A REPORT

ON

UNDERWATER SEARCH AND RECOVERY

BY

Names of the students	**ID. numbers**
MOHIT MAURYA	2018A3PS0542G
PATNANA VENKATA SAI	2018AAPS0468G
TANAY KUMAR	2018A8PS0574H

AT

Maritime Research Center, Pune

A Practice School-1 Station of

BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE PILANI

(June, 2020)

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Title of the Project: UNDERWATER SEARCH AND RECOVERY

STUDENTS:

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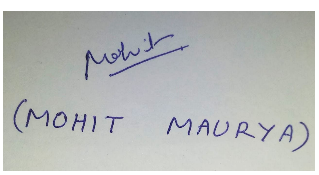
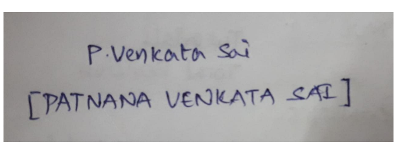
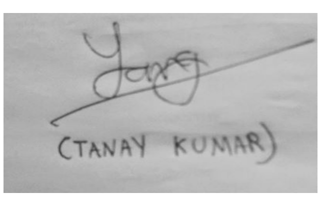
Project Areas: State of art in Technology, Modelling and Regulatory framework in Underwater Search and Recovery operation.

Abstract

Industrial training and experience are quite important for a future engineer. It helps them to explore the insights of industry. Through this report, we wish to tell our internship experience at the Maritime Research Centre, Pune. Through our project we have discovered the fundamental steps involved in underwater search and recovery for any given distressed vehicle. We have done a substantial amount of literature survey reading about many such operations carried out by different organizations globally which has helped us to decide on what the course of action should be for future recovery processes. Our specific focus has been on the Indian ocean region for which an exhaustive study of present technologies deployed has been done and a comparison has been made to look for the use of technology that is both efficient and economical. We have also compared various organizations that do the same work that is required as a part of this process and have proposed certain norms and deals that the coast guard can sign with these organizations to make the process obstacle free and efficient in the Indian Ocean Region.







Signatures of Students **Signature of PS Faculty**
Date: 27/06/20 **Date:**

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1. Introduction

No environment is more extreme and dangerous in its hostility than the deep ocean/sea. Intense cold, tremendous pressures and the total absence of light combine to make the deep sea the most difficult region in which man has to work for various activities.

Underwater search and recovery refers to the search, recovery, and salvage of objects with high value (e.g., aircraft black boxes, underwater vehicles, and crashed vehicles) that are lost on the seabed. The search and recovery of underwater objects has two main steps. In the search step, the underwater position of the salvage object needs to be accurately obtained as a prerequisite for underwater recovery. Depending on whether the salvage object carries acoustic beacons, the underwater search can be divided into two types: onboard acoustic signal search and near bottom sweep search and search. Once the underwater position of the salvage object is accurately known, it can be recovered and salvaged with a deep-sea recovery system in the recovery step.[1]

Traditionally, recovery and salvage at sea refers to handling emergencies in offshore and shallow-water areas (water depth of several hundred meters), especially in navigation channels. However, deep-sea areas with a depth of more than 2000 m account for 84% of the oceans. Therefore, most of Earth's surface is covered by deep sea. [2]

Underwater search and recovery is essentially about estimating a search area by quantifying a number of unknowns (the last known position, the object type and the wind, sea state, and currents affecting the object), then compute the evolution of the search area with time and rapidly deploy search and recovery units (SRU) in the search area. [3]

As human activities continue to expand into deep seas, such as the airline crashes of Air France 447 and Malaysia Airlines MH370, new challenges are arising for deepsea search and recovery.

As we were not able to achieve the goals of the operation like in the case of Malaysia Airlines MH370, Air France 447 there's a need to build efficient mathematical models that can ease our search and recovery operation.We also need to work on technology aspects to get better performance and to make it even more efficient.

The Indian Ocean Region (IOR) is strategically gaining substantial relevance, resulting in the massive maritime build-up. The increasing maritime build-up, exposes us to vulnerabilities related to accidents and losses at sea. Underwater Search and Recovery (UWSAR), is becoming critical, thus effective & efficient capability and capacity building is inescapable. The entire process of UWSAR has multiple dimensions and the sequence of steps to be taken, needs to be understood.

2. <u>Underwater search and recovery objects</u>

Underwater salvage objects mainly include aircraft black boxes, damaged underwater vehicles (e.g., ROVs, AUVs, submarines, etc), and other objects lost on the seabed (e.g., deep-sea landers, aircraft, ships, tankers and military targets).

