Designing Ships for Deep Sea Mining

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Abstract

Deep sea Mining ship is one entirely new ship type – a strange mix of an Offshore Support/Construction/ SPS vessel with accommodation for 200+ persons, a Bulk Carrier, a Tanker, a Drill Ship, a FPSO for ore – all in one ship. From a ship designers' perspective, there are not many direct previous references and deep sea mining methods and associated equipment are also a new & developing technology. This paper aims to share our own experiences and some insight into the design process that SeaTech went through during development of this new ship type for this emerging industry.

KEY WORDS

Ship Design, Deep Sea Mining, Ship Motion, Ship-to-Ship Transfer, Dynamic Positioning, Side-by-Side Mooring, Cargo Handling

Introduction

SeaTech Solutions International (S) Pte Ltd, Singapore are the designers of world's first Deep Seabed Mining ship. The ship is now under construction and expected to be delivered next year. The Deep Sea Mining industry is eagerly awaiting commencement of her seabed mining operations and the success of this story will go a far way in accelerating investment in the new industry of Deep Sea Mining.

Deep Sea Mining ship is an entirely new ship type – a strange mix of an Offshore Support/Construction/SPS vessel with accommodation for nearly 200 persons, a Bulk Carrier, a Tanker, a Drill Ship, a FPSO for ore – all in one ship. The exact rule requirements that the Flag Administrations and Ship Classification Societies should apply to such vessels need to be discussed in depth and agreed to by all stakeholders at an early stage. Similarly, there is to be an agreement on the environmental issues and the proposed means of addressing them through design of the ship and the mining process and operations.

From a ship designers' perspective, there are not many direct previous references available, the seabed mining methods and associated equipment are also a new technology and products are still developing. There is no standard method and equipment for processing of mineral ore onboard and above all there is the huge challenge of loading, storage and discharge of ore cargo efficiently in the confines spaces. Associated with the uncertainties of such issues is the uncertainty of weight, space, power, services and maintenance requirements of mining and processing equipment. Local strength for ultra-large loads form appliances for lifting huge mining machines, ship to ship transfer and side by side mooring in deep sea, crew and supplies transfer or other challenges posed.

This paper aims to share our own experiences and some insight into the design process that SeaTech went through during development of this new ship type for this emerging industry.

Deep Sea Mining: Variety of Scenarios

Driven by growth of population and development globally, the demand for precious metals, minerals and rare earths is growing continuously. The current supply from land is gradually diminishing - both in terms of quality and quantity. As against this, the seabed offers abundant supply of some of the key metals such as Copper, Manganese, Rare Earth, Zinc, Nickel and even Gold. Also, the percentage and mineral density of these ores from sea are proven to be much higher than those found on land.

Deep Sea offers a large variety of minerals that can be exploited at different locations in the seas. The minerals come in forms of nodules or deposits in certain areas where there are higher undersea volcanic activities e.g. around the Pacific Ring of Fire, spanning over an area of more than 6 million square kilometres at water depth from 800m up to 6000m.

For example, Sea-floor Massive Sulphides (SMS) and Metalliferous muds are found at water depths ranging between 500m and 4,000m. The key deposits have been found at east, southeast and northeast Pacific Rise and Red Sea. The key products of this mineral include Copper, Zinc, Gold and Silver. There are 250 known deposits, ranging from 1 million to 100 million tonnes each.

On the other hand, Cobalt-rich Manganese crusts muds are found at water depths between 800m and 2,500m. The key deposits occur at South Pacific island states. The key products of such minerals include Cobalt, rare earths, Tungsten, and Tellurium. The resource size is estimated at 6.35 million km2, producing up to 1 billion tonnes of cobalt.

Further, Manganese Nodules are found at water depths between 4,000m and 6,000m. The key deposits occur at Clarion-Clipperton zone, Peru Basin, Southern Ocean, and North Indian Ocean. The key products of this mineral include Cobalt, Copper, Nickel, Manganese, and rare earths. The total tonnage from known sites is estimated to be in the range of 100 to 600 million tonnes.

Methods of Deep Sea Mining

The methods to extract the mineral ores from the seabed depend very much on the properties of mineral, the geology and the water depth. Different methods are used according to the specific needs and characteristics of the seabed mining operations.

