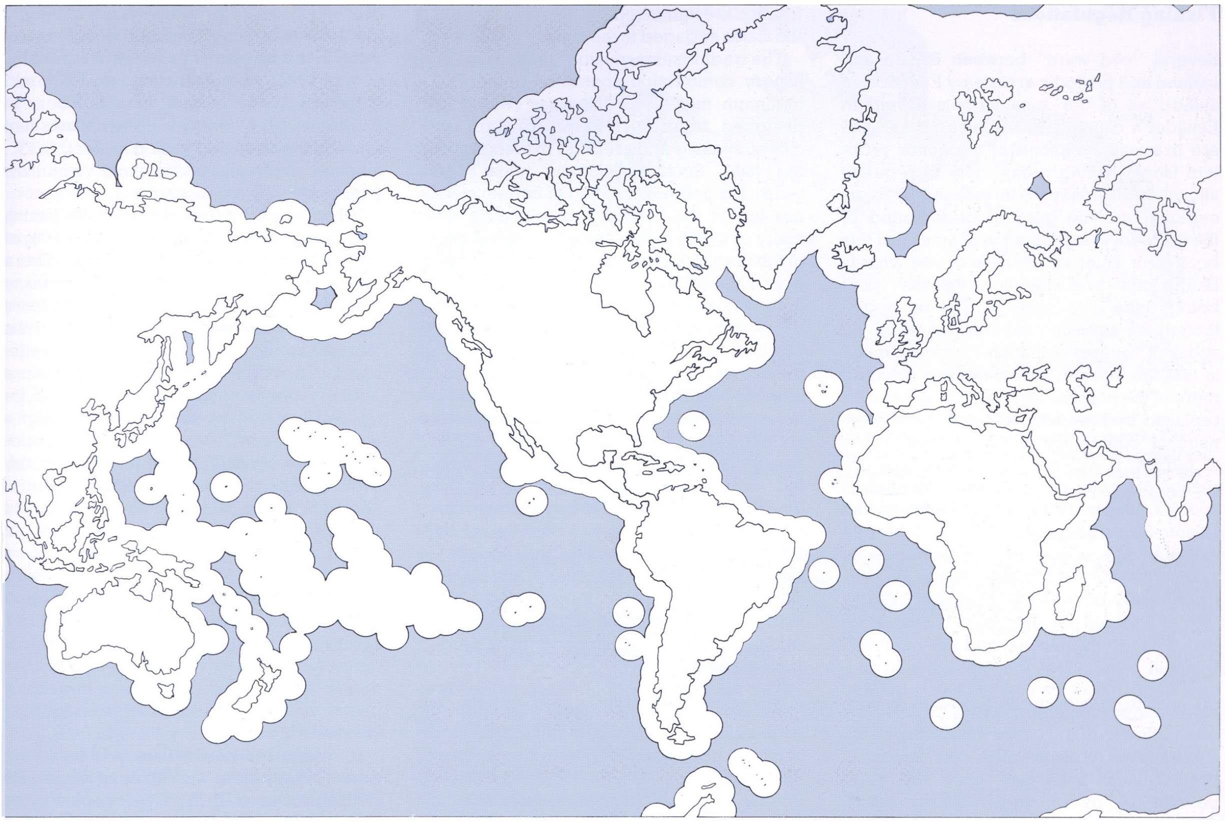
Condensed from BBC News, Europe. 18 April, 2002. (http://news.bbc.co.uk/1/hi/world/europe/1938294.stm)

bodies of custom, tradition and law arose defining the rights of the ships and mariners who plied its surface waters and of the States that rim the ocean. Now, those political and national boundaries have reached out into the sea.

The ocean itself had long been subject to the Freedom-of-the-Seas Doctrine - a principle put forth in the seventeenth century limiting national rights and jurisdiction over the oceans to a narrow belt of sea along nations' coastlines. This gave coastal states the right to exercise dominion over their territorial seas; the area of control only extended as far as the ranges of cannons based on the shore, with the remainder of the ocean proclaimed to be free to all, belonging to none. While this situation prevailed into the twentieth century, by mid-century there was an impetus to extend national claims out over offshore resources. There was growing concern over the toll taken on coastal fish stocks by long-distance fishing fleets and over the threat of pollution and wastes from transport ships and oil tankers carrying noxious cargoes that plied sea routes across the globe. The constant hazard from pollution, threatening coastal communities and all forms of ocean life. In addition, with all this the navies of the various maritime powers competing as well to maintain their presence across the globe on and under the surface of the sea. This tangle of claims, spreading pollution, overlapping demands for lucrative fish stocks in coastal waters and adjacent seas, growing tension between coastal nations' rights to these resources and those of distant-water fishermen, the prospects of a rich harvest of resources on the sea floor. The increased presence of maritime powers and the pressures of long-distance navigation and a seemingly outdated, if not inherently conflicting, freedom-of-the-seas doctrine - all these were threatening to transform the oceans into another arena for conflict and instability.

> The words of Thor Heyerdahl are most pertinent here: "It is necessary for the People to realise the huge responsibility they have to this and future generations. The marine currents are not political boundaries. Nations can divide the land among themselves, but the Ocean, - the Ocean knows no boundaries, and without it, life is not possible, - it will always be a common and indivisible property of Man".

Throughout the twentieth century there were numerous attempts made to regulate the use of the oceans in a single convention that was acceptable to all nations. This effort finally culminated with the adoption of the 1982 United Nations Convention on the Law of the Sea, which has gained nearly universal acceptance since its entry into force on 16 November 1994, after the sixtieth nation signed on. This convention imposes a limit on the areas administered by individual nations to a two hundred nautical mile exclusive economic zone, with the remainder of the ocean outside this zone now administered by the

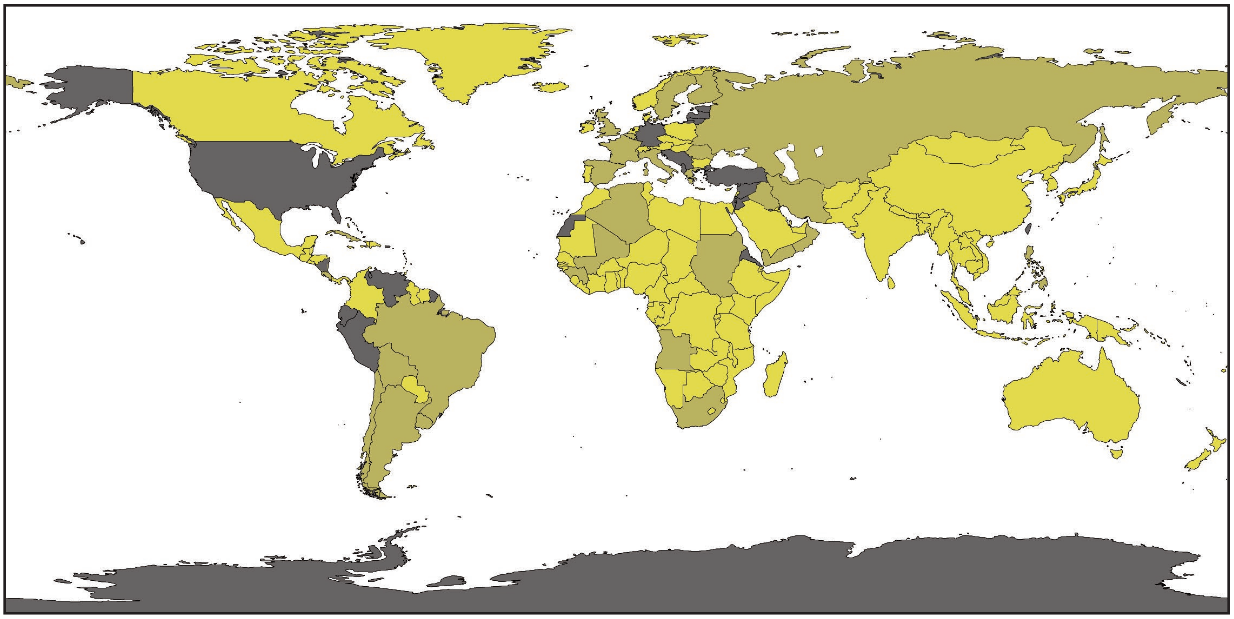


Map indicating the areas of the globe under full or partial national control.

world body. A majority of nations has declared that the deep ocean belongs to no single nation but is a common heritage to all. There is reason to know this water; life emerged from the ocean; its watery realm nourishes us, sustains us, and endows us with a benign climate. Our very existence depends on its richness.

One of the most important discoveries of the twentieth century is the realization that ocean is a continuous habitat from top to the very bottom. The density of life in this habitat varies widely from place to place and from top to bottom, but nowhere is there an azoic zone where there is no life. Our new understanding of the biological richness of the ocean has highlighted how underrated and misleading our knowledge of the ocean has been. Today only, a handful of ocean scientists innately understand this fact; it has not made it out into the public at large, to whom the ocean remains inaccessible and unknown, largely ignored, overlooked, or simply taken for granted.

Right now, nearly fifty percent of the six billion people on this world live with in one hundred and sixty kilometres of the seashore and within fifteen years, this percentage will to rise to almost seventy five percent of the estimated eight billion plus people that will be on this world. For most of humanity, the ocean is something remote and alien. Most have no idea of the time kept by the ocean, in its tides and cycles. They are conscious of it but not consciously



Map of the UNCLOS treaty menmbers

gold - signatory nations
dark gold - declared but not signed
black - non member nation

affected by it and they give it no emotional thought. One of the greatest challenges left for humanity might be, very simply, to find out what the sea is, and more importantly, what its relationship with humankind should be. We are of the sea, and the sea is of us.

We face many threats on many fronts and the ocean can save us. The ocean can provide some of the food to feed our multiplying populations, if done in a sustainable manner. It can provide the energy source to power our homes and industries. It can provide some of the minerals that we will soon deplete in their terrestrial deposits. It can inspire peace. For in protecting the ocean and we will protect ourselves, understanding that, we cannot protect what we do not yet understand.

The global ocean may be vast but it is still finite. It is our highway for trade and a growing source of food and mineral wealth. We have radically affected this vast complex ecosystem at an ever-increasing rate; just as we are having to turn to it more and more. We have continually taken resources and have only returned our wastes and pollution to the oceans.

We are at the crossroads right now and it is up to us to decide what our relationship with the sea will be. Do we continue to plunder and systematically destroying its richness or do we learn to develop a sustainable relationship with it. Humanity faces this crisis on the land, and the sea can save us. However, for it to do so, we have to radically change our current practises.

The ocean can provide a new home to humanity, easing our burden on the land. These new communities could harness clean energy, food, mineral, drug and other new resources from the ocean in a sustainable manner. We have to learn to farm the open ocean in the proper sense of farming, where one returns as much as one takes out, doing no harm in the long term. Before embarking on such a large undertaking, we need to understand the oceanic realm. We need to develop this understanding soon before our own ignorance forces us down a wrong path without the opportunity for choice.

2.0 Oceanic Realm

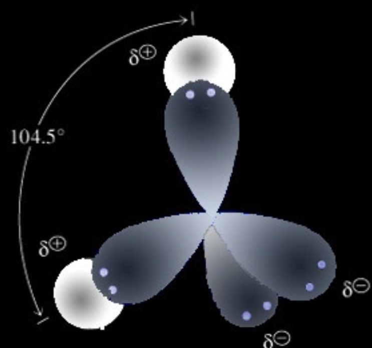
With the formation of the ocean over four billion years ago, a hot barren lifeless world was gradually transformed into the world we know today. The only water covered planet in the solar system or known in the universe at this time. This ocean is the birthplace of life and still affects all life on this planet to this day. It is home to both the smallest and largest living creatures that have ever existed this planet.

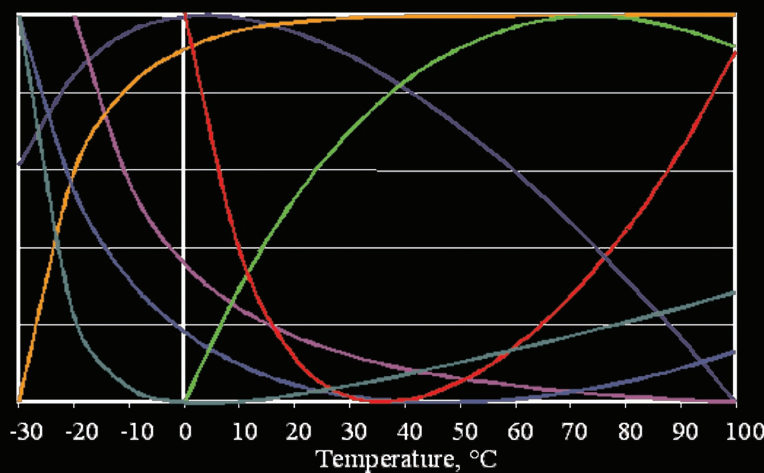
2.1 Water

Water is one of the simpler molecules and accounts for 96.5% of the ocean. Made up of two hydrogen atoms and one oxygen atom that combine and form a single water molecule. This molecule is asymmetrical, both of the positively charged hydrogen atoms are joined on the same side of the negatively charged oxygen atom. This makes water a "dipole" molecule, with one side slightly positive and the other slightly negative. Several molecules can come together easily attracting each other and linking their oppositely charged sides forming molecule clusters. These links between the water molecules known as hydrogen bonds and are the key to the unique properties of water.

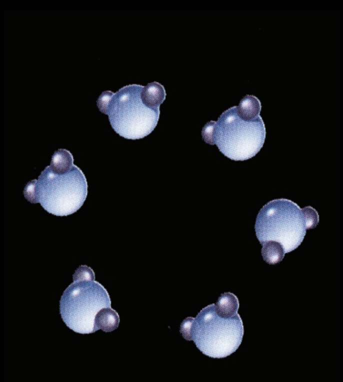
There is one very anomalous characteristic of water, which is crucial to life on earth. When water changes from its liquid to solid phase (freezes) it increases in volume, the solid form is ninety one percent of the density of its liquid form. The result that the solid form of water (Ice) can float in its own element, in keeping with Archimedean principle that states that a body immersed in a fluid will be buoyed up by a force equal to the weight of the displaced fluid. If this were not so, the ocean would progressively freeze solid from the bottom up. Water attains its maximum density at 3.8°c which any further cooling only decreases the density and that colder water rises to the surface where it can freeze.

Some of the other unique properties of water are its unexpectedly high freezing (0°c) and boiling points (100°c) as compared to similarly structured molecules such as hydrogen sulfide, and ammonia. Another result of these strong hydrogen bonds is that it takes a lot of energy to heat water and thus as it cools a lot of heat is released. Water can store ten times the amount heat as dry ground or dry air. As well, in its liquid state the individual water molecules are very close together and cannot be forced any closer together before they start to repulse each other. This makes water in its liquid state almost incompressible.

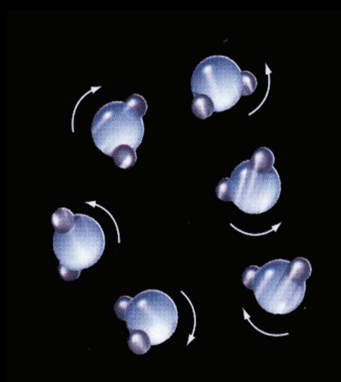




Some of the anomalies of water related to temperature.
The graph above uses data that has been scaled between their maximum and minimum values



Solid: Below zero degrees Celsius molecular movement is reduced. Hydrogen bonds can now form between the individual water molecules. Due the geometry of these bonds the molecules form a rigid open lattice, the openness of which means that this solid form is only ninety one percent as dense as its liquid form.



Liquid: To much molecular movement for the strong hydrogen bonds to form between molecules. Molecules can pack together tightly due to electrostatic forces. In it liquid state water is sometimes referred to as the universal solvent due to its ability to dissolve a wide range of substances. In this state it also acts as a medium for biochemical reactions.

Gas: To become a gas a great deal of energy is required to get the water molecules moving sufficiently fast so that they are not longer held together by electrostatic forces.

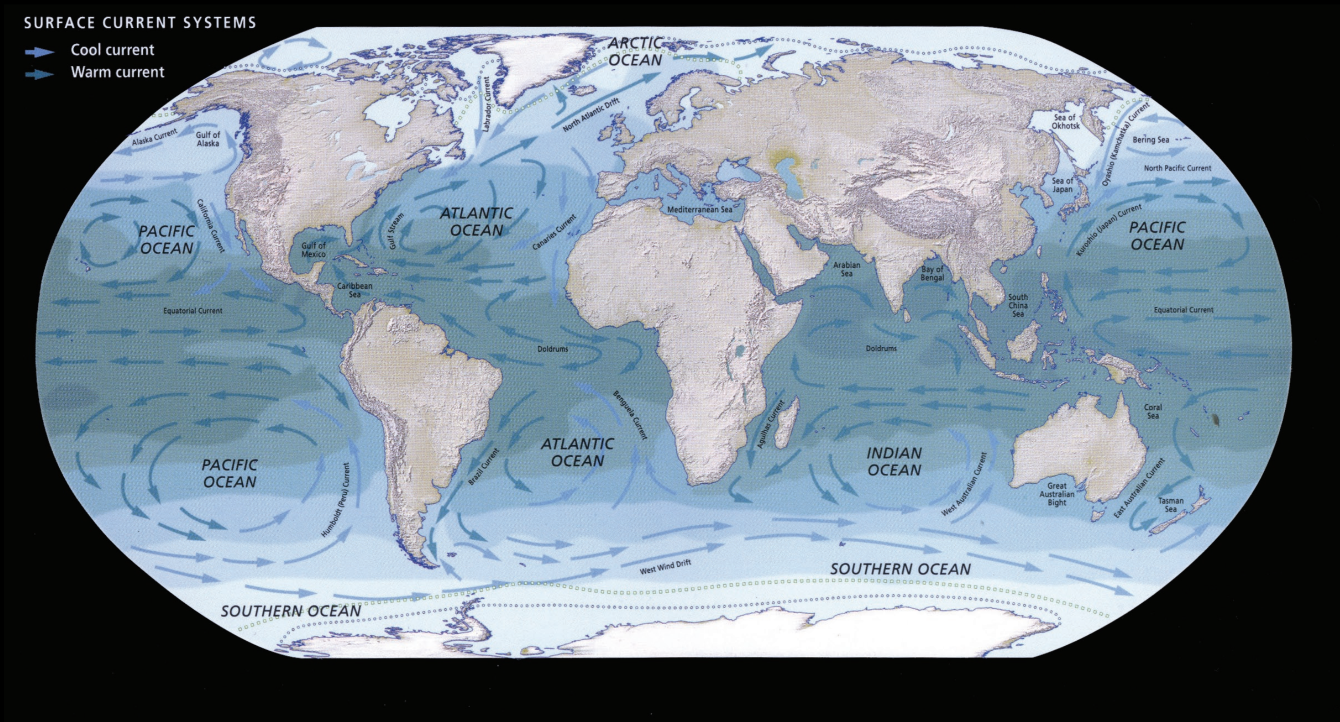
2.2 Currents - surface and deep water

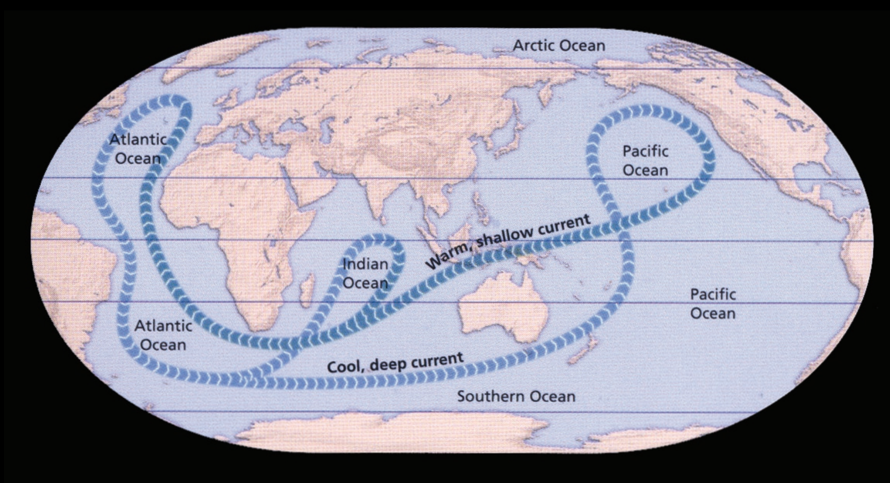
The ocean being several thousand times wider than it is deep, the majority of all movement within it is horizontal, with a few critical exceptions. The ocean can be divided up vertically into five major water masses: surface waters down to a depth of two hundred meters; central water extending down from the surface water to a point where there is no further drop in temperature (the bottom of the thermocline), this varies from the equatorial to the polar regions; intermediate water that extends down to fifteen hundred meters; deep water that is below the intermediate water but not in contact with the bottom, extending down to four thousand meters; and bottom water that is in contact with the ocean floor. These water masses do not mix easily and can take up to centuries to complete their circulation in the global ocean

Surface temperatures vary around the world but these only affect the upper ten percent of the ocean, on average. This is the part of the ocean affected by wind driven surface currents. The main currents driven by the trade winds with corresponding boundary currents running along the edges of the continental margins. The interactions of these eastward and westward counter flowing currents cause large gyres to form in the subtropical latitudes north and south of the equator.

The remaining ocean from the bottom of the thermocline down to the seafloor averages three point eight degrees Celsius over the entire globe. Movement in this vast body of water is slow and driven by density and salinity differences. Thermohaline circulation is the phrase used to describe this circulation that manifests itself in what is known as the great conveyor, a deep current that links the Pacific, Atlantic, and Indian oceans. There are two critical regions where this cold and salty deep water is generated; first is in the North Atlantic off the coast of Greenland and the other is the Weddell Sea in the Southern Ocean. It is slow moving with water taking up to one thousand years to circulate, but it is massive, with twenty to fifty million cubic meters forming every second in the Weddell Sea alone. The deep thermohaline current system is vital to life in the deep ocean since it carries oxygen down from the surface layers.

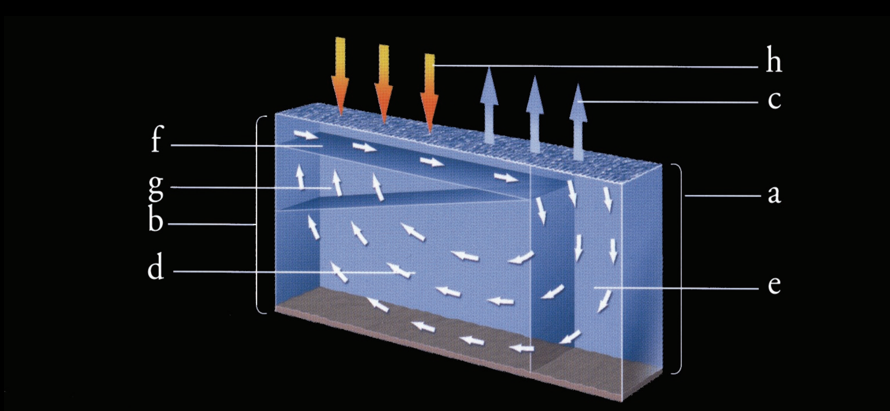
Due to the properties of water, the ocean stores vast quantities of energy in the form of warmth. This combined with the mobility of the oceanic waters in turn transports this warmth around the entire globe, controlling the global climate. Even minor fluctuations in these currents can have a major effect on our planets surface climate.





Oceanic Circulation systems

Maps indicating warm and cold surface currents (above) and the deep water thermohaline circulation known as the great conveyor (left) and the diagram (below) showing the power source for the thermohaline circulation. Cooling of the surface waters at the higher latitudes causes the density of that water to increase as well as its salinity this colder saltier water then sinks and travels slowly away from the polar regions where it was formed, eventually rising and returning in the surface water as counter currents to this deep flow



Thermohaline Circulation

a. Polar regions
b. Equatorial regions
c. Cooling
d. Deep spreading
e. Sinking
f. Surface flow
g. Thermocline
h. Heating

2.3 Waves

Waves are generated by wind blowing over the surface of the ocean. The important factors in the development of waves are the wind speed, duration and more importantly the overall distance that the wind is in contact with the surface of the ocean, this is known as the fetch. The ultimate size of the wave depends directly on the fetch. Some of the largest waves recorded were in the Southern Ocean where the fetch at some latitudes encircles the entire globe. Despite appearances, a wave is not a ridge of water traveling across the surface of the ocean; it is a manifestation the energy being transferred from the wind to the water.

A wave does not simply raise and lower the surface of the water, neither does it move the water forward. In fact, as each crest passes by, the water molecules rise up, advance, descend, and move backwards back to their starting point, describing an almost perfect circle as they do. This motion is passed down to the molecules below but each time the cycle of movement is smaller, setting an entire column of water oscillating. As a wave passes it is only the energy that has moved on, for all the water molecules have completed their orbits and have returned to their original positions. The depth of all this movement is half of the crest to crest distance taken at the surface. Where the depth of the water is greater, there is no interaction between the wave and the sea floor; these waves are known as "deep-water waves".

The wind does not blow uniformly; at any one time there is a mixture of waves of different heights and lengths. This is referred to as a spectrum of waves, just as we refer to a spectrum of visible light. After a while, depending on the wind speed and fetch, the wind will have created the biggest waves, both the highest and longest, as possible. At this point the sea is referred to as "fully arisen". This was thought to have a maximum wave height of eighteen meters, and that reports of larger waves were just exaggerations. It is now known that the waves themselves interact with each other and can occasionally give rise to what are know as "rouge waves". These waves suddenly appear and are much larger than the waves around them, they can be over thirty meters in height. One of these rouge waves was encountered by the ocean liner Queen Elizabeth II in 1995 while enroute from Cherbourg to New York.

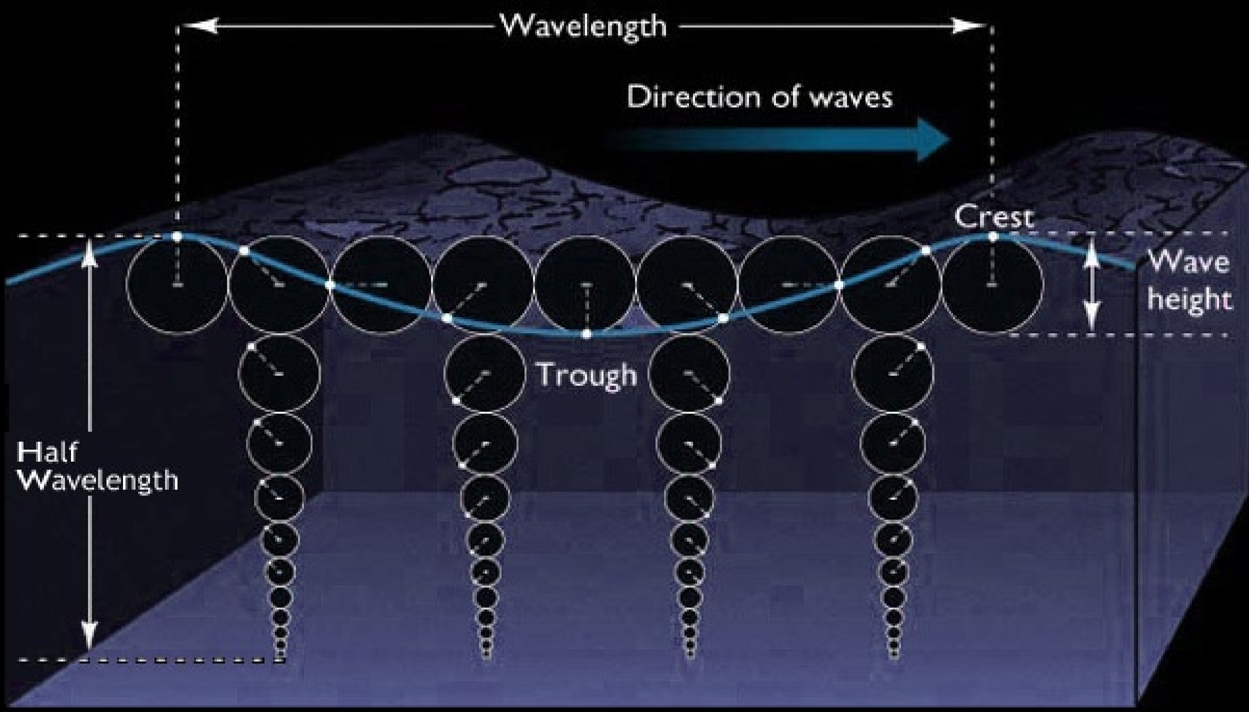
September 11, 1995. North Atlantic. While crossing of the Atlantic, the Queen Elizabeth II had to change course to avoid Hurricane Luis. Despite this precaution, the vessel encountered seas of 18 meters with occasional higher crests. At 0400 the Grand Lounge windows, 22 meters above the water, stave in. But this was only a precursor.

"At 0410 the rogue wave was sighted right ahead, looming out of the darkness from 220°, it looked as though the ship was heading straight for the white cliffs of Dover. The wave seemed to take ages to arrive but it was probably less than a minute before it broke with tremendous force over the bow. An incredible shudder went through the ship, followed a few minutes later by two smaller shudders. There seemed to be two waves in succession as the ship fell into the 'hole' behind the first one. The second wave of 28-29 m (period 13 seconds), whilst breaking, crashed over the foredeck, carrying away the forward whistle mast.

.....

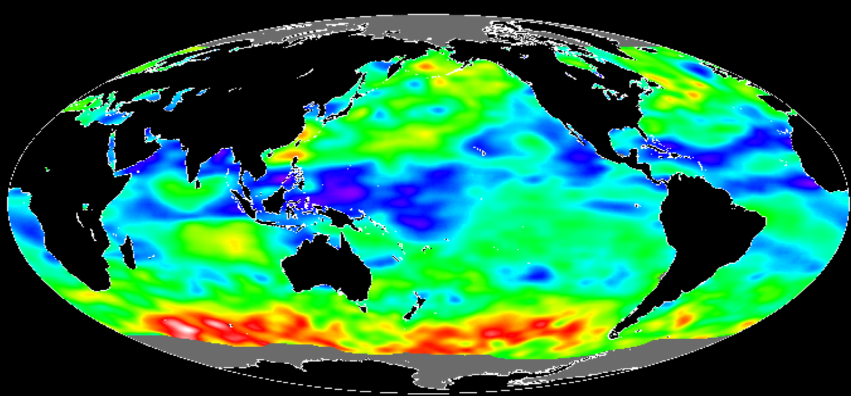
"Captain Warwick admits that sometimes it can be difficult to gauge the height of a wave, but in this case the crest was more or less level with the line of sight for those on the bridge, about 29 m above the surface; additionally, the officers on the bridge confirmed that it was definitely not a swell wave. The presence of extreme waves was also recorded by Canadian weather buoys moored in the area, and the maximum measured height from buoy 44141 was 30 m (98 feet.)"

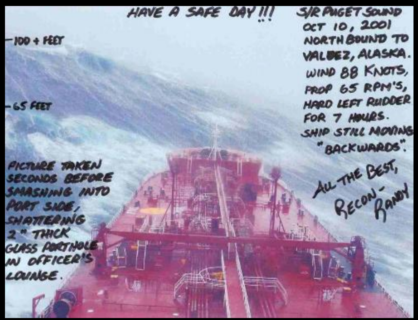
Warwick, R.W., et al; "Hurricane 'Luis', the *Queen Elizabeth 2* and a Rogue Wave," *Marine Observer*, 66:134, 1996

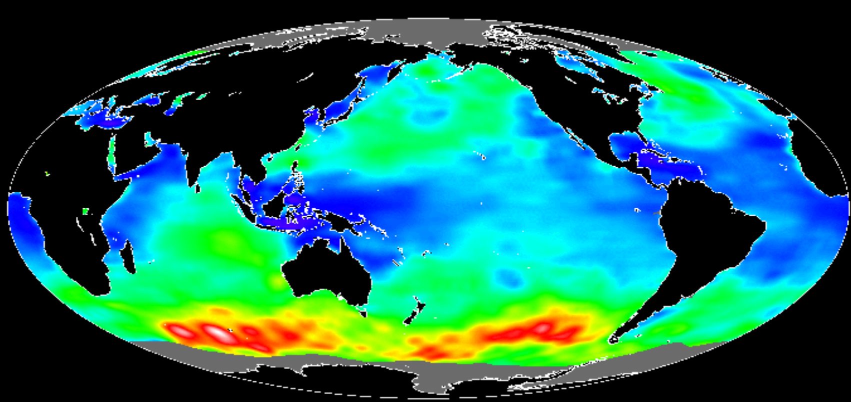


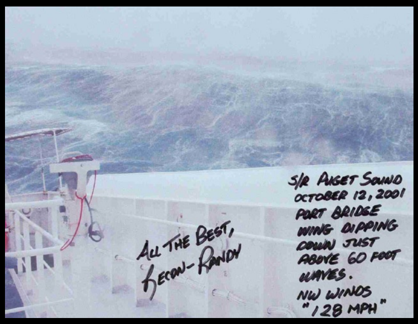
Wave Generation

Diagram depicting deep water wave properties (above) maps from satellite data showing the correlation between wind and waves (left) Photos of waves in the North Pacific taken aboard the SeaRiver enroute to Alaska (below).





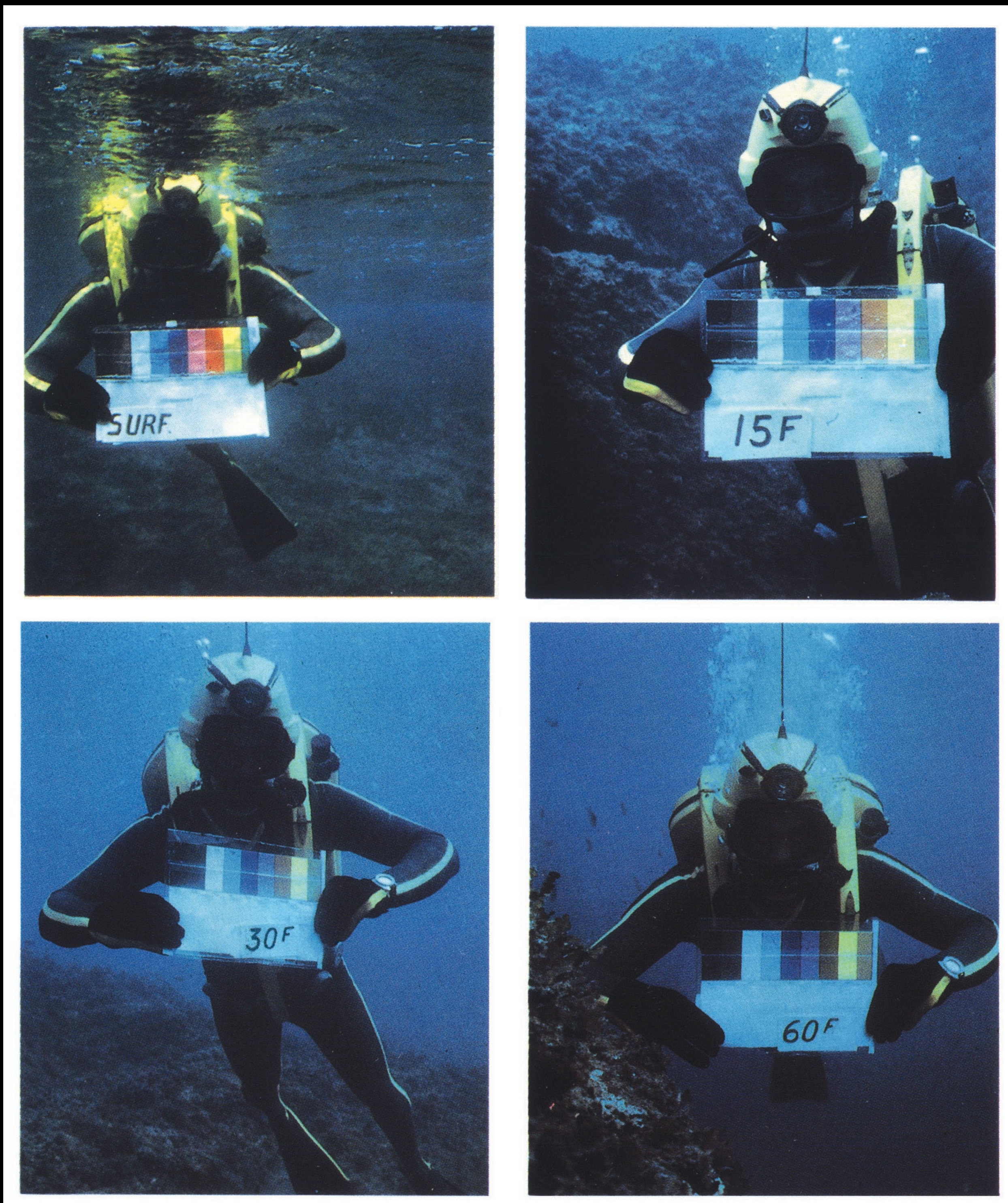




2.4 Light

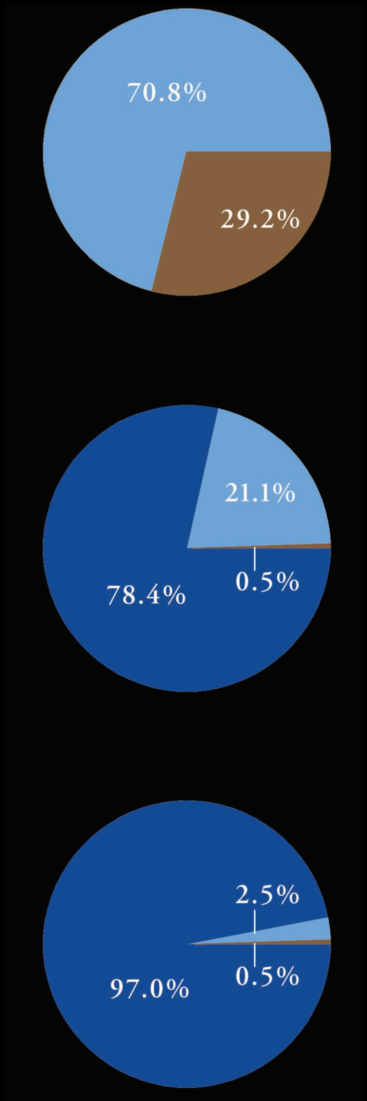
All light entering the sea is eventually absorbed and scattered. At a depth of only seven-and-a-half meters virtually all red light discernable to the human eye is gone; a bright red air tank on a diver would appear dark dull brown. By twenty meters, a yellowish air tank looks greenish blue, because almost all the discernable yellow light has been absorbed. The still shorter wavelengths of green light are the next to go. By thirty meters, only the shortest wave lengths of visible light are left; the blues, indigos, and violets. After thirty meters, all is a monochromatic deep blue, and shadows no longer exist. Below a maximum depth of six hundred meters, human eyes can no longer detect any light, but yet trillions of other eyes can still see.

There is often some residual surface light in the upper mesopelagic zone, around three hundred meters, where a majority of the creatures in habiting this zone are semi-transparent. This done by modifying the proteins in their bodies to match the optical qualities of water and thus blend in to the background and cast no silhouettes to predators below. Go deeper, and fishes become silvery, as a form of counter shading and at the deepest parts of the mesopelagic around nine hundred meters creatures, especially the invertebrates are a rich red or orange. With red light being utterly absent at this depths these creatures appear black, or an ill defined grey when illuminated with the feeble blue light present. This feeble blue light finally fades away completely at a maximum depth of thirteen hundred meters. The remaining inhabitants of the two thirds ocean below this point never see any light from the sun the only light is from bioluminescence or volcanism and there is no longer any consistent trend in colouration.


SURF.
15F
30F
60F

2.5 Biosphere

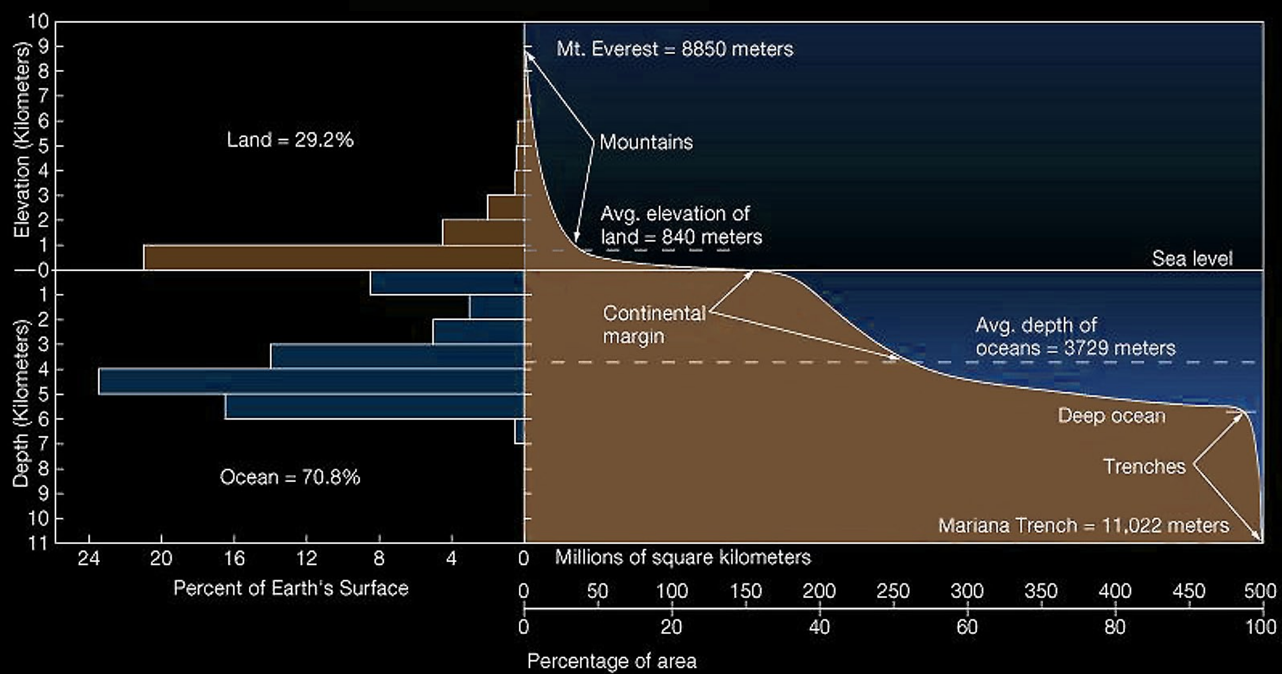
A new approach to understanding the true biological significance of the ocean is the volumetric approach. Land can be seen as an essentially a two-dimensional habitat. From the very tops of the tallest trees down to the bottom of a few meters of living soil, a narrow band in which terrestrial life is confined. By contrast, the ocean teems in three dimensions over its entire breadth and depth, down through the dark middle waters, down to the bottom, and down to the lowest recesses of the canyons over eleven kilometres deep; it is animate space. By this volumetric approach, the land accounts for only a meagre one two-hundredths of the entire biosphere of the planet. In other words, all of Africa, all of Siberia, all of the continents, archipelagos, and mountains that humans have slowly discovered over the centuries, account for only half-a-percent of this planet's total habitable space, by this estimation. With the ocean accounting for the remaining ninety nine-and-a-half percent, and the almost entirely unknown deep accounting for seventy eight-and-a-half to ninety-seven percent depending on which interpretation on where the deep sea begins one uses. Simply put, the deep is the Earth's largest habitat and its inhabitants are the most typical form of life on the planet.



Land and Sea as habitats, because of its innate properties and enormous volume, the deep sea it's the largest area of the planet that spports complex life. It is estimated to make up somewhere between 78.5 percent and 97 percent of the global biosphere.