2.1. Aircraft black boxes

An obvious advantage of conducting submarine searches for aircraft black boxes is that such objects are equipped with underwater positioning beacons, whose acoustic signals can be picked up by the shipboard acoustic positioning system. When an aircraft crashes in a vast ocean, the seabed search for the black box faces several great difficulties. First, obtaining a relatively accurate crash location is difficult, which makes the search scope very large. For example, researchers analyzed the “handshake signal” between aircraft and satellites and between satellites and ground receiving stations to determine the area where Malaysia Airlines MH370 may have crashed. The area was approximately 60,000 km2 with an average water depth of 4000 m and maximum depth of more than 7800 m. Second, the lack of ocean-related data increases the search difficulty. For example, the Malaysian Airlines MH370 crash area did not have an accurate multi-beam topographic map. Instead, satellite altimetry was used to retrieve the topographic map of the seabed with limited accuracy. [1]

Aircraft carry simple water activated acoustic transmitters to mark the location of the flight data recorder, the so-called “black box.” The concept of operations for these “pingers” was originally quite simple: when an aircraft crashed the sound emitted by the pingers would help recovery teams home in on the black box for prompt recovery and analysis. In this operation the location of the crash is presumed known. With an entry point known, a 30 day window to find the specific locations of the flight data recorders was seen as entirely adequate. The tool was designed for a specific requirement with the assumption that aircraft crashing into the sea would do so while being monitored from shore, providing a good starting point for undersea search and recovery operations. This held true in incidents such as TWA flight 800 and Egypt Air flight 990. [4]
Unfortunately, two recent airline incidents, Air France flight 447 and MH370, have presented situations where the crash site was not precisely known. In the case of Air France 447 the story of the accident and the search for the lost airframe has been widely reported. [5]

Fig. 2.1 Malaysia Airlines (MH370)[20]

Fig. 2.2 Air France 447[21]

In the case of MH370 the circumstances remain in flux. But in both cases, the objective was to locate a flight data recorder without knowing the exact location, or circumstances, of the aircraft loss. Especially in a remote ocean region, this is an entirely different requirement from that originally presented to aviation pingers. The objective here is first to find the airframe or debris field and then begin homing in on key items such as the flight data recorders. [4]

2.1.1. Aviation pingers

Pingers (also called underwater locating devices (ULD)) are the most basic type of undersea locator. They simply transmit a simple signal, a ping, upon a trigger. This can be contact with water or some other change, such as loss of power. In the case of black boxes the pingers are water activated. Because a pinger issues a signal constantly it begins draining the battery immediately. While certain pingers can be designed to delay the onset of transmissions, known as a time delay pinger, this is not the approach used by aviation pingers today. The key parameters of an aviation pinger are shown in table 1 [4].

Frequency	37.5 kHz (+/- 1 kHz)
Acoustic Output re 1µPa@1m	160.5 dB
Pulse Length	10ms
Pulse Repetition	1 pulse/sec

Table. 2.1 Typical "black box" pinger specifications [4]

These specifications can be met with a compact (usually within 12 cm long by 3.5cm diameter) and light (under 200g) device, even given the requirement to withstand pressures to full ocean depth (6,000 meters). These mechanical specifications are desirable as airliners strive to conserve space and minimize weight. Fig. 2.3 shows a pinger attached to a flight data recorder.[4]

Fig. 2.3 A flight data recorder with a pinger attached[4]

To address challenges seen in recent events, prior to MH370, regulatory guidance has evolved. [15] New black box pingers will slowly be required to provide 90 days of pinging. This is a factor of three increase from the current 30 day requirement. In addition there is upcoming guidance on “airframe locator” specifications. This will require 8.8 kHz transmissions and an increase in source level to 180 dB. This will increase the size of the pinger device to roughly 15 cm long by 5 cm diameter with weight increasing to just over 700 grams. This is an important evolution as it provides increased detection range.[4] Approximate ranges of detection are shown in table 2.

Frequency	Source Level	Approximate Detection Range
37.5 kHz	162 dB	Typical 2-3 kms depending on sea conditions
8.8 kHz	180 dB	Typical 3-4 km depending on sea conditions

Table. 2.2 Approximate aviation pinger detection range [4]

Recognizing that ocean depths can exceed 6km and average ocean depth is over 4km it becomes clear that these improvements are modest. When detection ranges are approximately the same as the ocean depth this requires the search system to effectively pass right over the pinger to detect it. In the case of MH370 the estimated search zone has been estimated at some 60,000 square km, a huge area to cover even with 90 days of pinging. Simple pingers might not be the answer.[4]