For mining in shallow waters, traditional four basic methods are: i) Scrapping the surface of the seabed, ii) Excavating, iii) Fluidizing and iv) Tunneling. (See Fig. 1)

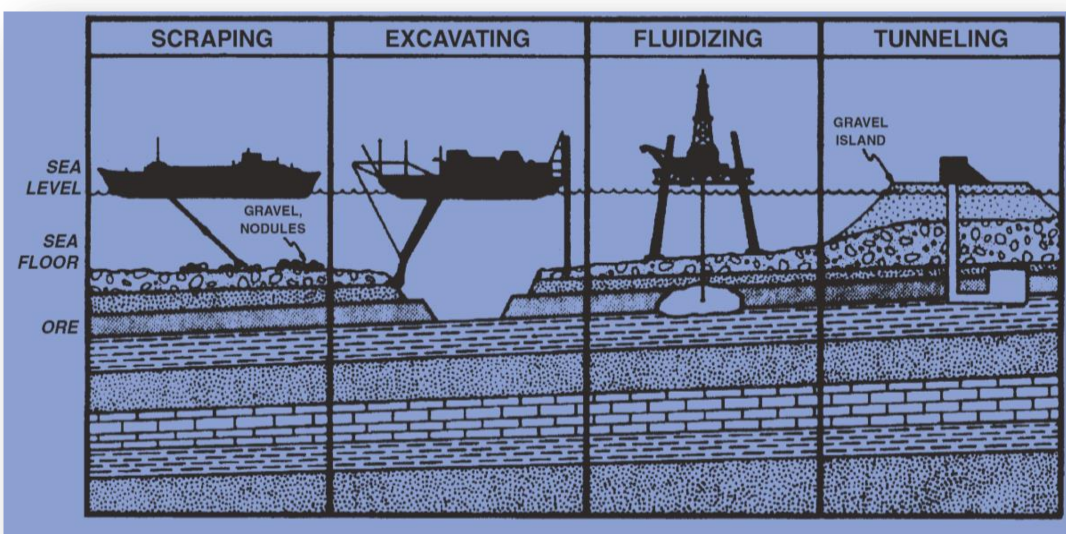

Fig. 1 Methods for Mining in Shallow Waters

However, for deep sea mining, novel solutions have to be specially evolved; not only for the transportation of minerals from seabed to surface; but also for offloading and transportation logistics from deep sea to shore. Every deep sea mining operation is unique - depending on the method of mining, the area of operation, the depth of operation, the types of deposits, and the endurance required. Different environmental conditions at different locations require different logistics which directly affects the design of a Deep Sea Mining Vessel and poses a huge impact on economic viability.

It is easily seen that in case of deep sea mining there cannot be one standard method or ship and one size will not fit all. Deep sea mining is not one typical scenario, but various different scenarios depending on the mineral, water depth, locations and logistics. Deep Sea Mining Vessel requires a lot of customization to achieve fit for purpose design suitable for specific operations. Ship designers are integrators who must ensure that all technologies work together as one. Deep sea mining involves collaboration of several technologies include ship design, ship building, cargo handling, dynamic positioning, ROV and power system, to name a few. It is critical for the vessel to be capable of meeting the typical Requirements of a Deep Sea Mining Vessel.

World's First Deep Sea Mining Vessel

The world's first Deep Seabed Mining ship, *Nautilus New Era*, was launched early this year at the Mawei Shipyard, China and is scheduled for delivery in 2019. The dynamically-positioned vessel will be used by Nautilus and its partner Eda Kopa (Solwara) Limited to undertake deep sea mining operations at the Solwara 1 Project site, in the Bismarck Sea off Papua New Guinea. Solwara 1 will be the world's first commercial high-grade seafloor copper-gold mine project.

Fig. 2 : World's First Deep Sea Mining Vessel- *Nautilus New Era*

The Deep Sea Mining industry is eagerly awaiting commencement of her seabed mining operations and the success of this story will go a far way in accelerating investment in the new industry of Deep Sea Mining.

The vessel designed by SeaTech Solutions International (S) Pte Ltd, Singapore measures 227 M x 40 M x 18.2 M and has a displacement of 100,000 T at the design draft of 13.2 M. She accommodates up to 199 people and has power generation capacity of 32 MW. It is a unique and new ship type which has functionalities of many specialized ships, such as - drillship, bulk carrier, tanker, offshore construction vessel etc. all in one ship. Thus, a mix of rules and regulations were considered based on our experience with designs of multiple types of ships and the applicable set of rules & regulations and the Class Notations were discussed and agreed with both Class and Flag.