Three representations of the biosphere of the earth (left) top most is the conventional two dimensional surface distribution 29.2 percent land and 70.8 percent water. Middle is the volumetric approach with the water broken down into deep and shallow waters with the deep water staring at one kilometre a very conservative number. Bottom is volumetric approach with the deep water set to begin at lower edge of the euphotic zone at 100 metres

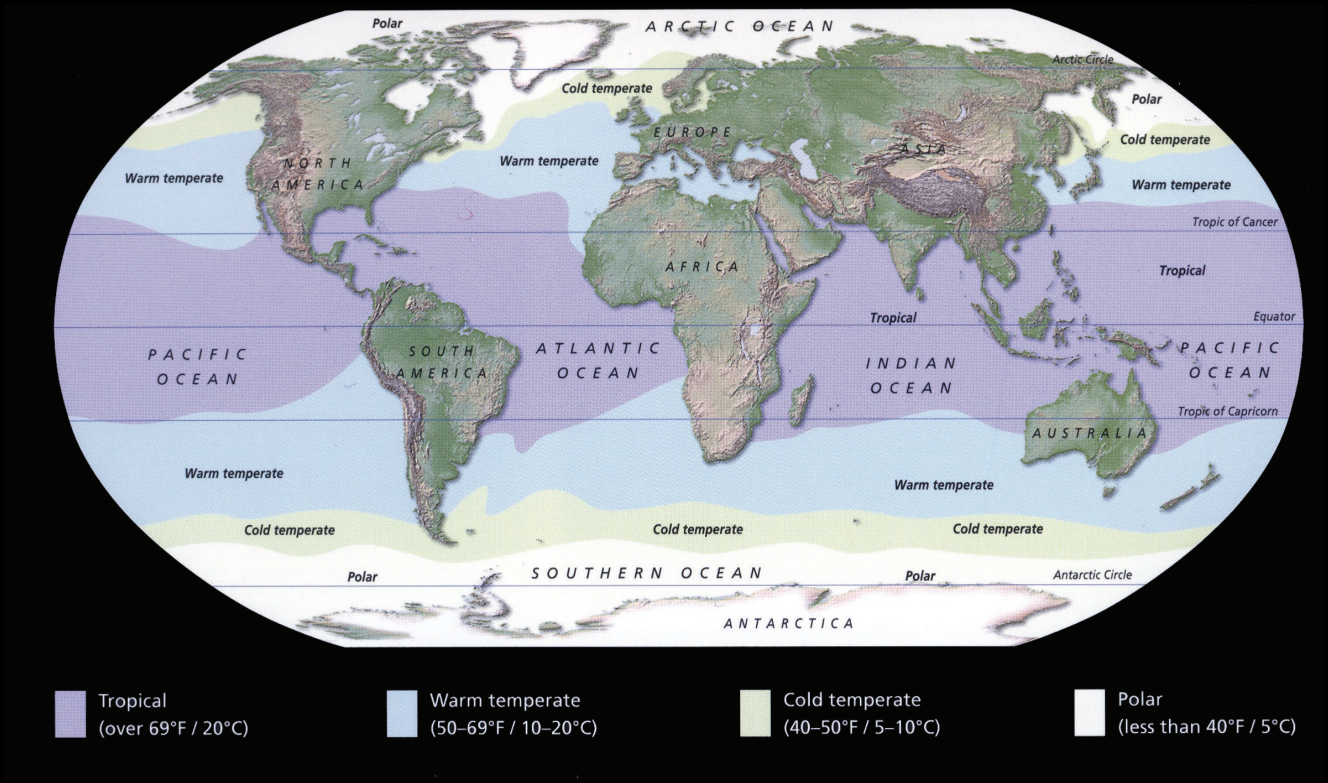
The hypsographic curve (below) is used by oceanographers to visualize land and ocean relationships the curve plots area (Km^2) versus elevation or depth (Km) volumes (Km^3) are also revealed.



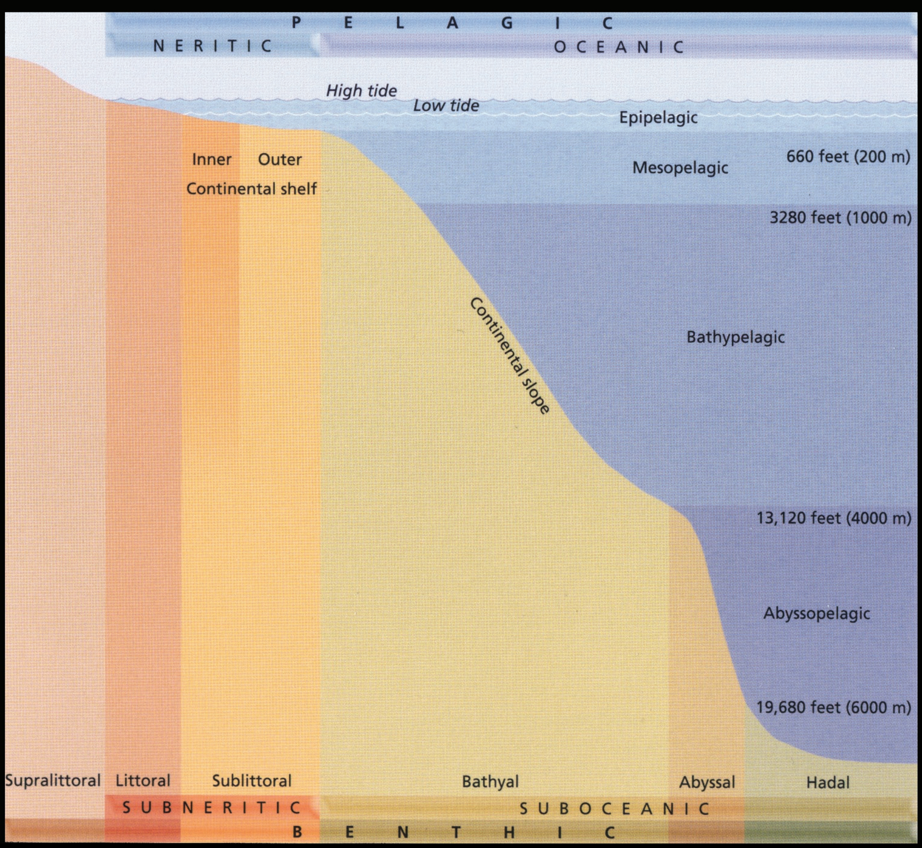
2.6 Zones and Habitats

With the ocean a thousand of times wider than it is deep, it is governed mainly by horizontal systems and is broken down into zones by layers. These layers are mainly determined by three factors - light, heat and salinity their limits are variable and in constant flux. Temperature has a major effect on the marine environment, influencing the biogeographical distribution of marine species. Warm-blooded (homeothermic) animals can regulate their body temperatures and can therefore withstand moderate fluctuations in water temperature. They are able to migrate across the oceans, encountering different water temperatures. Cold-blooded (poikilothermic) animals are unable to regulate their temperatures and are more severely affected by external changes. Temperature also controls the rate at which many biological processes and chemical reactions occur. Temperature and salinity affect the density of water, which in turn influences vertical water movements. The temperature also affects the amount of gases which can be dissolved in water. Together, temperature, salinity and dissolved gases aid in the stratifying of the ocean into distinct zones and habitats; each with their own communities of life.

One of the most unique habitats in the ocean is the ocean floor around mid ocean hydrothermal vents. Only discovered in the late 1970s, this habitat is home to an alien system of life. This life system is not based on photosynthesis as is all other life on the planet, both in the sea and on land. Instead, it is based on chemosynthesis, converting not sunlight but hydrogen-sulphide, a highly toxic substance to most creatures, into energy. This is a system of life we never knew, nor or even imagined, could exist. Moreover, it encompasses the entire globe wherever the right conditions exist. Their home is so far removed from what we thought were the normal prerequisites for life. It is acidic, foul with chemicals, under pressures hard to imagine, and both freezing cold and blistering hot. These creatures live in and around waters whose temperature varies from just above freezing, to more than 350°c, hot enough to melt lead. These chemosynthetic life forms survive in temperatures that kill all other forms of life. Thriving at temperatures up to 113°c, well above the boiling point of water, and are suspected to survive temperatures up to 350°c, albeit briefly. It is now suspected by many scientists that these life forms are not just oddities, but are in-fact ancient, and may be direct offspring - four billion years later - of the very first forms of life to appear on the Earth. Their homes are the hydrothermal vents, stoked by the nuclear fires deep within the Earth. This hellish place just may be the cradle of all life on this planet.



THE ZONES



The surface habitats (above) of the ocean based on temperature do not coincide exactly with the geographic climates zones because of the nature of ocean currents. An example of this is the cold currents extend the warm temperate zones up the tropical west coasts of Africa and South America.

The most basic distinction in the oceanic realm (left) is made between the features and the processes of the water column -pelagic- and those processes and features relating to the seafloor -benthic-. Moving out from the shore to the edge of the continental shelf is a shallow area that is know as the neritic zone. The oceanic realm lies beyond the edge of the continental shelf. Most ocean life and human activity is centred around the continental shelf zone.

3.0 Mission and Design Criteria

Knowledge of the oceans is more than a matter curiosity. Our very survival may hinge upon it.

US President John F Kennedy, in a message to the US congress in 1961

3.1 Mission

Triton is a monitoring and exploration program into the global ocean, now under the jurisdiction of the United Nations Convention on the Law of the Sea (UNCLOS), mandated to protect and monitor the ocean for the benefit of all the nations of humanity. A new class of vessel will be required to help facilitate this mandate, a class that will have free passage through the territorial waters and Exclusive Economic Zone of any UNCLOS member nation, operating out of a majority of the major oceanic institutes around the world and having no dedicated homeport. It would operate in the deep ocean, independent of shore-based refurbishment for extended periods of time, capable of independent exploration for three months at nominal operations, with the capacity to extend this indefinitely, with sea-based resupply. This vessel would be a mobile platform performing general-purpose oceanographic research in deep ocean areas.

The vessel will enable to the crew to perform:

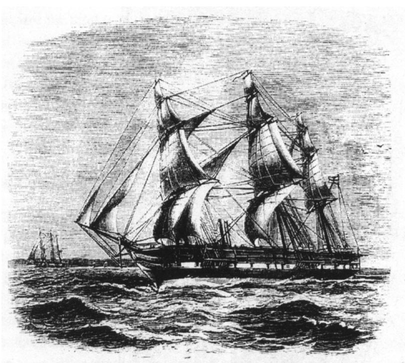
- Sampling and data collection of air, surface, midwater, and seafloor parameters.
- On site calibration of satellite and acoustic remote measurements.
- Monitoring of pollution in the air and water, process of bioaccumulation of pollutants.
- Full ocean depth seafloor surveys.
- Launch and recovery of science packages.
- Handling and servicing both tethered and autonomous science pakages.
- Handling and servicing of a manned submersible (such as the new ALVIN II)
- Shipboard data processing and sample analyses.

To do all the above:

- The vessel would require precise navigation, station-keeping, in support of deep sea operations.
- It would be operational in all but the worst sea states.
- It will have to operate for long periods of time at low power.
- The vessel operations to be handled with a minimal crew (most ship operations to be autonomous with minimal crew interventions).
- The vessel will continuously broadcast telemetry to shore.

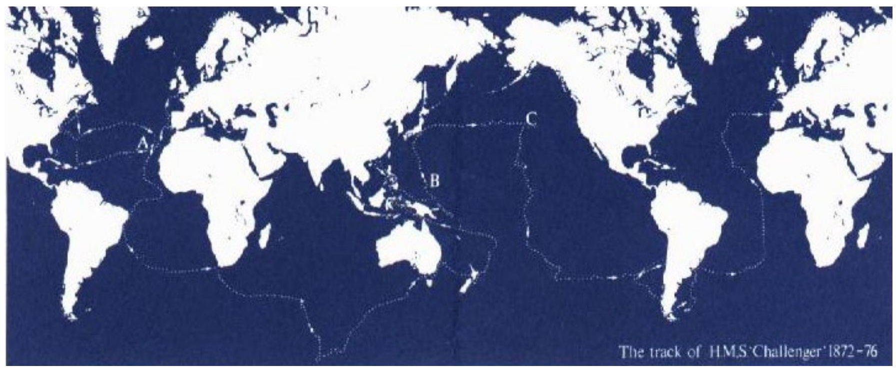
In addition the vessel will aid in the introduction of humanity to life beneath

H.M.S. Challenger a converted British navy ship left Portsmouth England in 1872 and returned in 1876. Its mission, assigned by the British admiralty, was to investigate the conditions of the deep sea throughout the great oceanic basins. The ship logged almost 70,000 nautical miles on its voyage around the world. Challenger scientists took hundreds of depth soundings, discovered and described over 4,000 new species of marine life, and studied currents, temperature, and salinity of the oceans throughout the world. The expedition's report fills 50 bulky volumes. The Challenger expedition set the foundation for every major branch of oceanography and its mission is considered the birth of modern oceanography.



the sea; paralleling the space program in its study of physiological and psychological responses to long-term inhabitation of extreme environments. In order to achieve all this, the vessel is designed around three key principles of dedicated, continuous and open study.

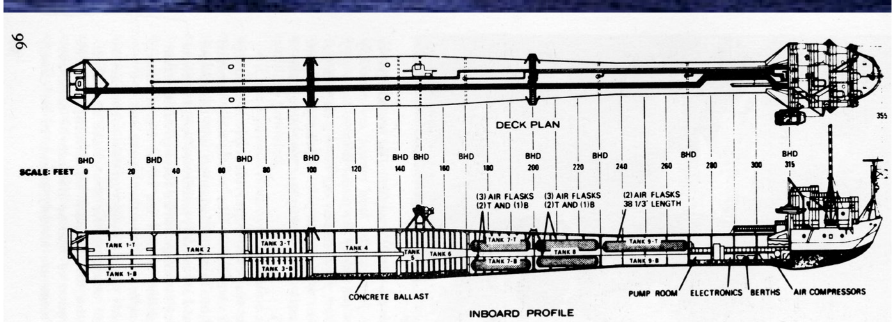
First this is a mission dedicated to pure science, to understanding and to observation. The mission will follow in the footsteps of *Challenger*, one of the first missions sent to sea solely dedicated to science. *H.M.S. Challenger* was a British naval corvette, stripped of her guns and filled with all the scientific equipment available at the time. The ship's charter was to investigate, top to bottom, the waters that bounded the vast majority of the Earth - especially the dark regions far beneath the waves - during it's almost four year long expedition. Unlike the Challenger, this new vessel will not be an existing ship adapted to fill this role, but an entirely new type, specifically designed for its intended role.



Several examples of this vessel optimization exist. The *R/V Kilo Moana* is one of the newest dedicated scientific vessels. Built in 2003 and constructed as a SWATH (Small Waterplane Area, Twin Hull) ship. She was built for general science and has the ability to be adapted for a variety of roles. And with her SWATH construction, she can continue to operate in heavier seas than a conventional ship allowing for more scientific operations.

R/V Kilo Moana (AGOR 26) is a small waterplane area, twin hull (SWATH), oceanographic research ship designed to perform general purpose oceanographic research in coastal and deep ocean areas. The unique SWATH hull form is designed to provide a comfortable, stable platform in high sea conditions. The ship is operated by the University of Hawaii, School of Ocean and Earth Science and Technology under a charter agreement with Office of Naval Research (ONR). Kilo Moana was the first UNOLS Ocean Class vessel and is also the first vessel in the Fleet to have the SWATH hullform configuration

The *R/V Flipship* an extremely specific and unique vessel, designed for a single purpose only: to study subsurface acoustics for the US Navy. Built in 1962, she has long finished her intended task but her unique abilities led to a major refit in the mid 1990s. With this new lease on life, the Flipship is now a scientific research vessel, operated by the Scripps's Oceanic Institute. The Flipship has no propulsion of its own; it has to be towed into position. Although she can operate anywhere in the world ocean, towing effectively limits the ship's operations to off the west coast of the United States, where the ship is based.

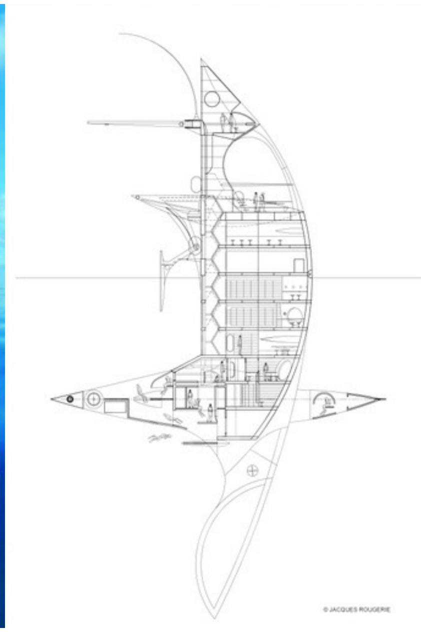


The R/P FLIP is an open ocean research vessel. The FLIP (FLoating Instrument Platform) ship is a 355 foot vessel designed to partially flood, resulting in only the forward 55 feet of the vessel pointing up out of the water. Pictures of this ship are frequently mistaken for a capsized ocean transport ship. The FLIP ship is designed to study wave height, acoustic signals, water temperature and density, and for the collection of meteorological data. FLIP has no engines or other means of propulsion. It must be towed to open water, there it drifts freely or is anchored.

And there is *The SeaOrbiter*, a proposed vessel largely derived from, and an expansion on the very successful mission of the *Ben Franklin*, a manned submersible that drifted (underwater) with the Gulf Stream for over thirty days in 1969. The program of the SeaOrbiter was developed on this principle. Its first mission is scheduled to begin in 2008-2009, when it will begin drifting with the Gulf Stream. It has subsequent missions slated for the Pacific and Indian oceans, over its projected fifteen year life.

Each vessel in its own way, is trying to capture the elusive fourth dimension of time in oceanic research. Time is the key, by analogy, this can be seen in the study of a forest. A brief walk through a forest - even repeated numerous times - does not allow one to see the complexities and intricacies of life there. These brief incursions are not long enough for the fauna to become accustomed to

SeaOrbiter, the latest in a long line of marine and undersea vessels and habitats by the noted French architect Jacques Rougerie is an entirely new type of craft, one which drifts along in the ocean currents. It will allow scientists to carry out simultaneous measurements both above and below the sea's surface, associating the study of the marine environment with data collected by satellite. Constantly manned, this veritable ocean sentinel will be capable of broadcasting huge volumes of information to experts and members of the public alike, in a bid to meet some of the great environmental challenges of the 21st century. Scale models of this vessel have been undergoing trials and the full-size version should be ready to begin its first missions in 2008.



human presence and resume normal behaviour. Living in a cabin in the woods, where we become background can we really begin to observe. Exposure to the same cast of characters day in and day out allows the observation of long term patterns and connections.

Historically ships at sea have been isolated. The development of radio in the early 1900s allowed for limited voice communication to shore. While being a great safety benefit, it did not allow for the transmission of large amounts of data quickly. Only in the past few years has capacity for the transmission of large amounts of data in real time become available to ocean scientists. The transmission of hot data in real-time to shore-side collaborators, opens up the opportunity for telecommuting. Mission scientists can, for the first time, direct missions, and analyse data from missions, via HiSeasNet and Csat, while they remain onshore, in the comfort of their workplace or at home. These new systems open up basic communications such as email and voice and video teleconferencing for scientists, engineers, and crew at sea. This enables real-time educational interaction between shipboard scientists, teachers and the classroom. The Jason project, founded by Robert Ballard in the 1990s, streamed real time-data back to various downlink sites set-up in educational institutions across North America. Students were able to participate in an ongoing deep-water marine archaeology project; some even got to control the projects exploration vehicle for short periods.

In order to reach as wide a group possible, the vessel would include a digital media studio supplying the latest events, summaries, and data to experts and amateurs everywhere over the internet.

Proposed Mission Profiles

The following five missions are designed to take full advantage of this new class of ship's abilities. Each of them makes use of its remarkable endurance and stability.

Marine Ranger Station, *fixed long-term studies - monitoring a specific marine region.*

An example of this mission is the stationing of the vessel in particular sensitive marine region, such as the Grand Banks of Newfoundland, to monitor and study a rich marine habitat that is currently in trouble. In this role the vessel could stay on station for periods of six months or more. Mission duration is fuel dependant, consumption is higher than in the drifter mission the vessel will use power to fight a current to stay at a particular location.

Drifter, *long term study, for periods ranging from months to a year, of ocean currents.*

This mission would station the vessel in one of the oceans strong surface currents, such as the Gulf Stream, the vessel would then drift along with the current, for up to a year, conducting experiments, taking measurements, and calibrating these results with data gathered from orbiting satellites.

Sampler/Census, *going to several regions for various short term studies.*

These missions are short term studies at particular sites which the vessel returns to year after year establishing a baseline for determining long-term trends. Each study period lasts between one and two weeks.

Marine archaeology, *fixed study for a period of weeks at one location.*

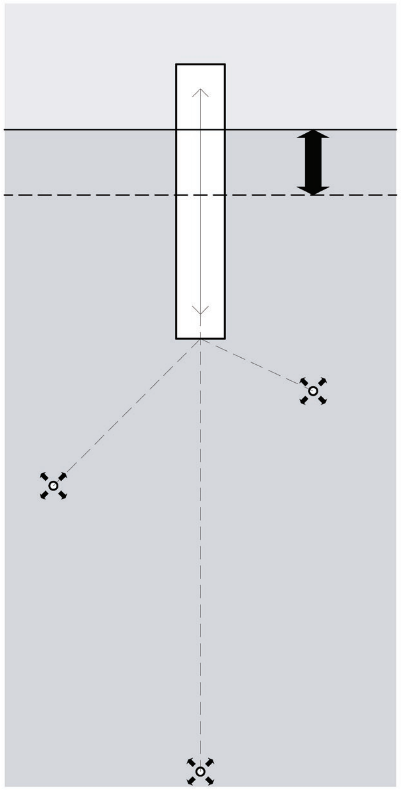
Example sites are the wrecks of the Bismarck and the Titanic. There are thousands of such deep water archaeological sites scattered across the deep ocean, covering a large portion of humanities history, it is the largest museum of humanities endeavours on the sea.

Benthic studies, *fixed study for a period of weeks of various benthic formations and communities which are poorly understood.*

Communities such as those found around hydrothermal vents, only found in the past thirty years, which little is known about. Such as how long they last, how do the creatures find these isolated and widely separated places, as the same creatures are found at these vents all around the world.

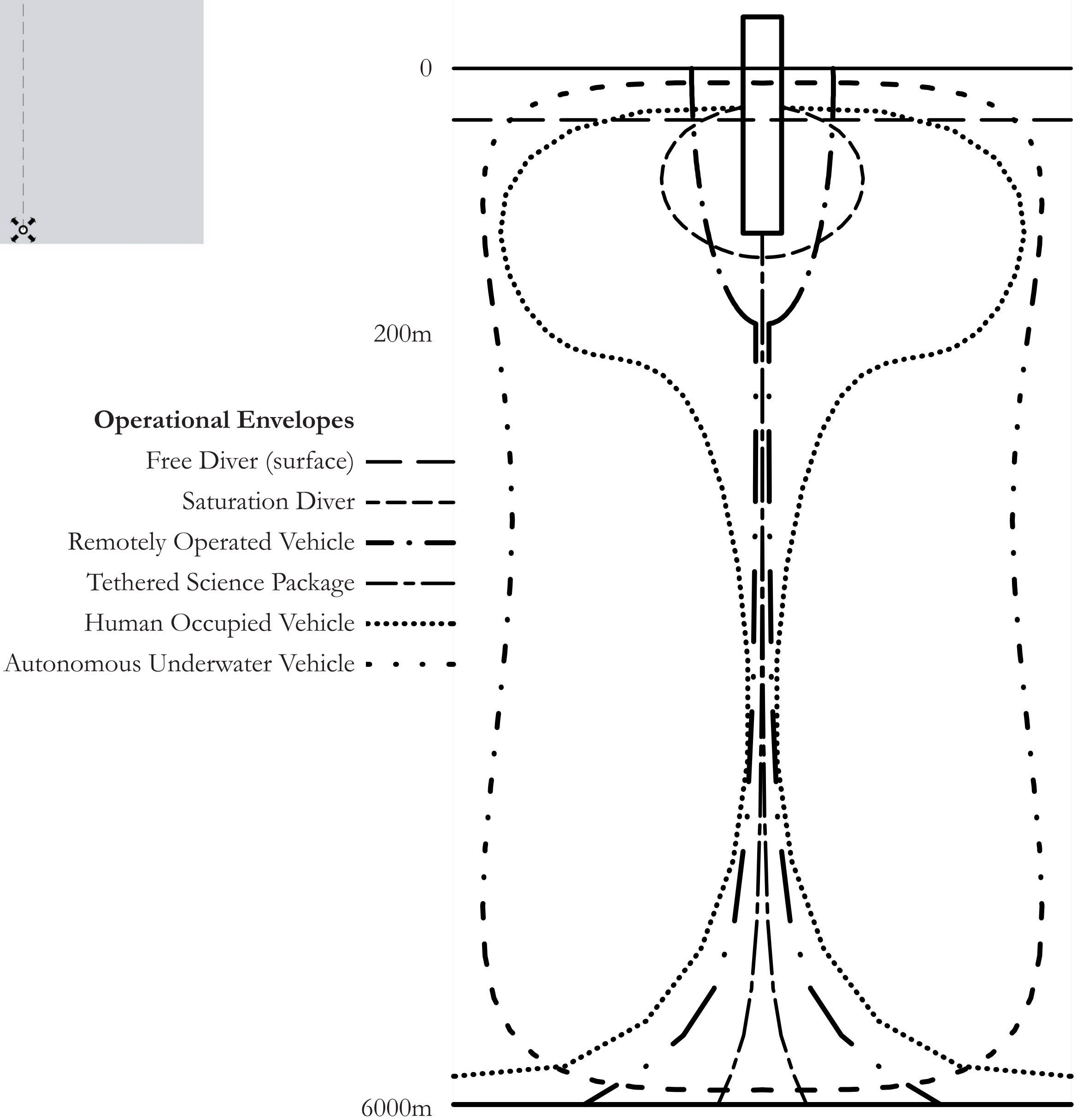
3.2 Design Characteristics

The mission of dedicated, continuous and open study, at sea, imposes certain criteria on the design of the vessel. First, the vessel must function as a node for numerous auxiliary craft, both manned and unmanned, extending the range and data collecting capabilities of the vessel though the entire water column. Second, the vessel should allow easy access to the upper layer of the ocean, and the vessel has to be mobile, to relocate itself to anywhere in the deep ocean. Third, in operations, the vessel has to remain stabile and strong to handle all weather and sea conditions, providing for as much scientific operational time as possible. Finally, the vessel has must provide a comfortable and unique environment for the crew, who will spend long periods of time onboard, one that will keep them in constant contact with the ocean. The vessel will continuously relay all this data back in real-time to scientists working onshore. Each of these criteria in turn directly and significantly affects the form and structure of the vessel.

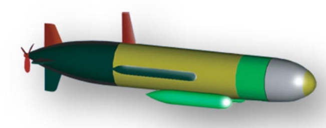


Access to the depths

The vessel is to provide a continual shirtsleeve access throughout the safe and typical depths achieved by free-swimming scuba divers, which is limited to 30-40m (100-130 feet) for all but the most skilled divers, due to time and skill restraints in returning to the surface safely. The vessel itself is to reach down through at least half of the epipelagic zone - the upper 200 metres- of the ocean, this is the most densely populated zones in the ocean, and the vessel is to be a staging post for various craft and other equipment giving us safe long term access to the vast remainder of the ocean below. Some of the auxiliary craft that the vessel will accommodate are described to the right.

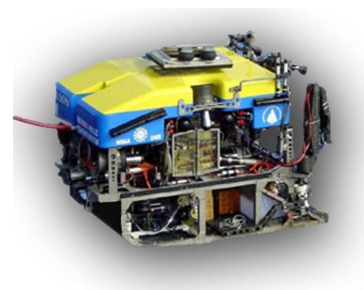


REMUS - AUV (surface/midwaters)



Remote Environmental Sensing Units (REMUS), a 1.5 metre long Autonomous Underwater vehicle (AUV) designed to operate in open waters. REMUS can survey areas up to 80 kilometres at 3 knots or more than 100 kilometres at lower speeds. A standard vehicle equipped with an up/down-looking ADCP and sidescan sonar can run for more than 8 hours at 5 knots, or up to 20 hours at 3 knots. Many other instruments have been integrated since its inception, including fluorometers, bioluminescence sensors, radiometers, acoustic modems, forward-looking sonar, altimeters, and acoustic doppler velocimeters. REMUS can also carry a video plankton recorder and an electronic still camera, making it a versatile tool for any mission.

JASON / MEDEA - ROV



Jason/Medea, a remotely operated vehicle (ROV) system designed by the Wood's Hole Oceanographic Institution's Deep Submergence Laboratory for scientific investigation of the deep ocean and seafloor. It is a two-body ROV system, with Medea serving in a tether management role. Together they offer wide area survey capabilities with Jason as a precision multi-sensory imaging and sampling platform. Both Medea and Jason are designed to operate to a maximum depth of 6,500 meters (21,385 feet).

PROTOTYPE - HROV

Hybrid Remotely Operated Vehicle (HROV), a craft which will be able to switch back and forth to operate as either an AUV or an ROV on the same cruise. It will use a lightweight fibre-optic cable, only 1/32 of an inch in diameter, which will allow the HROV to operate and manoeuvre at unprecedented depths without the high-drag, and expensive cables and winches typically used with ROV systems. Once the HROV reaches the bottom, it will conduct missions while paying out as much as 20 kilometres (about 11 miles) of microcable.

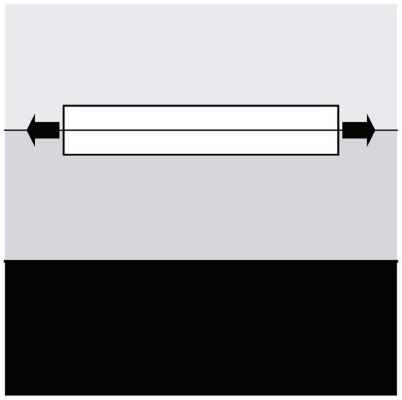
ABE - AUV (bottom waters)

Autonomous Benthic Explorer (ABE), an Autonomous Underwater Vehicle (AUV) that was designed to address the need for long term monitoring of the benthic regions. Sonar transponders are employed to provide accurate vehicle navigation, and monochrome cameras are used to capture images of the ocean floor. It has a range of 50km and a course accuracy of centimetres.

ALVIN II - HOV

Alvin was delivered in 1964; forty years later scientists at the Woods Hole Oceanographic institute have embarked on designing a new replacement Human Occupied Vehicle (HOV) the Alvin II, funded by the National Science Foundation, with many improvements, including an increased diving depth of 6,500 meters (21,325 feet) that will allow it to reach 99 percent of the seafloor. Some of the other improvements are as follows:

- Dive to 6,500 meters allowing access to 99% of seafloor.
- Improved fields of view for pilot and observers.
- Larger interior space and increased science payload.
- Variable ballast allowing for mid-water studies.
- High-speed data transmission to support ship via microfibre-optic cable.



Mobility

The vessel will be able to relocate itself and operate at any point in the deep ocean. Once on location it will have to hold that position for long periods. The vessel will not have a dedicated home harbour, but will operate out of any of the major oceanographic institutions in any of the UNCLOS member states, and will be able to return to any of these harbours for shore based resupply and or re-equipping. While in horizontal mode, the sections of the vessel in contact with the water have a moderately hydrodynamic form, allowing for relatively efficient passage through the water, with the non-hydrodynamic sections kept clear of the water. This allows the vessel a moderate cruising speed balancing, the need to keep transit times short and fuel requirements modest. To achieve this degree of mobility, the vessel needs its own source of onboard power generation, one that can supply both the scientific equipment needs and propulsion requirements and allow the vessel to operate independently without the need of a support vessel.

Several options are available; including nuclear power, fuel cells, solar/wind power, wave power, and diesel power. Each of these options has their own set of benefits and drawbacks, as shown in the breakdown to the right.

Nuclear Power, a powerful, long lasting energy source, but has an extremely high initial capital and ongoing maintenance costs. It is a highly complex system and requires a dedicated and highly trained support crew and specialized home port to maintain it. Also the spent fuel has to be dealt with, a very expensive, and is not really well developed endeavour at this time.

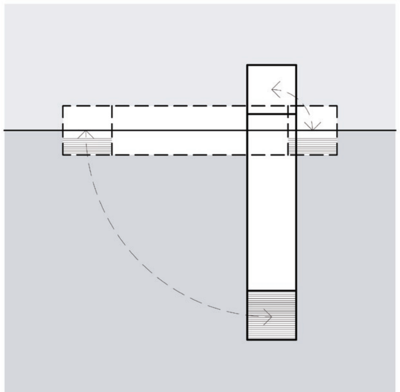
Fuel Cells, are a very clean power source. It has fuel storage problems as the fuel has a very low energy density requiring complex fuel storage systems. Fuel has to be created from either reforming petroleum products or by electrolysis of water; both have low efficiencies in production. Fuel not widely available so production facilities will be required to be built at every port the vessel would operate out of.

Solar/Wind Power, are another clean energy source, but both require large surface areas exposed to the energy source. It is globally available but not consistently so; a secondary power source would be required. With most of the vessel submerged for a majority of the time this power option is not viable.

Thermal Energy Conversion, exploits the vertical temperature differences in the ocean waters to generate power. The system is more efficient if the vessel was larger and reached deeper colder waters and if the vessel operated mainly in tropical areas, where there is a much larger temperature difference between deep and surface waters. Only works when the vessel is in vertical mode so a secondary system would be required to propel the vessel in its horizontal mode.

Wave Power, uses the rise and fall of the water around the vessel to generate electricity providing clean power production. This is available globally but not all the time so again a secondary storage or production system would be required.

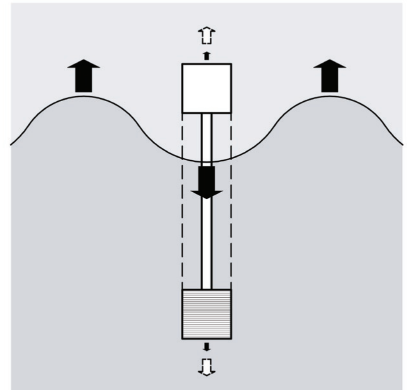
Diesel Power, is historically a dirty power source in the marine industry. Recent developments have led to new cleaner and efficient running equipment coming online. Diesel fuel is energy dense and easily stored and is globally available. A complete diesel electric system can be consolidated into one compact package. For these reasons this was chosen as fuel source to power the vessel but this can be altered during one of the vessels five projected major upgrades during its design life.



Transition

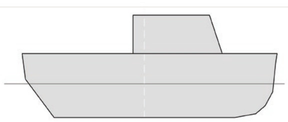
To solve these two contradictory criteria, of an extremely deep draft and mobility, the vessel will have to transition from horizontal for transit, to vertical for studies. To do this one end of the vessel needs to be able to take on ballast and sink with the opposite end remaining above the surface, too ease life support requirements and maintain continual contact with the shore.

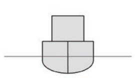
Stability



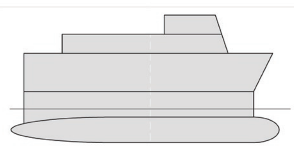
Considering selected hull configurations below, it is clear that a minimal interaction between the vessels hull and the ocean surface gives best stability; in this regard the spar buoy is the best for vessels that still remain, at least in part, above the surface. Its stability comes from the narrowing of its hull at the waterline and for some distance above and below. This is the model to be used for the R/V Pelagic Explorer. This minimising of the hull at the waterplane allows for the rise and fall of the waves, with a very small percentage change in the displacement of the vessel overall; the vertical motion imparted to the vessel by the passing wave are slight compared with those of a conventional monohull vessel. Combined with its extremely deep draft, this gives the vessel its stability allowing for longer and more productive research, greater comfort and safety over a wider range weather conditions, and a stable platform for accurate measurements and reliable communications with orbiting satellites. The benefits of stability come at a price: poor mobility.

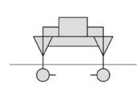
Because the vessel should relocate itself to any point in the world ocean, it must be at least moderately mobile hence the re-orientation of the vessel, vertical to horizontal. This change in orientation increases the mobility, but, at the same time, sacrifices the stability that the vessel has in its vertical orientation. But it is only in horizontal mode while in transit and transits are undertaken during favourable weather conditions.



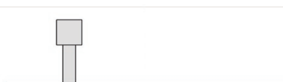


Hull Form - Monohull
Mobility/Speed - Moderate
Manuverability - Moderate
Seakeeping - Moderate/Poor
Max Sea State - 4
Draft - Moderate

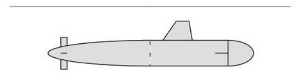


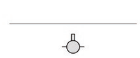


Hull Form - S.W.A.T.H
Mobility/Speed - High
Manuverability - Good
Seakeeping - Good/Excellent
Max Sea State - 7
Draft - Moderate

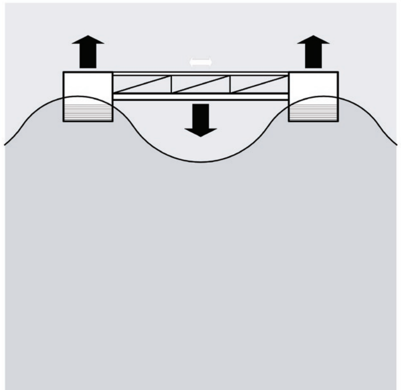


Hull Form - Spar Buoy
Mobility/Speed - n/a
Manuverability - n/a
Seakeeping - Excellent
Max Sea State - 10
Draft - Deep



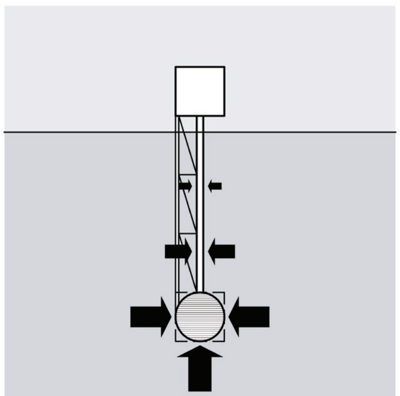


Hull Form - Submarine
Mobility/Speed - Moderate / High
Manuverability - High
Seakeeping - Excellent (submerged only)
Max Sea State - n/a
Draft - Moderate



Strength

With the narrowing of the vessels hull to reduce is waterplane area while vertical the strength of the vessel when horizontal is compromised. To solve this and to keep the waterplane area reduced to a minimum while vertical the main structure of the vessel is a truss. This truss is asymmetrical so that while the vessel is horizontal the majority of the truss is kept above the waterline to reduce drag, facilitating vessel movement.



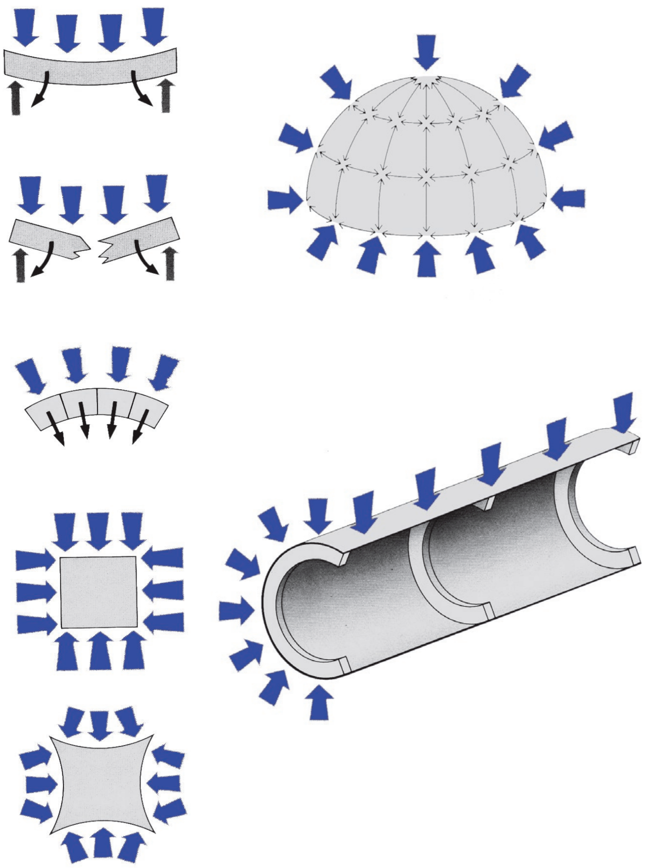
Pressure

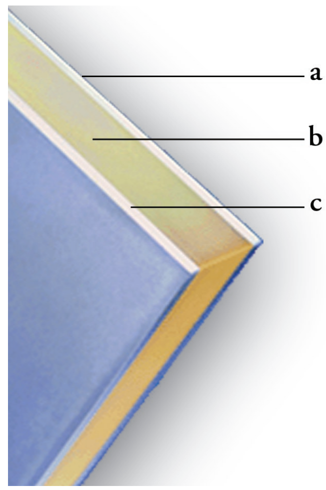
The vessel while vertical will have to be able to resist the ever increasing water pressure due to depth. This water pressure increases at a rate of one additional atmosphere of pressure - 101.3kPA (14.7psi) - for every 10 metres in depth. Any submerged air filled structure that is either, not pressurized to match the surrounding water pressure or not strong enough to resist the pressure on its own, will be quickly crushed.

The vessel is to be primarily of a monocoque construction, where the skin - in its shape and material - of the vessel itself provides most of the hull's strength. This is a lighter and efficient form of construction. The hull material has to be strong enough to withstand the water pressure, with no or very little interior structure, and it must be able to transfer forces evenly over itself without any local buckling.

The structure for most submarines and submerged habitats is a cylindrical tube, which has the strengths of the arc in one axis only - around its circumference - and has the weaknesses of a flat beam along its length, where the structure is prone to local bucking leading to collapse. When this axis is reinforced with a series of circular ribs it can withstand considerable pressure, but this is at a cost of a great deal of additional weight.

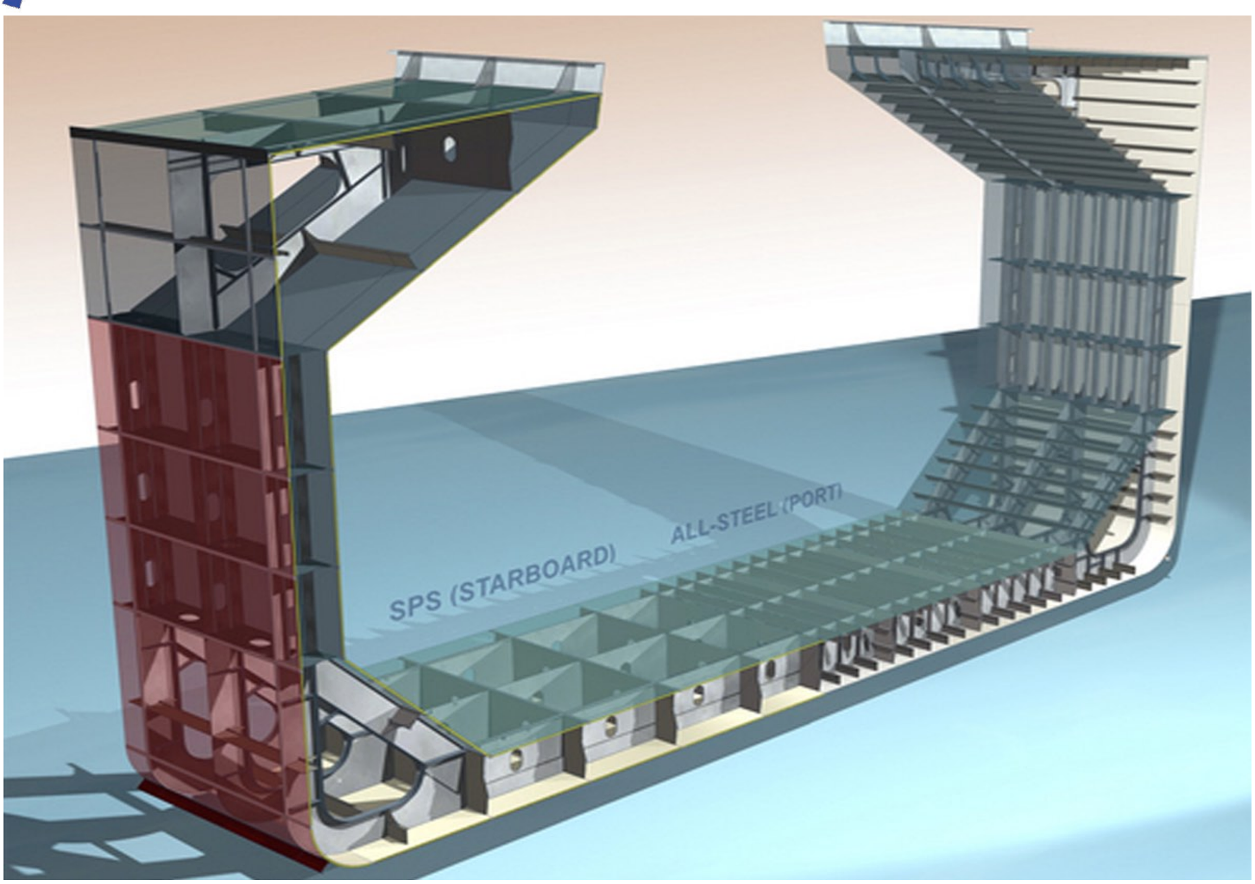
The best shape is the sphere, with the strengths of the arc in all three axes. This shape can resist considerable pressure, because it redistributes the forces equally over its surface in all directions. A sphere under compression may shrink slightly, but since every point on its surface is reinforced from other points this equalizes the forces over the entire surface and inhibits collapse. This form is used for all deep diving submersibles, which typically have pressure hulls two metres in diameter and 150 millimetres thick.