There are a large variety of technologies available that might improve the prospects of finding lost airliners in deep water. These are all currently available on the open commercial market and can be made compatible with the rigors of aircraft deployment. One of them is Transponder. A transponder can be much like a pinger in that it can be triggered by an external event, such as entering the water. But a transponder is a bit "smarter." It can enter a standby mode and wait for a signal, what we call interrogation. If a pinger always shouts "here I am" a transponder waits for the question "where are you" before responding. With modern electronics a transponder can wait for an extended period, perhaps years, in this standby mode. Thus a search effort would face much reduced time pressure.[4]

2.2 Underwater vehicles

Continuous developments in science and engineering technology have increased the operating depth and working time of various types of underwater vehicles (ROV/AUV). However, the unusual complexity of the water surface and underwater environment means that underwater vehicles inevitably experience various kinds of component failures (e.g., sensors, cables, software systems, actuators, and buoyancy materials). In general, these underwater vehicles operate at depths of several kilometers or under thick ice, so the failure of any part has catastrophic consequences. [1]

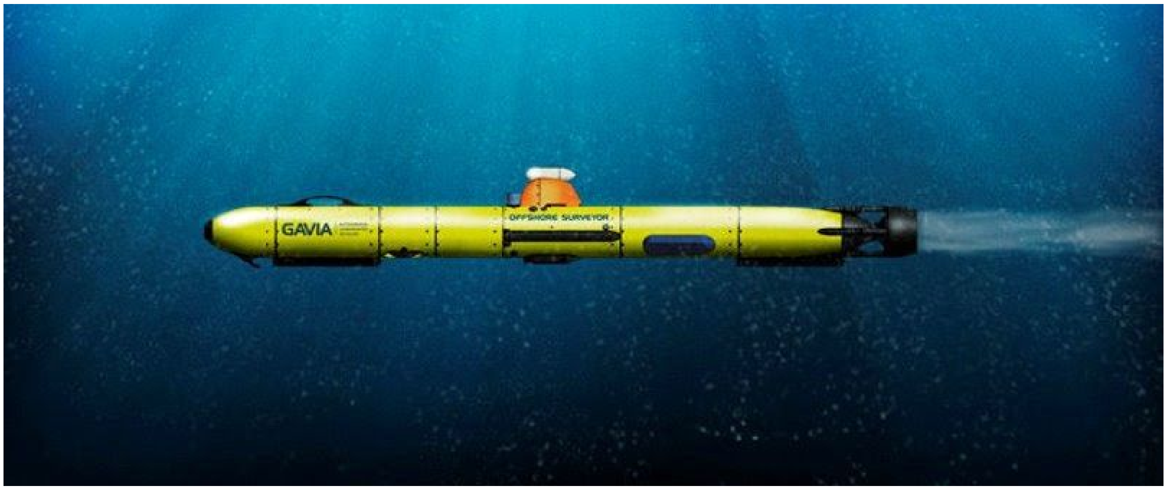

Fig 2.4 Autonomous Underwater Vehicle (AUV) [19]