Nautilus New Era is capable of providing full support for the mining operations i.e. support for the specialized Seafloor Production (Mining) Tools (SPTs), Riser & Lifting System (RALS) which bring the ore up from the seabed, the Seafloor Production Equipment (SPE) for processing onboard and the ROV's that support the subsea operations.

Additionally, the vessel houses the huge launch and recovery systems (LARS) that handle the 300T SPTs and equipment for Vehicle Control and Maintenance, Product pumping from the seafloor, Product Dewatering, and Product Offloading. The vessel is equipped with a 10 M x 10 M moon pool through which the Subsea Slurry and Lift Pump (SSLP) and riser system are deployed.

Nautilus New Era provides a stable platform for operations. Using world-class dynamic positioning technologies, and 7 thrusters totalling 21 MW power, she is capable of staying at Solwara 1 location in the Bismarck Sea; in the envisaged wind and wave conditions. The vessel will be designed for use in offshore construction and seafloor mining. It employs many new technologies for very specialized mining operations and the side by side transfer of ore from the vessel to the handy-size bulk carrier export vessels.

Environmental Requirements of Deep Sea Mining

Seabed Mining companies have the obligation to minimize the impact of its operations on the environment and comply with the local /international environmental laws and regulations. Careful Environmental Impact Assessment needs to be conducted for every mining project considering various causes that can cause environmental disturbance. (See Fig. 3).