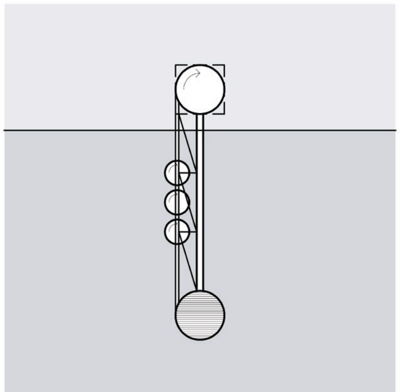




SPS panel composition
a. Exterior metal plate
b. Elastomer core
c. Interior metal plate

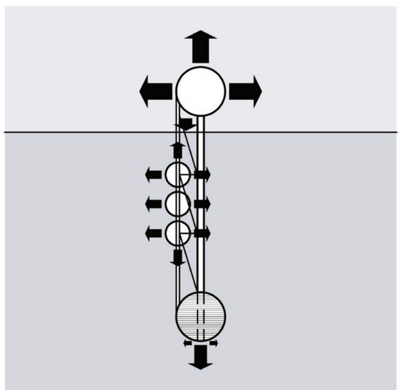
The hull structure of the vessel is composed of a Sandwich Plate System (SPS). SPS is a composite material comprised by two much thinner metal plates separated by a light-weight elastomer core, which transfers shear between each plate, eliminating the need for stiffeners and precludes local faceplate buckling. The thicknesses of the composite elements are adjusted to meet the individual needs of each application within the vessel. The use of this SPS system dramatically reduces construction complexity (see below) and removes the majority of fatigue and corrosion prone details when compared to a conventional stiffened steel structure. SPS construction is much lighter than conventional stiffened steel structures due mainly to due to their simplified construction but also in part to the lower density of the elastomer core, and with built-in protection against fire and vibration eliminating the need for any additional protective materials.





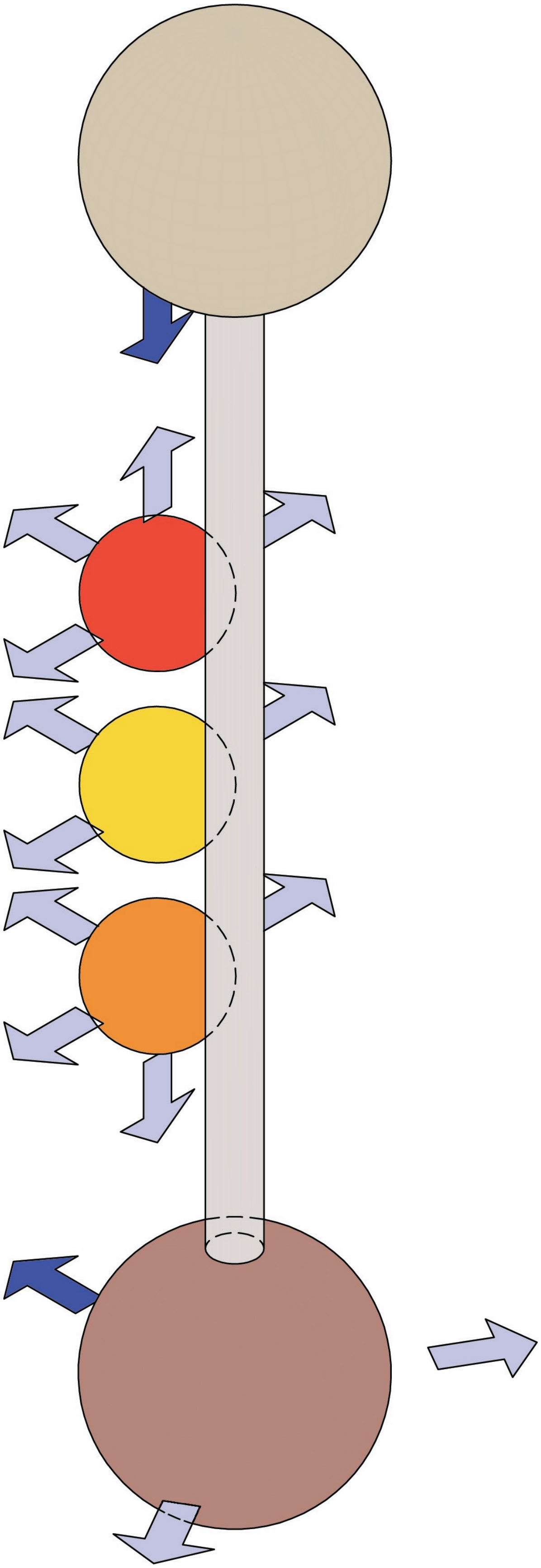
Accommodations

The vessel will accommodate the crew providing space to live for extended periods of time. These crew spaces with a minimum of complexity and duplication are to accommodate the vessels transition between horizontal and vertical modes, and the crew accommodations are to be both above and below the surface. As with the truss these spaces should be located as to not increase the vessels drag while the vessel is horizontal.



Visual and Physical Access

The vessel is to provide access both visual and physical to the waters that surround it. Allowing the occupants of the vessel, and though it is various systems the rest of us, to have continuous access through the oceans obscuring surface to the world below, via viewports, sample ports and lockout chambers.



The crew live and work in spaces both above and below the waterline. This environment has to be comfortable and inspiring; average mission lasts three to six months. At maximum there is a crew of twenty two onboard; six permanent crew members for ship operations (including Master), twelve permanent crew members for science operations (technicians). The crew remain on board for the duration of the mission; additional space for four guest crew members, who typically are onboard for only two to four weeks. Most of the crew space below the waterline is kept at one-atmosphere to facilitate easy access between above - and below - surface and to ease life-support and mechanical systems. One dedicated area below the waterline at a depth of around sixty metres is devoted to an ambient pressure compartment, maintained at a pressure just below that of the surrounding water. This area will operate independently and contains all the facilities required for two to three week occupancy.

Inhabitated Spaces Parti

Visual Connection

Physical Connection

Dirty Work Module

Connecting Passage
(vertical & horizontal)

Clean Work Module

Communal Module

Privacy Module

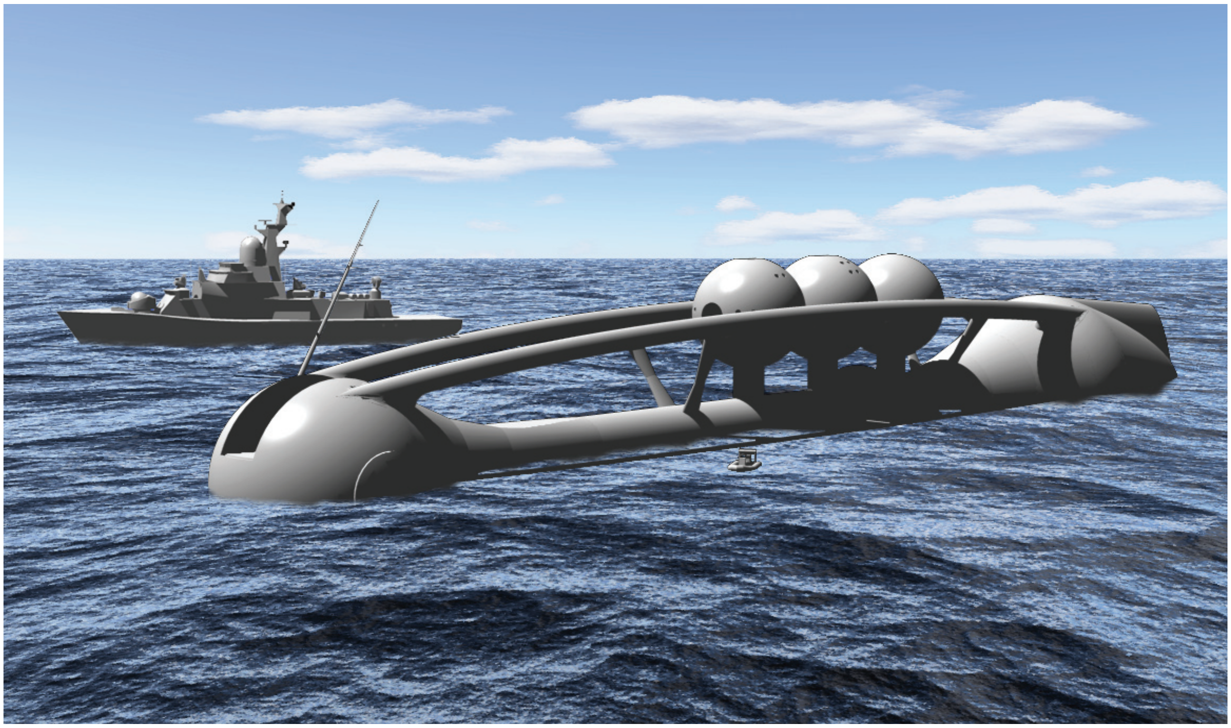
Ambient Pressure
Module


- Triton -
illustro atrum regio

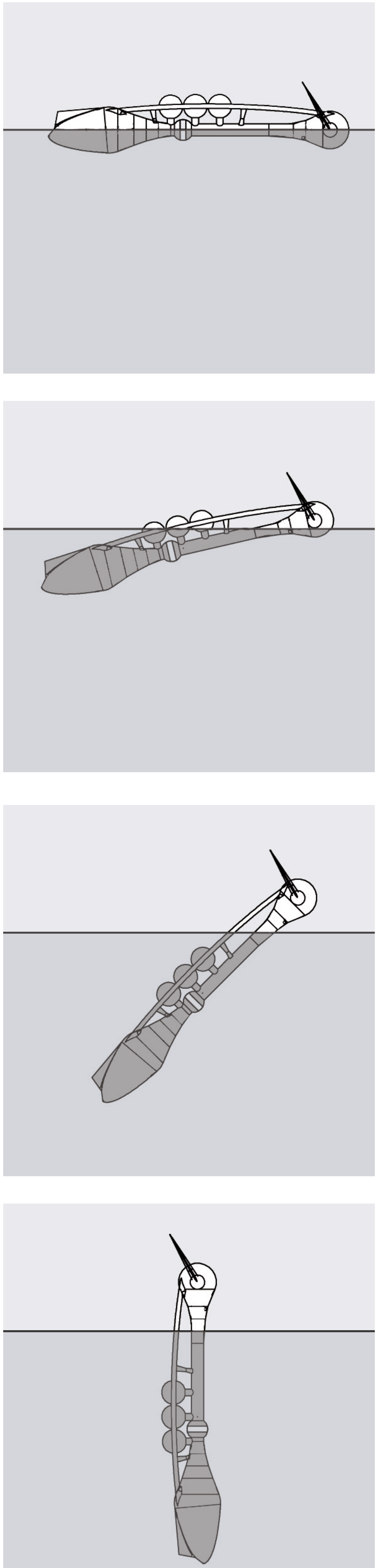
4.0 Ships' Layout

"What motive power is confined in it? What contrivances determine its operation? What powerful agent propels it?… How do you return to the surface of the ocean? And how do you maintain yourselves in the requisite medium? Am I asking too much, captain?"

Jules Verne, Twenty Thousand Leagues Under the Sea



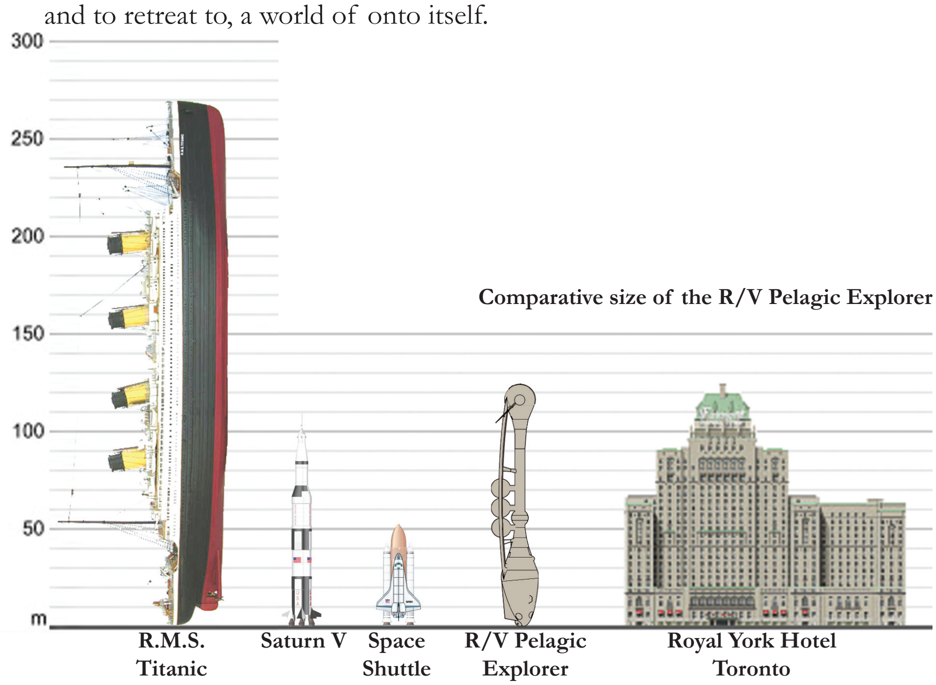
R/V Pelagic Explorer is an example of this new type of vessel. It is made up of four major sub-assemblies. The first of which is composed by two large spherical hulls, the forward one being used for the main working space (Engineering Module) of the vessel while the aft is comprised by the Main Ballast Modules. These two separate spherical hulls together form the primary hull for the vessel. They are connected together by the second major sub-assembly; a truss which connects the primary hulls together and whose elements house the living spaces for the crew. These together form a large dumbbell shaped structure. The third major sub-assembly allows the vessel to travel through the water more efficiently. This is accomplished with a secondary hull which used to fair the connections between the truss and primary hull reducing the water resistance of the vessel while underway. The secondary hull is broken into three separate pieces. One section each at the fore and aft truss/primary hull connections as well as a third aft of the aft section primary hull. The space between these sub-assemblies is used for equipment and components that can be immersed in water and are pressure resistant. The fourth and final sub-assembly is the extensive array of dedicated scientific sensors mounted in numerous locations all over the vessel one such location is the large sensor blister on the aft secondary hull.

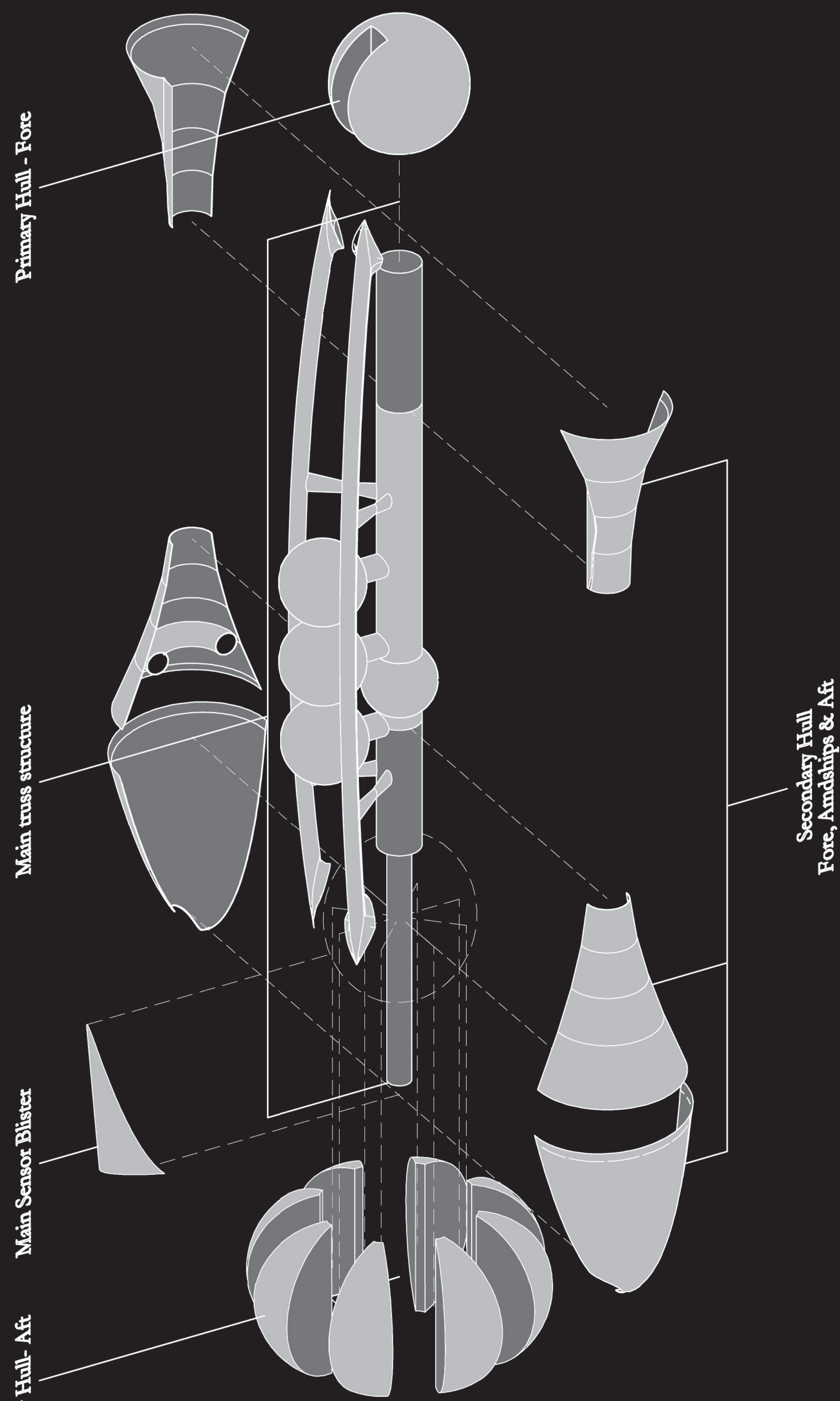


With the vessel in its horizontal mode it moves across the surface of the ocean like every other ship, but once in area that has been targeted for study the aft portions of the ship take on seawater and begin to sink. Approximately thirty minutes later the stern of the vessel is nearly entirely flooded and the vessel is standing vertically in the water with five-sixths of its structure now submerged below the surface, with only the forward primary hull remaining above.

The transformation allows to the vessel to detach itself from the motions of the surface of the ocean. Thus the vessel is able to remain stabile in very rough seas allowing research operations to carryon uninterrupted in a wider range of weather conditions. The vessel is a mobile, yet ultra stabile platform from which we can make longer and more extensive excursions into the ocean. Another benefit of this transformation is that the living spaces are now both above and below the surface allowing the crew to stay in direct contact with the object of study; it is not enough just to peer in from the surface and occasionally make brief excursions in. This vessel allows for a long-term presence above and below the surface giving us a chance to start understanding the intricacies and complexities of this vast habitat.

The living spaces for the crew are in spherical modules with trunnioned deck structures so that they are equally usable in either orientation, the only exceptions to this being the observatory and ambient pressure habitat both of which are only accessible and usable when the vessel is in its vertical mode. The vessel can accommodate up to a maximum of twenty-two people who live and work in the vessel although this number is usually between sixteen and eighteen. The design of these internal spaces is to accommodate long term missions of three to six months giving the crew members adequate places to gather, study, work, and to retreat to, a world of onto itself.




Primary Hull - Fore
Main truss structure
Main Sensor Blister
Primary Hull- Aft
Secondary Hull
Fore, Amdships & Aft

Ship Characteristics

Dimensions:

Length Overall	123.35m (404’-8”)
Beam	18.60m (61’-0”)
Draft (design waterline)	9.30m (30’-6“)

Displacement:

Lightship	2920 tonnes (2874 LT)
Full load (vertical)	7940 tonnes (7814 LT)
(horizontal)	3790 tonnes (3730 LT)

Performance:

Speed (design maximum)	12 KTS
Sustained Speed	10 KTS
Operability	Sea State 4 (Horizontal Mode) Sea State 8 (Vertical Mode)
Range	10,000 NM at 10 KTS
Endurance	120 Days Nominal (food, fuel limiters)
Mission Payload	100 LT

Propulsion Plant:

Type	Diesel electric
Propulsors	Two Rolls Royce, AWJ-21 water jet propulsion units
Motors	Two Westinghouse, 1200 kW DC
Diesel Generators	Two Caterpillar 3512B, 1135 kW One Caterpillar 3406, 320 kW
Bow Thruster	One Elliott White Gill Model 40

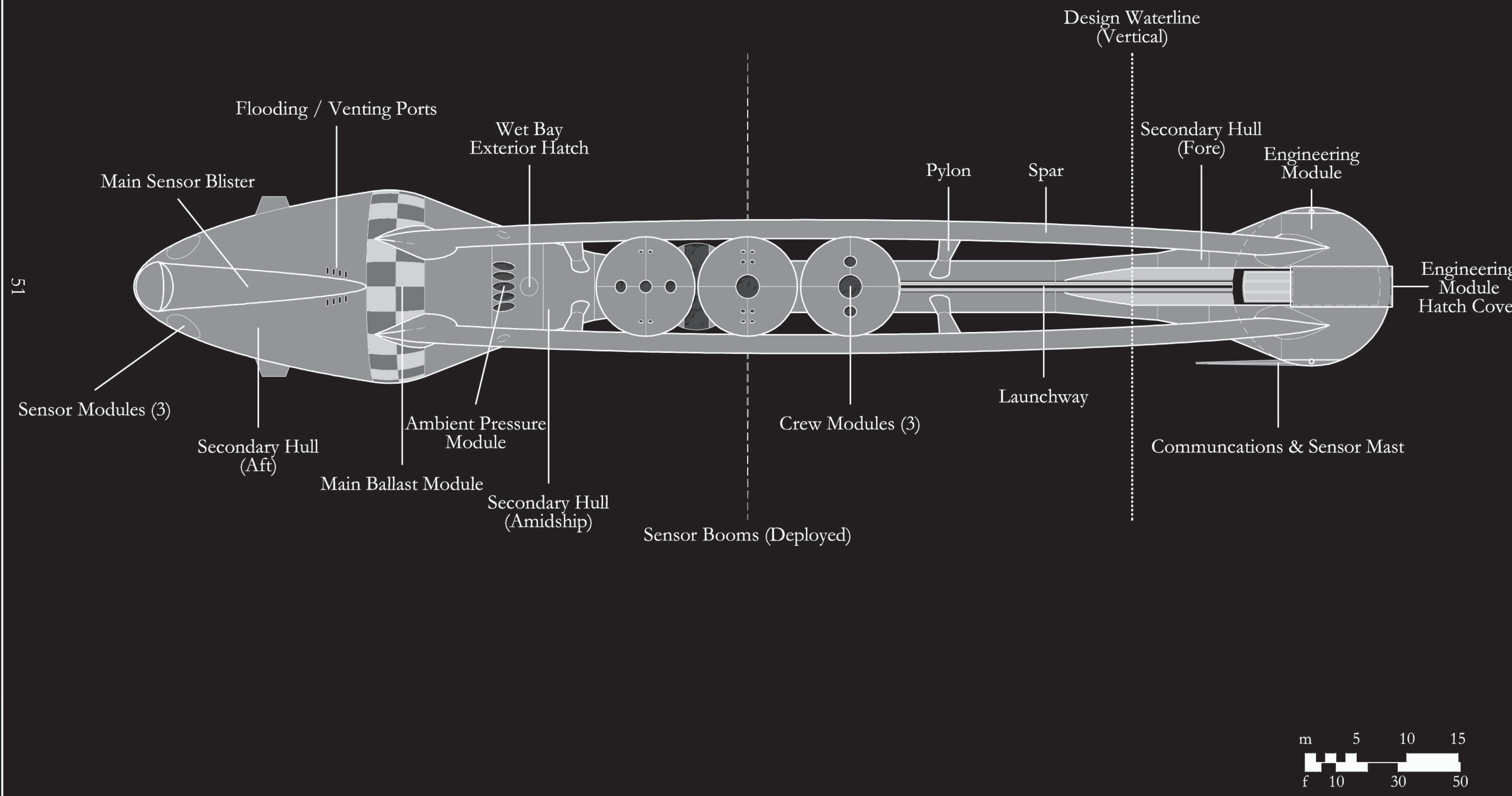
Navigation Equipment:

Integrated Bridge	EDI Vessel Control System
Inertial Reference Unit	TSS, Inc. Model POS/MV 320
Gyro Compass	Raytheon STD-20
Differential GPS	Raytheon Raychart 420
Surface Search Radars	Raytheon Pathfinder (1) 10cm and (1) 3cm
GMDSS	Certified for all operational areas
Wind Speed/Direction System	RM Young 26700

Accommodations:

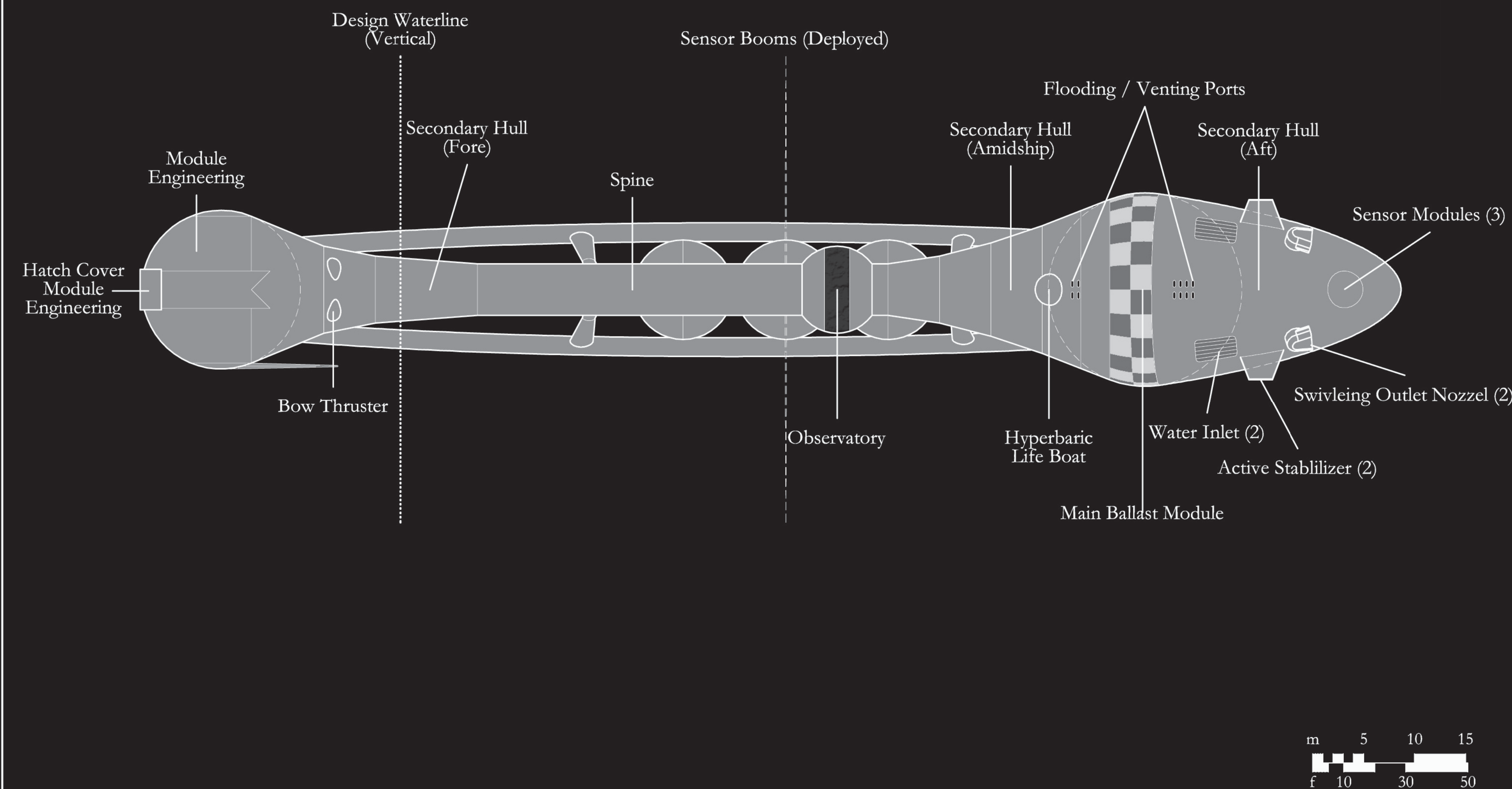
Ship’s compliment	22 persons maximum 6 Crew / 8-12 Scientists / 4 Guest

Dorsal View

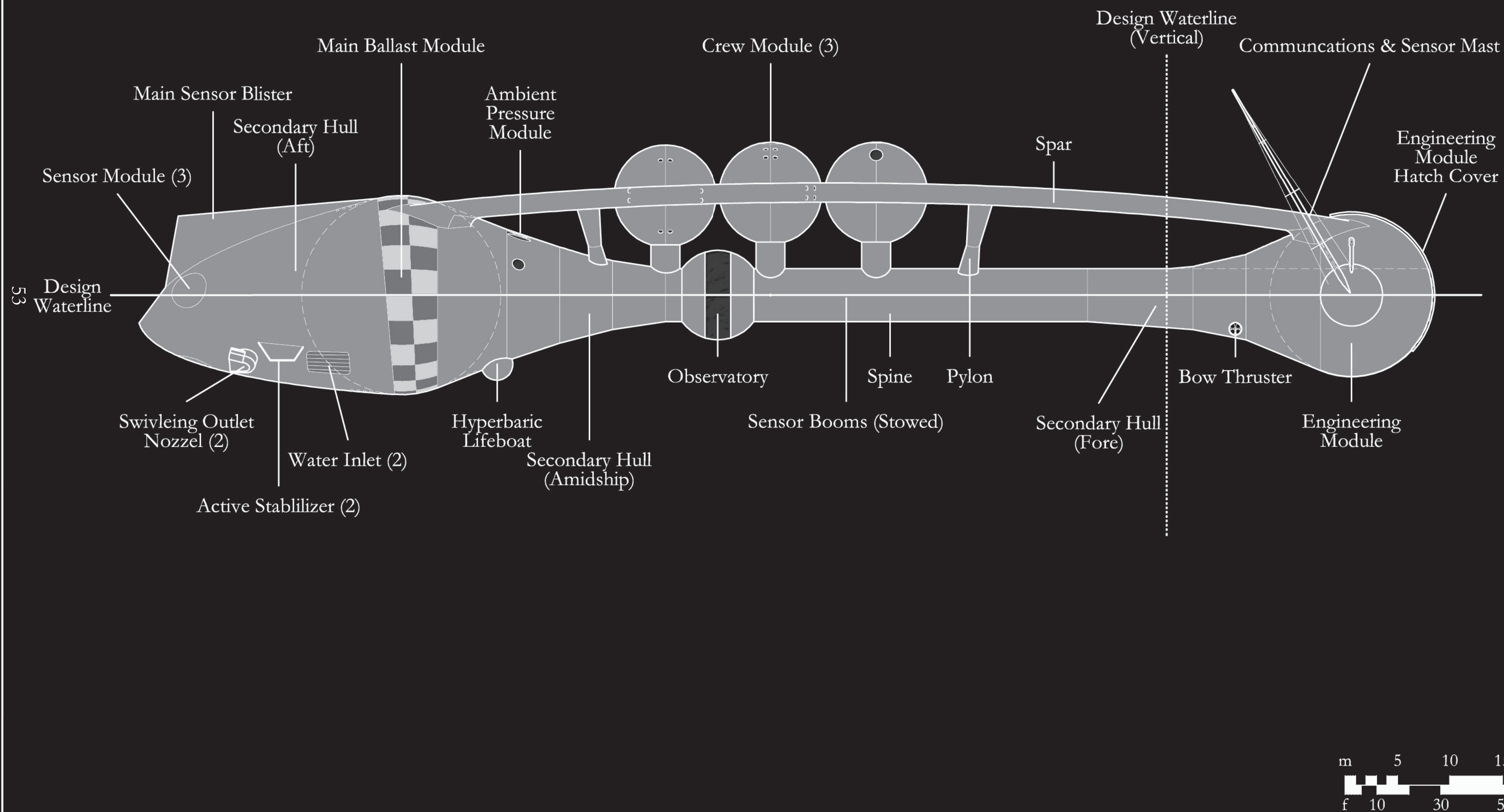


Flooding / Venting Ports
Wet Bay
Exterior Hatch
Main Sensor Blister
Design Waterline
(Vertical)
Secondary Hull
(Fore)
Engineering
Module
Pylon
Spar
Engineering
Module
Hatch Cover
Sensor Modules (3)
Secondary Hull
(Aft)
Main Ballast Module
Ambient Pressure
Module
Secondary Hull
(Amidship)
Sensor Booms (Deployed)
Crew Modules (3)
Launchway
Communcations & Sensor Mast
m 5 10 15
f 10 30 50

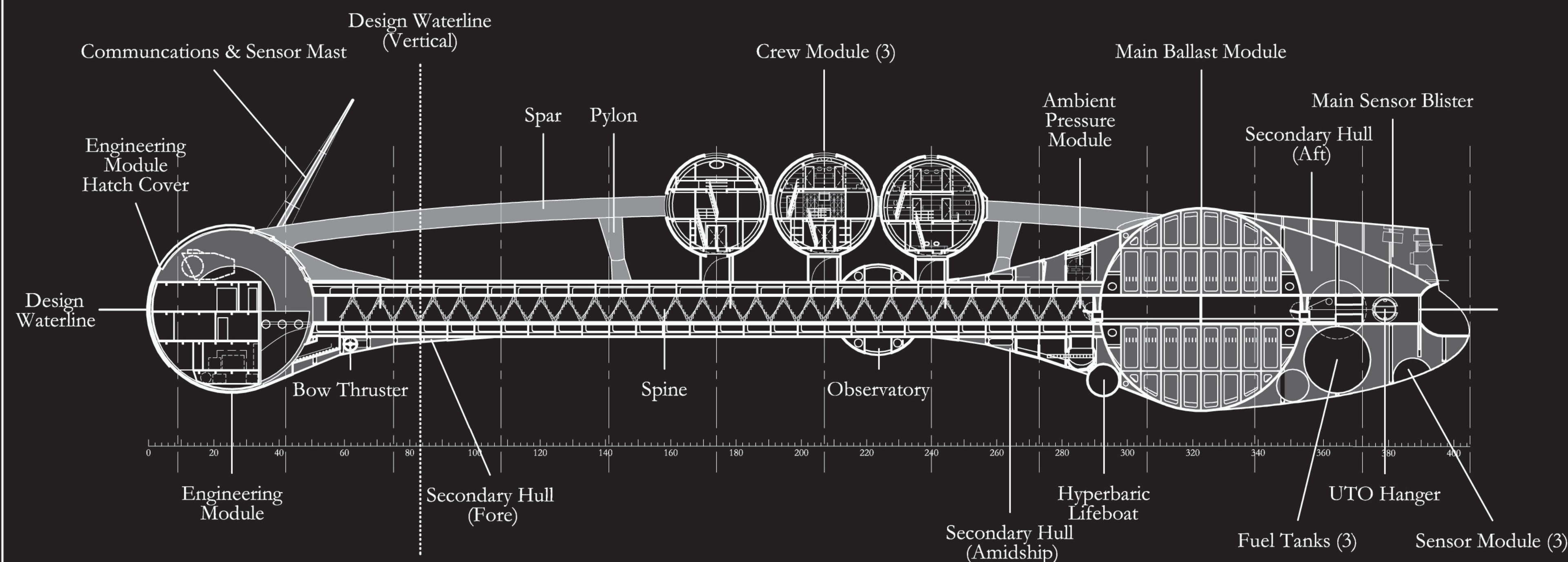
Ventral View

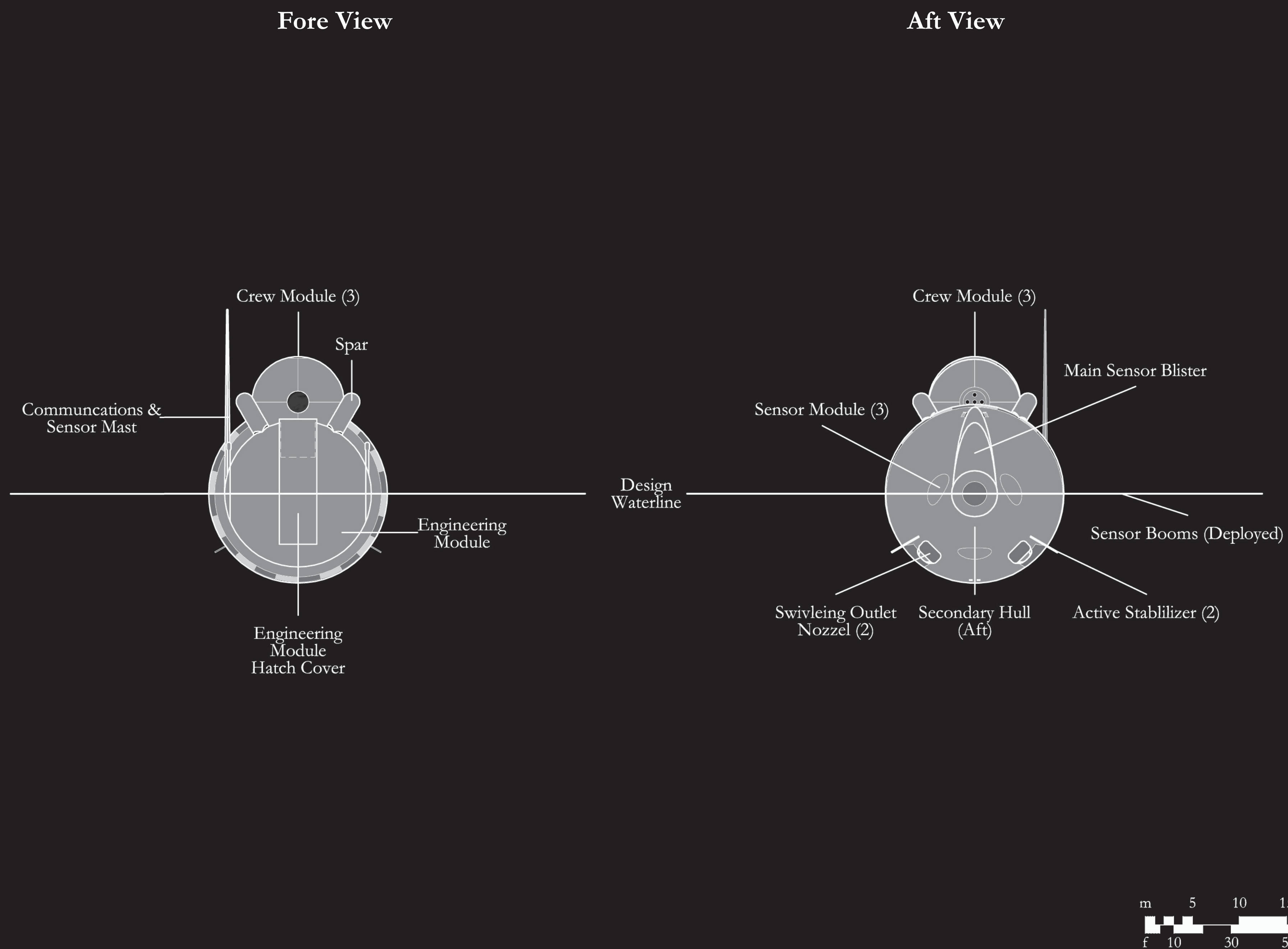


Profile


Main Ballast Module
Crew Module (3)
Design Waterline
(Vertical)
Communcations & Sensor Mast
Main Sensor Blister
Ambient
Pressure
Module
Secondary Hull
(Aft)
Spar
Engineering
Module
Hatch Cover
Sensor Module (3)
Design
Waterline
Observatory
Spine
Pylon
Bow Thruster
Swivleing Outlet
Nozzel (2)
Hyperbaric
Lifeboat
Sensor Booms (Stowed)
Secondary Hull
(Fore)
Engineering
Module
Water Inlet (2)
Secondary Hull
(Amidship)
Active Stablilizer (2)
m
5
10
15
f
10
30
50

Inboard Profile

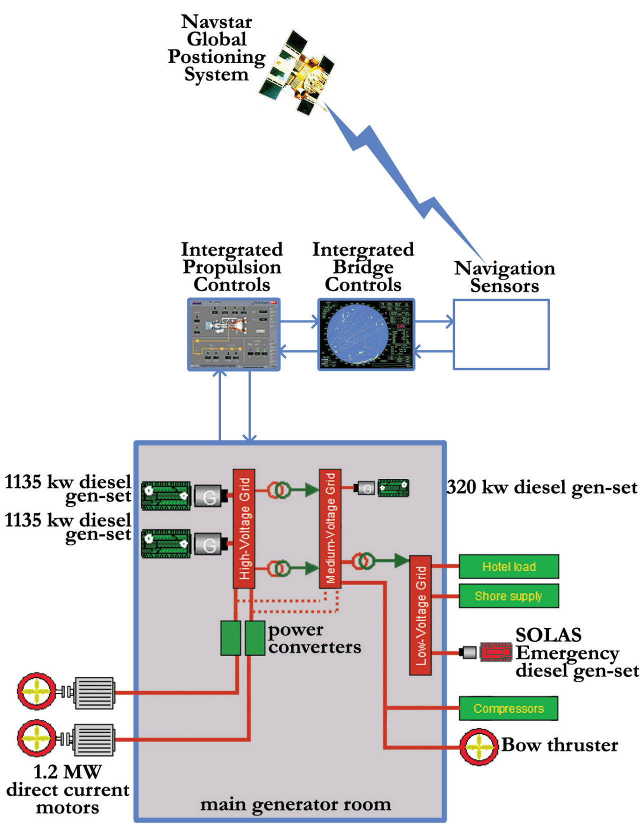



Fore View
Aft View
Crew Module (3)
Spar
Communcations &
Sensor Mast
Engineering
Module
Engineering
Module
Hatch Cover
Design
Waterline
Crew Module (3)
Main Sensor Blister
Sensor Module (3)
Sensor Booms (Deployed)
Swivleing Outlet
Nozzel (2)
Secondary Hull
(Aft)
Active Stablilizer (2)
m 5 10 15
f 10 30 50

Ship Systems

For flexibility and economy of operation, R/V Pelagic Explorer is designed with a fully integrated electric system providing power for both propulsion and ship's service uses. An integrated system is particularly appropriate for a research vessel where demands can vary from very low to extremely high depending on the operation being conducted. The three diesel generators forming the vessels' power plant are located in the lower level of the engineering module. This plant is designed for a speed of 12 knots at 100% power and sustained speed of 10 knots at 63% power, and is designed for unattended operation in accordance with regulatory body requirements; it provides for Command Centre and Main Control Station throttle control over the complete range of plant operation. This digital power management and control system provides highly detailed monitoring and automatic control of the ship's engineering functions including propulsion control system, centralized machinery control system, power management system, vital alarm system, and fire alarm system all in a single integrated bridge system.

Schematic Power and Control Layout

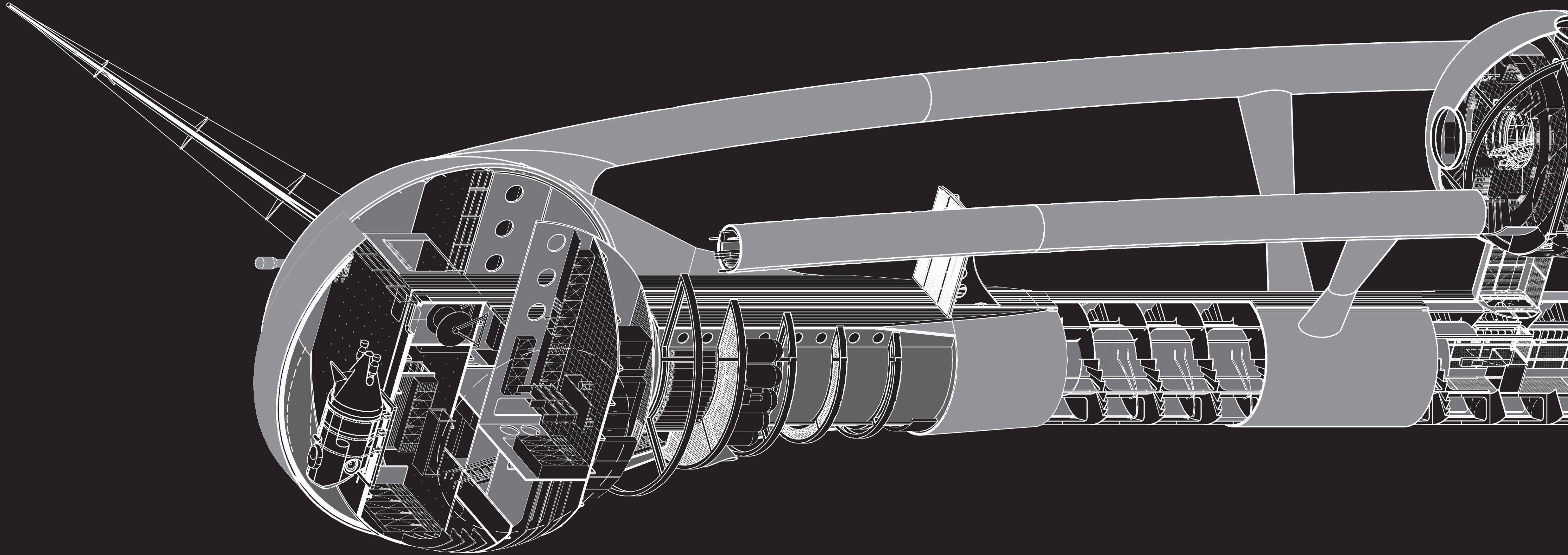


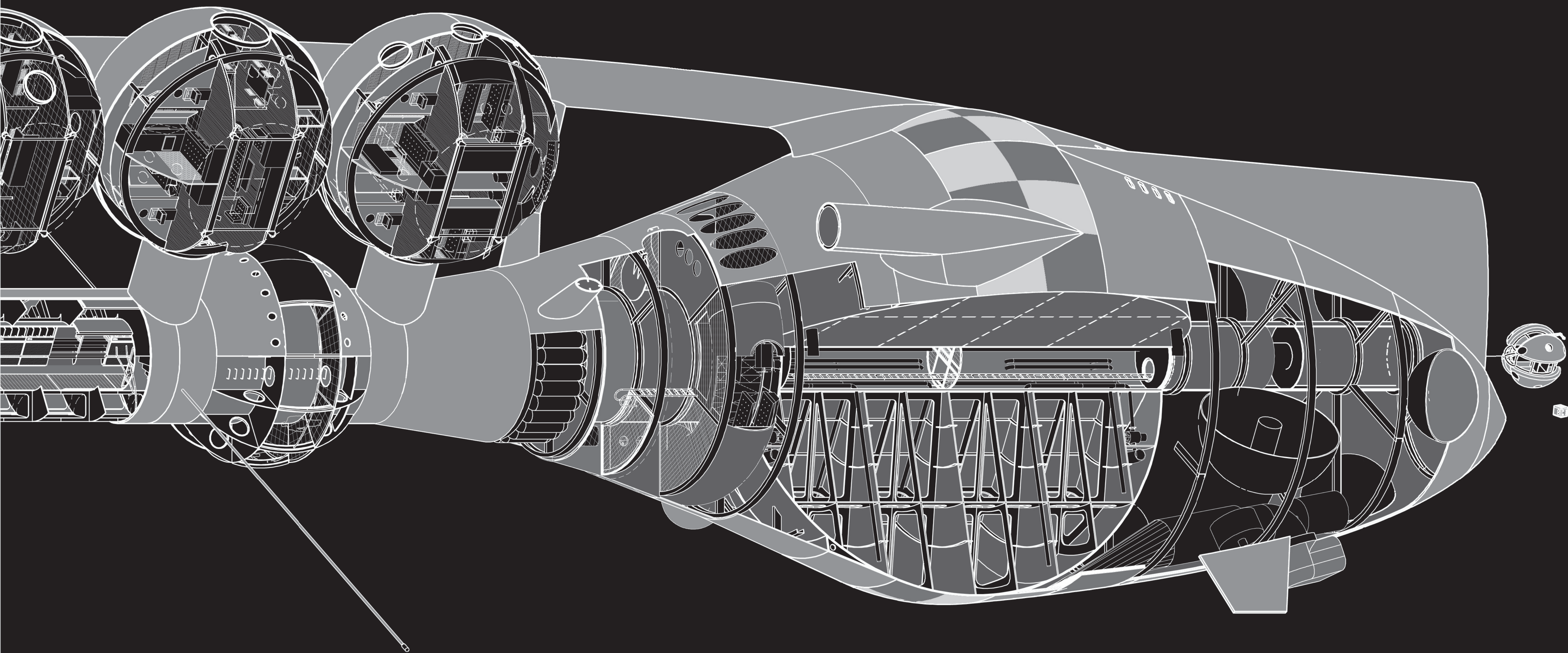
Ship Control

The ship is driven by two ducted impellers with swivelling outlet nozzles propelling the vessel at a maximum of 12 knots. Aft adjustable stabilizers are provided to adjust ship trim and dampen pitching and rolling motions. A single ducted bow thruster is located in the forward secondary hull. The bow thruster allows for greater vessel control. The vessel is designed to precisely hold position in seas up to 9 meter significant wave height and a wind speed of 60 knots at best heading; in its vertical orientation.