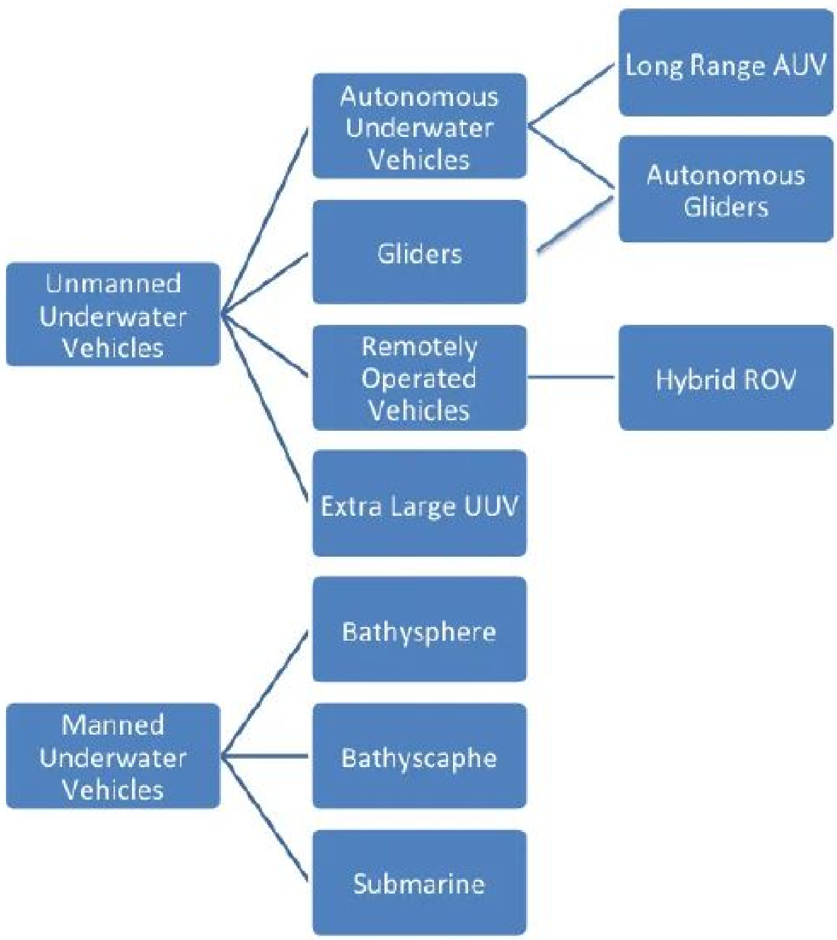

Fig. 2.5 Types of Underwater vehicles

As the deployment of **Submarines** increased in the Indian Ocean region (IOR) the risk of submarine disasters also increased.Hence for submarines, depending on the type (nuclear or non-nuclear) a large large search and recovery (SAR) operation is required.
For eg: On the morning of August 12th 2000, a Russian submarine (Named: Kursk) sank in international waters east of Rybatschi Peninsula in the Barents Sea. The submarine, a Russian Oscar II class attack submarine, sank to a depth of 116 meters, north-east of Murmansk about 250 km from Norway and 80 km from the coast of Kola. Hence for this case, a huge radiation survey and a huge SAR operation took place.

Fig. 2.6 Russian nuclear submarine (Kursk) that went into an accident[22]

2.3 Others

The deep-sea lander can be equipped with a variety of sensors and cameras for long term, fixed-point, and continuous in situ observations of the deep-seafloor and has been widely used in modern oceanic expeditions. In recent years, several deep-sea landers have been lost on the seabed. Because they record a large amount of valuable data, salvaging them would have great significance. These landers have a large number of hookable and force-receiving positions that can be remotely linked to recovery and salvage equipment through the design of suitable mechanical mechanisms.[1]

3. Marking of the last known position of the distressed object

The process of location of the distressed vehicle can be done by the use of different technology depending on the nature of the distressed object.

3.1. Airplane

The various technologies that can be deployed to trace the last known location of the Aircraft can include satellite communication and tracing with the help of conventional radar systems.

3.1.1. Satellite communication

The satellite-tracking system is operated by a trio of companies: **Aireon, SITAONAIR, and FlightAware**. It uses a constellation of 72 communication satellites operated by US firm Iridium (whose main business is selling satellite phones connected to its network). The flights will be tracked using an industry-wide standard known as “automatic dependent surveillance – broadcast” or ADS-B, which usually shares data on flight location via ground-based receivers. Using satellites will offer more comprehensive coverage in remote regions. Various technologies that can be deployed to trace the last known location of the Aircraft can include Global Navigation Satellite System(GNSS) and tracing with the help of conventional radar systems. In the past, primary radar was used but now a more advanced Secondary Surveillance Radar (SSR) is in use.

Malaysia Airlines was the first SITAONAIR airline customer to benefit from this revolutionary flight-tracking partnership. Under the agreement, all Malaysia Airlines aircraft will have access to minute-by-minute, 100% global, flight-tracking data, delivered by SITAONAIR’s AIRCOM FlightTracker.