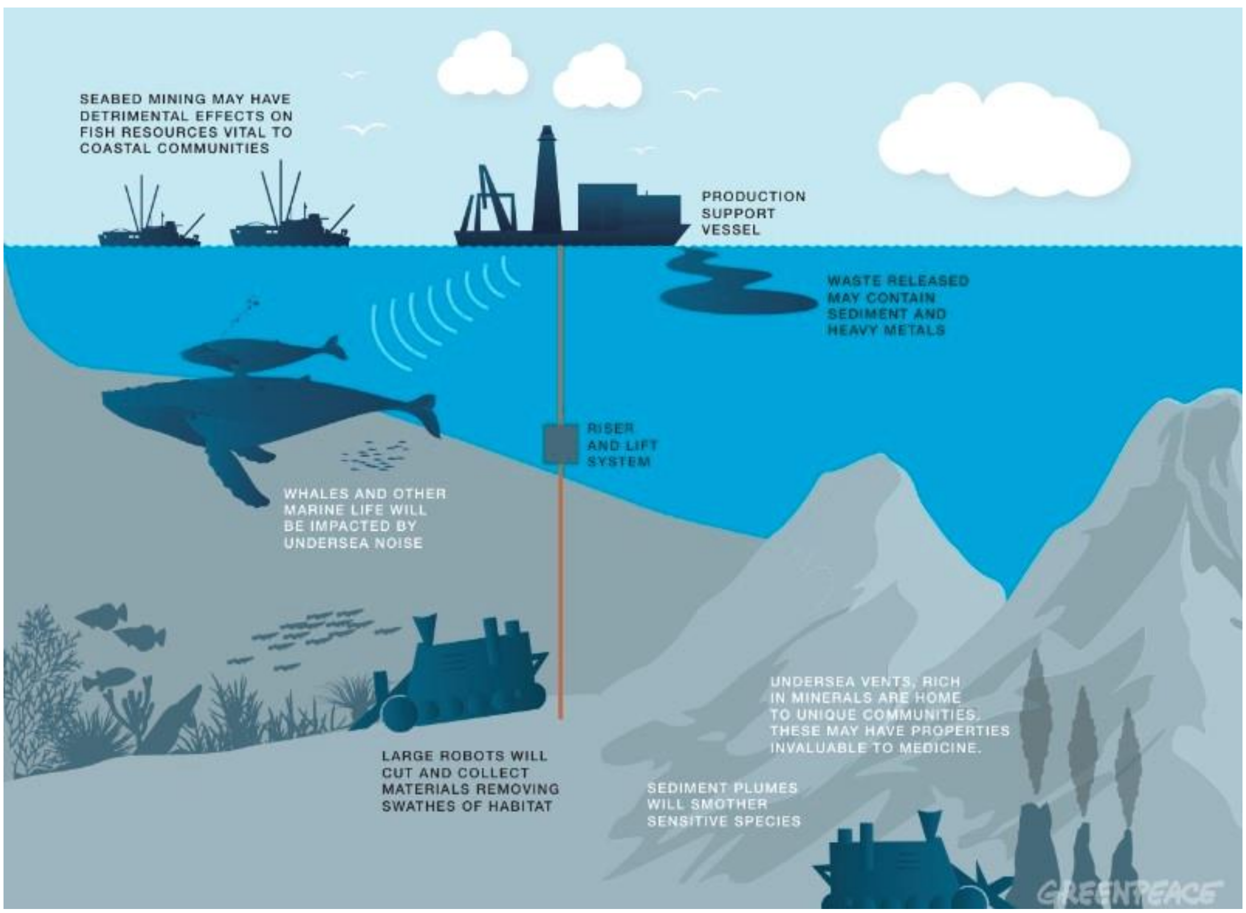

Fig. 3 : Possible causes of Environmental Impact from Deep Sea Mining Operation

The Seafloor Production Tools may affect water quality by generation of suspended plumes of sediment in a number of ways - plumes may be generated when the SPT lands on the seafloor after being lowered from the sea surface and also as it moves along the seafloor. As ore is cut during mining activities, finer fractions of the cut ore may escape the SPT cutter head and suction system and generate plumes.

Similarly, attention needs to be paid to the Return Water Plumes. Ore collected at seabed may be pumped as slurry to the vessel via the RALS. Once onboard the vessel, the ore is dewatered and the slurry water still containing solids; albeit of small particle size <8 μm in diameter has to be disposed of off the ship and returned to sea. The method of this disposal must be such as to cause least disturbance to the environment. It would be a good idea to return it the same space as it was taken from and without much turbidity and temperature difference. The discharge velocity and the distance above the seafloor are to be chosen such as to minimize the impact of the returning water on seafloor.

Other potential causes of impacts to water quality include small hydraulic fluid leaks, fuel spills during transfers at the site of the MSV, ore spills during transfer to barges and bulk ore carriers and accidental collisions resulting in loss of vessels.

All such requirements of course pose additional demands on the mining system as well as on the ship design.

Operational Requirements of Deep Sea Mining

Each seabed mining project is different in terms of minerals to be exploited, Method of mining/uplift, Water depth, Current, Wind and wave environment, Distance from shore, etc. and accordingly the actual methods and operations will vary from project to project. However it can be generalized into : a) Mining & collection of ore on seabed, b) Uplift of the mined ore from seabed to the ship above, c) Processing (mainly de-watering) of ore onboard, d) Storage and retrieval of the ore, e) Side by side mooring, f) Transfer of ore to export vessels, and of course g) The Dynamic Positioning. Fig. 4 below shows a general overview with the various systems that are integrated on the vessel to support these various operations.