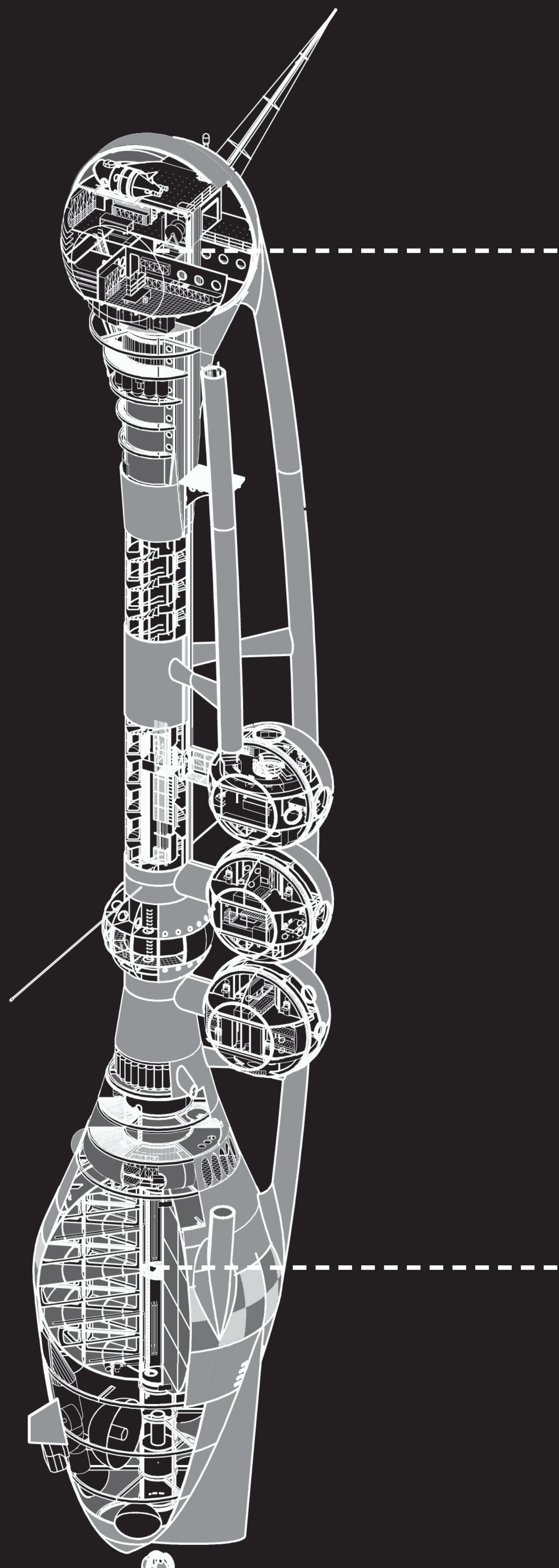
R/V Pelagic Explorer incorporates a sophisticated dynamic positioning system which accepts data input from position and environmental sensors and automatically controls propulsion and steering to perform precise manoeuvres. Automatic manoeuvres include steering a fixed heading, holding position at a designated location, or moving from one position to another. The system also allows manual control by means of a joystick. The Command Centre main console serves as the primary control station, with secondary control stations located in the Digital Laboratory and Wing Bridge located in the engineering module. Propulsion, steering and thruster control is configured to accept commands from the dynamic positioning system.

Vessel Cutaway Axonometric (Vertical Mode)





4.1 Primary Hull

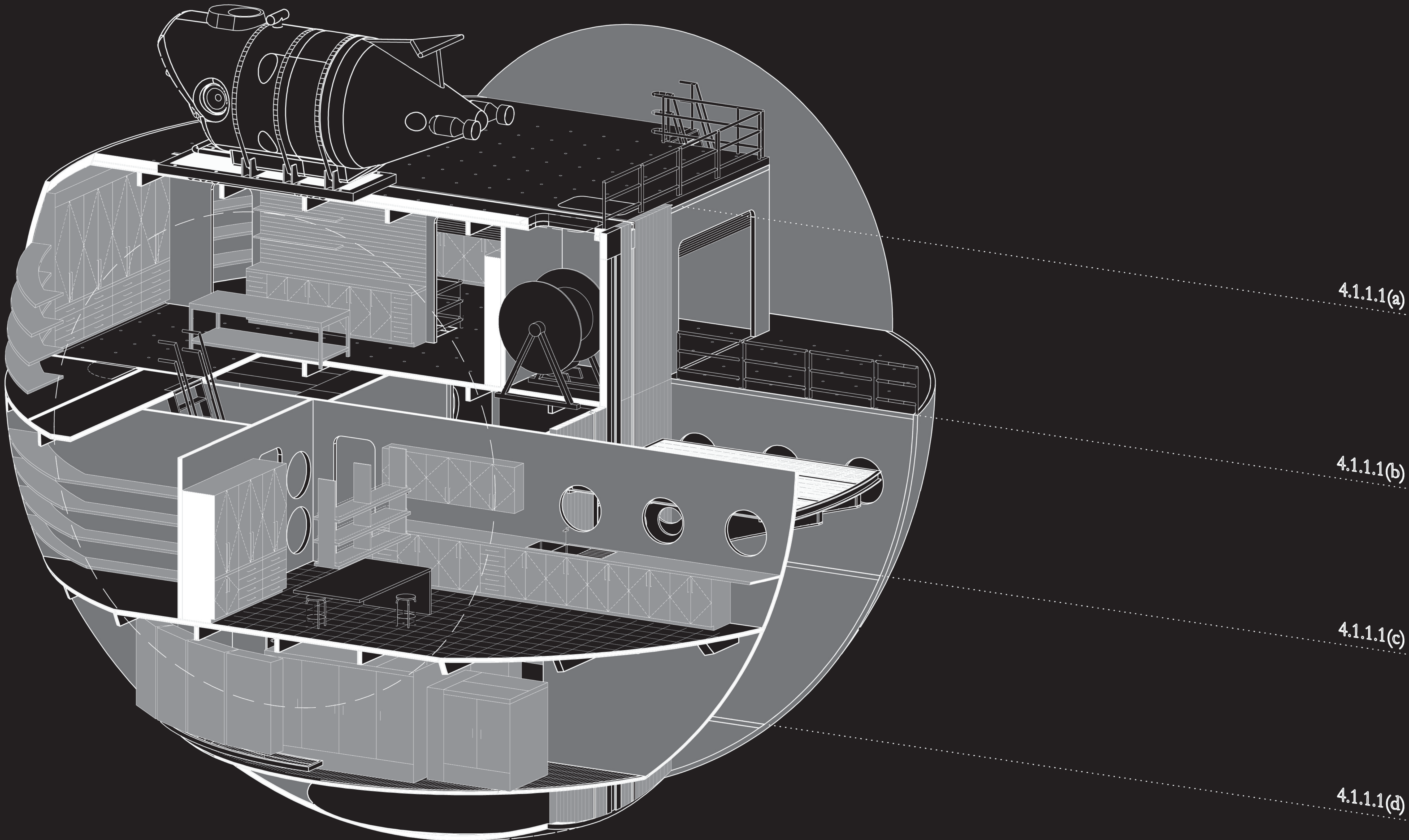


4.1.1 Primary Hull - Forward

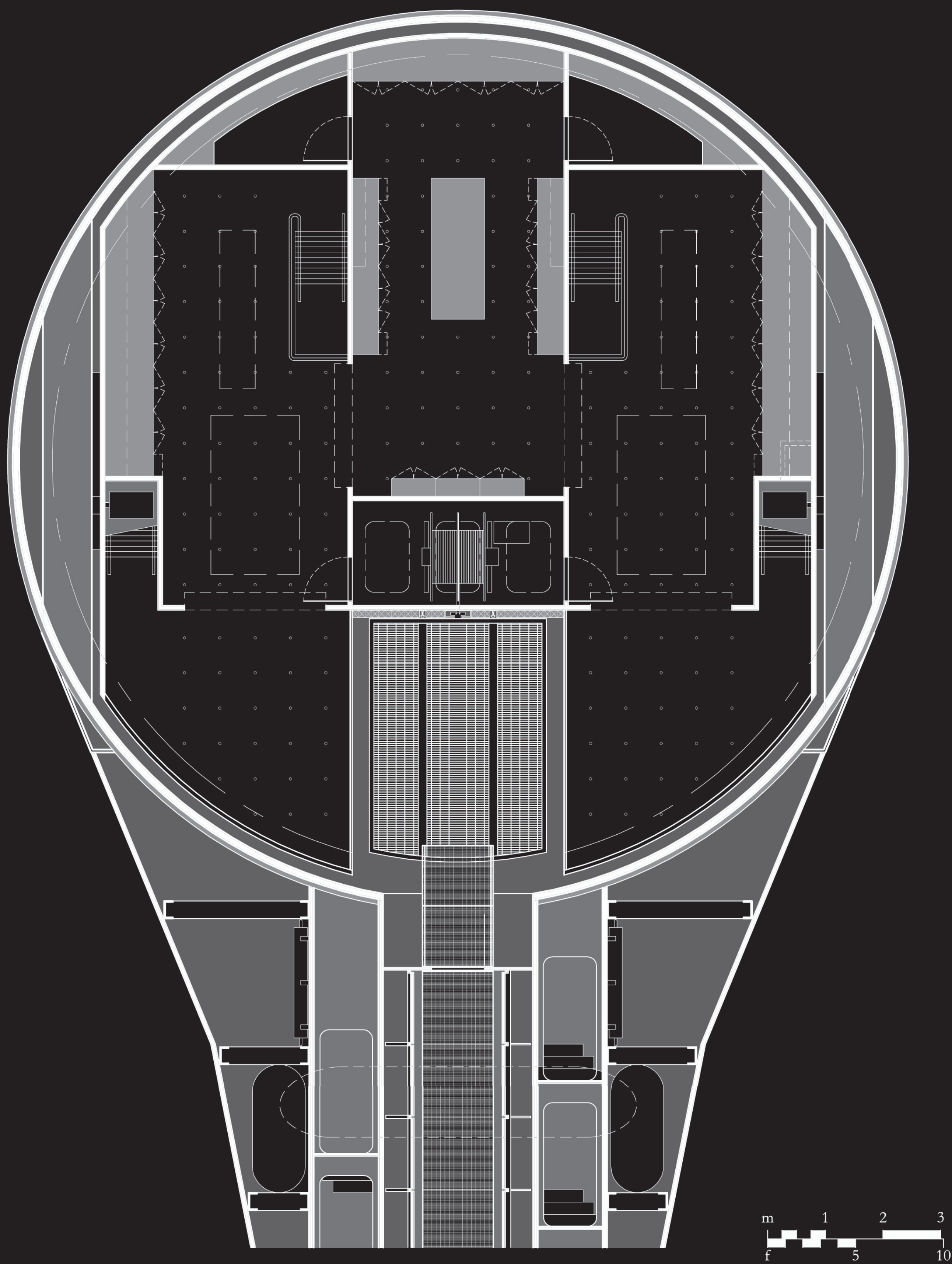
The forward section of the primary hull houses the engineering module. It is the only section of the vessel that is never fully submerged; it is completely raised out of the water when the vessel is in its vertical mode, sitting ten meters (33 feet) above the surface of the ocean. The communications mast and a large hatch cover are both significant parts of this module. This hatch covers nearly half of the central portion of this module, protecting a large opening from which smaller craft and scientific equipment deploy. The hatch cover is a large two-piece weather-proof, rotating structure protecting the exterior shell of the engineering module from weather and waves while the vessel is in horizontal mode. The outer hatch is a shell constructed out of the same sandwich plate system panels as the rest of the vessel. The inner hatch is an aluminium frame with a translucent fabric skin (Kevlar) allowing light into the engineering module. While this hatch is shut the elevator platform is cannot be used. Mounted to the starboard side of the exterior hull structure is the Communications / Sensor mast; this mast also serves as the exhaust stack for the generators in the engineering module.

The exterior hull of the engineering module is a spherical shell structure fifteen-and-a-half metres (51 feet) in diameter, comprised of steel sandwich plate system. This shell structure transfers all of the loads on the module back to the main truss structure of the ship, keeping the interior of this module free from structure. Contained within this shell structure, helping to brace it, is another shell structure with four lightweight decks. This interior shell structure is trunnioned, allowing it and the decks within it to rotate through ninety degrees, accommodating the vessels' rotation from horizontal to vertical. The interior structure rotates on bearing rails attached to the exterior hull at ten degree increments, running perpendicular to the axis of rotation. The close spacing of the bearing rails and the individual roller bearings along each rail allows for a smooth passage of forces between the two structures. The interior rotates by gravity; as the heaviest deck is the lowest deck and acts as a ballast, but there is also some supplementary power, provided by two electric motors; on the second deck these motors also hold the decks in place once in position.

Cutaway Axonometric



Midline Deck Plan



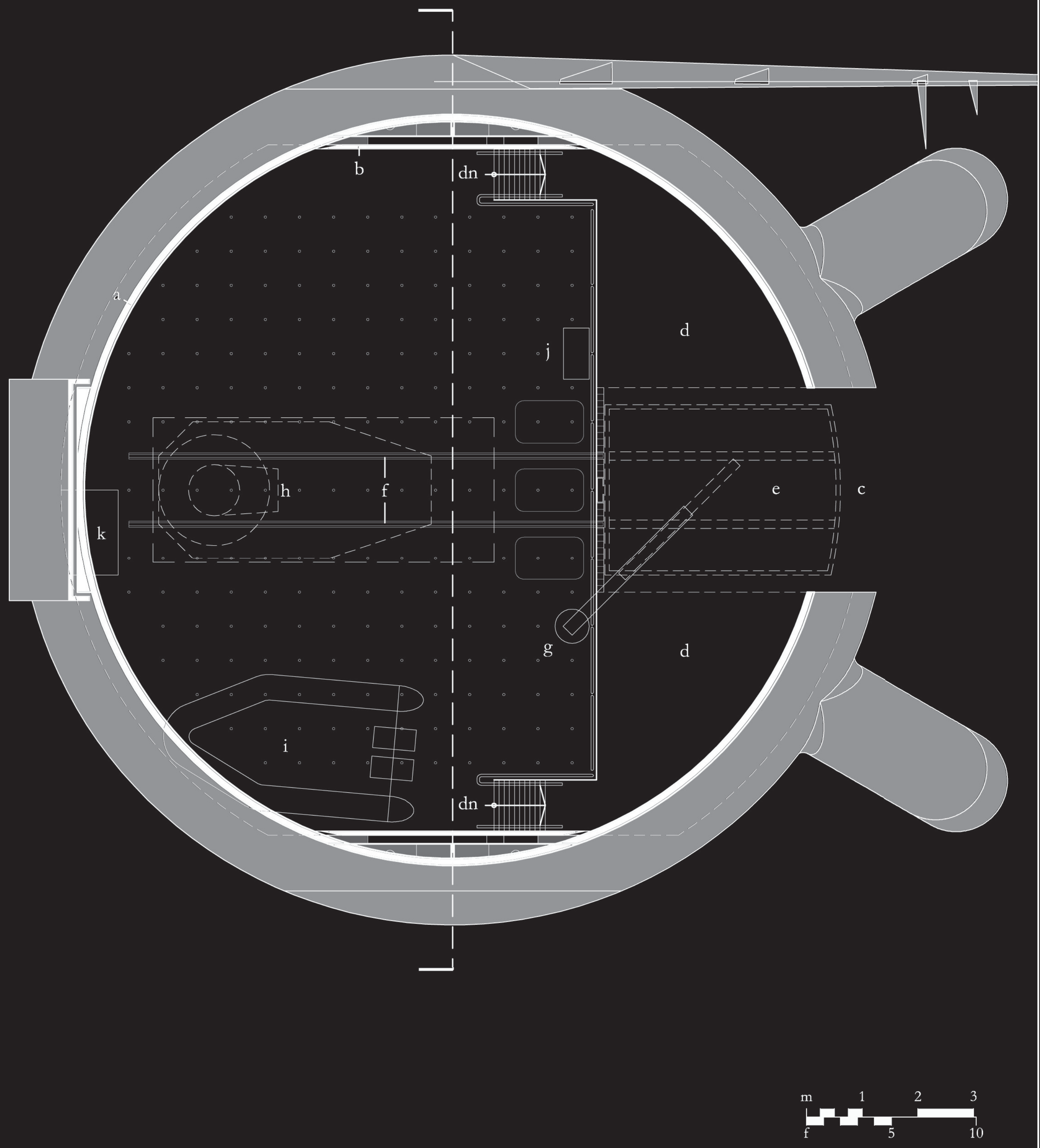
4.1.1.1(a) Working Deck

The vessel accommodates approximately one hundred and ten square metres (1,200 sq. ft.) of exterior working, configured to carry, launch and recover equipment via the launch platform, for a variety of oceanographic operations: including: coring, water sampling, equipment launch and recovery. This area is designed with a two foot bolt socket grid for flexibility to support a variety of scientific equipment. The main complex of mission spaces are located under the working deck, including the staging bays, science office, hazardous materials locker and nearly all of the laboratories and scientific storerooms. The library, meteorological laboratory, and computer laboratory are located in the crew modules.

Key

a. Exterior hull
b. Interior shell
c. Exterior hatch opening
d. Lower working deck below
e. Launching platform
f. Heavy equipment guide track
g. Heavy lift crane (five meter radius)
h. HOV on rail mounted docking cradle
i. RIB ocean rated Launch
j. Launching platform control station
k. Remote Bridge Station (Wing Bridge)

Deck Plan



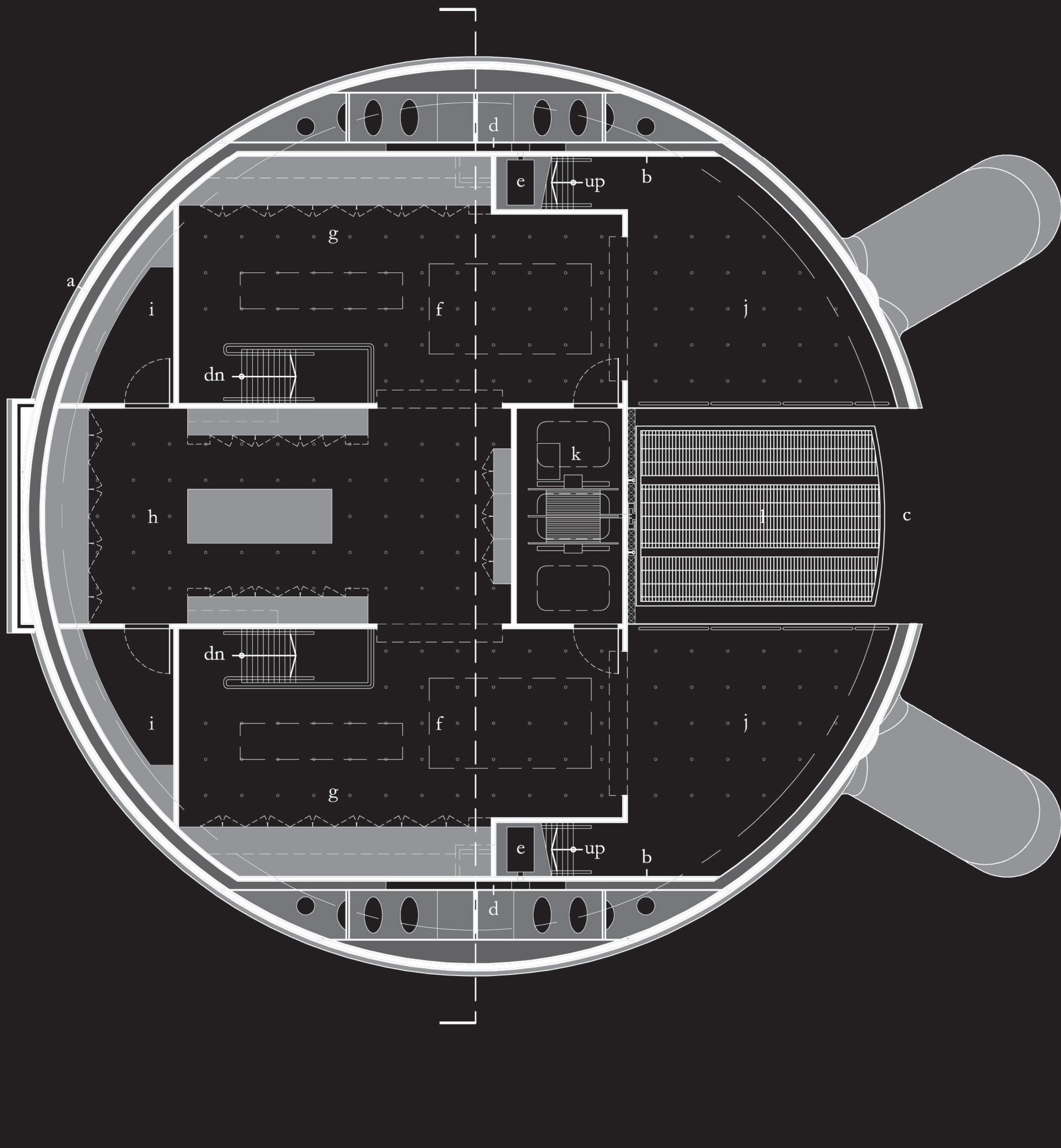
4.1.1.1(b) Staging Bays

The Staging Bays are organised to store, repair & maintain any of the numerous auxiliary explorer craft that can be brought onboard. These craft are housed in the Hanger / Workshop and are deployed from the launching platform via the working deck. The Hanger and Workshops are also designed with a two foot bolt socket grid providing the flexibility to relocate and secure equipment.

Key

a. Exterior hull
b. Interior shell
c. Exterior hatch opening
d. Trunnion machinery
e. Trunnion drive motor
f. Auxiliary craft hanger
g. Machine shop
h. Electronics workshop
i. Stores
j. Working deck
k. Winch room for launching platform
l. Launchway

Deck Plan



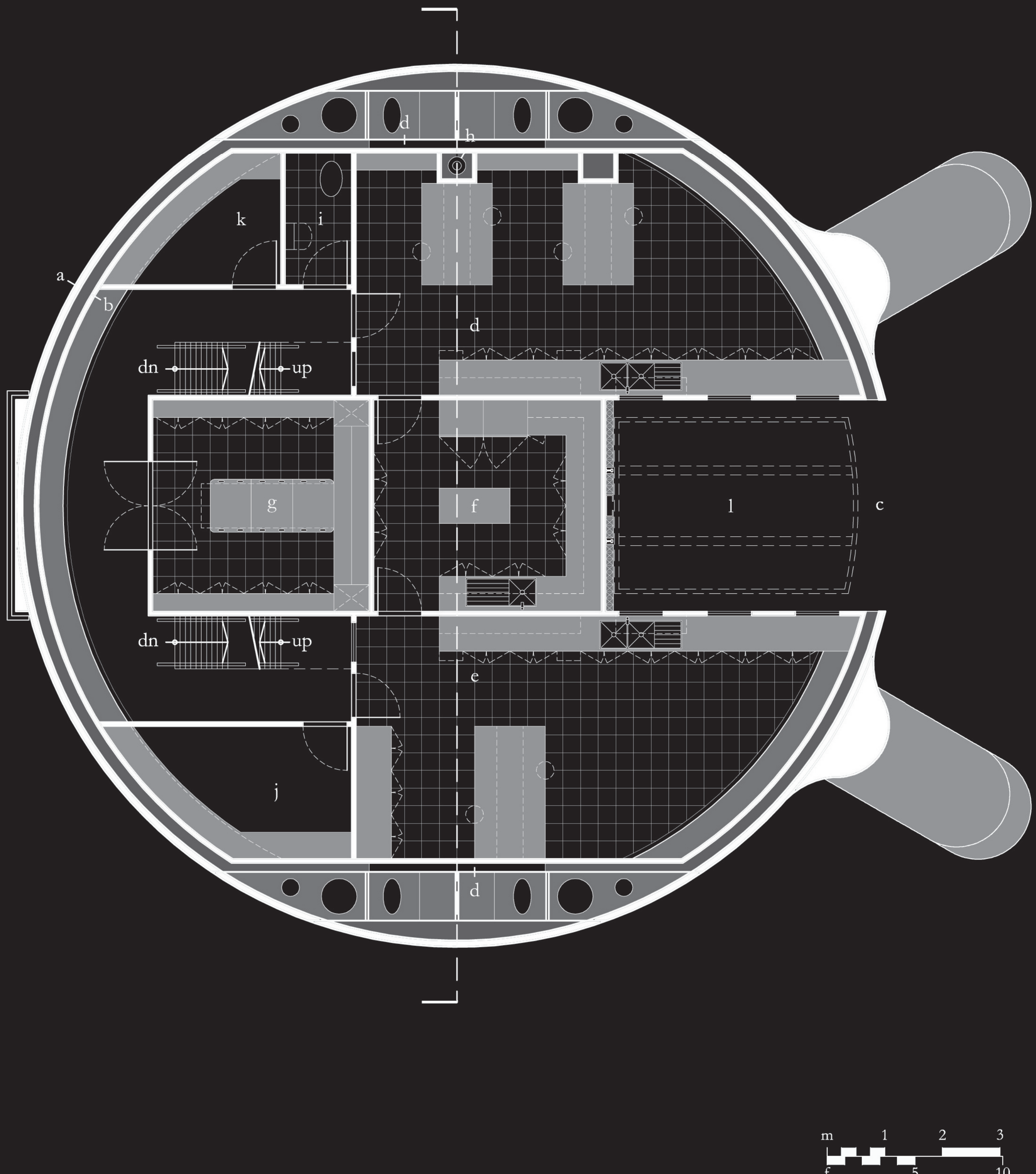
4.1.1.1(c) Science Deck

The Science Deck is dedicated to laboratory space. Here are the wet and chemical laboratories, as well as the specimen laboratory, located close to the launch and recovery facilities to facilitate sample and specimen transfers from the explorer craft. These laboratories are all above the water line to keep their hazardous elements out of the more confined atmosphere of the vessel below the surface. Also on this level is the medical facility, designed for treating and stabilizing a crew member who has been critically injured. When the patient is stabilized, and can be moved safely, he will recover in his own bunk or be transferred to the VIP quarters, where there are hook ups for various monitoring devices and medical gases. Because they share equipment the medical facility is located near the laboratory space but the two are kept separate to prevent cross contamination.

Key

a. Exterior hull
b. Interior shell
c. Exterior hatch opening
d. Chemical laboratory
e. Wet Laboratory
f. Specimen Laboratory
g. Medical facility
h. Power plant exhaust/intake
i. Head
j. Stores
k. Hazmat Stores
l. Launchway

Deck Plan



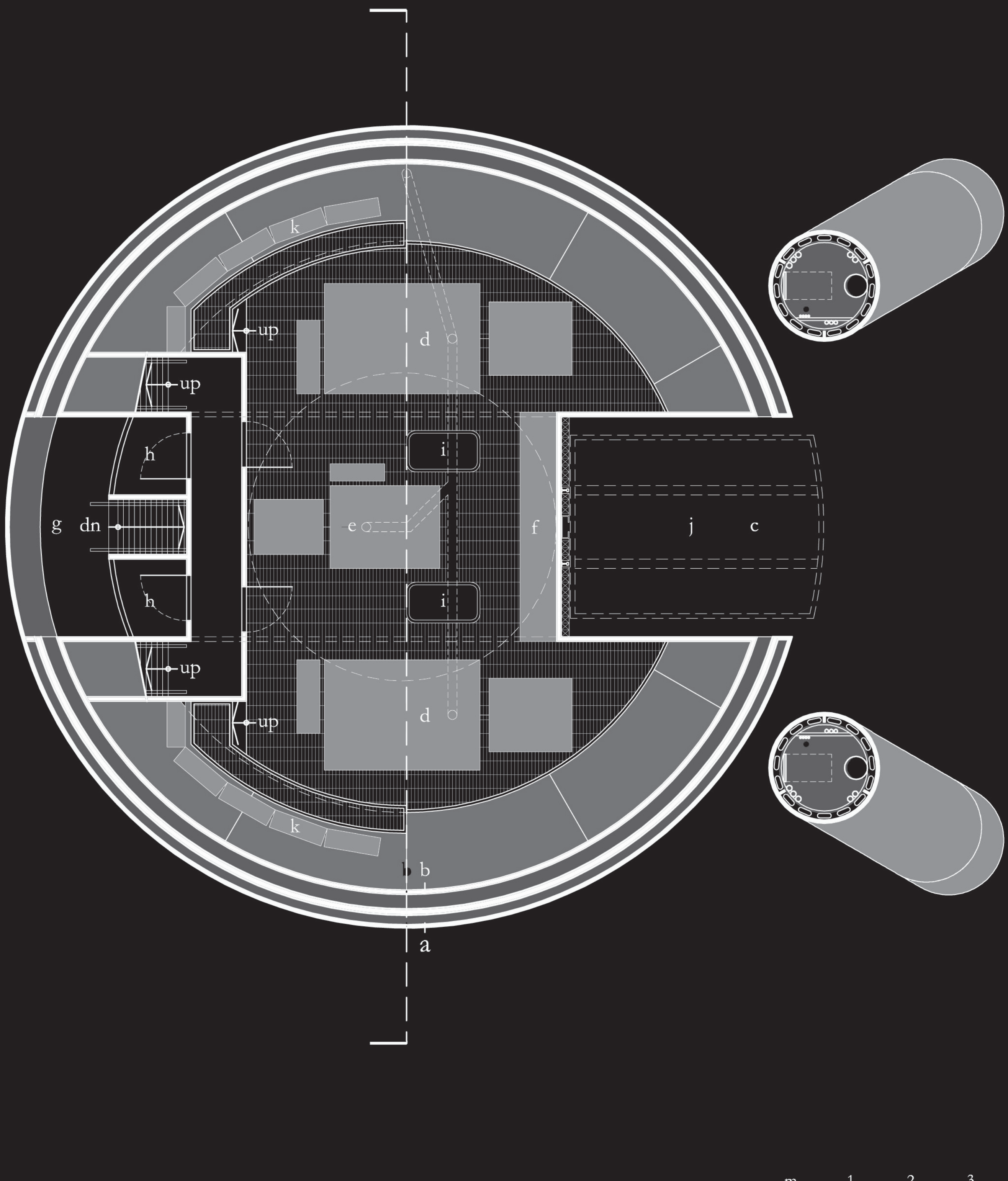
4.1.1.1(d) Main Generator Room

All energies for onboard scientific equipment, life support and propulsion are generated here in the Main Generator Room. There are three diesel generator sets, two of which are designated as auxiliary generators. These two 1135kw secondary generators are only required for full power when underway in horizontal mode; the water jets can draw up to 1Mw each at full power. The power required to run the various systems and equipment - the hotel load of the vessel - is much less and this load is handled by the 320kw diesel generator running at just over half capacity. This smaller primary generator is more efficient for the lower power requirements while on station. One of the larger generators is kept on stand-by at all times as backup. Keeping the generators and other mechanical equipment above the water line - in combination with the vessel's construction - reduces the noise transfer into the water, making the vessel exceptionally quiet, allowing for highly accurate acoustic measurements.

Key

a. Exterior hull
b. Interior shell
c. Exterior hatch opening
d. Auxiliary diesel generator set (1135 kw)
e. Primary diesel generator set (320 kw)
f. Main switch gear
g. Spine access way (fixed section)
h. Spine access way (rotating section)
i. Access hatch (to Auxiliary machine space below)
j. Launchway

Deck Plan

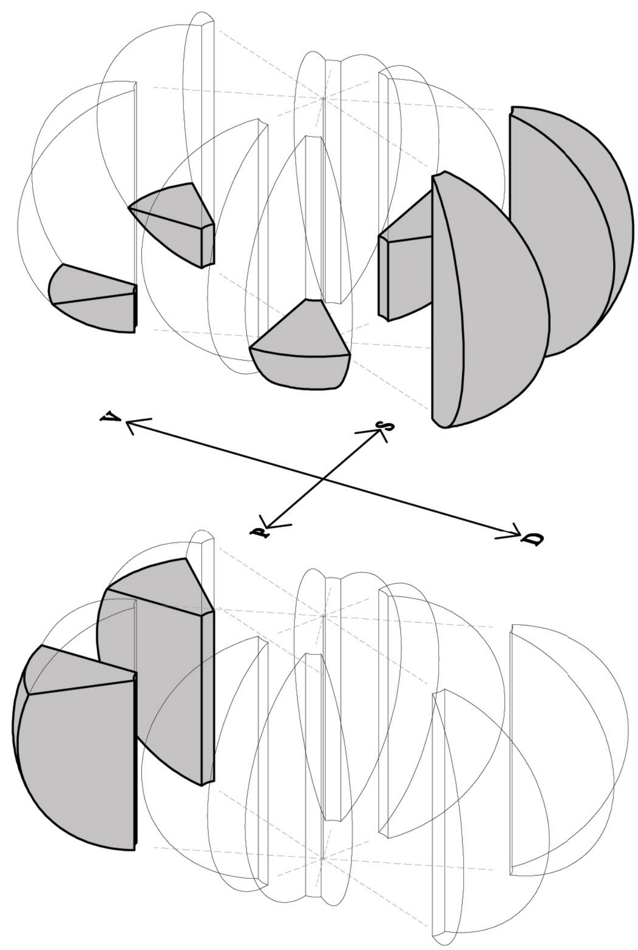


4.1.2 Primary Hull - Aft

The aft section of the primary hull is entirely dedicated to the main ballast tanks. There are eight of these tanks, each of which is baffled and pressure resistant. Each tank has a capacity of four hundred and thirty-five tonnes of seawater: a total ballast capacity of approximately thirty-five hundred tonnes. These tanks orient the vessel in the water as seawater is pumped into, out of, and in-between the eight main tanks. Each of the eight wedge-shaped segments is further divided into four internal sections, to keep the ballast water from moving around, maintaining control over the vessel's centre of gravity. Using this precise control of ballast placement, the entire vessel can be flipped to stand vertically in the water, with five-sixths of the vessel submerged beneath the surface. While the vessel is in vertical mode seawater, is actively pumped from tank to tank to maintain the balance, counteracting any weight shifts within the vessel.

Ballast configuration
(Vertical mode)

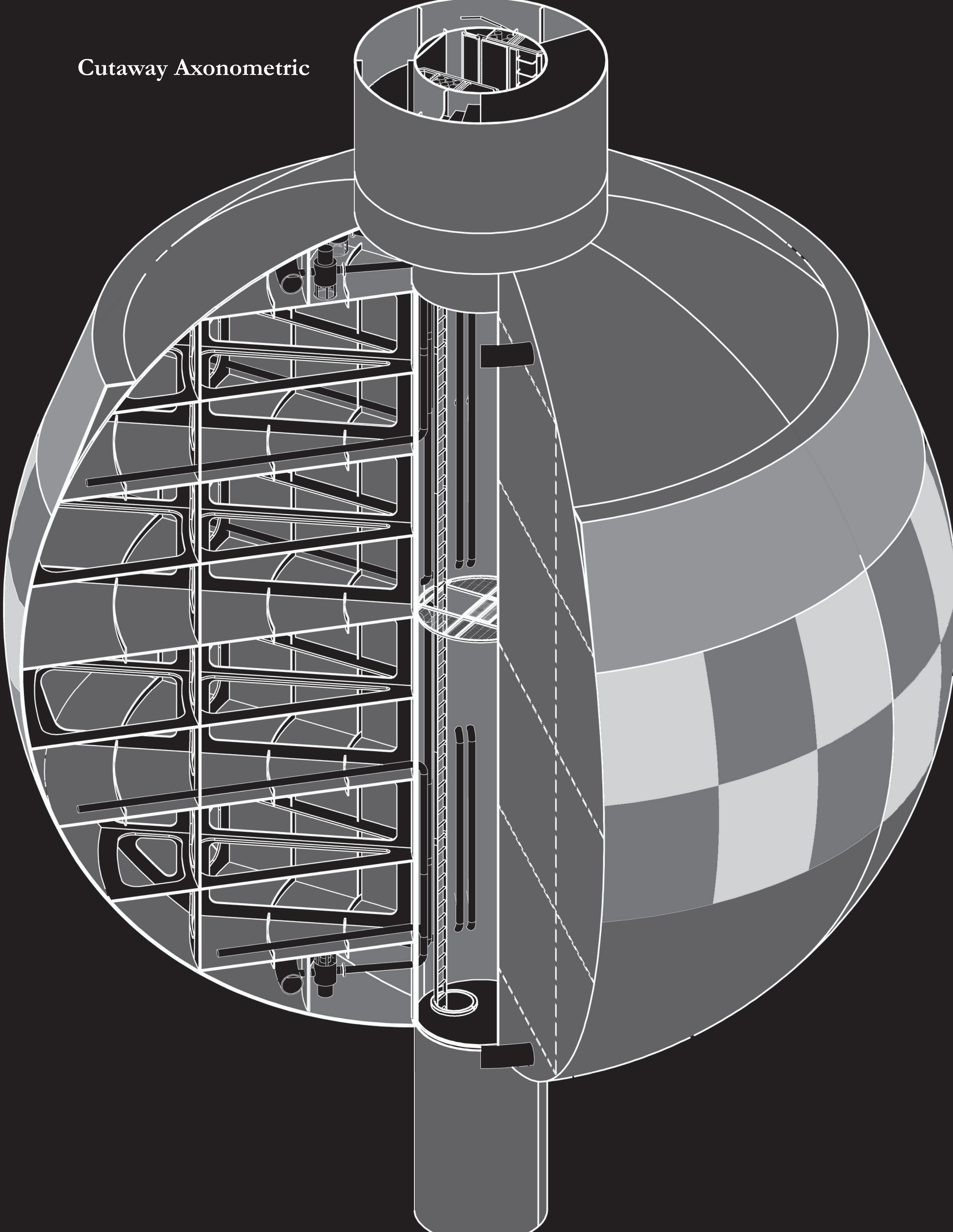
Tanks 1&8 -	5 %	filled
Tanks 2&7 -	0 %	filled
Tanks 3&6 -	25 %	filled
Tanks 4&5 -	100 %	filled



Ballast configuration
(Horizontal mode)

Tanks 1&8 -	78 %	filled
Tanks 2&7 -	0 %	filled
Tanks 3&6 -	0 %	filled
Tanks 4&5 -	0 %	filled

Cutaway Axonometric



4.1.2.1 Transition Sequence

Horizontal → Vertical Sequence

Once the vessel reaches a study area the vessel is brought to a complete stop and all systems are locked down and all lose objects stowed away. The entire crew gathers on the working deck of the engineering module, from where the transition processes is controlled, the crew remains on deck for the duration as a safety precaution.

t=0 Seawater begun to be pumped into port and starboard ventral main ballast tanks, beginning the transition process, as these tanks are filled the vessel starts to pitch the aftward.

t=3min Aft ventral and dorsal flooding/venting ports are opened and seawater begins to flood the aft secondary hull structure.

t=6min The locks fixing the trunnioned deck structures in place are released and they begin to rotate.

t=12min Once the vessel reaches a pitch of 10°, the ventral flooding ports are opened in the secondary hull amidships, allowing seawater to flood in. Air is not allowed to escape from this section, as it floods, the air in this section is continually compressed by the incoming seawater till it matches the surrounding pressure of the sea and thereby stops the flooding process. The air in the section occupies one sixth of its former volume when the vessel is operating vertically

t=27min At a pitch of 30° the aft secondary hull is almost entirely flooded. At this point seawater is begun to removed from the ventral main ballast tanks and transferred to the dorsal tanks to start offsetting the buoyancy of the crew modules.

t=30min This is the tipping point and things begin to happen fast, the final transition from 45° to 90° occurs very rapidly.

Final trimming of the ballast tanks to balance the vessel in the vertical position, is a continuous process, with pumps constantly shifting ballast water in the tanks to counter weight shifts. The trunnioned decks are locked back down and the vessels system are brought online for vertical operations.

Vertical → Horizontal Sequence

Once finished in a study area all vessel systems are locked down and all lose objects stowed away. Again the entire crew gathers on the working deck of the engineering module. Then the locks holding the trunnion decks in place are released and the transition sequence begins.

t=0 The dorsal main ballast tanks begin to be emptied, this quickly starts to pitch the vessel forward.

t=3min As the vessel pitches forward the dorsal vent ports in the aft secondary hull are closed.

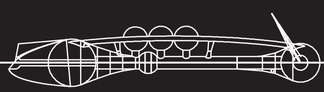
t=6min Compressed air is then pumped into the dorsal half of the aft secondary hull; the stern of the vessel begins to rise.

t=12min As the vessel continues to pitch forward and the stern rises the air trapped within the secondary hull amidships is under more pressure than the surrounding seawater thus it expands, forcing seawater back out the aft ventral flooding ports.

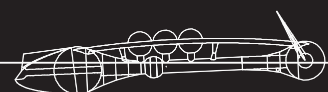
t=18min As the crew modules begin to breach the surface seawater is pumped in to the ventral tanks of the Main ballast module. Air is continuously pumped into the aft secondary hull till all the water contained within it is forced out the ventral flooding ports, and the vessel is sitting horizontal in the water.

t=30min Once this happens the ventral ports are closed and the dorsal ports are partially opened, reducing the air pressure within the aft secondary hull, when equalized they are then closed again.

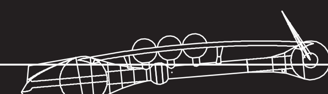
The trunnioned decks are locked back down and the vessels system are brought online for horizontal operations.



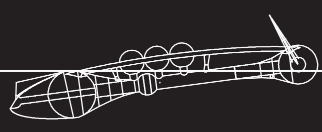
T=0 min (H-V)
T=31.5 min (V-H)
P=0°



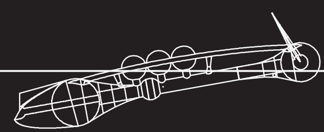
T=3 min (H-V)
T=28.5 min (V-H)
P=2.5°



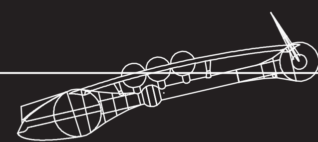
T=6 min (H-V)
T=25.5 min (V-H)
P=5.0°



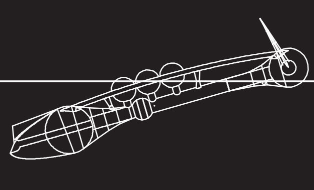
T=9 min (H-V)
T=22.5 min (V-H)
P=7.5°



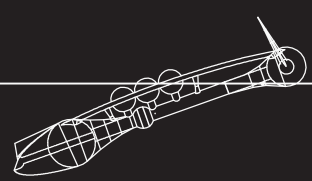
T=12 min (H-V)
T=19.5 min (V-H)
P=10.2°



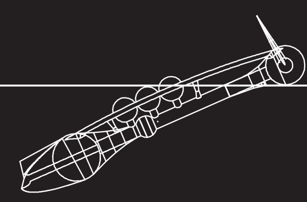
T=15 min (H-V)
T=16.5 min (V-H)
P=13°



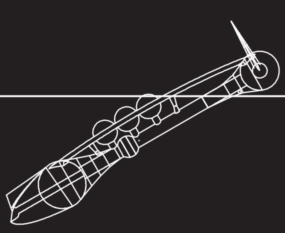
T=18 min (H-V)
T=13.5min (V-H)
P=15.8°



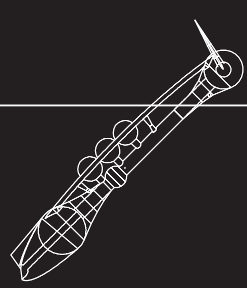
T=21 min (H-V)
T=10.5 min (V-H)
P=19.6°



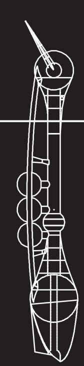
T=24 min (H-V)
T=7.5 min (V-H)
P=23.8°



T=27 min (H-V)
T=4.5min (V-H)
P=30°

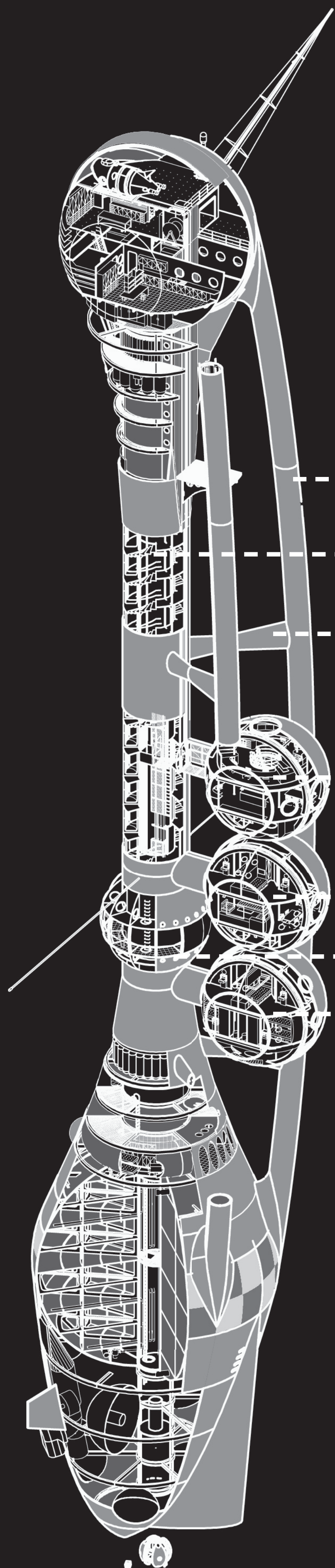


T=30 min (H-V)
T=1.5 min (V-H)
P=45°



T=31.5 min (H-V)
T=0 min (V-H)
P=90°

4.2 Main Truss



4.2 Main Truss

The truss is the most unique and largest feature of the vessel. It forms the vessel's main structure, as it links the fore and aft sections of the primary hull. The structure of the truss is composed by four elements: Spars, Pylons, Spine, & Crew modules. The interiors of these various elements are used for passage, mechanical systems, and crew. This truss structure is used to reduce the water plane area of the vessel, which greatly increases the stability of the vessel. The less interaction the vessel has with the surface of the ocean, the less the vessel is affected by the motions of the surface. This allows the vessel to continue to operate in all but the worst weather conditions, greatly increasing the data collection time.

4.2.1 Spars

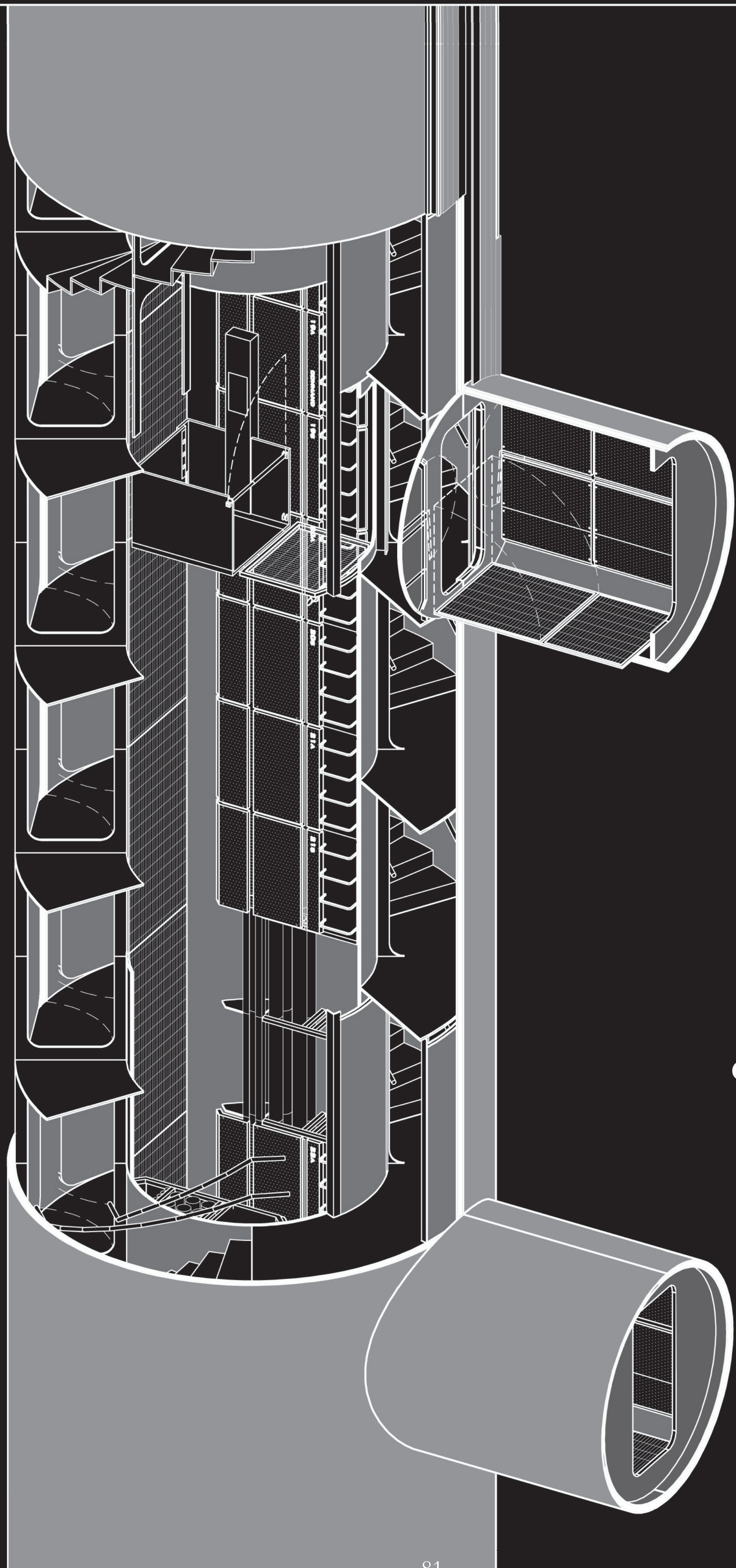
The Spars are two, two-metre diameter curved steel tubes connecting both the primary hulls together. The curvature of the tube increases the effective depth of the truss, increasing the overall stiffness and strength of the structure. The interior of the spars houses the HVAC system for the Crew Modules. It is also a mechanical riser connecting all the Crew Module systems to each other and to the forward primary hull. The aft third of the Spars is used a trim ballast tank to fine-tune the buoyancy of the vessel.

4.2.2 Pylons

The Pylons are four elliptical steel structures connecting the Spars back to the Spine. These structures are free-flooding and contribute no buoyancy to the vessel when submerged.

4.2.3 Spine

The Spine is the main structural element of the truss. The interior of the spine is a passageway linking all the inhabited areas of the vessel, in both vertical and horizontal modes, while the outer ring which encloses the main stairs acts as a double hull, protecting the critical systems in the central core. The cellular structure of this outer ring gives the spine its strength, allowing the central core to remain free of any structure, allowing it to be both a corridor and lift shaft. The central core is also a mechanical riser, linking the forward and aft systems in the vessel.



Cutaway Axonometric

Interior Perspective (looking aft)

4.2.3.1 Corridor Design

Several safety and survival features are built into the walls on either side of the central corridor. These walls conceal a variety of supply lines, conduction systems, data networks, and power trunks reached by way of the snap lock panels which cover them. These snap lock panels are covered by a layer of padding and fabric, protecting against injury during any sudden ship movement, and deadening the sound amplification and echoes that occur in cylindrical enclosures. The panels are colour-coded at the various access points within the corridor for location. The panel colours immediately adjoining these access points: Engineering Module, grey; Crew Module 1, green; Crew Module 2, red; Crew Module 3, blue; Observatory, light blue; Ambient Module, yellow, in all other areas the panels are light grey. At both ceiling and floor, LED lighting panels provide illumination. The uppermost removable panel on the port side conceals an emergency equipment locker, with breathing masks, oxygen bottles, fire extinguishers, tether lines, and other firefighting equipment. On the starboard side, this panel is replaced by the emergency access ladder running the entire length/height of the central corridor.

4.2.3.2 Lift Design

With the main stair the equivalent of twenty-eight stories in height, the central lift is used to transport two crew members or supplies (approximately 250kg max.) to and from the engineering hull, crew modules, and Ambient Module during vertical operations. Crew passage between the various crew modules and the observatory are primarily by way of the main stair, with the emergency ladder in the central core acting as the emergency back-up. The lift runs in a geared track on the starboard side of the central corridor; the track also supplies the electrical power to operate the lift through two contact strips within the track. The lift is constructed out of lightweight aluminium composite panels that fold up and can be stowed out of the way while the vessel is operating in its horizontal mode, allowing unobstructed access through the central corridor.

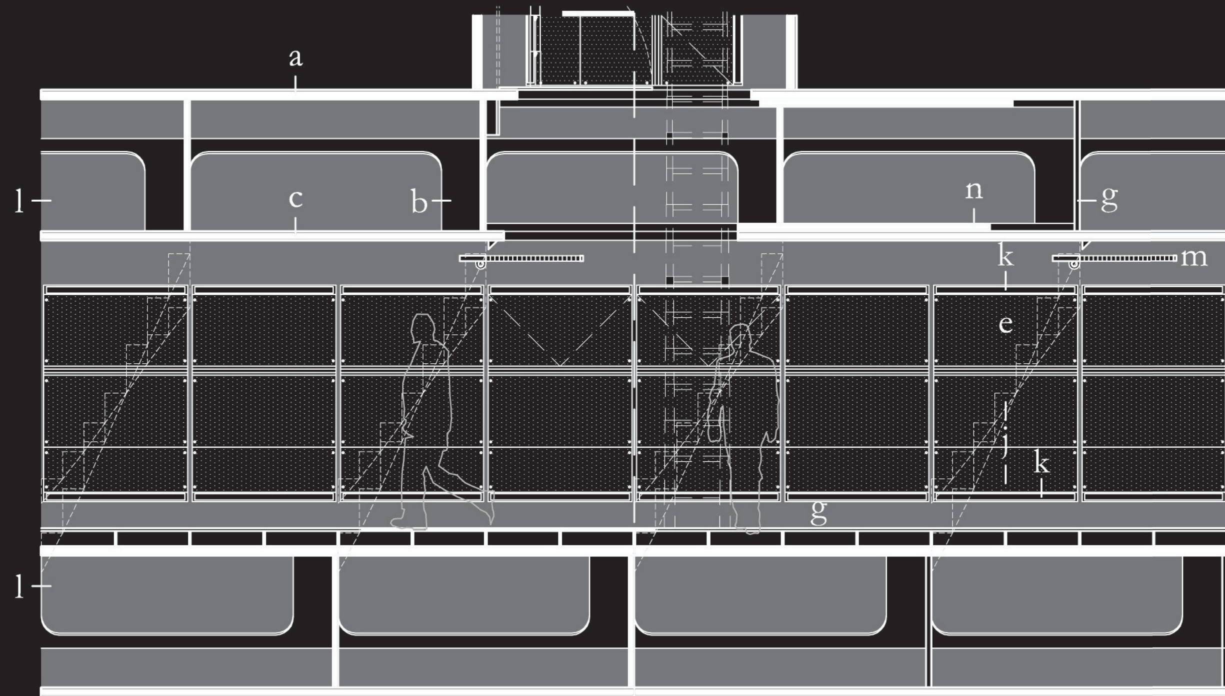
4.2.3.3(a) Spine (Horizontal Mode)

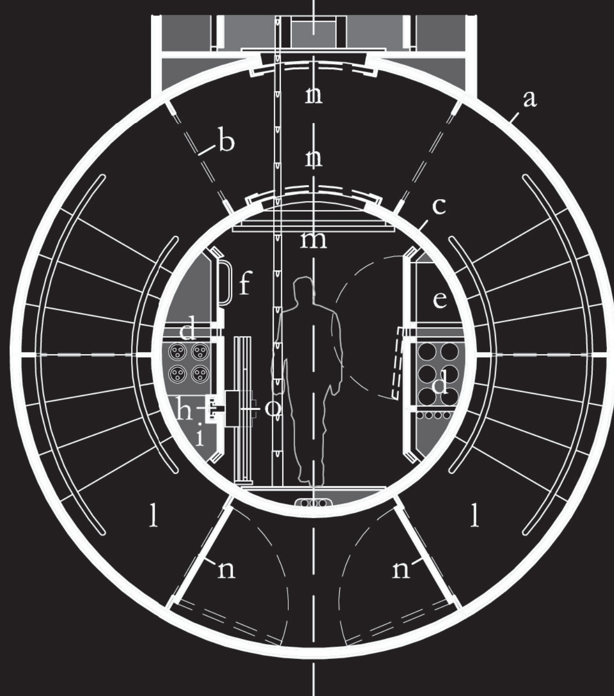
While the vessel is in horizontal mode, the only accessible part of the spine is the central core. In this orientation the central core is a corridor accessible from the engineering module and, via ladderways, the crew modules. The ladderways are only required for the limited time that the vessel is in its horizontal mode. The ladders are telescopic and are stowed behind the removable wall panels in the corridor by each of the crew modules when not required.

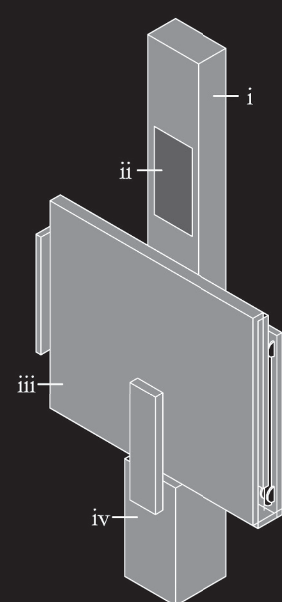
Key

a. Exterior hull
b. Internal brace (6)
c. Interior hull
d. Mechanical riser
e. Emergency equipment locker
f. Emergency access ladder
g. Deck plating
h. Lift track
i. Lift track support
j. Snap lock panels
k. LED lighting panel
l. Inaccessible area (horizontal mode only)
m. Fold out platform (stowed position)
n. Watertight door
o. Lift (stowed configuration)
    i. Drive housing
    ii. Control panel
    iii. Floor panel (stowed position)
    iv. Electric drive motor

Sections (looking port & aft)







Lift (Stowed Configuration)

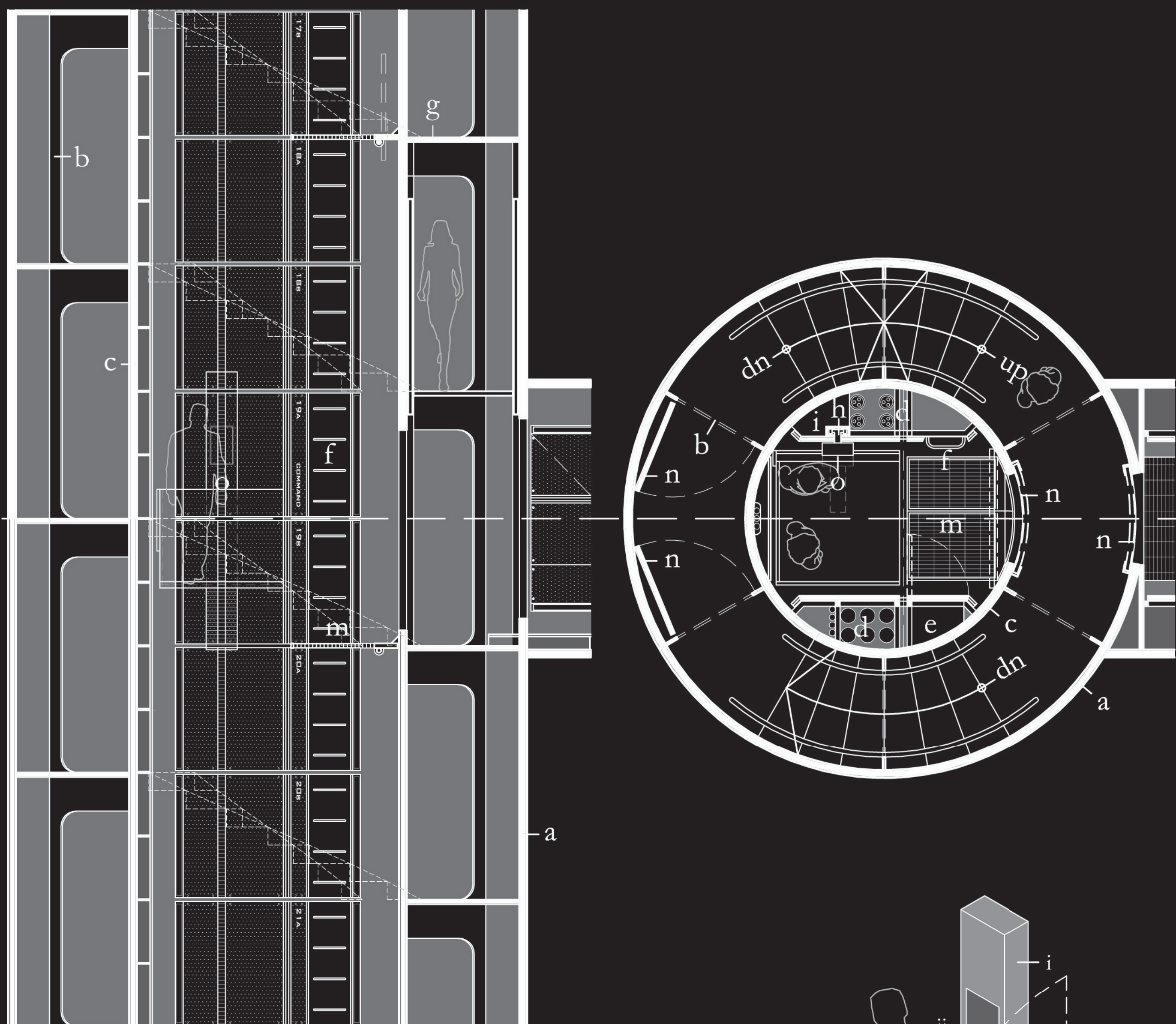
4.2.3.3(b) Spine (Vertical Mode)

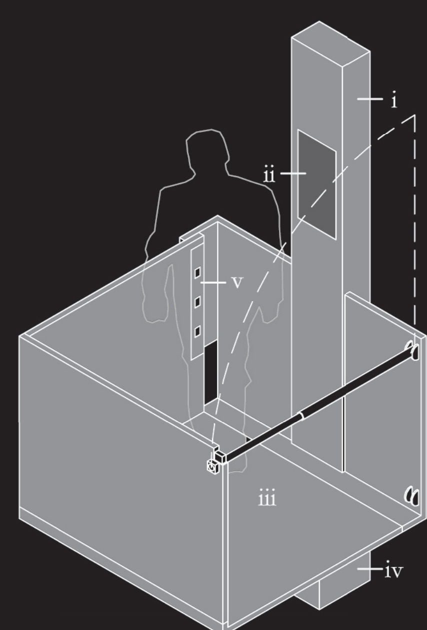
When the vessel is in vertical mode, both the central core and outer ring of the spine are accessible. The outer ring houses the main stair and the central core is a lift shaft for the geared lift. From either, one can access the engineering module, crew modules, observatory, and ambient module.

Key

a. Exterior hull
b. Internal brace
c. Interior hull
d. Mechanical riser
e. Emergency equipment locker
f. Emergency access ladder
g. Deck plating
h. Lift track
i. Lift track support
j. Snap lock panels
k. LED lighting
l. ----
m. Fold out platform
n. Watertight door
o. Lift (deployed configuration)
    i. Drive housing
    ii. Control panel
    iii. Floor panel (deployed position)
    iv. Electric drive motor
    v. Panel locks

Sections (looking starboard & aft)





Lift (Deployed Configuration)

4.2.4 Crew Modules

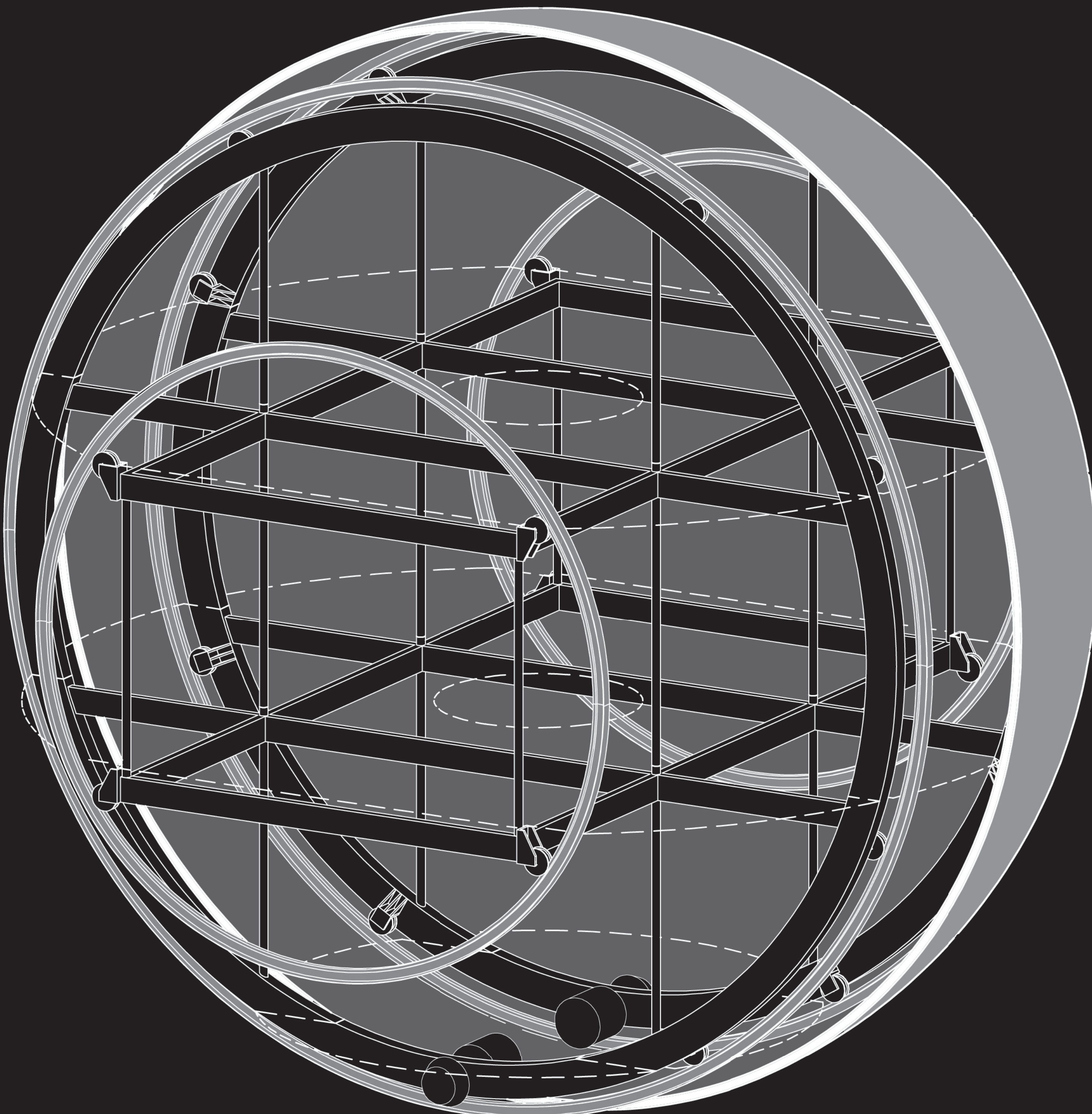
The three crew modules form an integral part of the main truss structure tying together the two spars and the spine. They provide the majority of the habitable space for the crew in both vertical and horizontal modes. The modules rise completely out of the water when the vessel is in horizontal mode and are fully submerged when the vessel is in its vertical mode. Thus they need to be able to support themselves against the forces of gravity and buoyancy as well as resist the pressure of the water when submerged, with no internal structure to interfere with the crew space. These modules are thus designed as true monocoque structures with all stresses and forces they are subjected to all handled by the skin itself, with for the only internal structure, four guide rails welded to the inner surface to accommodate the rotating deck structure.

The interior deck structure is lightweight, to keep the centre of gravity of the vessel low when in it's horizontal position. It consists of three decks, each is composed of light-weight aluminium Sandwich Plate System composite decking, for noise and vibration control, on an extruded aluminium structure, all of which rests on twenty-four nylon wheels that run on the guide rails. This configuration allows the entire deck structure to rotate, accommodating the vessel's ninety degree change between horizontal and vertical modes. The deck structure rotates mainly due to gravity as the ship transitions from horizontal to vertical modes, with some assistance from an electric motor to overcome any weight imbalances in the structure. This motor, mounted below the lower deck, drives a rubber wheel pressed up against the exterior shell. Once in the desired position, the deck structure is locked in place by the use of hydraulic clamps that lock onto the guide rails attached to the exterior shell.

All mechanical services passing through the crew modules do so where the module intersects with the spars. These mechanical services: power, water sply for heating and cooling, potable water, data, fresh air, stale air, waste - ar all (except for the air supply and exhaust) connected to the interior structure via flexible connectors which have enough slack and flexibility to accommodate the rotation of the deck structure. The air system has a rigid rotating connection made at the pivoting axis of the interior structure.

There are several features common to all three of the crew modules. First there are numerous small viewports, with large viewports where possible, letting natural light flood the modules and allowing the crew to keep in visual contact with the world they are studying. There are also openings between the decks, wherever possible, bringing light from the view ports further into the module, opening up internal vistas. The internal and external openings, combined with the visually lightweight interiors, relieve the feeling of claustrophobia that comes with being submerged. The interior partitions are composed of light weight panels covered in wood veneer or padded fabric for acoustic control. Densely-packed nylon bristles are used to span the gaps between the partitions, decks, and the inner surface of the pressure shell, blocking light and vision between compartments.

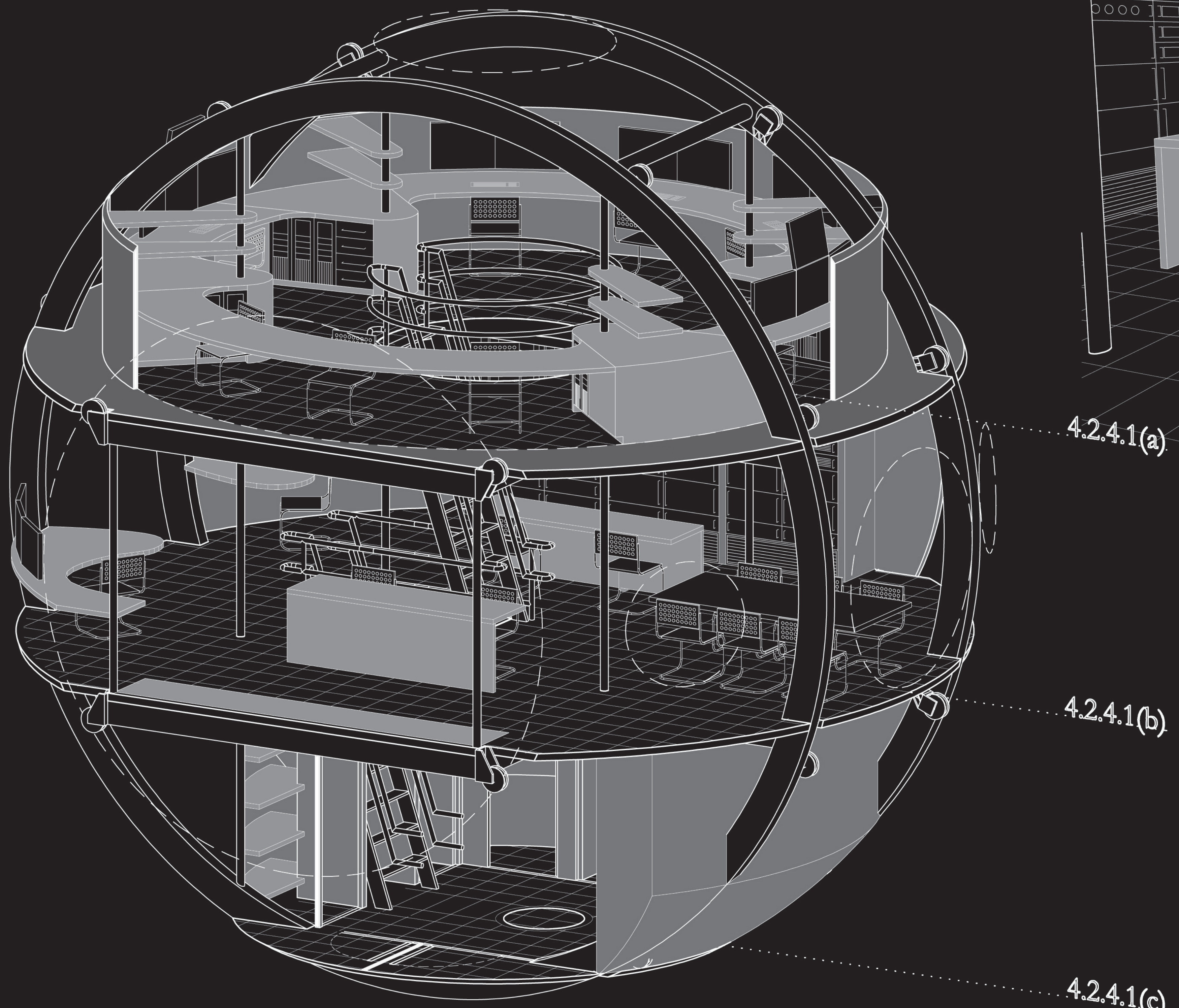
Interior Structural Axonometric

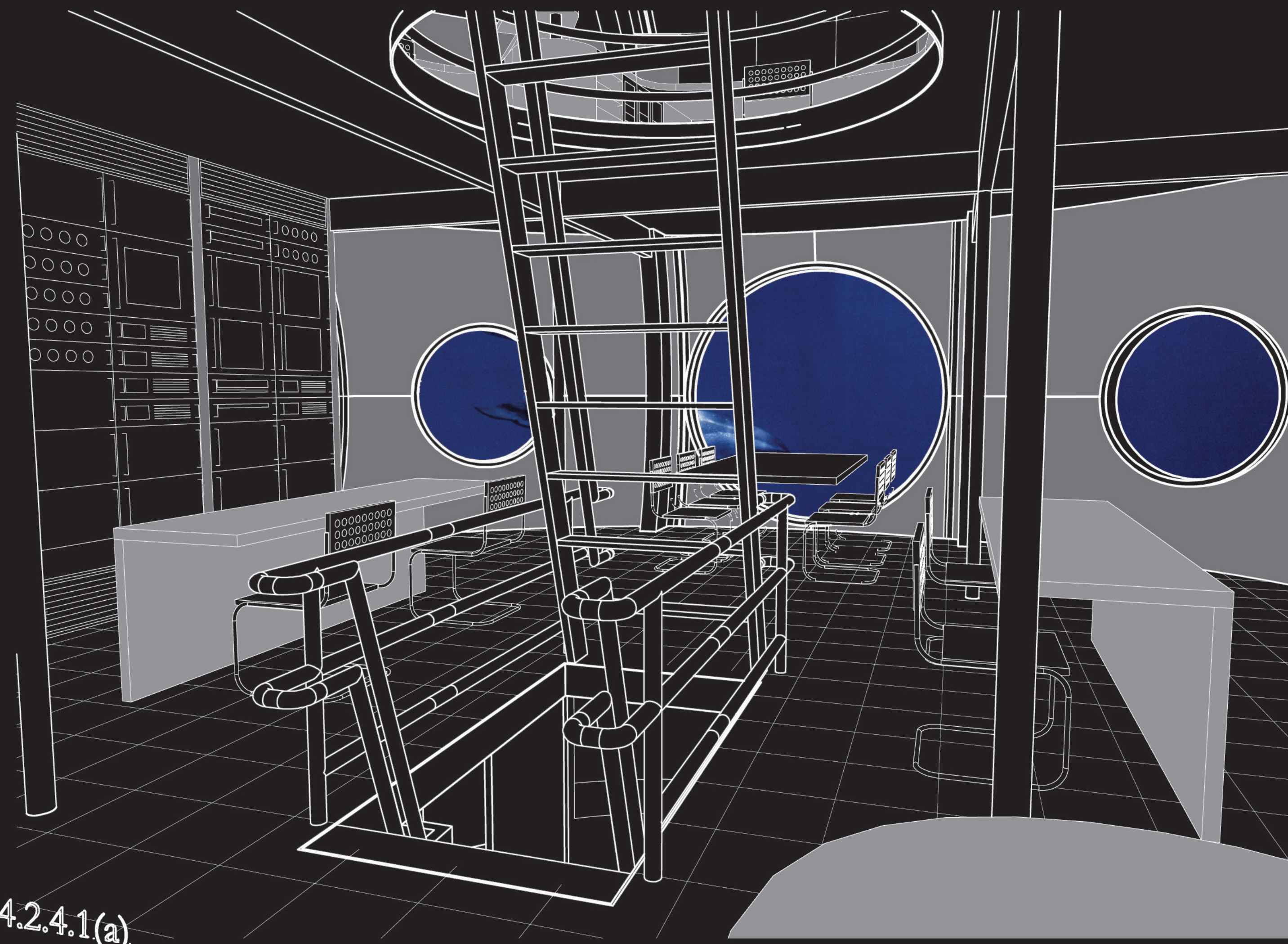


4.2.4.1 Crew Module 1 - Work

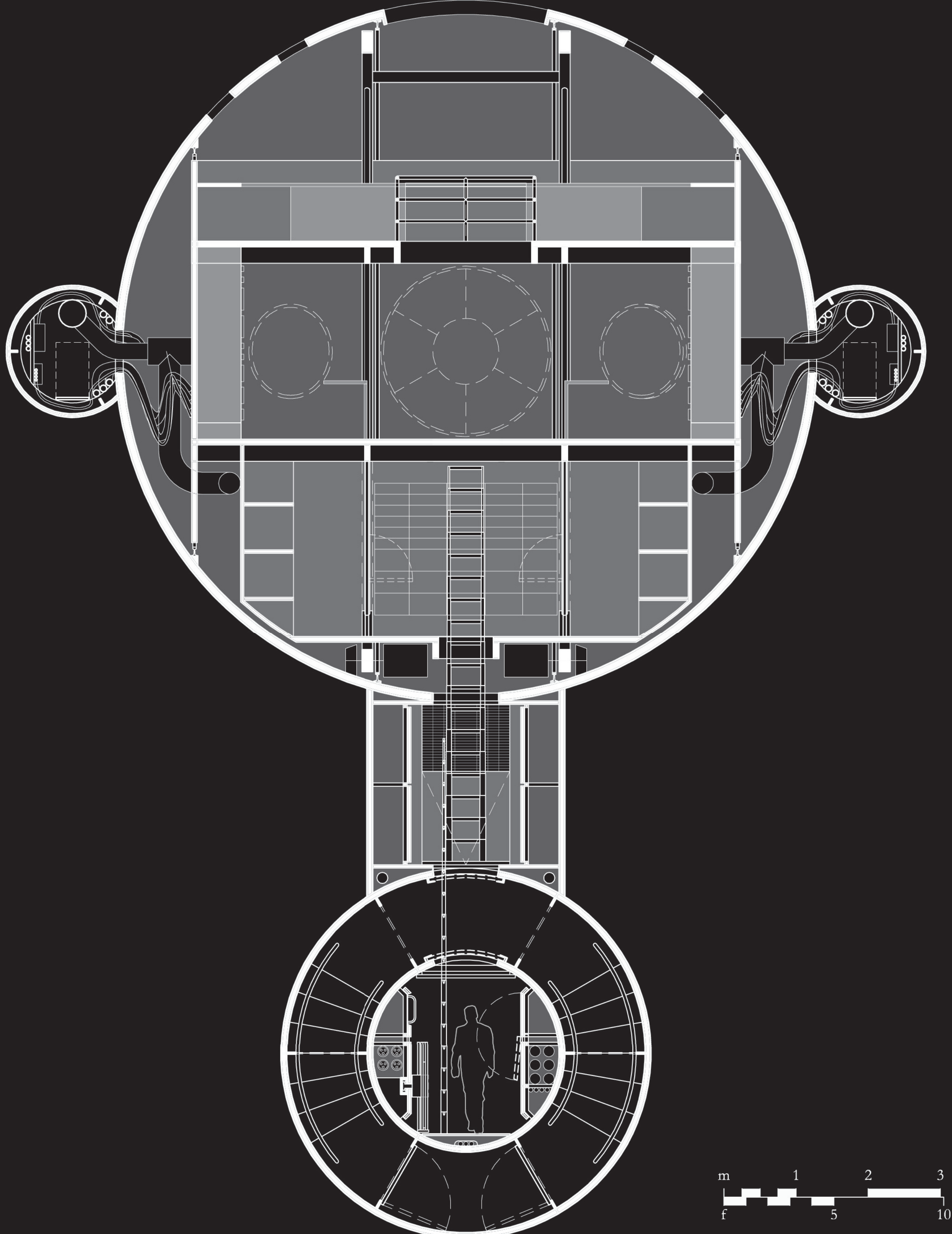
The fore most of the three crew modules is the work module. Housed is within the confined space and controlled atmosphere of the submerged section of the vessel. The work module is configured for clean work that does not require the use of toxic chemicals or gases. This module is closest to the surface when submerged and receives the most light while having to resist the least water pressure of the three modules. It can have many large viewports, giving the module extensive views out into the waters around at a minimal structural cost.

Interior Axonometric & Perspective





Transverse Section (Horizontal Mode)



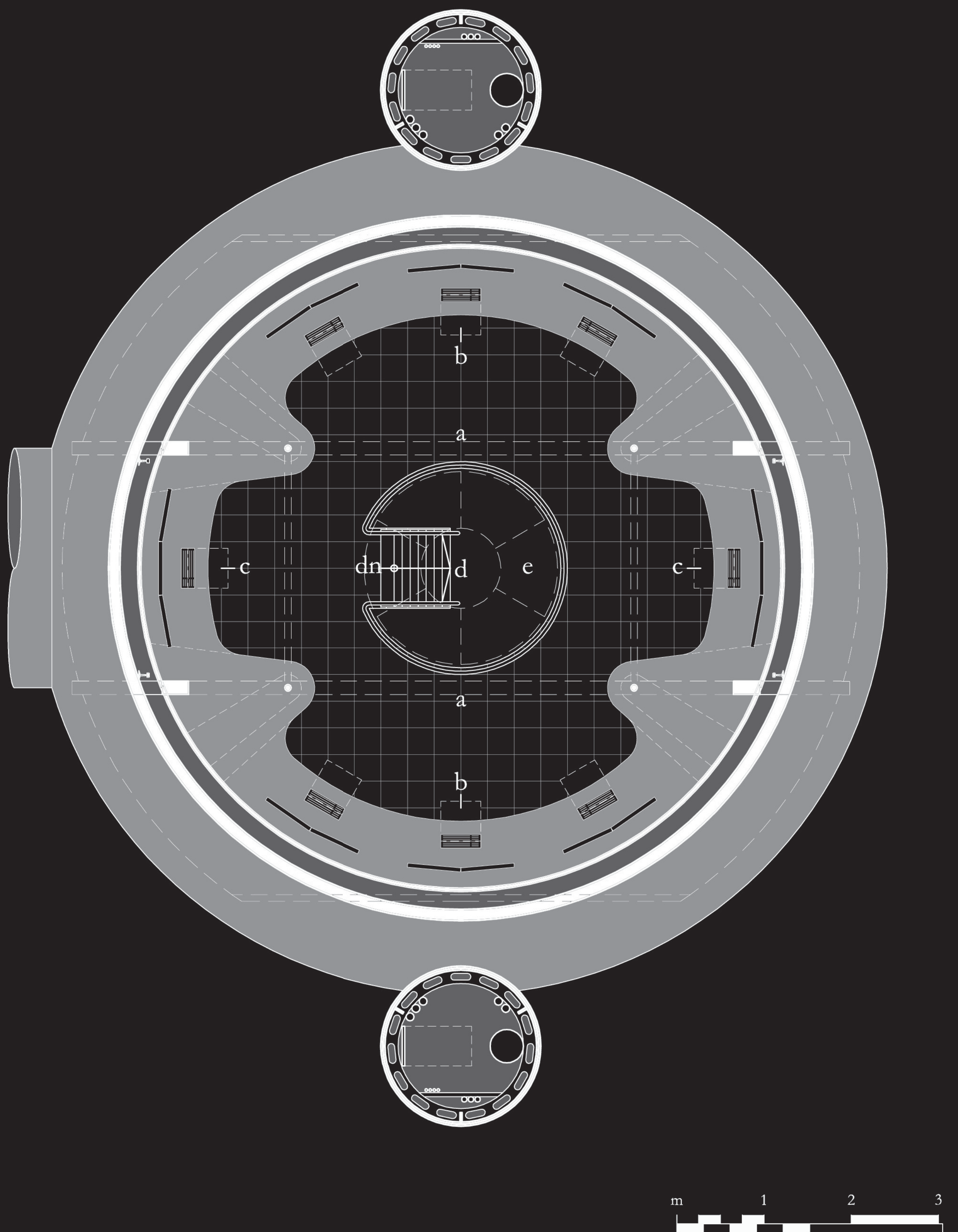
4.2.4.1(a) Upper Deck - Digital laboratory

The upper level consists of a single room dedicated as a digital laboratory. From here once launched, all of the ROV's and HROV's are piloted and controlled . This is also the control centre for manned submersible operations. This area doubles as the media centre for all onboard-generated broadcasts. The centre of this level is open to the command centre below; located directly above this opening is a two meter diameter viewport which allows for a unique vantage point of the launch and recovery operations taking place directly above the module.