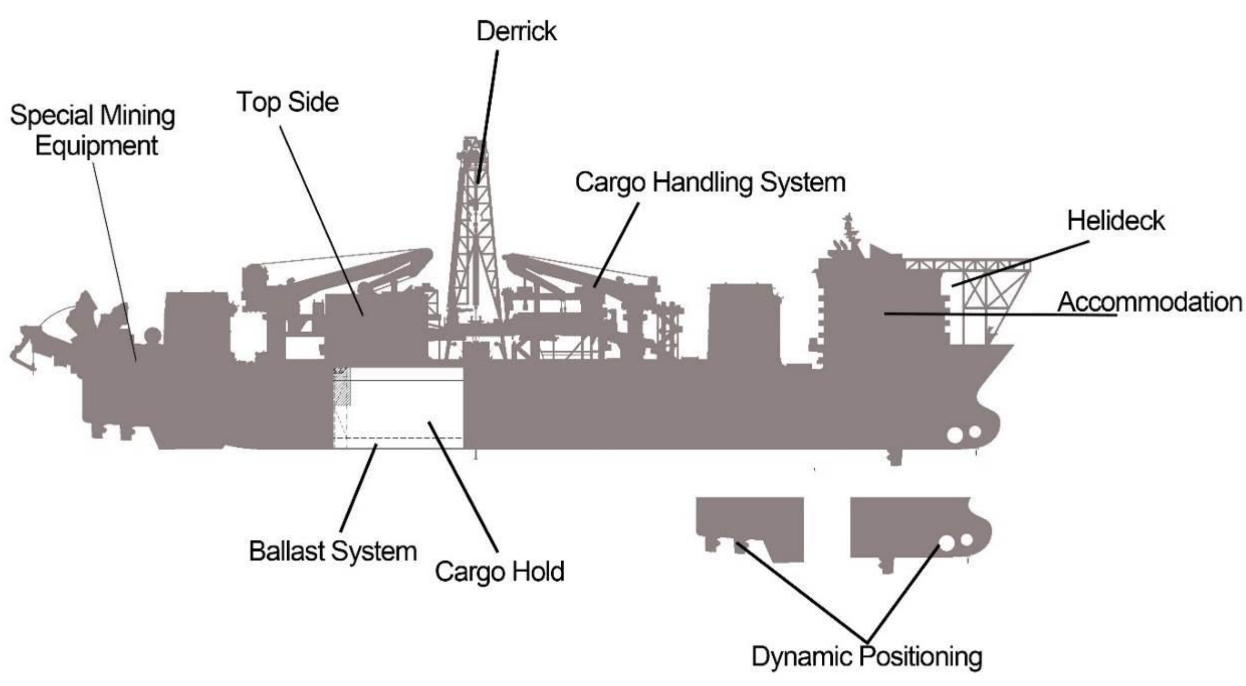

Fig. 4 : Various systems on a Deep Sea Mining Vessel

Apart from the specific mechanical and structural requirements for efficient and safe functioning of each one of these systems, one important consideration is their requirement of electric power. The total power to be installed onboard requires careful consideration of the simultaneous power demand for operations of various systems in various operational modes and also in different weather conditions. For example, the DP power requirement is substantial in extreme weathers, however in these conditions full mining may not be feasible or required and therefore the total power can be optimized without any loss in efficiency practically losing in optimization of mining vessel design.

The mining machines operate remotely on the seabed and are powered from the mining vessel. These machines may carry out specific functions like levelling, bulk cutting and collecting etc.; or they could be multi-tasking. These machines are typically developed using well-proven land based hard rock mining technology and the subsea trenching and remote control technology. The power requirement of these machines is large, usually in the range of 1000-4000 kW each and considering the large lengths of power cables for operations in deep waters, the system voltage needs to be higher to minimize the power loss in transmission. These huge machines weighing in excess of 300 tonnes are deployed from the mining vessel using a lifting frame (LARS) and operated via a power and control umbilical. The static + dynamic loads on the lifting wire are indeed very large in the region of 1000T and therefore the reactions on the foundations of the lifting frames, the spooling devices and the winches are very large, posing a large demand for the under-deck supporting structure located in the busy under-deck space.