Key

a. Digital Laboratory
b. Work stations (6)
c. Mission Control/ROV pilot control station
d. Viewport Above
e. Open to below

Deck Plan



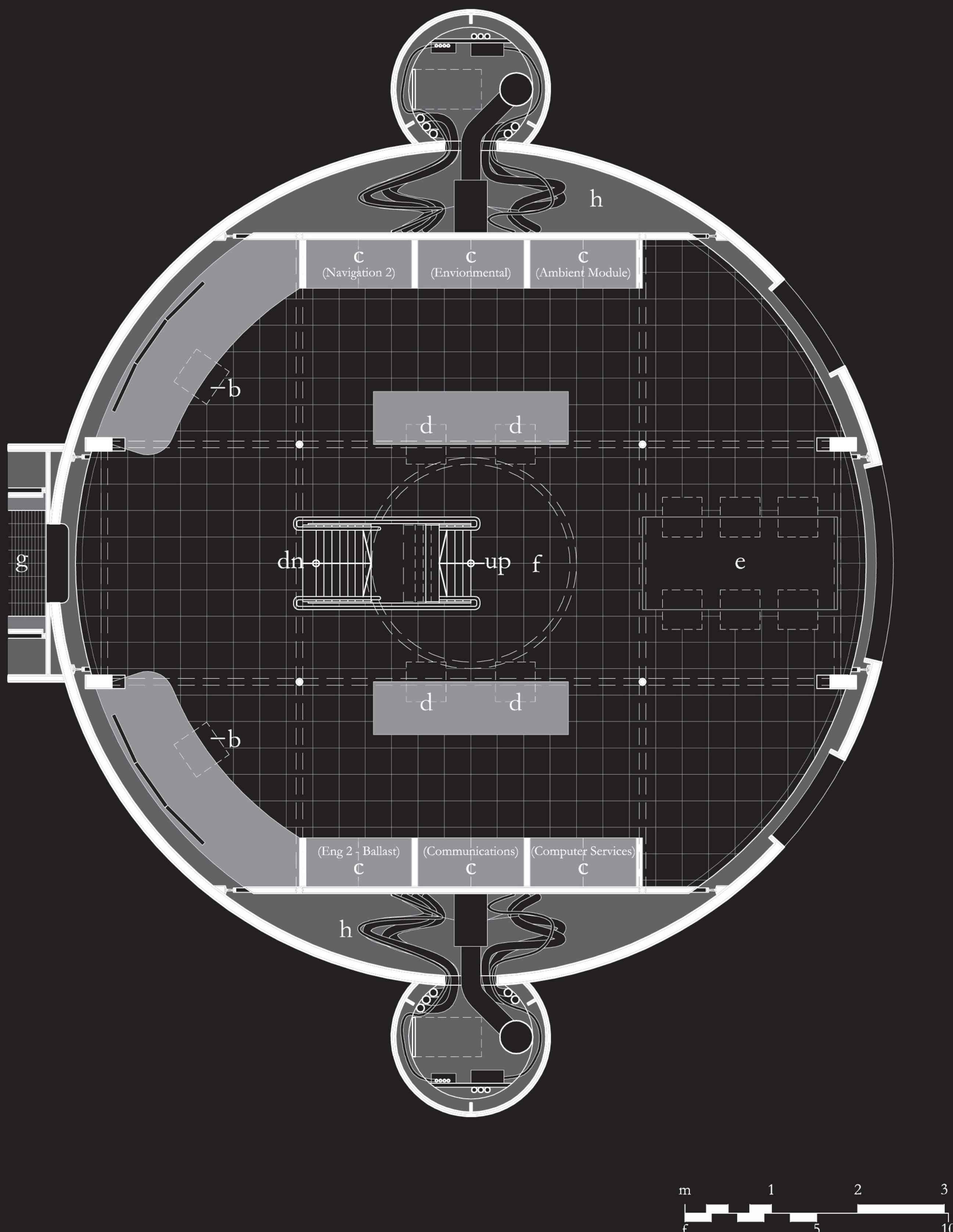
4.2.4.1(b) Mid Deck - Command Centre

In vertical mode, the middle level is the access point to the module. The level is the vessel's command centre (bridge), where all aspects of the vessel are controlled. Navigation and course control are carried out from the forward facing section of this level, and all information from the navigational sensors is routed to these two stations. Other stations are provided for the monitoring various vessel systems, such as engineering, environmental, communications, navigation, and computer services, with another station dedicated to the monitoring of all ambient habitat missions.

Key

a. Main Control Station (MCS)
b. Navigation station
c. System displays
d. Work stations
e. Ops table
f. Open to above
g. Access point from spine (vertical mode)

Deck Plan



h
c
(Navigation 2)
c
(Envionmental)
c
(Ambient Module)
b
d
d
g
dn
up
f
e
d
d
b
(Eng 2 - Ballast)
c
(Communications)
c
(Computer Services)
c
h
m
1
2
3
f
5
10

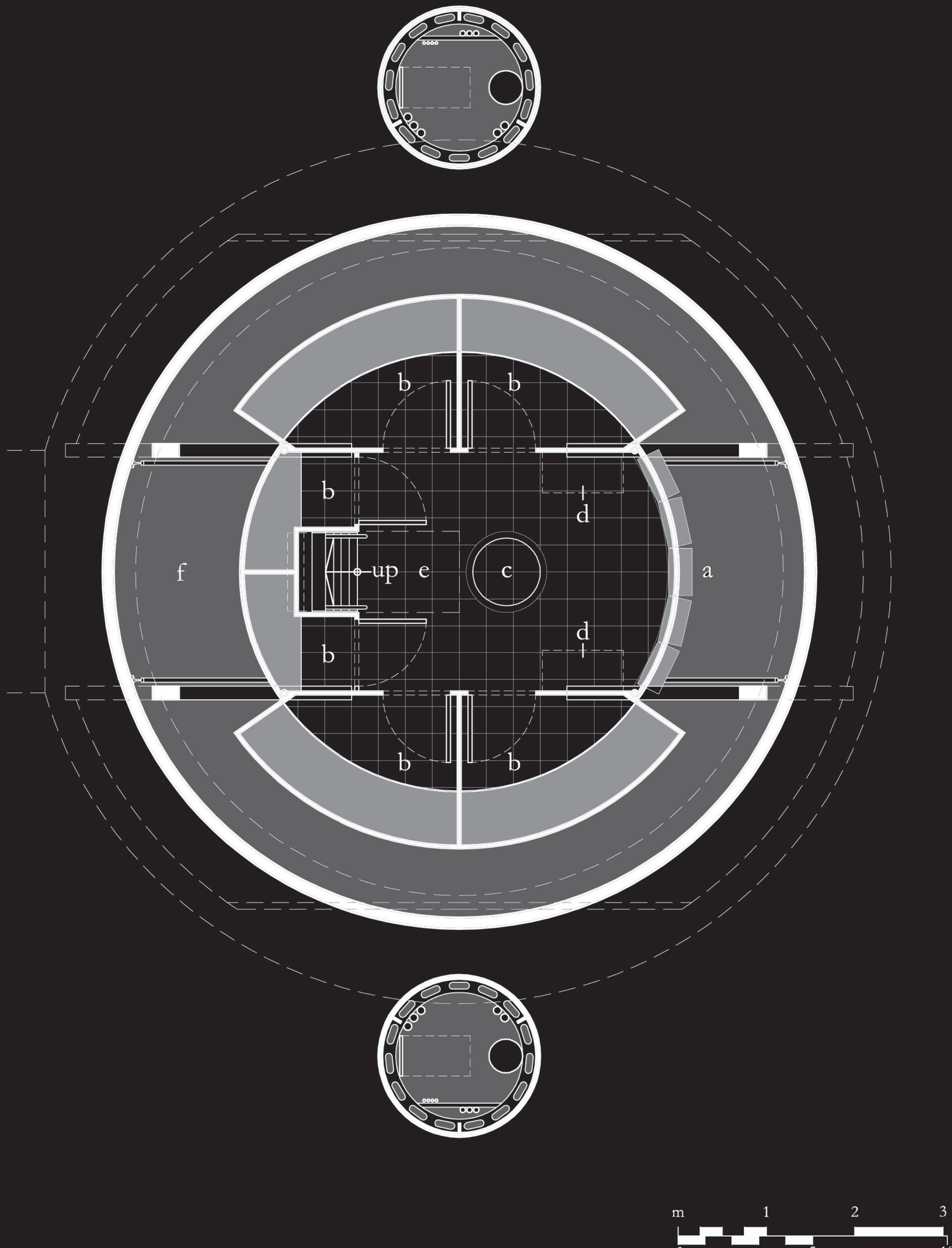
4.2.4.1(c) Lower Deck - Data Centre

The lower level houses the data centre, where the supercomputer that services the entire vessel is located. This is where vast amounts of mission data are collected and analyzed. Five panels mounted in the wall house a parallel computer that contains thousands of processors. This computer combs through the raw data and runs computational models. This computer is accessed via wireless connections to all the laptop computers on board. The computer uses the sea as a heat sink to remove the heat generated by the processors. There are also several rooms for various ships stores. This level houses the HVAC and mechanical equipment for the module within the perimeter ceiling space.

Key

a. Supercomputer
b. Ship stores
c. Access hatch and ladderway (horizontal mode)
d. Fold down worktable
e. Open to above
f. Mechanical Space

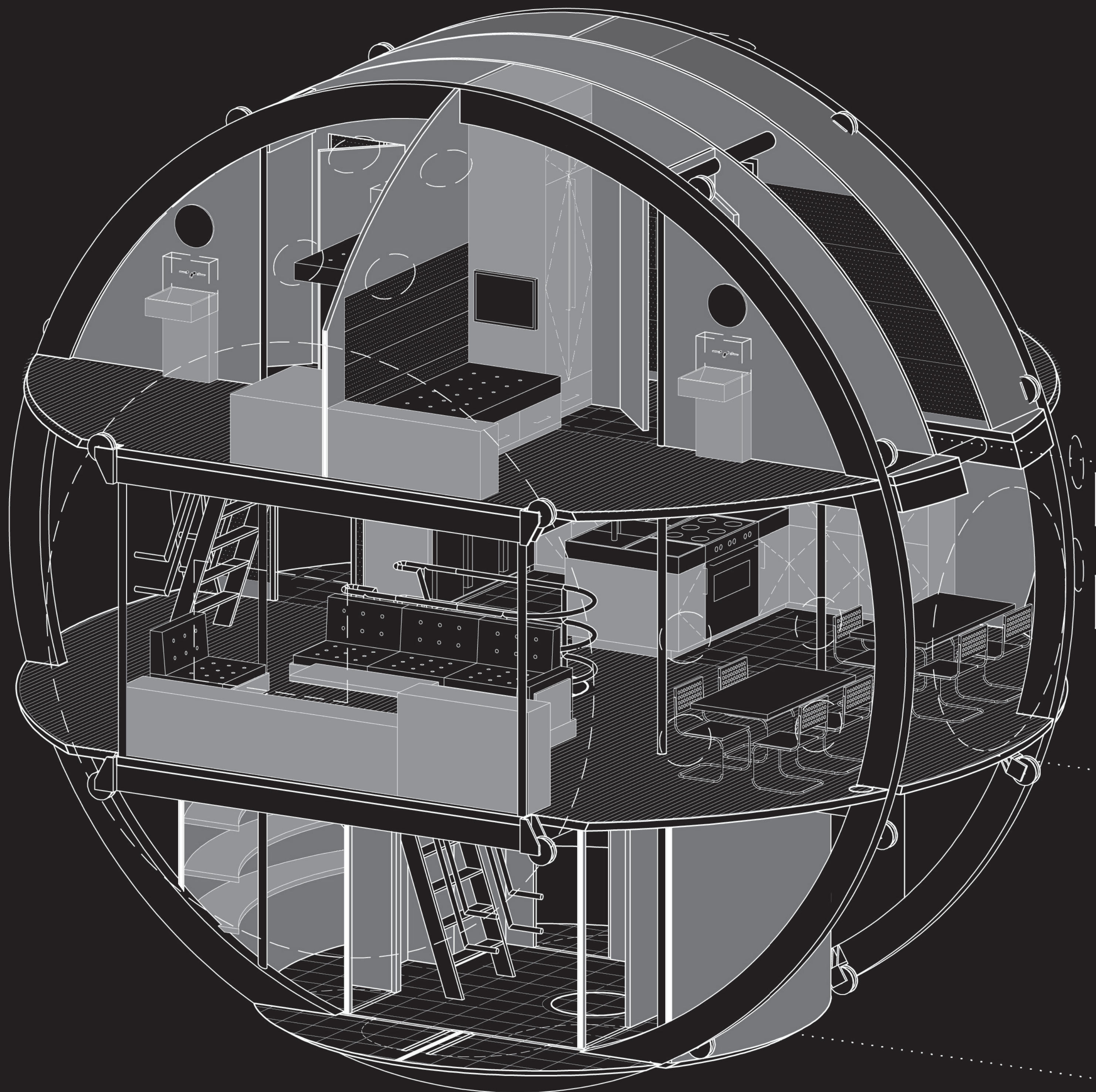
Deck Plan

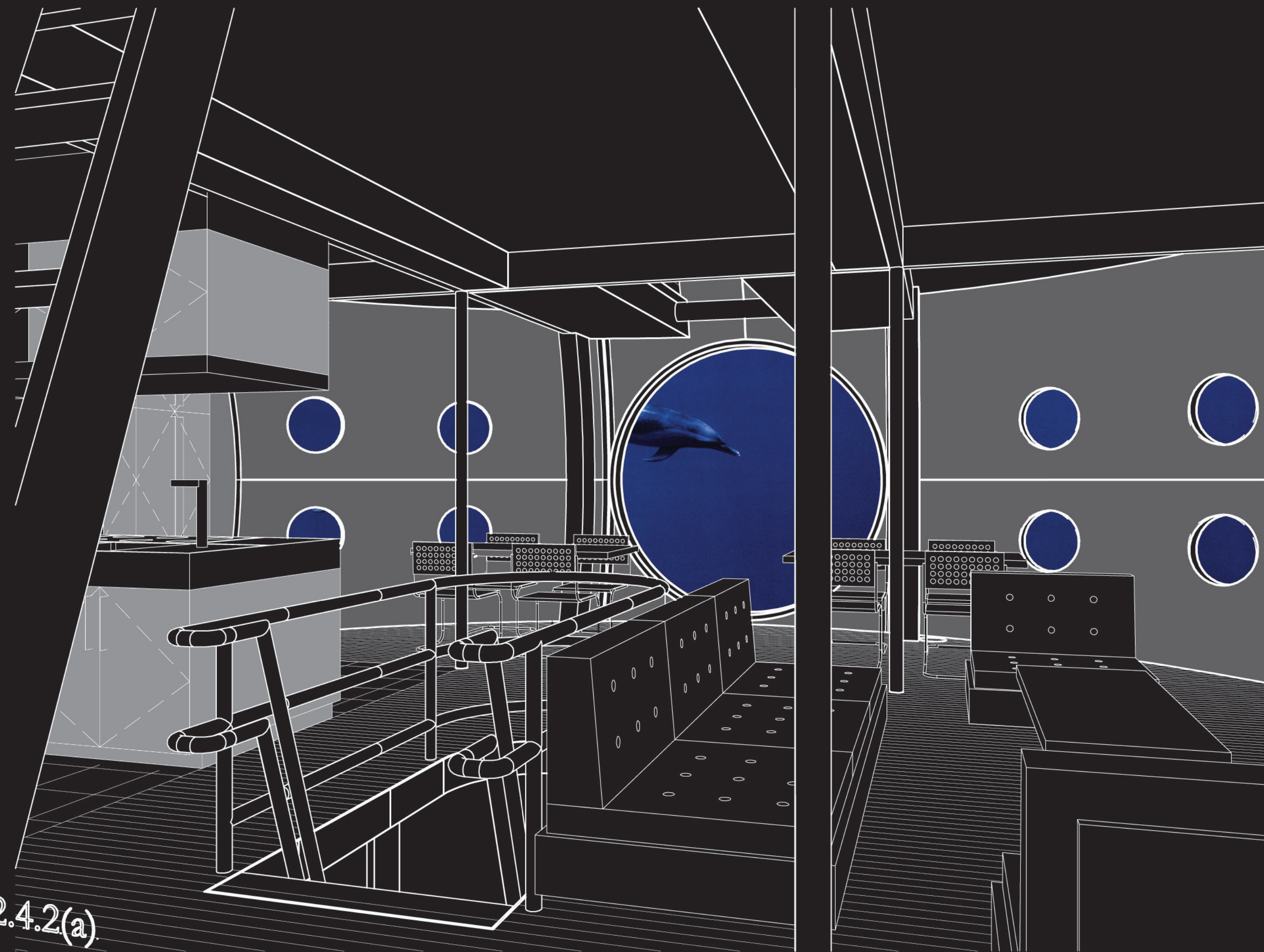


4.2.4.2 Crew Module 2 - Communal Spaces

The middle module is the communal module where the crew gathers, in their off hours, to eat meals, watch movies, and relax. With the small crew size, the vessel does not normally operate on a twenty-four hour schedule. There is a fixed down time of six hours with each crew member on duty for twelve of the remaining eighteen hours and crew members shifts are staggered so that eighteen hours of each day are covered. This schedule is maintained while the vessel is in vertical mode; when in horizontal mode there is a minimum of a three man watch twenty-four hours a day.

Interior Axonometric & Perspective



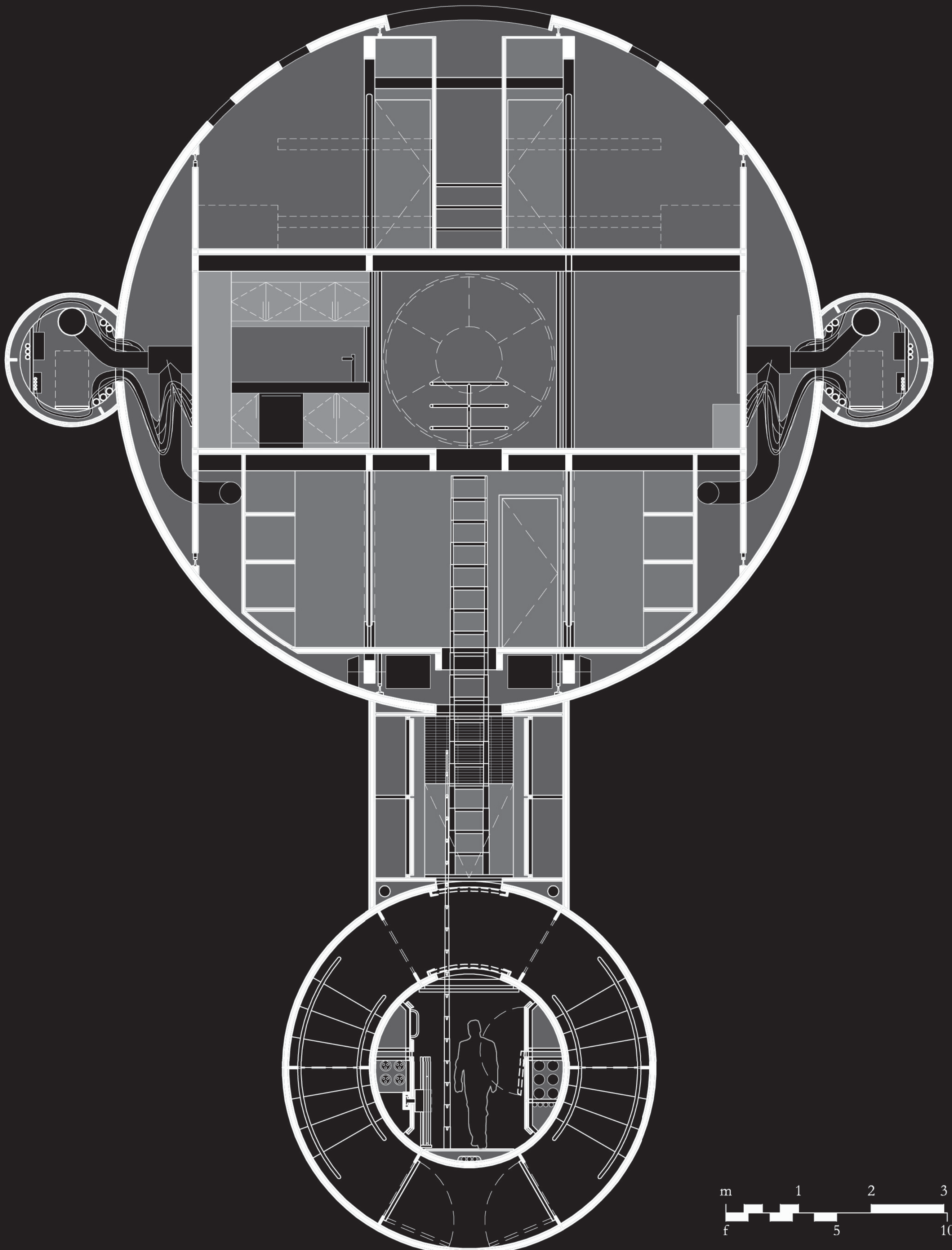


4.2.4.2(a)

4.2.4.2(b)

4.2.4.2(c)

Transverse Section (Horizontal Mode)



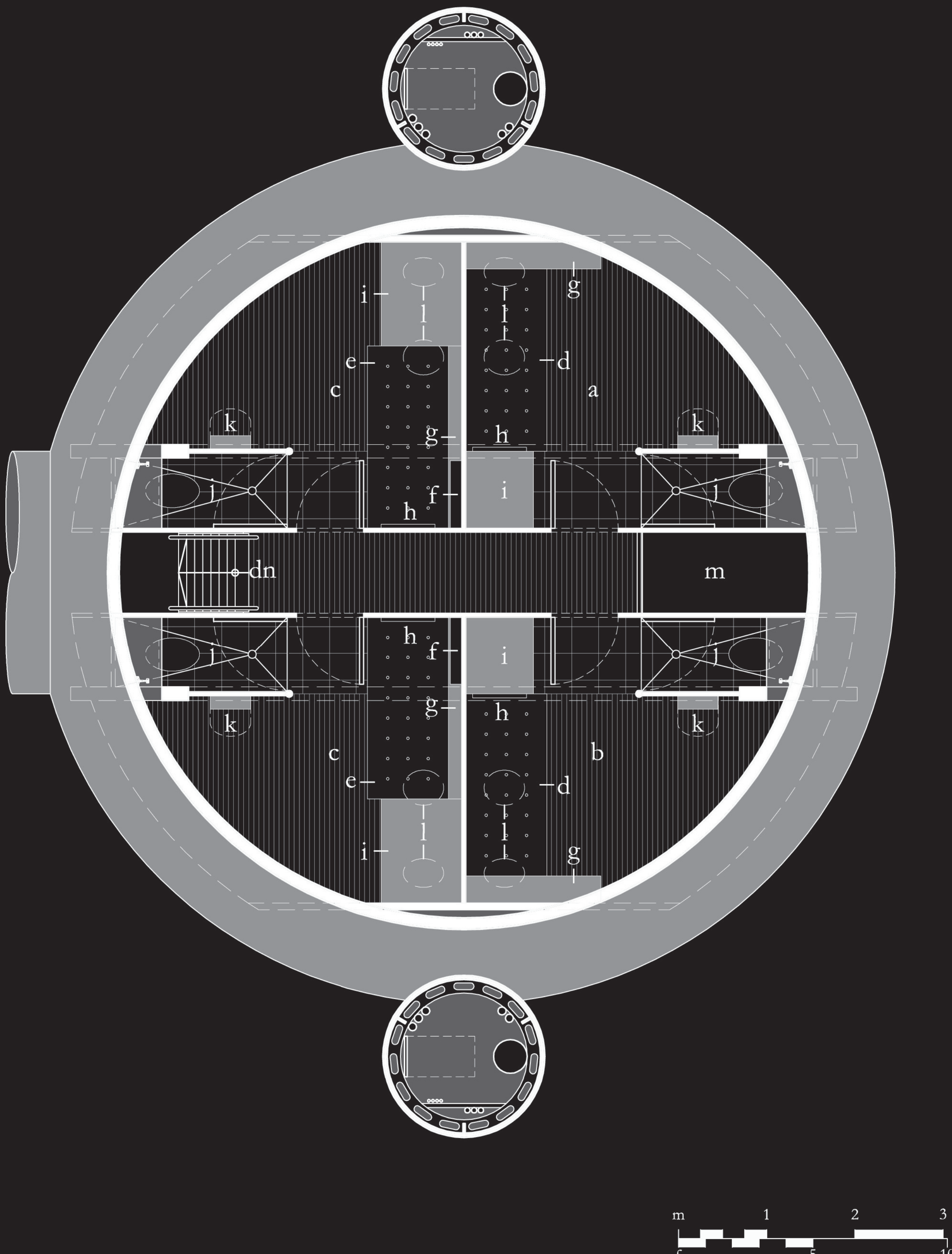
4.2.4.2(a) Upper Deck - VIP Quarters

The VIP quarters are located on the uppermost level, and has enough space to accommodate up to four visitors at a time. These quarters are occupied for short periods, normally two weeks or less; they also double as the treatment & recovery rooms for onboard medical emergencies, and there are hook-ups for medical equipment, monitoring units, and oxygen.. The remaining two quarters on this level are reserved for the ship's master and the chief engineer. There is also an overlook from this level down to the mess hall below and out though the large viewport.

Key

a. Master's quarters
b. Chief engineer's quarters
c. VIP quarters
d. Single bunk
e. Double bunk
f. Medical panel (monitoring equipment plugins & gases)
g. Shelves
h. Monitor (stowed position)
i. Viewport above
j. Shower/head
k. Open to below

Deck Plan



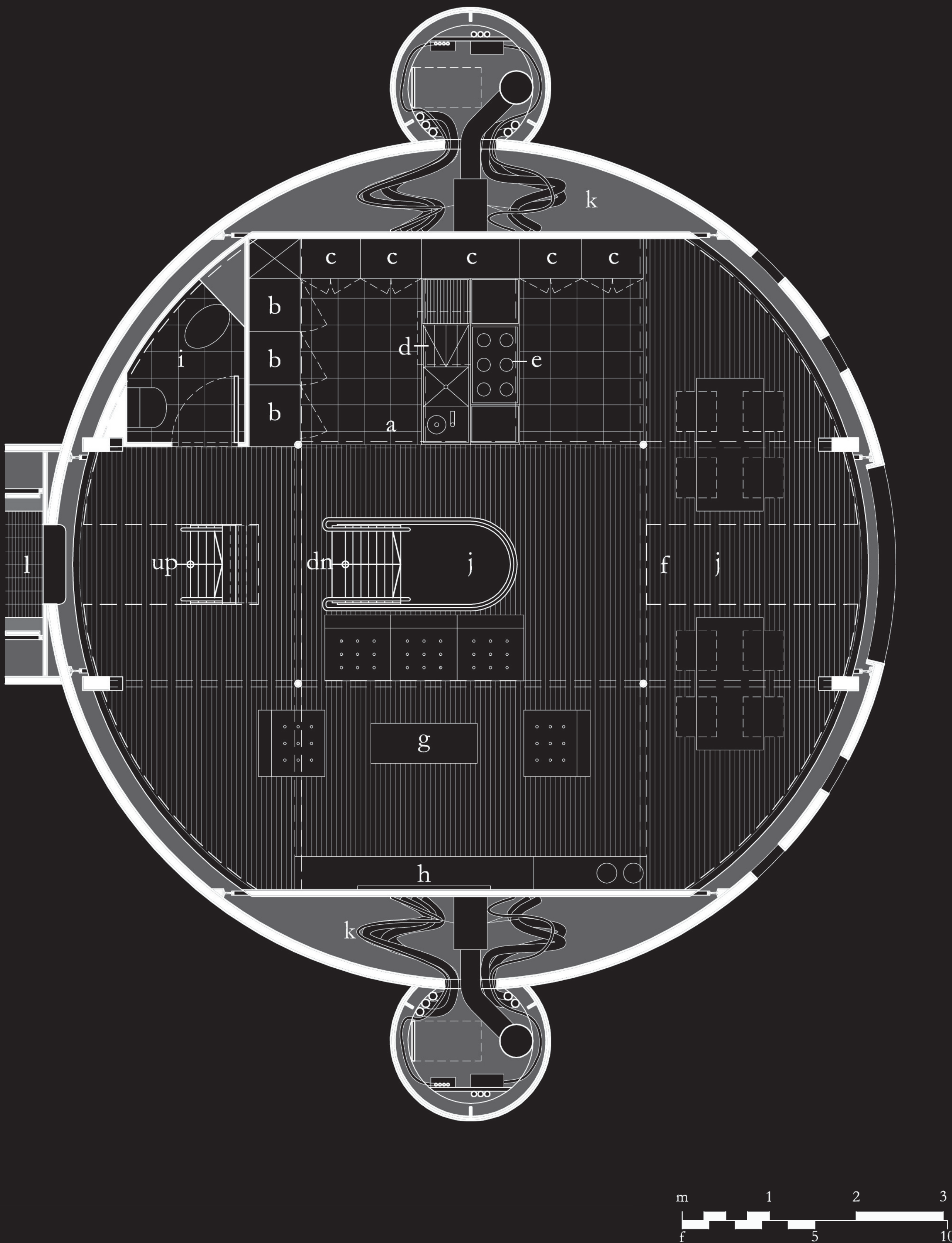
4.2.4.2(b) Mid Deck - Galley/Mess

In vertical mode, the middle level is the access point to the module. This level is occupied by the mess hall and galley. This is the social heart of the ship. As on most ships, the galley plays a large factor in the morale of the crew. The galley is on the starboard side of the module and opens on to the rest of the space. The remainder of the level is the mess hall to eat and to relax, and play games, or to hold informal meetings. On the portside is a media wall for movies, sporting events, or highlights from any of the probes or missions that day. The mission timer where the current shipboard time and the elapsed mission time are both displayed, is located here as well.

Key

a. Galley
b. Refrigerated/frozen stores
c. Dry stores
d. Preparation area
e. Cooking area
f. Mess
g. Wardroom
h. Media wall
i. Head
j. Open to above/below
k. Access point from spine (vertical mode)
l. Mechanical space

Deck Plan



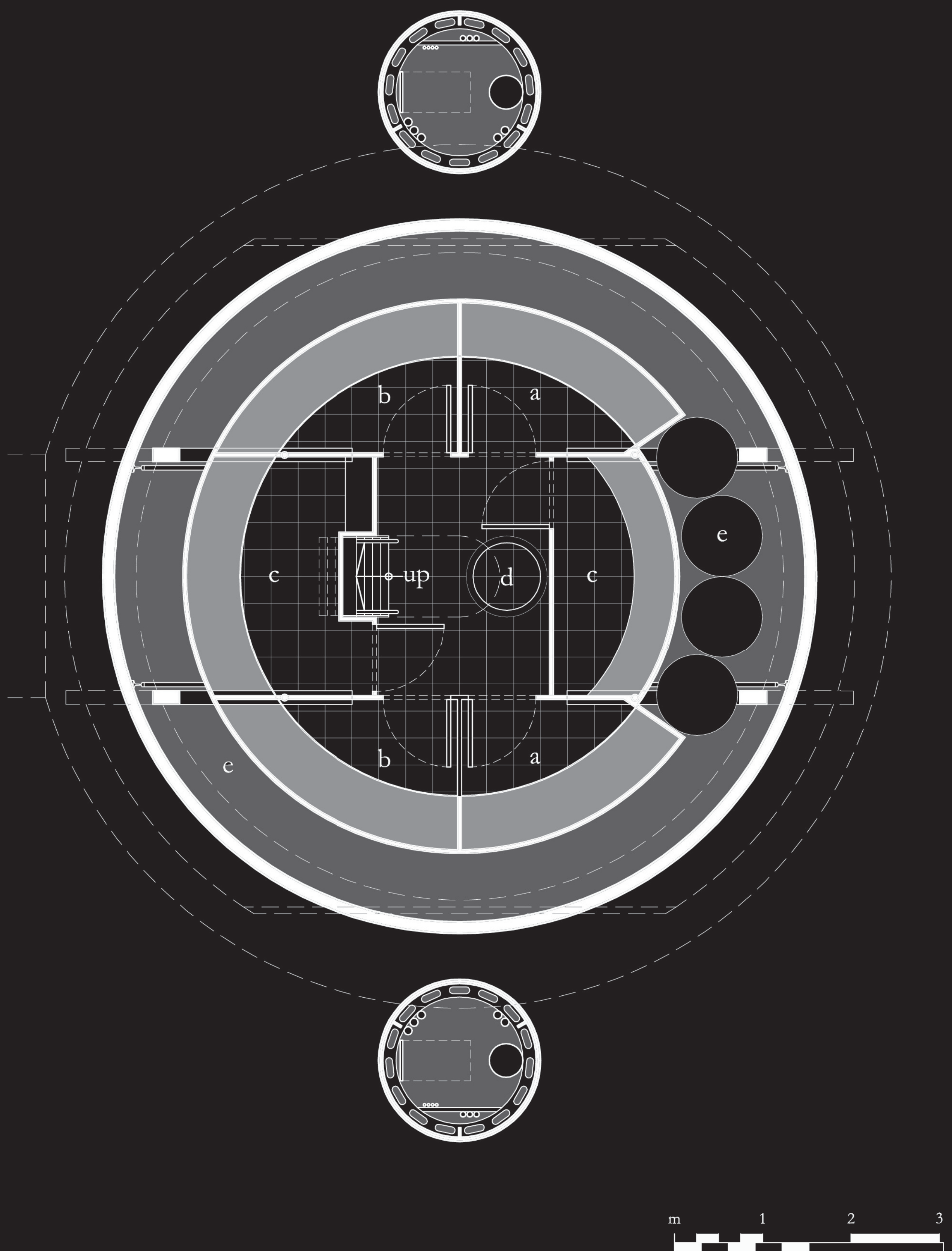
4.2.4.2(c) Lower Deck - Stores

The lower level, as in the first module, houses the HVAC and mechanical equipment, but also houses chilled, frozen, and dry stores for the galley.

Key

a. Chilled Stores
b. Frozen Stores
c. Dry Stores
d. Access hatch and ladderway (horizontal mode)
e. Mechanical Space

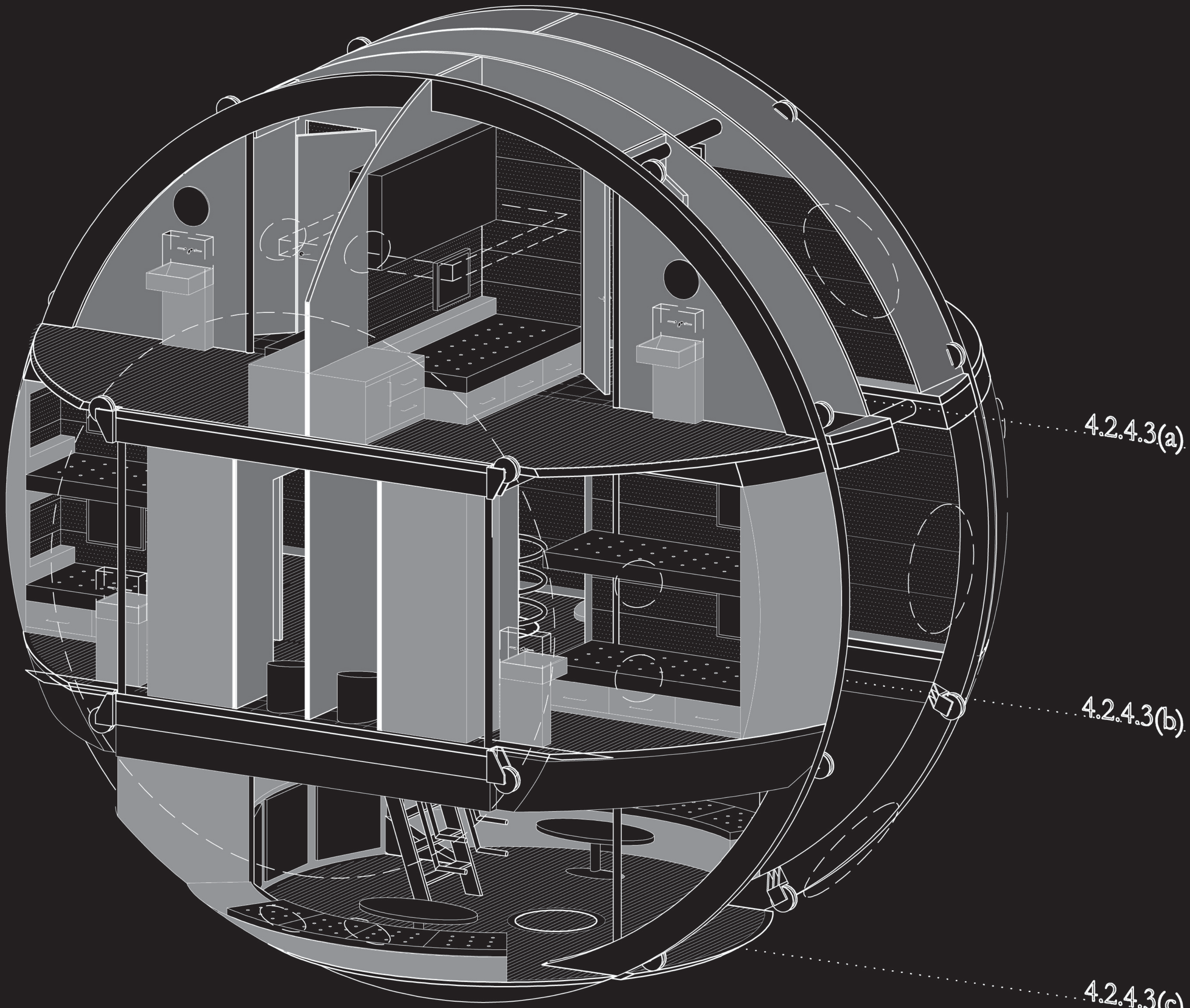
Deck Plan

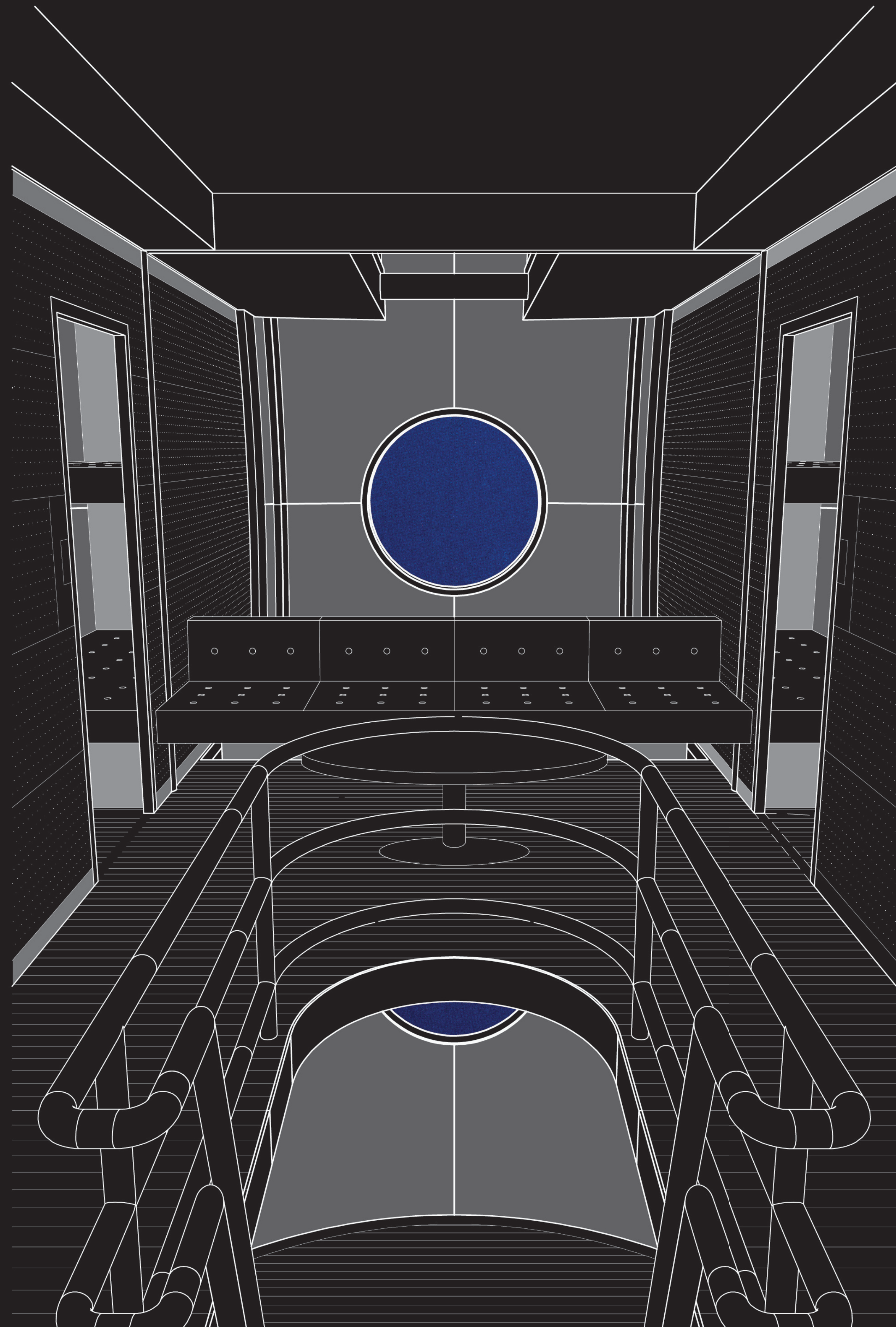


4.2.4.3 Crew Module 3 - Private

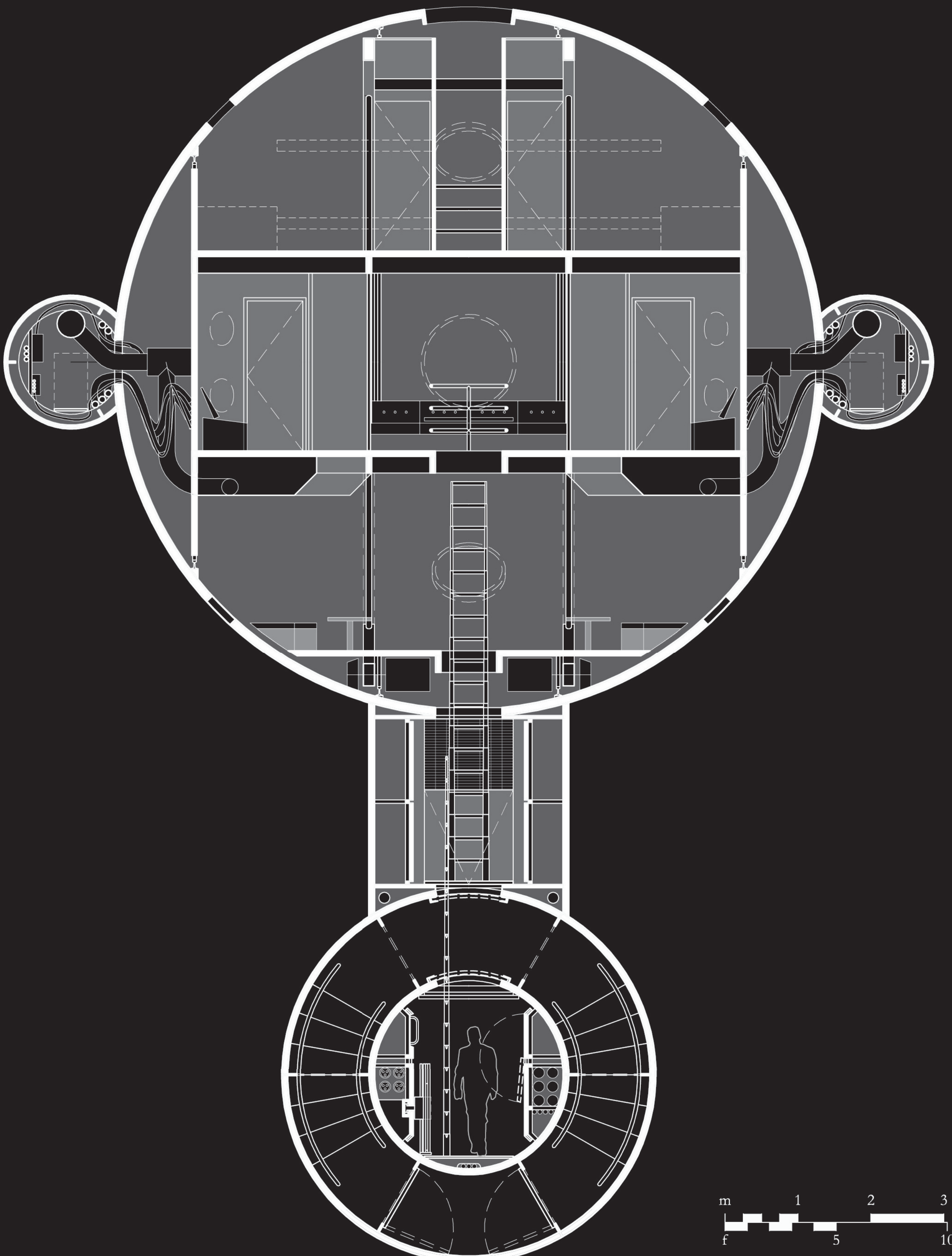
The aft module is the private module that houses the crew's quarters. There are sixteen berths for crew members and a small quiet lounge area. It is the quietest and darkest module, located far from the operational areas, where the crew members retreat to sleep, relax, or for privacy in their off-hours.

Interior Axonometric & Perspective





Transverse Section (Horizontal Mode)



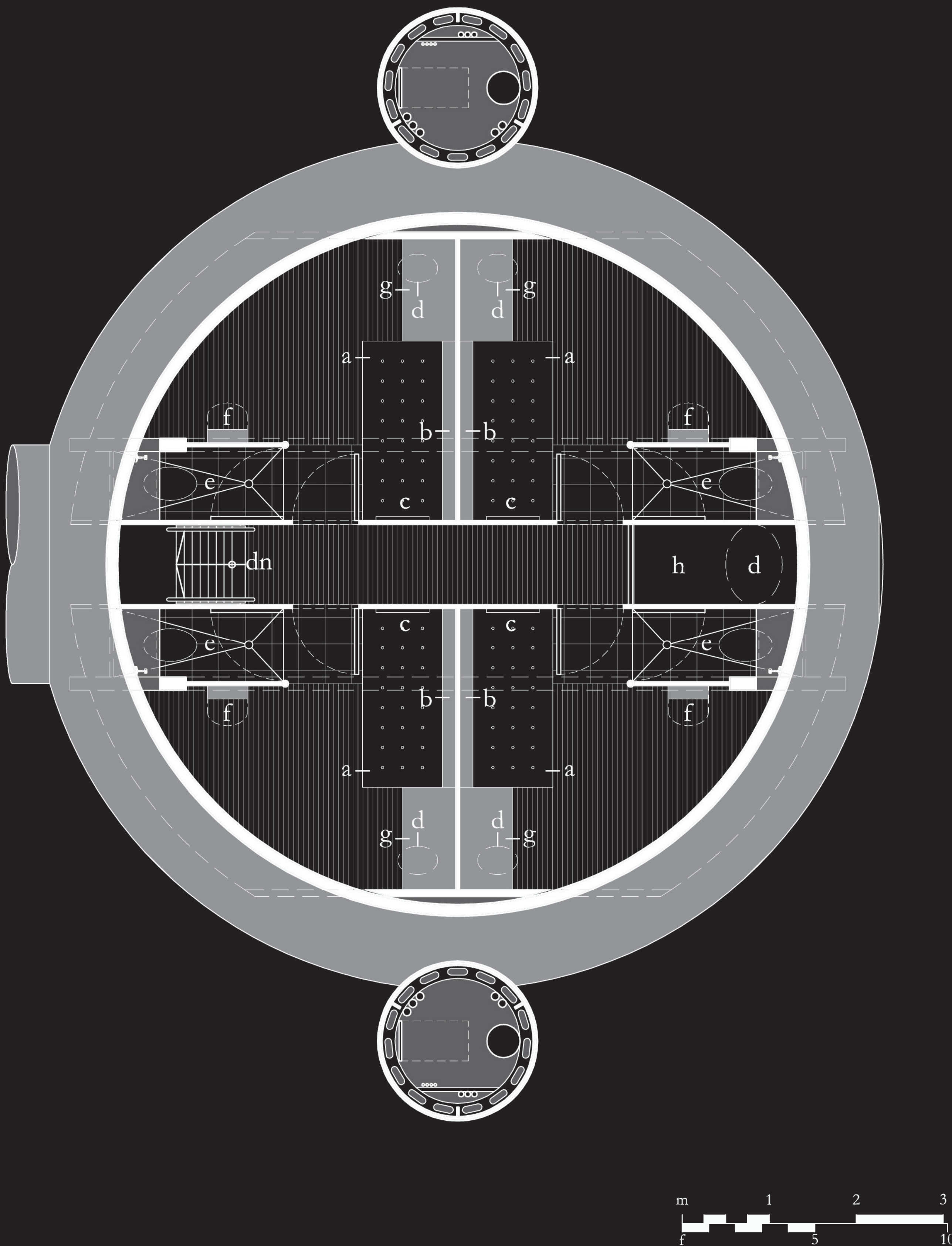
4.2.4.3(a) Upper Deck - Senior Crew Quarters

The upper level houses senior crew members' quarters. These quarters are doubles but typically are only occupied by one senior crew member. Each of the quarters is equipped with two bunks and an exterior viewport. Each of the bunks has storage space for personal effects and open shelving along with a touch-screen monitor that can relocated to any desired position. This monitor is connected wirelessly to the ship's computer network and can be used to display any information or video in the digital library or any imagery from the cameras mounted on the vessel's exterior, in effect becoming a virtual viewport. In each of the senior crew quarters, are a fold-up lavatory and a sanitary facility containing the head and a shower.

Key

a. Double bunk
b. shelves
c. Monitor (stowed position)
d. Viewport above
e. Shower/head
f. Folding lavatory
g. Personal effects locker
h. Open to below

Deck Plan



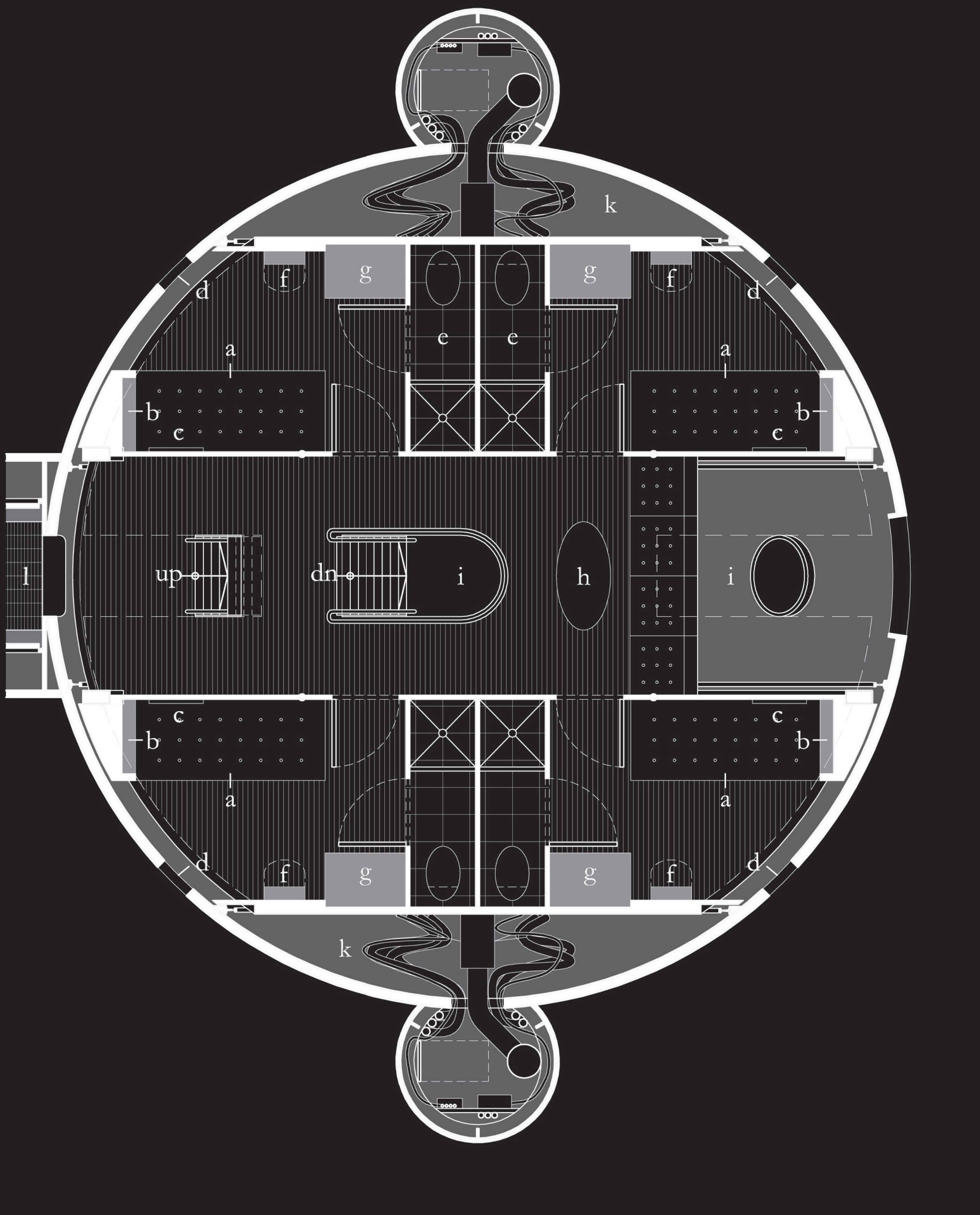
4.2.4.3(b) Mid Deck - Junior Crew Quarters

In vertical mode, the middle level is the access point to the module. This level houses the junior crew members' quarters. These quarters are similar in all aspects to the senior crew quarters above. Except that they are occupied by two crew members at all times. In the hall outside the quarters is a small sitting area overlooking the quiet lounge below and out though the three large viewports.

Key

a. Double bunk
b. Shelves
c. Monitor (stowed position)
d. Viewport
e. Shower/head
f. Fold-up lavatory
g. Personal effects locker
h. Sitting area
i. Open to below/above
j. Link to spine (vertical mode)
k. Mechanical space

Deck Plan



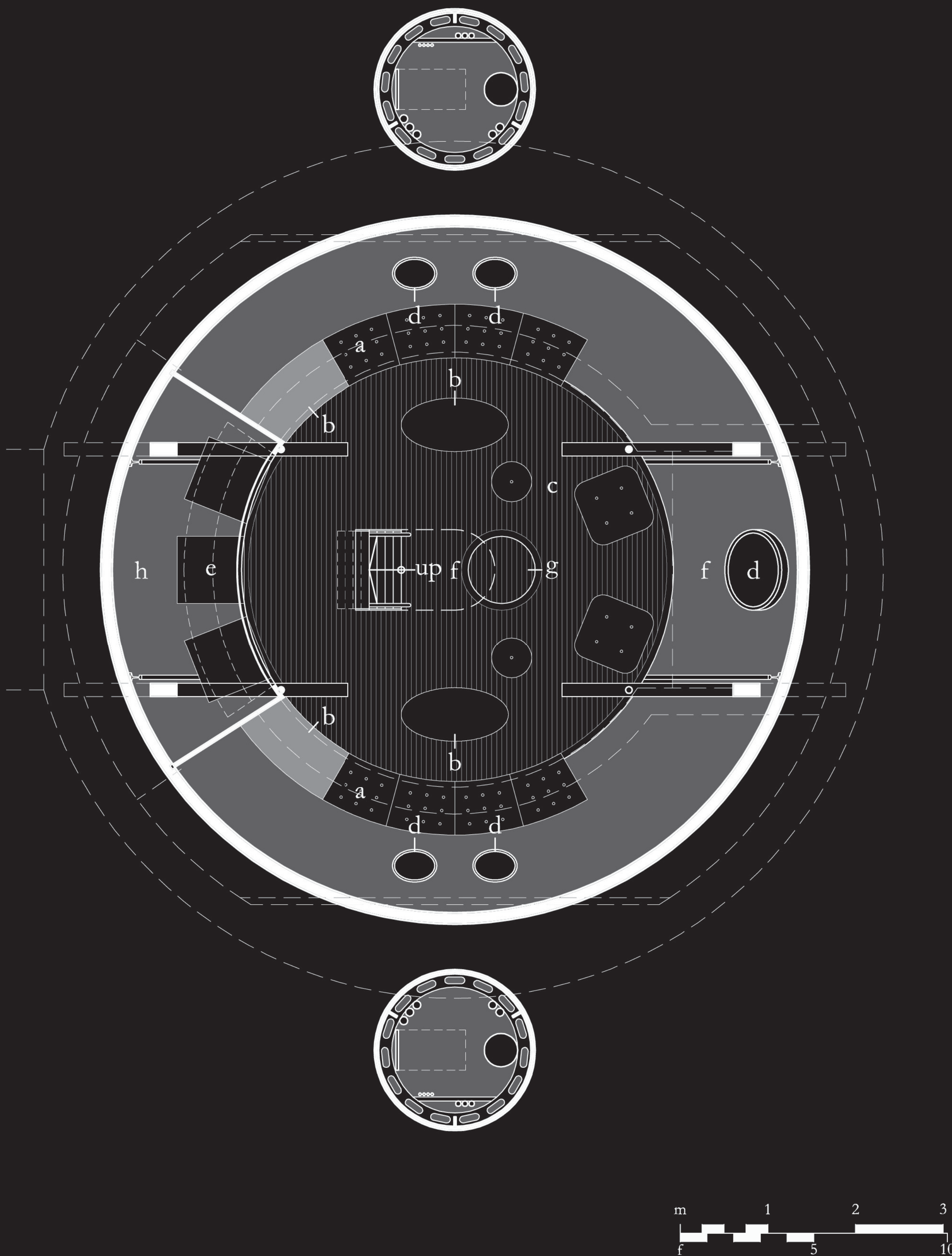
4.2.4.3(c) Lower Deck - Quiet Lounge

As in the previous two modules, the HVAC and mechanical systems are housed in the perimeter ceiling of the lowest level. In this module, there are four small viewports that look down and out to the exterior hatch of the ambient pressure module located in the secondary hull further aft. Located by these viewports, on the exterior shell of this module, are pressure-compensated lights used to light the exterior waters around the exit hatch for the ambient pressure module. The vessel's laundry facilities are located on this level.

Key

a. Fixed seating
b. Table
c. Flexible soft seating
d. Viewport
e. Laundry
f. Open to above
g. Access hatch and ladderway (horizontal mode)
h. Mechanical Space

Deck Plan



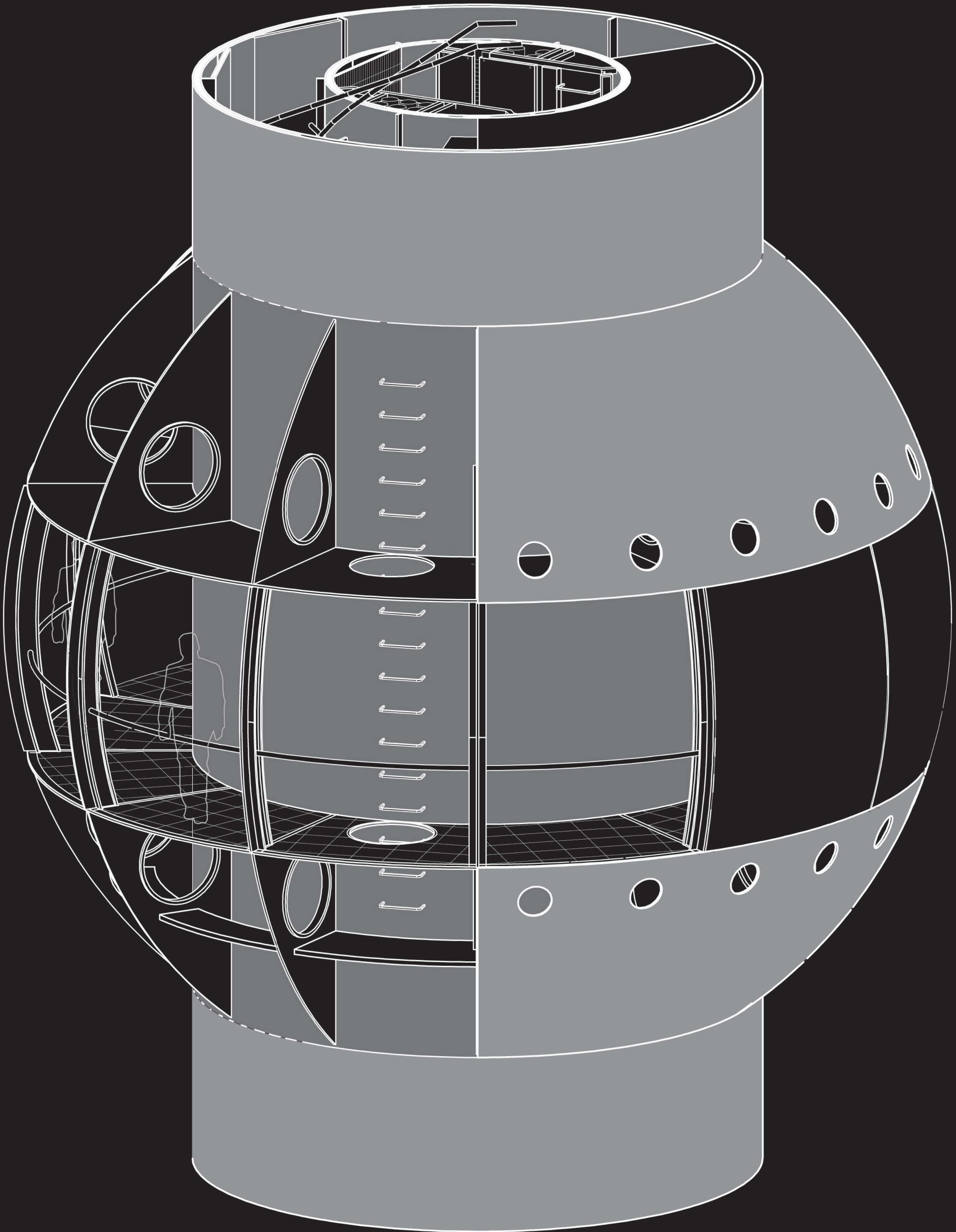
4.2.5 Observatory

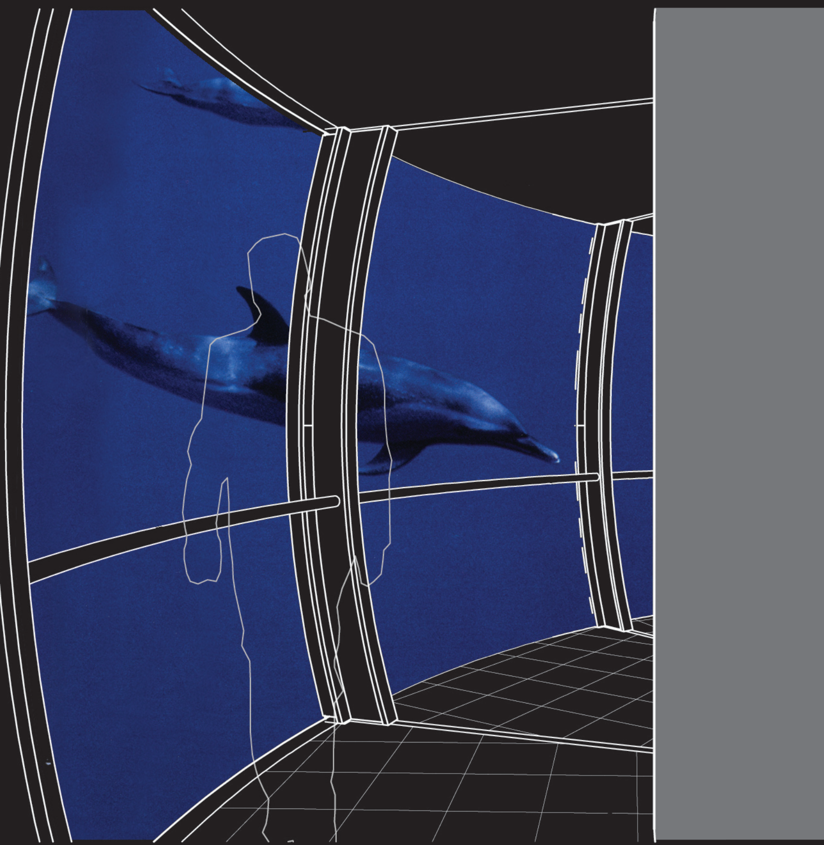
The Observatory is a fixed structure that encircles the spine at a point thirty-six metres (120feet) below the surface. It is accessible only when the vessel is operating in its vertical mode. Access is by way of the main stair or by the lift, through a watertight door leading into the observatory. The most striking feature is the full deck-height three hundred-and-sixty degree panoramic view-port. This viewport is constructed from one hundred and fifty millimetre thick acrylic panels, allowing for a continuous, unobstructed view into the ocean in a shirtsleeve environment. Above and below this viewport, in the floor and ceiling space, are exterior ports for cameras and lights operating in multiple frequencies.

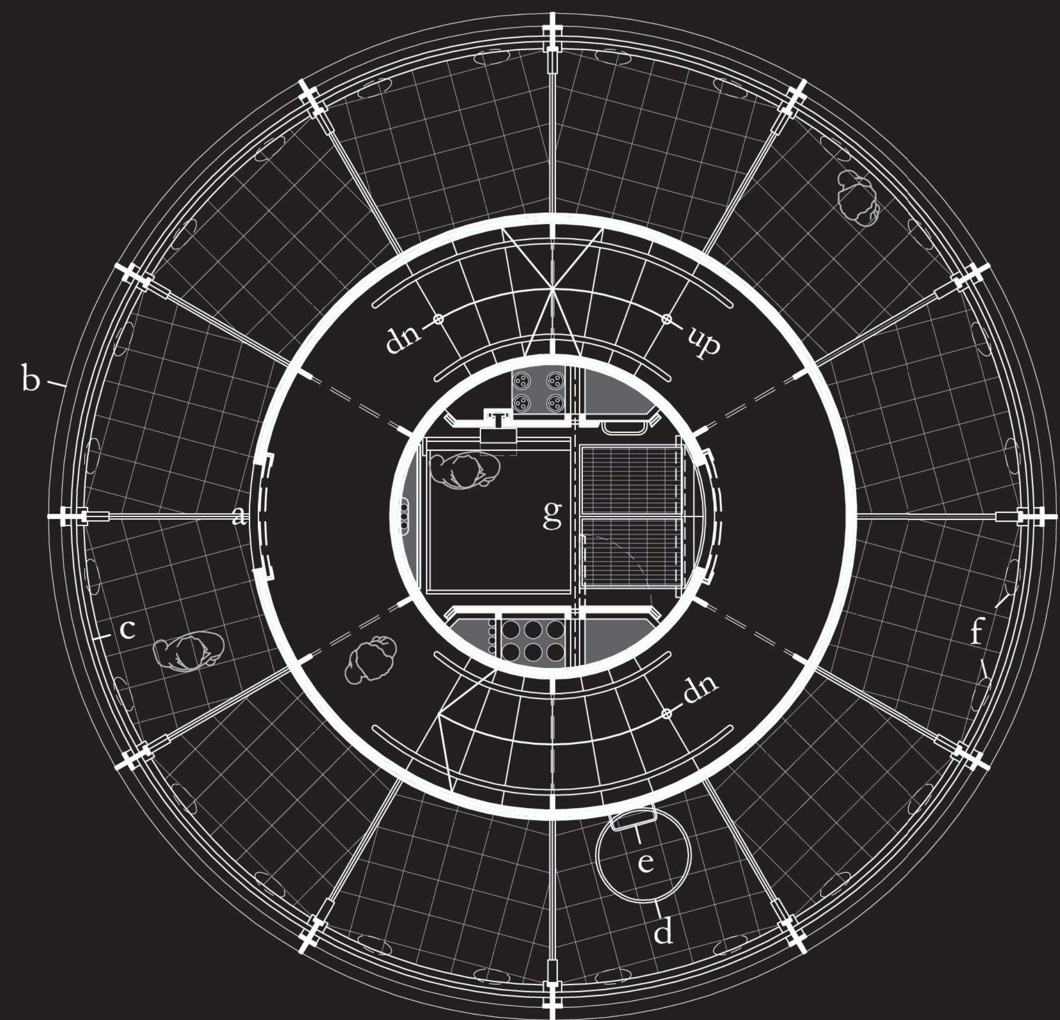
Key

a. Access point (watertight door)
b. Full height viewport (12)
c. Equipment mounting rail (data and power connects on the ceiling)
d. Access hatch to lower equipment bay
e. Access ladder to upper and lower equipment bays
f. Light and camera ports (24)
g. Spine

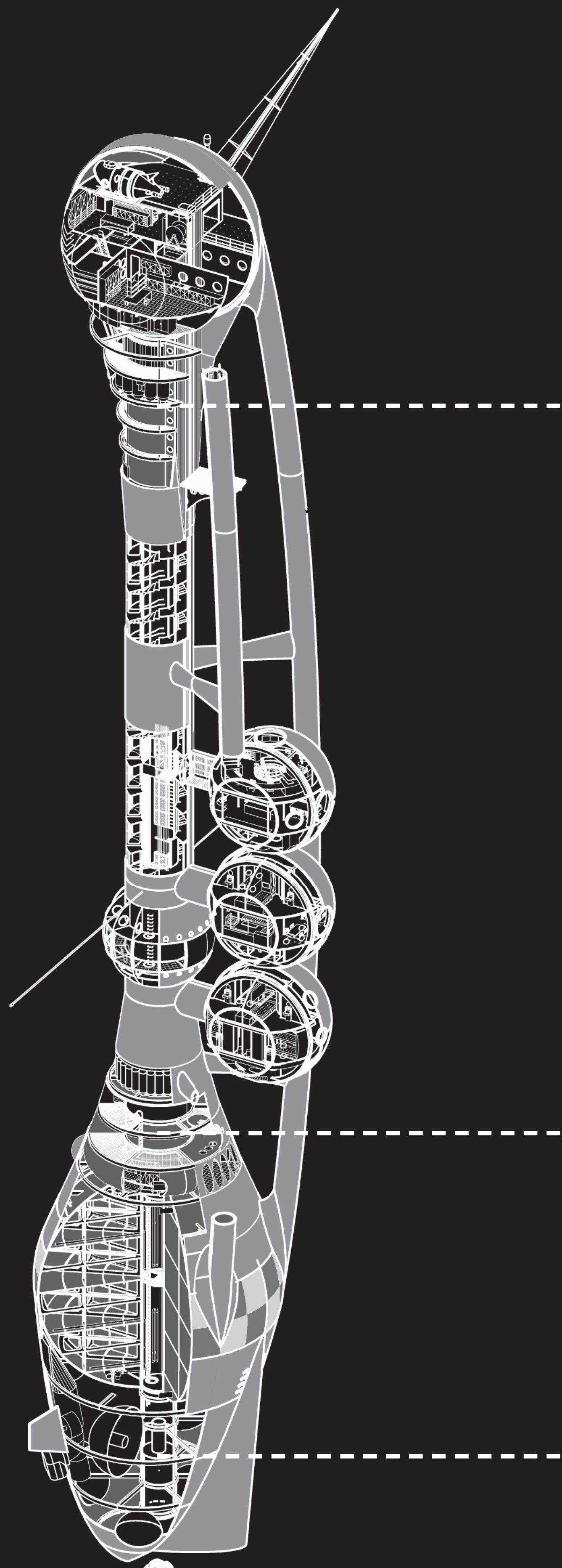
Cutaway Axonometric, Interior Perspective & plan







4.3 Secondary Hull

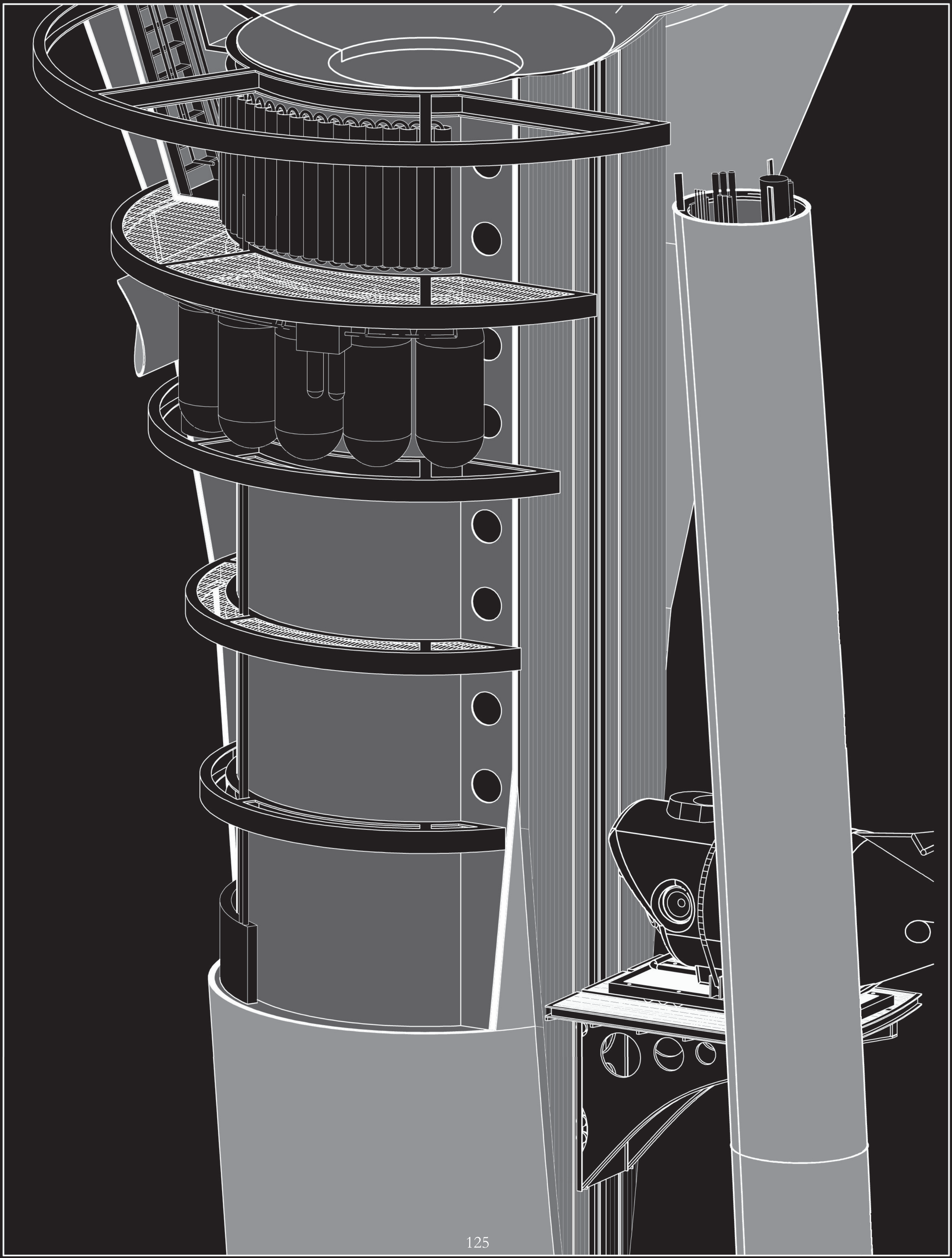


4.3 Secondary Hull - Fore, Amidships, & Aft

The secondary hull creates a hydrodynamic hull form for the vessel, providing for cleaner water flow around the primary hulls and the main truss, for efficient propulsion while vessel is underway. The secondary hull is formed from the same sandwich plate system panels as the rest of the vessel, except here they are attached to a secondary steel frame that stands off from the main hull. Large sections of the secondary hull are allowed to flood, neutralizing excess buoyancy. Various watertight and pressure-compensated equipment is placed in these flooding spaces.

4.3.1 Fore

The forward section of the secondary hull creates a smooth transition from the forward primary hull to the spine. This section of the secondary hull is clear of the water when the vessel is vertical and is the only section of the secondary hull which does not flood. Housed in this section are the heat exchangers using seawater for the cooling of the diesel generators, the freshwater generation equipment (reverse osmosis units), the compressed air flasks, and compressors. Also housed in the ventral part of this section is the bow thruster, used mainly to aid in port manoeuvring and docking. The dorsal section of the secondary hull is cut away to allow the launch platform to travel along the spine from the forward primary hull, engineering module. This launchway when the vessel is horizontal is an exterior deck area, well clear of the waters surface, that is open the engineering module and facilitates crew and cargo access while the vessel is in port.



4.3.2 Amidships

The amidships section of the secondary hull creates a smooth transition from the spine to the aft section of the primary hull and houses the ambient pressure module. The forward part of this section houses the compressed gas cylinders for the ambient pressure module, cylinders used to store the breathing gases of helium and oxygen for the ambient module. The mid-art of this section, fore of the ambient pressure module itself, is converted to a large pneumatic caisson while the vessel is in its vertical orientation and is only reached from the ambient pressure module. From there one can exit the vessel and go out into the surrounding water through a two-and-a-half metre hatch.

4.3.2.1 Ambient Pressure Module

When occupied, this module is sixty metres (200feet) below the surface. Water pressure at this depth is six times the surface pressure (seven atmospheres). Air pressure is at six-and-a-half atmospheres within the module, slightly less then the water pressure at this depth, because the wet exit for the module is at a slightly shallower depth fifty-five metres, a depth approaching the safe limit of sixty to seventy metres for breathing compressed air. Any deeper than this - or even remaining at this depth for any length of time - requires a safer breathing mixture, helium and oxygen, nitrogen, which makes up most of the air we breathe, becomes toxic at these pressures, and the partial pressure of oxygen has to be strictly controlled to keep the oxygen from having a toxic effect. The heliox mixture is used by surface and saturation divers who routinely venture well below sixty meters for long periods. There are two unique properties of the heliox atmosphere:

- Helium distorts the human voice, making it much higher pitched due to its lower density, but has no effect on electronically or mechanically reproduced sounds.
- Helium is also an excellent conductor of heat, requiring a higher ambient internal temperature of around 30°c for the occupants to feel comfortable.

The Ambient Pressure Module is occupied only in while vessel is in vertical mode; once the vessel is in its vertical orientation this module can be reached by way of the lift or main stair housed in the spine. While this module is occupied, the vessel has to remain vertical. The ambient module contains two DCC's (decompression/compression chamber) with living facilities for up to four in each. These chambers cycle between six-and-a-half and one atmosphere of pressure, so they have to be able to resist the crushing forces of the water at this depth. These chambers are linked via the main "dry" lock giving both of them access to the Hyperbaric Lifeboat. This lock also cycles between six-and-a-half and one atmosphere of pressure so it also has to be able to resist the crushing forces of the water at this depth. To do this, these three chambers are all located within a toroid that encircles the spine of the vessel. This toroid connects to the ambient pressure chamber with large full-height viewports. The pressure in this chamber is always kept slightly below the surrounding water pressure, up to half-an-atmosphere. This means the chamber is never exposed to extreme pressure, allowing for a much lighter construction and larger space. The main stress this chamber faces is from buoyancy forces.

Oxygen Toxicity

Oxygen is essential for life, but exposure to increased pO_2 levels can have a toxic effect on the lungs and brain. The pO_2 in the lungs can be raised by either increasing the concentration as a percentage of the total gas volume or by increasing the atmospheric pressure. In SCUBA diving, O_2 enriched gas mixes are often used in order to help flush nitrogen out of the body more rapidly, and divers also encounter raised atmospheric pressure.

Exposure to 100% oxygen at surface pressure over a prolonged period (8 - 12 hours) can lead to pulmonary toxicity in healthy adults. Symptoms of pulmonary oxygen toxicity include sub-sternal pain and coughing. Paradoxically, the lungs may become less able to supply the body with normal levels of oxygen because of damage to the gas exchanging lining of the air sacs within the lungs. Symptoms may last for several days. Although pulmonary toxicity is a result of prolonged exposure to elevated levels of oxygen, it is possible that SCUBA divers could become affected.

The greatest danger associated with pressurized oxygen is from its effect on the Central Nervous System. CNS toxicity occurs at oxygen partial pressures of around 1.5atmospheres or higher. Symptoms include dizziness, nausea, fatigue, anxiety, confusion and lack of co-ordination. The affected diver may suffer from convulsions similar to those of a tonic-clonic (grand mal) seizure. During a fit, the diver's mouth will open - losing the mouthpiece. Drowning ensues.

Nitrogen Narcosis

When breathing pressurized air, more molecules of nitrogen dissolve into the tissues and blood. Too much nitrogen can affect the brain because nitrogen is an anaesthetic at increased pressure. It causes a condition termed nitrogen narcosis - the "rapture of the deep" - which can lead to reduced manual dexterity, reduced cognitive and sensory ability, euphoria or even coma and death. The deeper a diver goes, the more likely they are to suffer these effects and the more severe they will be. It only takes around three minutes for the narcotic effects to reach maximum. Onset becomes apparent at a pressure of 4atmospheres (30msw) with symptoms increasing in severity with additional depth. At pressures greater than 10atmospheres (90msw) unconsciousness may occur.

There are conflicting reports of habituation to narcosis following repeated dives and experienced workers or those with high intelligence appear to be least affected. The effect of hyperbaric nitrogen (N_2) on the brain is similar to the 'normobaric' effect of nitrous oxide (N_2O), which is used as an anaesthetic agent.

The organization of two separate DCC's and an independent main lock allows for two four-man missions to operate at the same time, on different cycles, for continuous, manned operations at depth, or as one large eight-man operation. Minimum crew for any mission is three (two divers, and the one remaining crew member is a backup emergency diver, coordinating communications with the control centre). A typical mission profile is one hour to compress to the ambient pressure of six-and-a-half atmospheres, typically ten days of active mission time, then two-and-a-half days to decompress, returning to one atmosphere; then the crew rotates out for a minimum of two weeks.

Breathing Mixtures

Any breathing gas in addition to oxygen is a diluent but each will have unique characteristics that might affect the body. The most commonly used gas mixes at depth for long periods are explained below.

Nitrox (N_2O_2) is 'oxygen enriched air' produced by adding 100% oxygen to standard air (21% oxygen / 79% nitrogen) - also termed enriched air nitrox (EAN). This enables an increase in the oxygen and therefore a reduction in nitrogen content. Because Nitrox contains less nitrogen than air, the effects of narcosis are reduced. However, because the oxygen concentration is higher there is an increased risk of oxygen toxicity. The main use of Nitrox is to extend dive time rather than depth.

Heliox (HeO_2) is a mixture of oxygen and helium used primarily by commercial divers. The percentage of O_2 can be adjusted to suit the type and depth of the dive. Using helium instead of nitrogen eliminates the problem of narcosis. However, using helium as a diluent carries with it other risks. Helium has a higher rate of thermal conductivity than nitrogen care must be exercised when it is used in a hyperbaric chamber to prevent excessive heat loss from the body. The role helium plays in respiratory heat loss is less significant as this depends more on gas density and helium is less dense than nitrogen. Helium also has the effect of causing distorted speech. Its lower density makes it easier to breath than nitrogen at the same pressure.

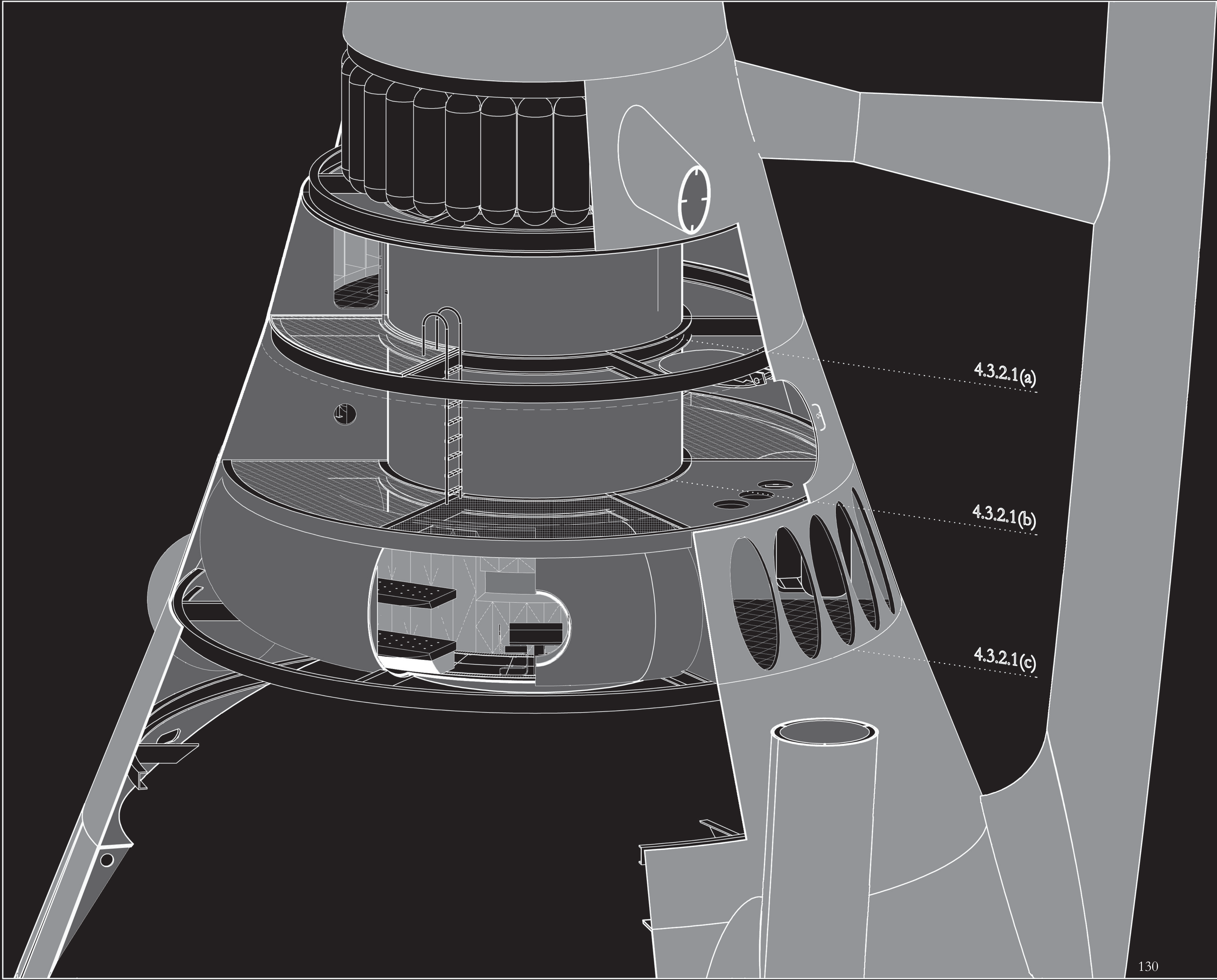
The use of heliox allows compression to depths that can result in a condition termed 'high pressure nervous syndrome' or 'high pressure neurological syndrome' (HPNS). This can occur at depths below about 160msw. HPNS is thought to be caused by hyperexcitability of nerves in the brain and may result in tremors, dizziness, nausea and tiredness. Pressure can be thought of as a convulsant, like oxygen, in high doses.

Helium is also relatively expensive due to its rarity. Although most of Earth's helium can be found in the atmosphere, the economic cost of extracting it is extremely high due to its low concentration in the air. Instead, it is obtained from some natural gas fields during extraction of methane. Most helium-rich reserves are in the USA and Canada. The cost of helium is expected to rise dramatically in the next 25 years as sources are depleted. The DCCs incorporate a reclamation system to recover up to 98% of the gas for re-use.