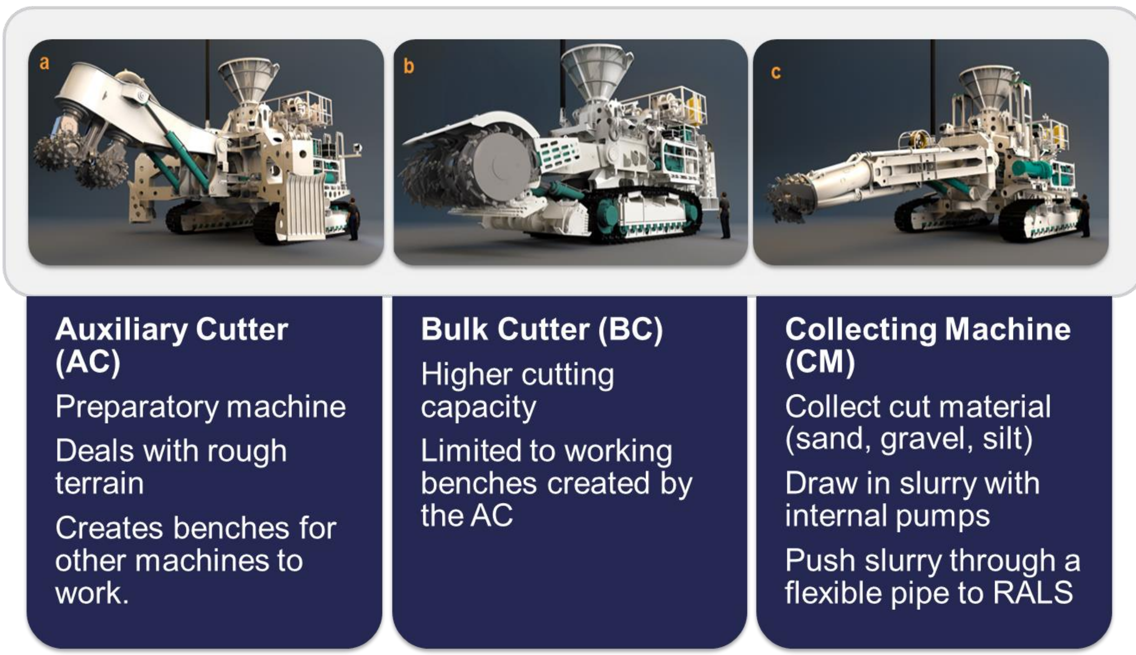

Fig. 5 : Large Mining machines Working on Seabed

The Riser and Lifting System (RALS) is designed to lift the mined material to the Production Support Vessel (PSV) using a Subsea Slurry Lift Pump (SSLP) and a vertical riser system. The seawater/ore slurry is delivered into the SSLP at the base of the riser, from where it is pumped to the surface via a gravity tensioned riser suspended from the Derrick Tower on the PSV. The riser pipes are deployed towards the seabed by a derrick and draw works system onboard the vessel.

Design of Mining Vessels - Special Features and Challenges

Design of any ship is a creative yet challenging experience. Ship design is a decision making process commencing from a set of owner specified operational requirements and performance guarantees to a fully defined Technical Specifications and detailed drawings for construction covering all matters of Hull, Machinery and Outfit in compliance with the Rules and regulations. Through a series of sequential iterations as shown in Fig. 6 below, an optimized solution is obtained within the constraints imposed.