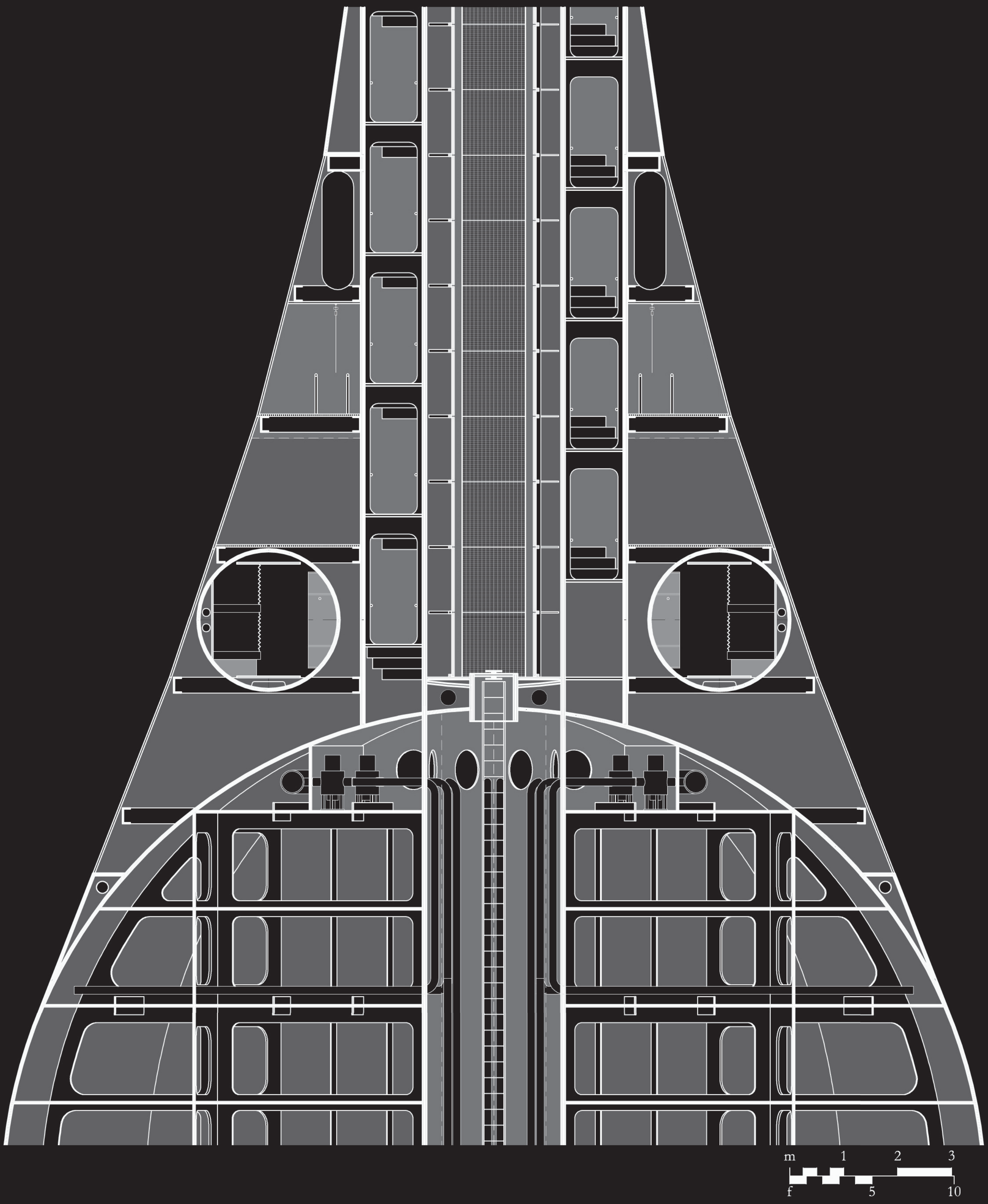
Trimix (HeN2O2) is a mix of oxygen, helium and nitrogen. The effects of nitrogen narcosis are limited by the addition of helium. Also, because of the counteracting effect of nitrogen narcosis, HPNS *symptoms* are reduced. The interacting effects of nitrogen and helium within decompressing tissues, and the role this plays in bubble formation, is not yet clearly understood.

excerpts on **Oxygen Toxicity, Nitrogen Narcosis,** and **Breathing Mixtures** from
National Health Service - Scotland, Scottish Diving Medicine, April 2005
(http://www.sdm.scot.nhs.uk/decompression_illness/index.htm)

Cutaway Axonometric



Midline Section



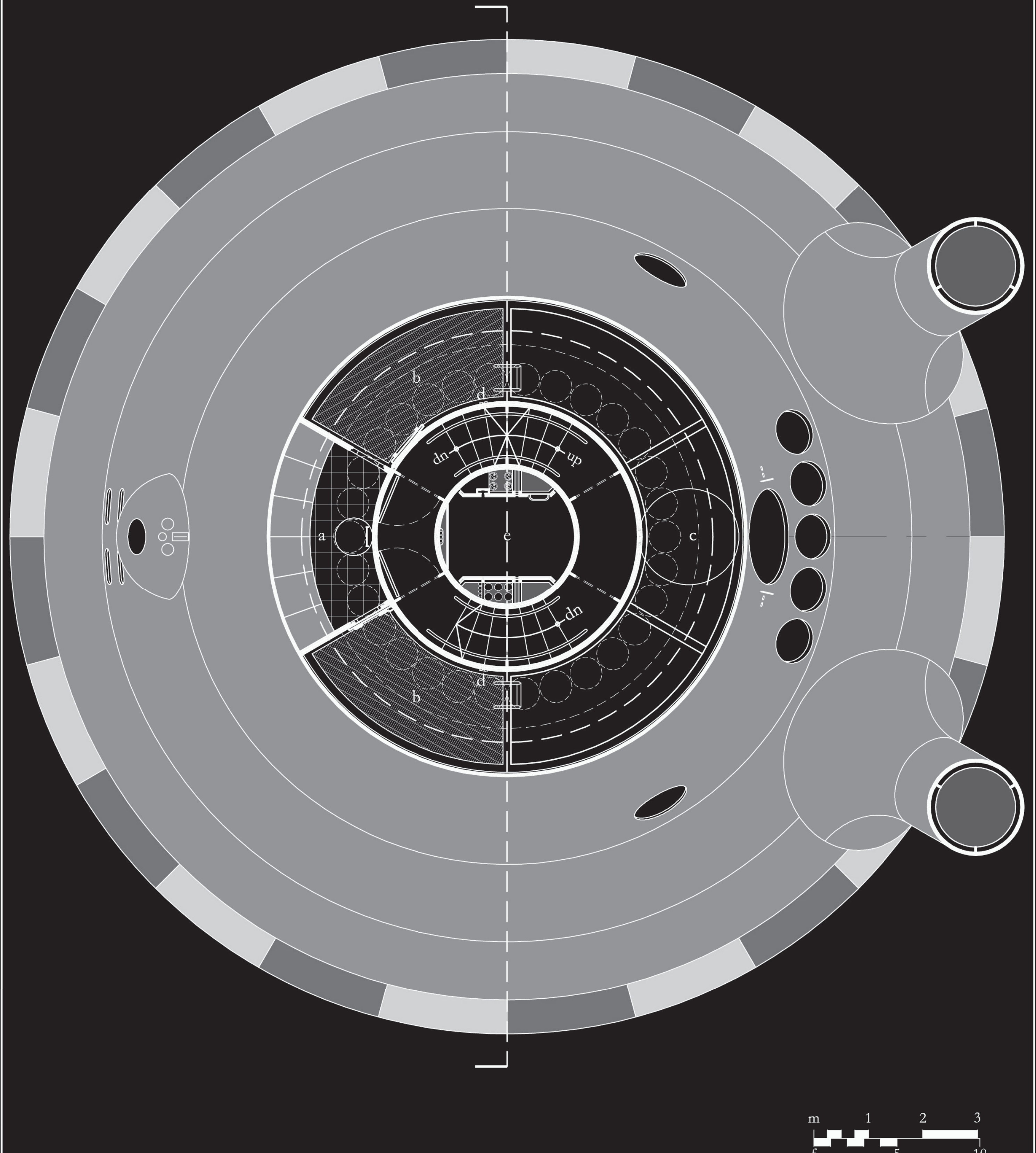
4.3.2.1(a) Wet Porch

Wet entry to the habitat is through the wet porch, which opens on to an enclosed moonpool. From the wet porch the remainder of the ambient pressure module below is reached by way of the wet lock. The wet lock houses dive equipment storage bays and a ladderway to the lower wet lock. Divers in this facility use heliox rebreathers, which are recharged in the lower wet porch and stored in the dive equipment lockers. For dives, and for work within the confines of the moonpool or within close proximity to the vessel, there is a tethered system that supplies the breathing gases via an umbilical hose. There are several connection ports for these umbilicals, both within the moonpool and on specially designed ports on the exterior of the vessel. Along with the breathing gases, the connection ports also supply power for equipment.

Key

a. Wet lock
b. Wet porch
c. Moonpool
d. Umbilical connect
e. Spine (one-atmosphere)

Deck Plan



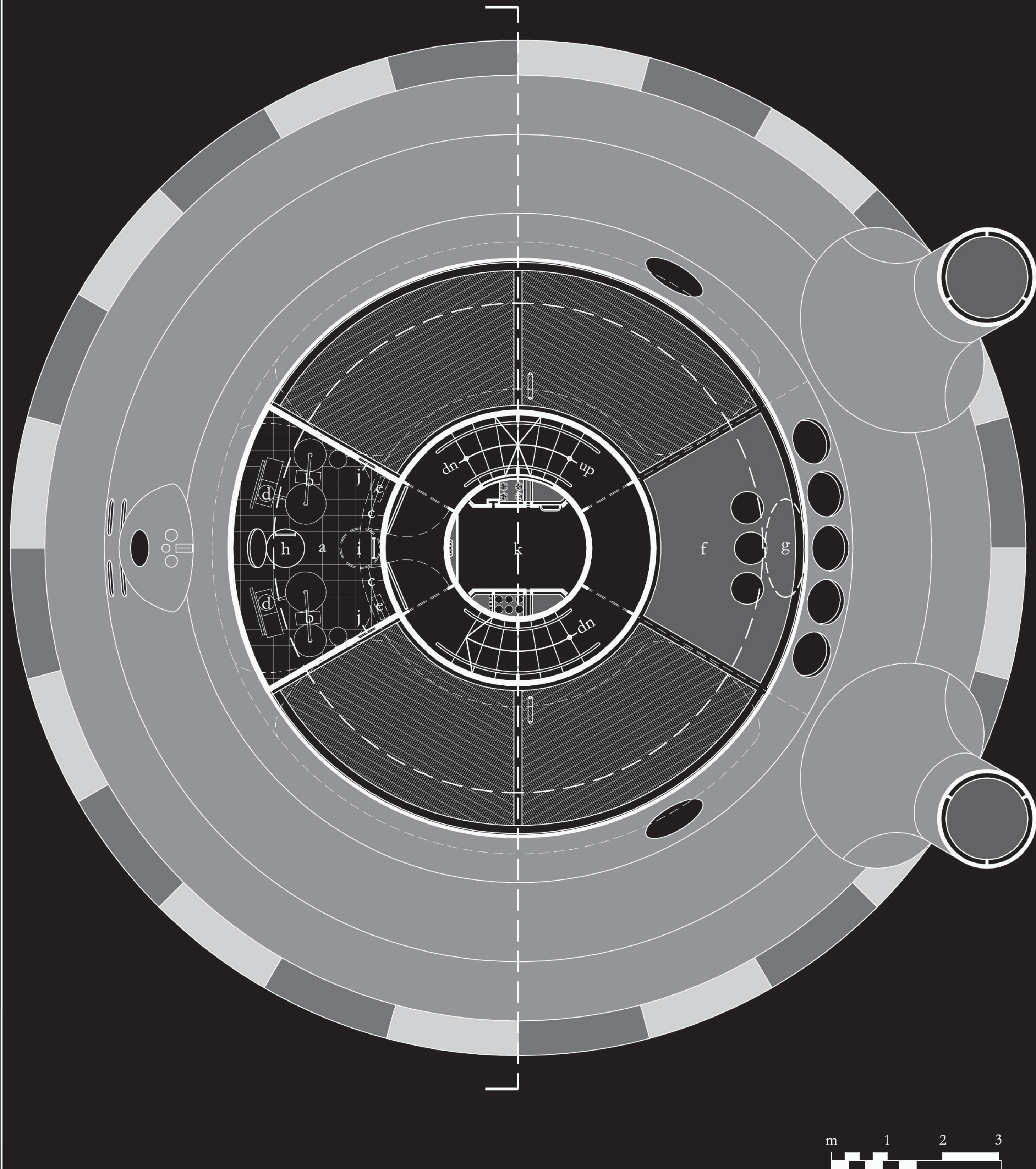
4.3.2.1(b) Wet Bay

The lower wet lock houses life support controls and pressurization equipment. Also housed here are the recharging ports for the rebreathers. These ports purge the units of their residual gases, clean, and refill the oxygen containers and provide replacement units for the carbon dioxide scrubbers.

Key

a. Lower wet Lock
b. Atmospheric gas regenerators
c. Atmospheric gas control panel
d. Atmospheric gas separator and compressors
e. Re-breather charging port
f. Enclosed Moonpool (wet bay)
g. Exterior hatch
h. Main lock hatch
i. Wet lock ladderway
j. Viewport (looking into Moonpool)
k. Spine (one-atmosphere)

Deck Plan



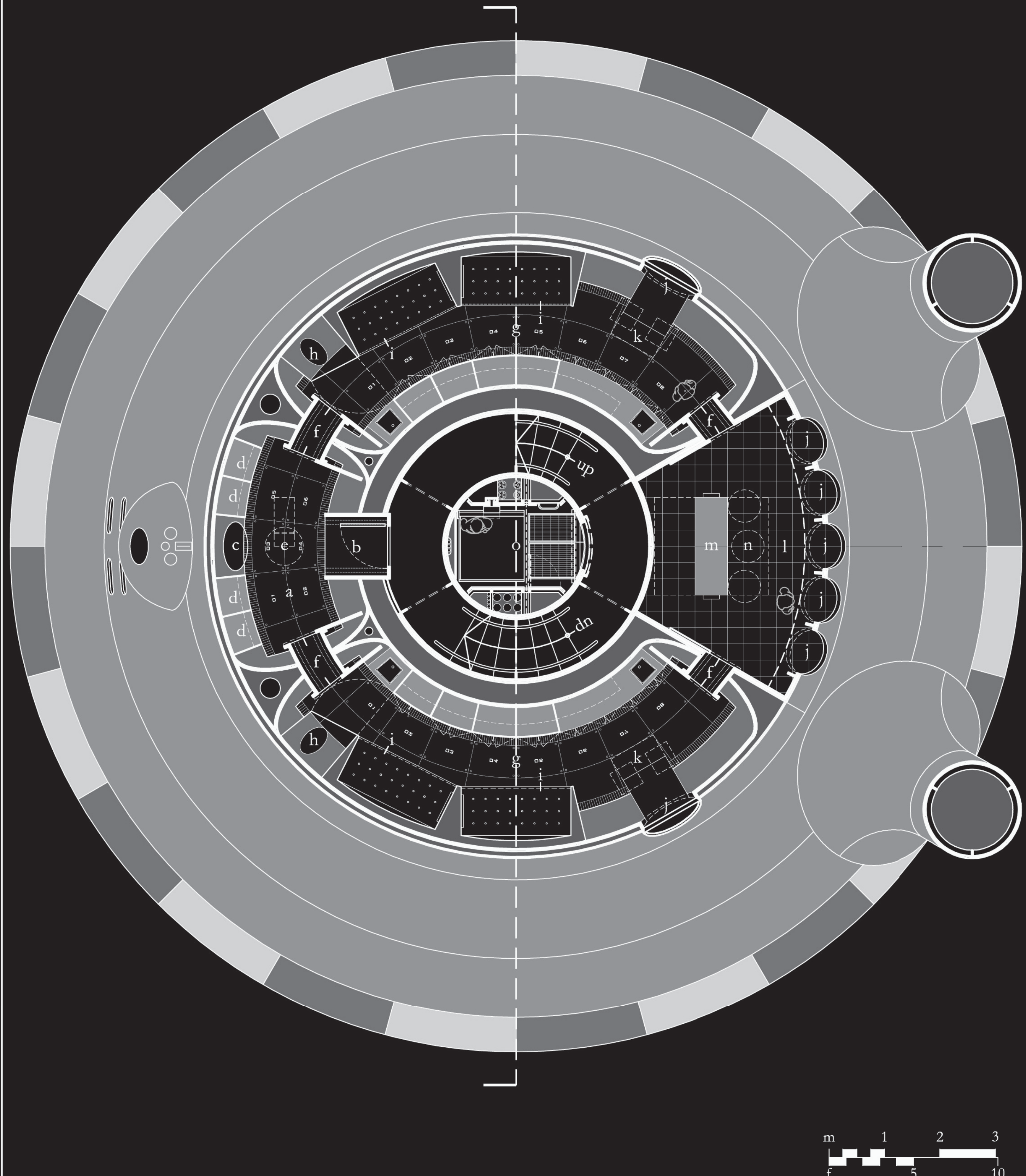
4.3.2.1(c) Habitat Module

The habitat module is an eighty-ton, double-lock pressure vessel approximately twenty-three meters long and, three meters in diameter. Scientists live and work inside the habitat when they are not diving outside. Wet entry to the habitat is through the wet porch above. There are three main compartments in the ambient pressure module. The four metre "dry lock," contains storage lockers and the access hatch to the hyperbaric lifeboat as well as the main hatch. It is the main connecting hub. Adjoining this are the two DCC's (decompression / compression chamber) providing the main living space of the ambient pressure module. Each includes sanitary facilities, berths for a four-person crew, personal storage lockers, large viewport, and kitchen facilities that include a microwave, instant hot water dispenser, refrigerator, sink, and dining area. The DCC's also contains life support controls, so both the dry entry and the DCC's can be independently pressurized. The ambient pressure chamber is the final piece of the habitat module and it contains the main work area of the module. The main work station is trunnioned to accommodate the rotation of the vessel, so that it does not have to be emptied after every mission. There are large viewports that give views of the adjacent waters and into the enclosed moonpool above.

Key

a. Main Lock
b. Main hatch
c. Hyperbaric Lifeboat access hatch
d. Dive lockers
e. Hatch and retractable ladder (to Lower Wet Lock)
f. Pressure doors
g. Decompression/Compression Chamber
h. Sanitary facilities
i. Double berths
j. Viewport
k. Kitchen/Dining area
l. Ambient pressure chamber
m. Trunnioned work centre
n. Spine (one-atmosphere)
o. Outline of viewports above (looking into moonpool)

Deck Plan



4.3.2.2 Hyperbaric Lifeboat

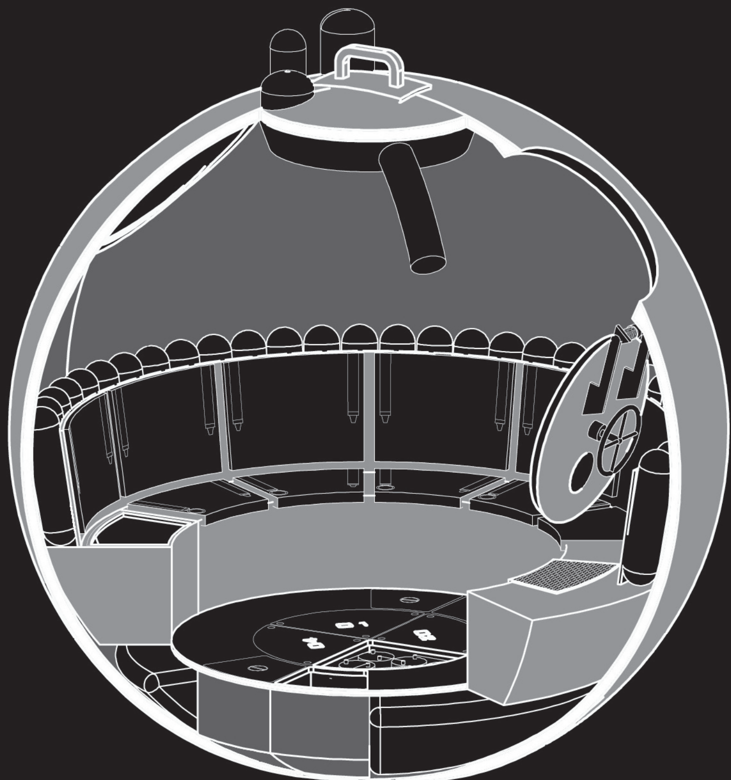
The hyperbaric lifeboat is a three metre diameter sphere, reached through a hatch from the main lock of the ambient pressure module. The hyperbaric lifeboat is to be used in emergency situations where the crew has to evacuate the module without decompressing. This hyperbaric lifeboat can be used in two modes. The first mode is as a safe haven for the crew if there is some failure in either decompression chamber, such as fire, atmospheric contamination, pressure loss, or power loss. The crew would evacuate to the pod but not detach it from the ship, and wait out the problem, or return to one atmosphere of pressure and then leave the pod for the unpressurized ship. In the second mode the crew evacuates to the pod but then the pod is ejected from the ship. The pod, being positively buoyant, then floats to the surface, where the slow process of decompression back to one atmosphere begins. This mode would only be used with a catastrophic failure in the decompression chamber or failure of the vessel itself.

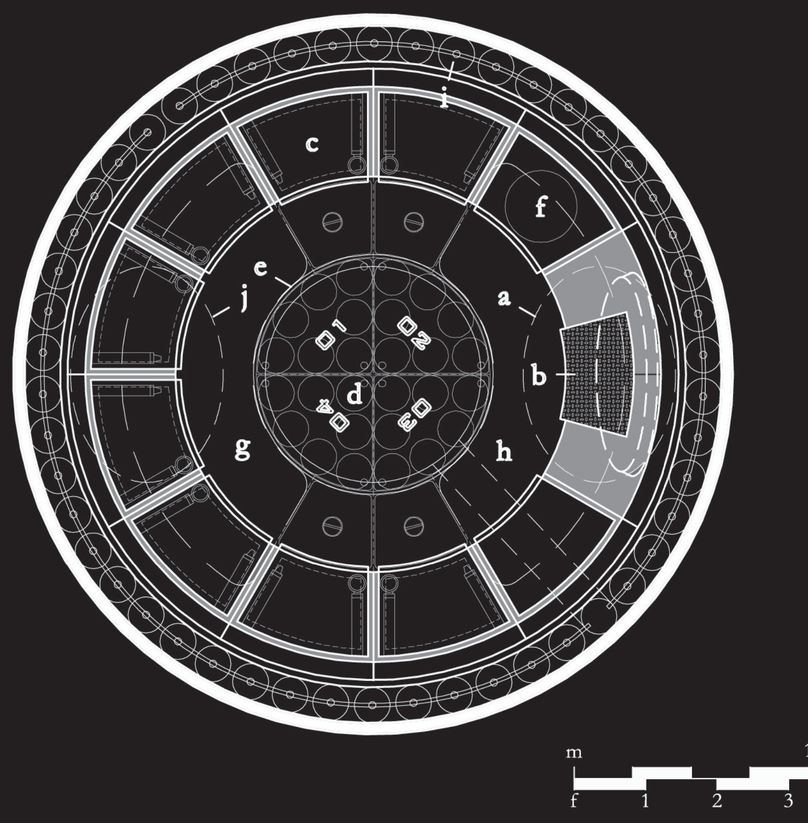
Sealed, the pod can maintain pressure and life support for a maximum of eight people for a minimum of five days, double the time required to return to one atmosphere. The hyperbaric lifeboat is stocked with one-time use chemical scrubbers to remove excess carbon dioxide and control humidity, and contains, food & fresh water supply for ten days, a term that could be extended by strict rationing.

Key

a. Hatch
b. Step
c. Seats with stores under
d. Batteries to power radio, beacon, air scrubbers
e. Electronics panel for communications radio, beacons, and atmosphere control
f. Chemical toilet
g. Sewage tank (below)
h. Freshwater tank (below)
i. Atmospheric gas storage bottle (50)
j. Outline of viewport

Cutaway Axonometric & Plan

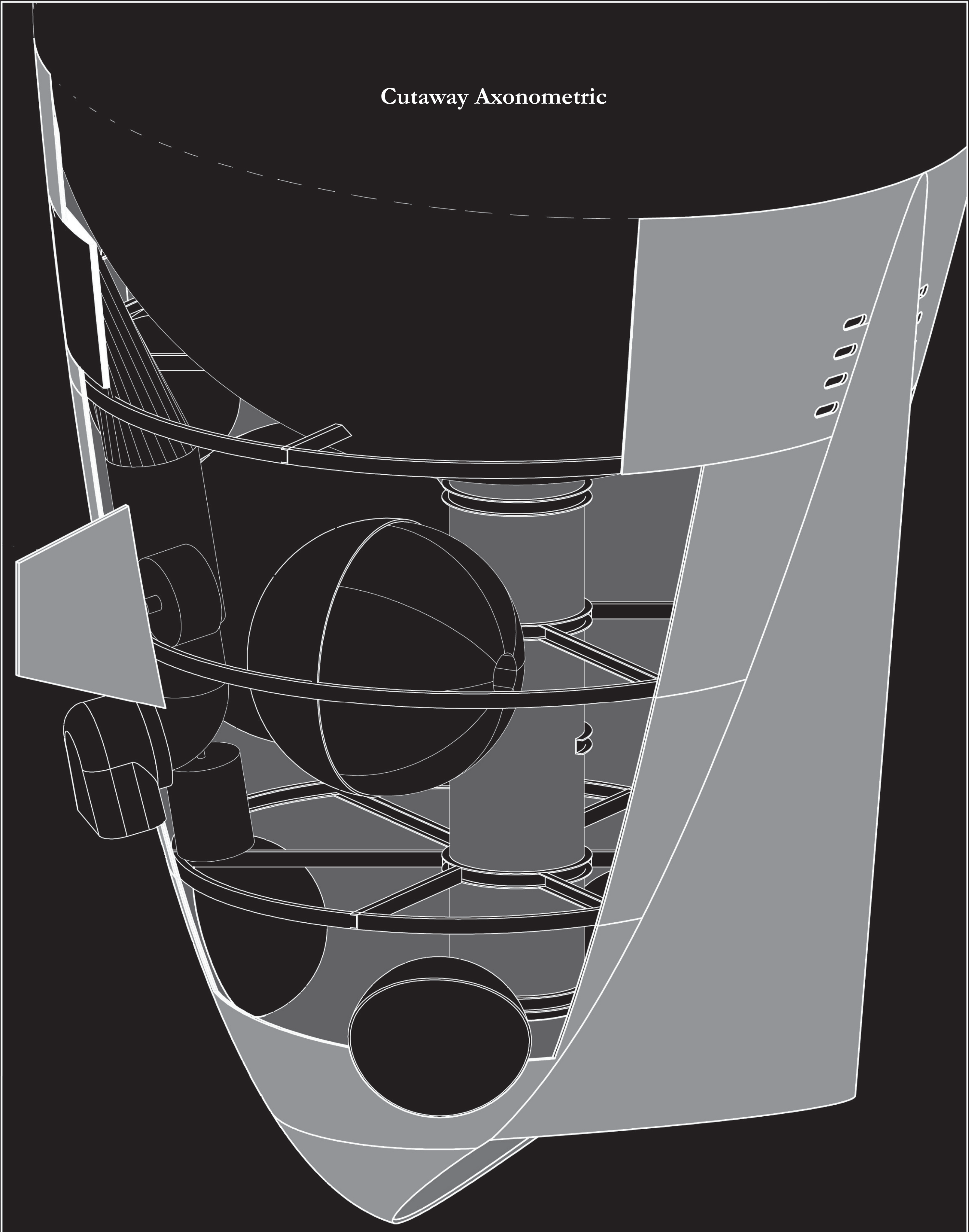




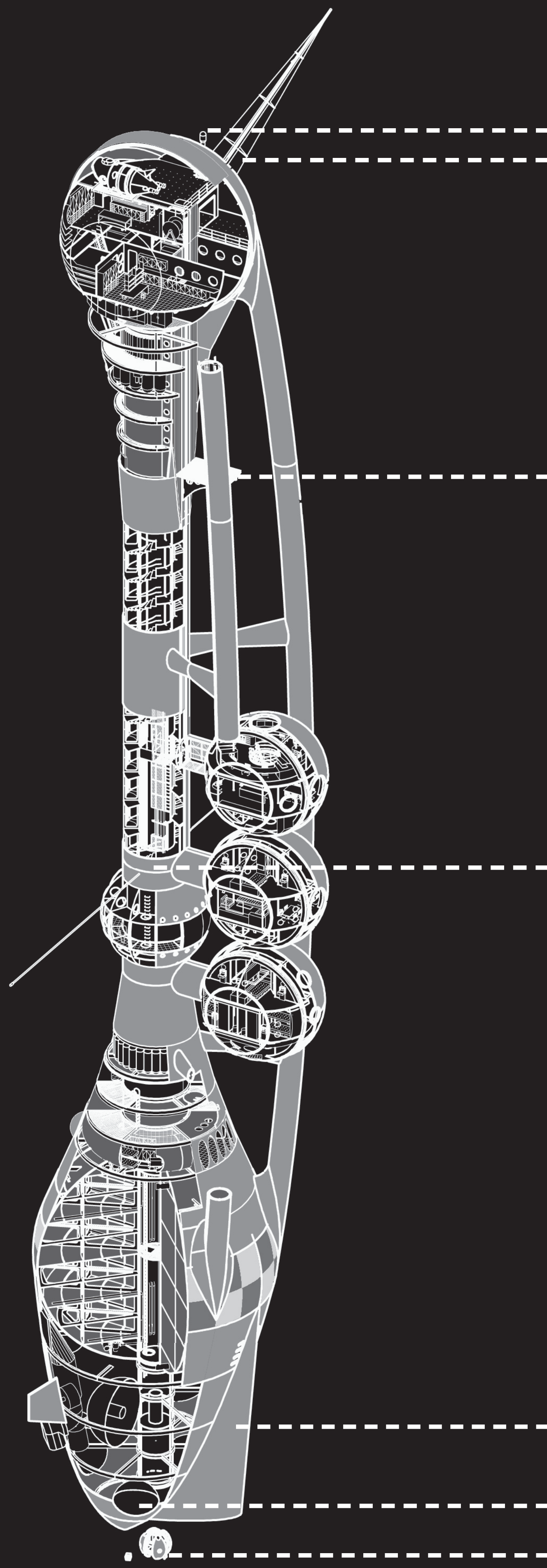
4.3.3 Aft

The aft section of the secondary hull is all free-flooding space, except for the central core, and is flooded via sixteen venting/flooding ports located foremost on the dorsal and ventral sections of the outer hull. In this flooded space is housed watertight and pressure-compensated equipment and tanks. Some of the major equipment housed in this section are: two water jet propulsion units with their housings, intakes, drive motors, and outlet nozzles. Along with three fuel tanks, one five metre diameter, two four metre diameter, each with eight fuel bladders containing seventeen thousand and ten thousand litres respectively; as fuel in the bladders is depleted, the void outside the bladder is filled by seawater. As well there the hydraulic drive motors for the two active stabilizers. This secondary hull section contains no inhabited spaces; while the central core is accessible and remains dry, albeit pressurized, it is not normally occupied, except in the case of problems with the tether deployment and or docking equipment for the unmanned observatory. A majority of the vessel's main sensors are located in this section, either mounted in removable modules in the exterior hull, or housed in the main sensor blister.

Cutaway Axonometric



4.4 Mission Systems



4.4.1 Main Mast

On this mast are mounted numerous Imet sensors to monitor weather conditions, together with other equipment surveying the area around the vessel, such as radar - both long and short range. There is also transmission equipment mounted to relay data between the shore and the vessel, via Communication systems which include: HiSeasNet, Csat, and INTELLSAT, INMARSAT, and AM/FM/SW connections.

4.4.2 Photonic Masts

There are two Photonic Masts for the vessel, mounted port and starboard on the forward primary hull. Sensors housed in these Photonic Masts include both wide -- and narrow - angle digital optics along with, LLTV (low light TV), thermal imager and laser rangefinder. Data from these imagers is carried to the command centre via dedicated fibre optic cables and displayed at the navigators station. These sensors are used in all ships manoeuvres to give a visual representation of what is around the vessel while its underway or on station.

4.4.3 Sensor Booms

These two booms - one port, one starboard - contain hydrophones and CTD (Conductivity, Temperature, Depth) sensors which are deployed away from the vessel in undisturbed waters. The wide spacing of the sensor booms allows for the hydrophones to precisely located acoustic signals.

4.4.4 Main Sensor Blister

This houses the permanent main mission equipment: wide and narrow beam sonars, acoustic doppler current profiler, and a high frequency high resolution sonar. This equipment is designed for full-depth studies and is housed pointing straight down.

4.4.5 Sensor Pods

These three pods are mounted in recesses in the aft secondary hull, 120° apart, housing mission specific equipment, and providing power and data connections to the vessel. These sensor pods are removable while the vessel is docked. This swapping-out allows for frequent upgrades to this sensor equipment. Equipment housed in these pods includes the: acoustic positioning system, side scan sonars, chemical sensors, and hydrophones.

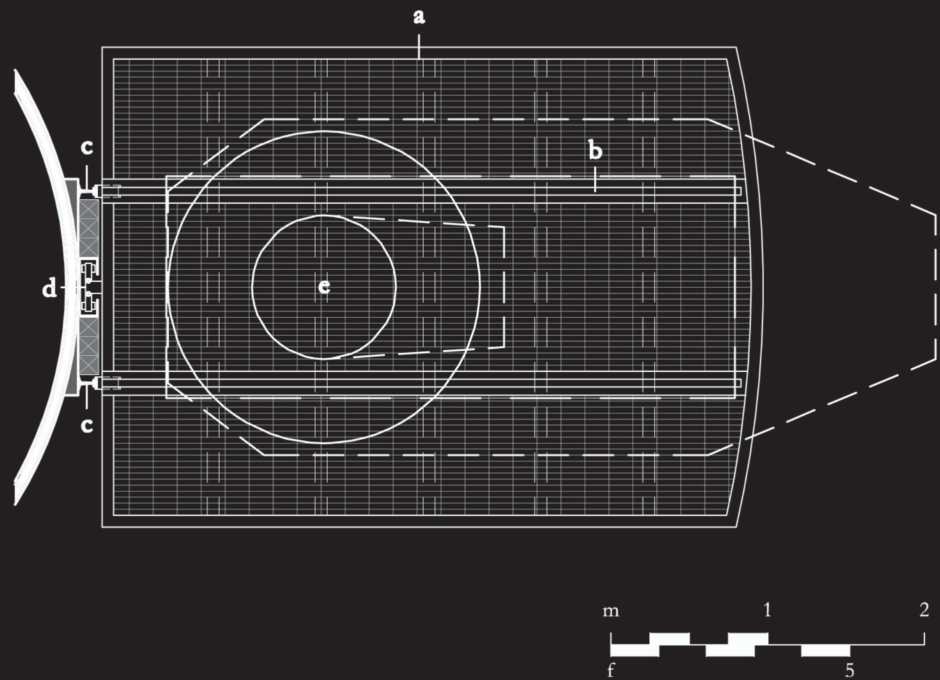
4.4.6 Launching Platform

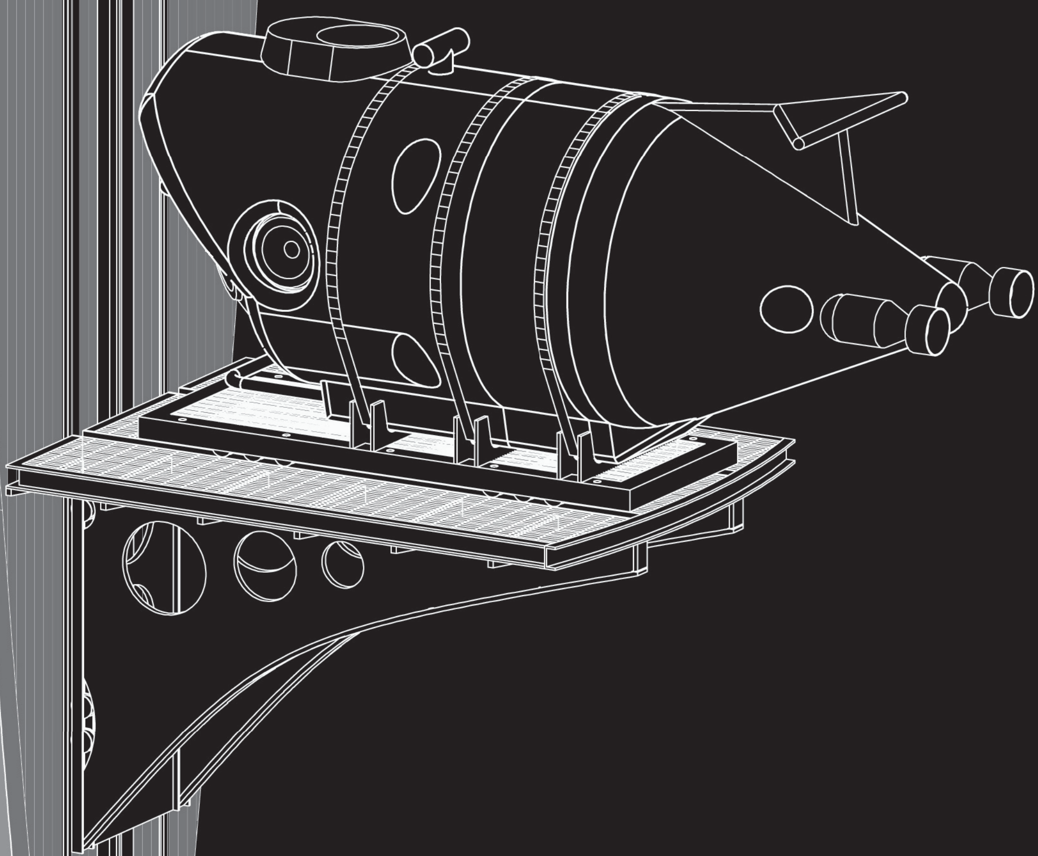
The launching platform is a key feature of this vessel while it is vertical. The launching platform is used to transport, securely and safely, auxiliary craft from the engineering module down through the oceans churning surface to a point below where the effects of the surface motion are greatly reduced. The platform is raised and lowered via winch housed within the engineering module, and runs along a trackway on the spine, to a nominal depth of twenty metres (60feet). At this depth the auxiliary craft can be safely launched and recovered in a much wider range of surface conditions than is possible with a conventional ship. The platform can also be lowered just to the surface of the ocean where it becomes a dock for surface craft. Facilitating personnel, equipment, and cargo transfers while in vertical mode. The platform is controlled from a panel on the working deck and it is lightweight and strong made from aluminium composite panels and sections. It measures three metres by four-and-a-half metres with rails to allow heavy equipment to be easily transferred to and from the vessel. The upper surface is an open aluminium grate allowing the platform to travel through the water without a lot of resistance.

Key

a. Launch Platform
b. Trackway
c. Guiderails
d. Winch cable
e. HOV on docking cradle (secured for transport)

Plan and Axonometric





4.4.7 Unmanned Tethered Observatory

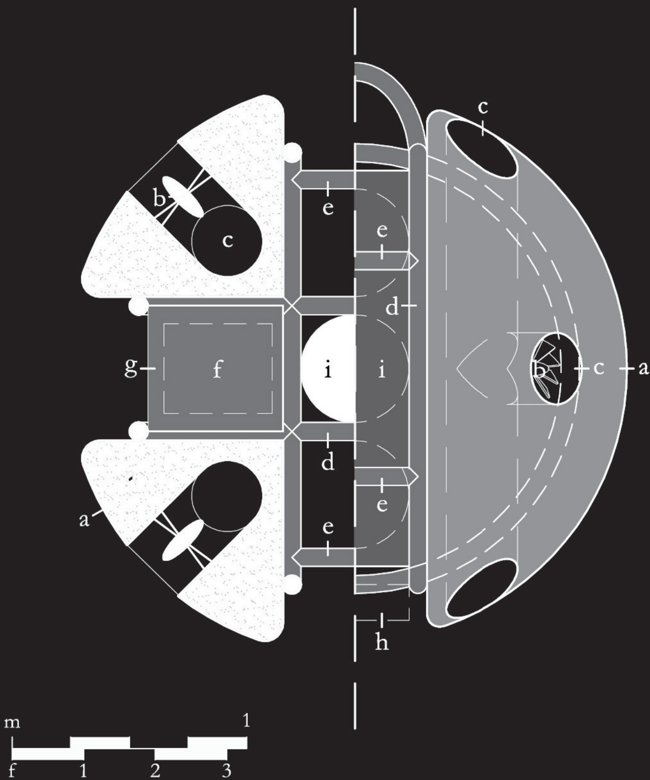
The unmanned, tethered observatory (UTO) is a craft designed to bring high resolution sensors into the deepest parts of the ocean. The UTO can stay down almost indefinitely. Human occupied vehicles have a bottom time of just hours -usually six to eight hours - with another four hours spent in transit. Autonomous underwater vehicles are limited by their batteries; while they can operate for days at a time, the actual active data gathering time is again usually measured in hours. While the UTO, has batteries they are just for emergency backup; it receives its operating power through the tether from the vessel. The UTO is loaded while the vessel is dockside, and is housed in the UTO launch bay in the aft secondary hull for the duration of the mission. When the vessel is in its vertical orientation the UTO can be deployed from its launch bay with a winch that spools out the tether. The UTO has slightly negative buoyancy in the water due to a steel drop weight, in the event of an emergency or massive systems failure this weight is released and at the same time the tether is severed allowing the UTO to rise to the surface and be recovered.

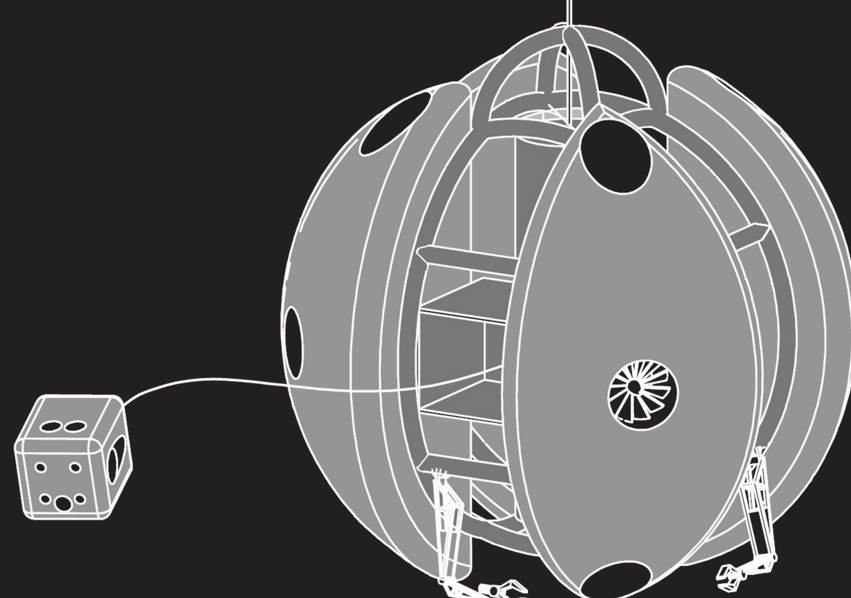
The launch bay is not easily accessible while at sea, so the UTO has to have a wide assortment of sensors and equipment onboard, all with a high degree of reliability or redundancy. This added complexity is necessary for two reasons: first, the UTO operates almost continuously when the vessel is in its vertical mode; second this continuous deployment means that the engineering module launch platform, would not be available for any other use while the UTO is deployed.

Key

a. Syntactic Foam (buoyancy element)
b. Thruster
c. Thruster ports
d. Stainless steel frame
e. Equipment mounting rails (Manipulator arms, Cameras, Lights, Sensors...)
f. Mini ROV w/35metre micro fibre tether
g. Mini ROV Hanger and cable spooler
h. Drop weight
i. Central core (computer, batteries, and other electronics mounted in high pressure resistant glass spheres within a fluid filled housing.
j. Tether (neutrally buoyant w/ power and data conductors)

Plan, Elevation and Axonometric





Epilogue

The ocean, our highway for trade and a growing source of food and mineral wealth, may be vast, but it is finite. Humanity has radically affected this vast complex ecosystem at an ever-increasing rate. Just as we have to turn to it more and more to save us from the ravages we have wrought upon the land. We have continually taken and have only returned pollution to the oceans. Our destiny is intrinsically linked to the fate of the ocean, and we will determine its future through our actions over the next few decades. Either consciously, through intelligent choices, or by default, through ignorance or inaction, this generation and the next will have a magnified impact thereon the course of civilization.

We still have time make choices concerning the fait of sea; choices that will be denied to us in another generation. Over the past one hundred years our actions, or lack of, have already closed the door on options we had, in this time we have changed the ocean more than during all preceding human history, and have set in motion events whose consequences, we do not know, but future generations will inherit. We have taken steps to address this, with the majority of the nations of this world signing a treaty declaring that the deep ocean is common to all owned by none. This first step is an acknowledgement of the ocean's significance to the fait of humankind, that its care is important to all.

The next step is to truly begin to understand this realm, to know it, to have it enter the consciousness of humanity. This vessel and its mission of dedicated, continuous, and open study will greatly help in this process. It brings together many unique abilities that are not currently available. One of its key abilities is the simultaneous access it allows to both above and below the surface allowing continuous access and operations in both. The vessel also supports and deploys many auxiliary craft, both manned and unmanned, with their ability to explore the entire water column from surface to seafloor. Its mobility gives the vessel access to any part of the deep ocean, which covers two thirds of the planet. Also it's extreme stability and strength allowing operations to continue in all but the most extreme weather conditions. Accommodations above and below the surface allowing for both visual and physical access of the ocean to the crew. These abilities of this new vessel will open up our current studies of the ocean allowing us to truly begin to understand it. It will be an outpost that bridges the world above the surface to the world below, helping us to shed our ignorance of the vast realm and allow us to start to make intelligent decisions, and actively decide what kind of a world we want to leave to future generations.

Glossary

Aphotic zone

- The lower layers of the ocean where sunlight never penetrates.

Azoic

- Absence of all life or traces of life.

AUV

- Autonomous Underwater Vehicle - an unmanned, self-contained submersible.

Benthic zone

- The Seafloor.

Bioluminescence

- The generation of light by living organisms using the enzyme luciferase.

Boat

- A relatively small, usually open craft of a size that might be carried aboard a ship.
- An inland vessel of any size.

Current

- A flow of water in the sea, generated by wind, tidal movements, or thermohaline circulation.

DCC

- Decompression/Compression Chamber - an inhabited enclosure in which the atmospheric pressure can be raised and lowered.

Dorsal

- Of, toward, on, in, or near the back or upper surface of an organ, part, or organism.

EEZ

- Exclusive Economic Zone - the area of ocean under limited national control extending from the outside edge of the territorial sea (which covers inland water, harbours and the area out to 12 nautical miles from the coast) out to 200 nautical miles from the coast.

Euphotic zone

- The upper layers of the ocean where sunlight is sufficient for photosynthesis to take place.

Fetch

- The distance over water in which waves are generated by a wind having a rather constant direction and speed.

HOV

- Human Occupied Vehicle - a small manned, self-contained submersible.

HROV

- Hybrid Remotely Operated Vehicle - A small unmanned, submersible that can be configured to operate either autonomously or remotely.

Hydrothermal vent

- A spring of superheated, mineral-rich water found on some ocean ridges.

Moonpool

- An opening in a vessels hull or a platform deck through which equipment is launched and recovered.

Ocean

- One of the five great bodies of seawater defined by continental margins, the equator or other arbitrary boundaries.

Pelagic zone

- The water column.

Radar

- Radio Detection and Ranging - the use of pulsed radio waves to follow moving objects by analysing changes in the reflected radio signals.

Reverse osmosis

- The use of pressure to force water through a semi-permeable membrane, leaving behind any dissolved salts. Used to create fresh water from seawater.

Rouge wave

- A single, unusually large wave amongst much smaller waves. Created by the interference and interaction of the smaller waves.

ROV

- Remotely Operated Vehicle - unmanned submersible controlled and powered from the surface by an umbilical cord.

Sea

- A division of an ocean or large body of saltwater partially enclosed by land. The term is also used for large, usually saline, lakes that lack a natural outlet.

Ship

- A vessel of considerable size for deep-water navigation.

Sonar

- Sound Navigation and Ranging - the detection of objects in or on the water using pulsed beams of sound waves and their reflected echoes.

SPS

- Sandwich Plate System - a new composite material technology, comprising metal plates and an elastomer core.

Submersible

- A small underwater vehicle designed for deep-sea research and other tasks

Thermocline

- Depth at which the rate of decrease of temperature with increase of depth is the largest.

Thermohaline

- Water movement generated by differences density produced by changes in salinity or temperature.

Toroid

- A surface generated by a closed curve rotating about, but not intersecting or containing, an axis in its own plane.

Ventral

- Relating to or situated on or close to the anterior aspect of the human body or the lower surface of the body of an animal.

Vessel

- A craft, especially one larger than a rowboat, designed to navigate on water.

Wave

- The disturbance in water caused by the movement of energy through the water.

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