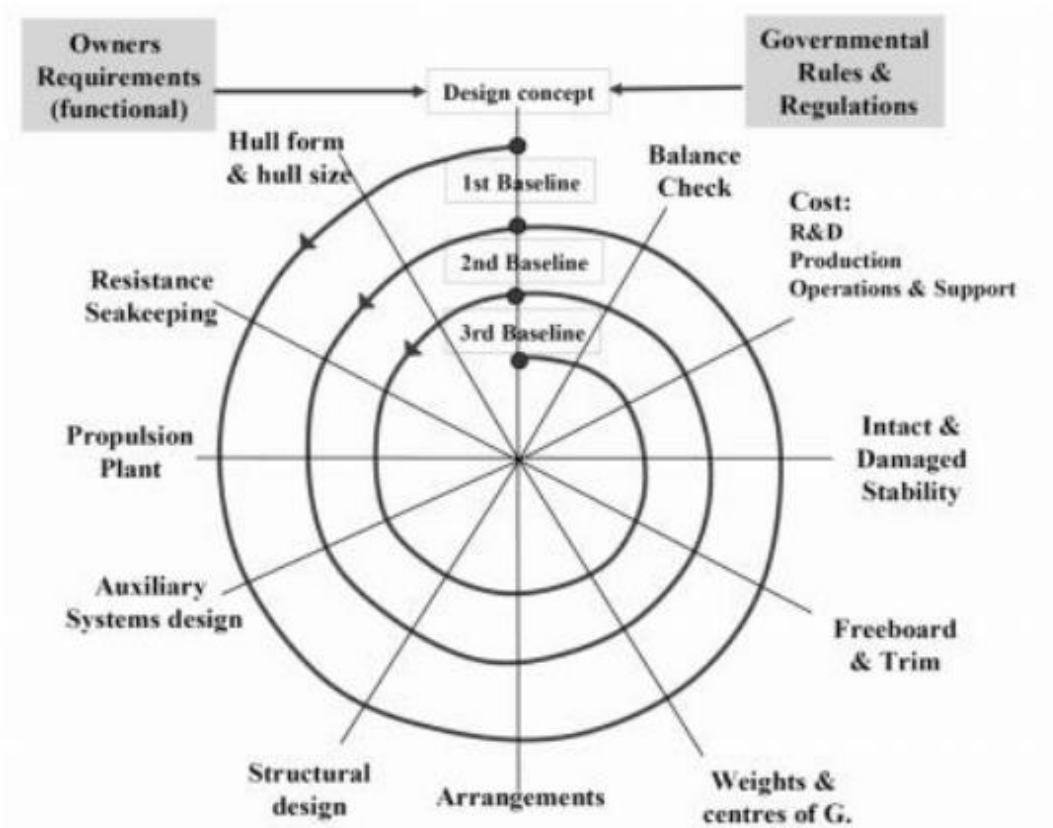

Fig. 6 : Typical Ship Design spiral

As compared to the normal merchant vessels, the deep sea mining vessel is very complex ship wherein many systems are integrated together. Additionally, some of the systems are evolved for the first time from their land based versions to account for the marine dynamics and consequently their design specifications are prone to frequent changes. Therefore the design spiral for a mining vessel involving complex multi systems and multiple stakeholders is not only larger but also longer time-wise.

From our experience of the concept to the final design, there were many surprises especially in terms of the footprint, weight, power and service requirements for most mining systems. We would recommend that unlike the sequential approach of the design spiral, the design process to be more concurrent and collaborative with all stakeholders, so that bias in one area does not limit feasible options in another.

It is very essential to consider the overall logistics of the entire mining operations in order to obtain an optimized design solution that will ensure safety as well as reduce the CAPEX and OPEX.

The optimization of overall logistics will include issues such as following:

- Gross mining on seabed
- Preparation of ore for uplift
- Uplift
- Processing Ore onboard
- Storage of Ore on-board & Retrieval
- Offload to Export Vessel
- Delivery to onshore facility
- Crew transfer
- Supplies to Mining Vessel
- Supplies from Mining Vessel to the field vessels

There are not many previous references for Mining Vessel as the seabed mining methods and associated equipment are a new technology, still under development. With no standard method and equipment for processing of mineral ore on seabed or onboard the vessel, there are several challenges present to overcome.

The design of vessel's storage & discharge of mineral cargo in confined spaces is specially challenging. Associated uncertainties of weight, space, power, services and maintenance requirements etc. can put the initial "well thought-out" ship design at huge risk. Sufficient design margins and constant & strict budget control are absolutely necessary for each technical aspect.

Size matters, in many ways. Larger vessel means there will be greater economy of scale, reduced motion, more areas and larger spaces and increased power to keep position. However, these benefits come with higher CAPEX & increased financial risks.

The vessel will be required to accommodate ultra-large loads due to tall and heavy mining equipment and modules, as well as their lifting/handling equipment/winches. As such, the vessel's local ship strength will be more important than global strength.

Cargo handling is another tough challenge to overcome, where getting ore back from the hold is perhaps as difficult as getting up from the seabed! Extensive study and planning is required to facilitate and optimize the process of cargo handling onboard the vessel.

During cargo discharge, conveyors, cranes and bucket elevators are used to discharge cargo to export vessel. In order to offload the ores to another vessel for transport to shore, Side–By-Side Mooring with the Export Vessel is critical. The Mining Vessel is required to offload the mined ores to the export bulk carrier while the vessel remains in position DP mode and the bulk carrier is moored side by side.

The economic viability of Deep Sea Mining largely depends on powering and the energy spend over the entire logistics. It is noted that the mining operation itself consumes a large amount of energy. Greater attention needs to be paid to the method of uplift of ore, especially when the operation is in deeper seas.

Finally, the design of the Deep Sea Mining Vessel must be fit for purpose and cost effective to minimize the financial risks. When mining operations vary from location to location, the vessel should be capable of adapting quickly through modular design of vessel to accommodate different equipment efficiently. Further, for such new industry, the financiers look to cover the risk of failure of the mining operations, for whatever reasons - technological, political, environmental etc. For this purpose, the vessel design must be fit for alternate use with little modifications. The required flexibility is therefore to be built-in right from the start.

Looking Forward….

Deep sea mining is soon becoming a reality with the operations of the world's first deep sea mining vessel expected to commence in late 2019. The Deep Sea Mining industry is eagerly awaiting the outcome of this project. Many rich mineral deposits have already been established and waiting for commercial exploitation. The success of the *Nautilus New Era* story will go a far way in accelerating investment in Deep Sea Mining. The design of deep sea mining ships needed for the future projects must allow for flexibility and for improvements based on "learn-as-we-operate" strategy as we cautiously deal with the unexpected challenges and mysteries of the oceans.