ADS-B

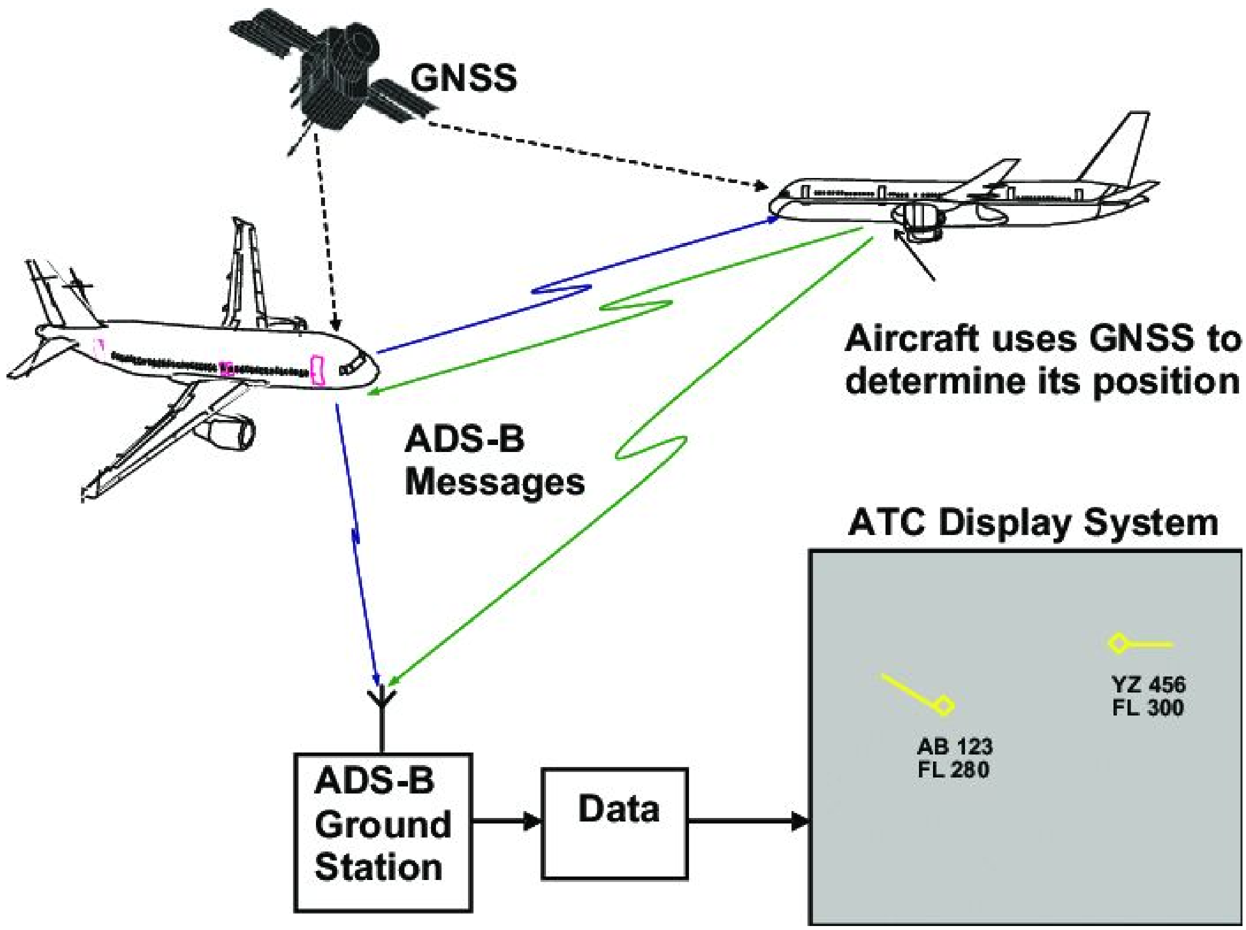

Fig. 3.1 Automatic Dependent Surveillance-Broadcast (ADS-B) system [7]

ADS-B is a system in which electronic equipment onboard an aircraft automatically broadcasts the precise location of the aircraft via a digital data link.

The data can be used by other aircraft and air traffic control to show the aircraft's position and altitude on display screens without the need for radar.

The system involves an aircraft with ADS-B determining its position using GPS. A suitable transmitter then broadcasts that position at rapid intervals, along with identity, altitude, velocity, and other data. Dedicated ADS-B grounds stations receive the broadcasts and relay the information to air traffic control for precise tracking of the aircraft.

Automatic – Requires no pilot input or external interrogation.

Dependant – Depends on accurate position and velocity data from the aircraft's navigation system (eg. GPS).

Surveillance – Provides aircraft position, altitude, velocity, and other surveillance data to facilities that require the information.

Broadcast – Information is continually broadcast for monitoring by appropriately equipped ground stations or aircraft.

ADS-B data is broadcast every half-second on a 1090MHz, digital data link.

Broadcasts may include:

- Flight Identification (flight number callsign or call sign)
- ICAO 24-bit Aircraft Address (globally unique airframe code)
- Position (latitude/longitude)
- Position integrity/accuracy (GPS horizontal protection limit)
- Barometric and Geometric Altitudes
- Vertical Rate (rate of climb/descent)
- Track Angle and Ground Speed (velocity)
- Emergency indication (when emergency code selected)
- Special position identification (when IDENT selected)

The ability of a ground station to receive a signal depends on altitude, distance from the site and obstructing terrain. The maximum range of each ground station can exceed 250 nautical miles. In airspace immediately surrounding each ground station, surveillance coverage extends to near the surface.[6]

Currently using the ADB-S system isn't economically viable and hence conventional radar systems are used to track the airplanes in India and IOR.

3.1.2. Radar system

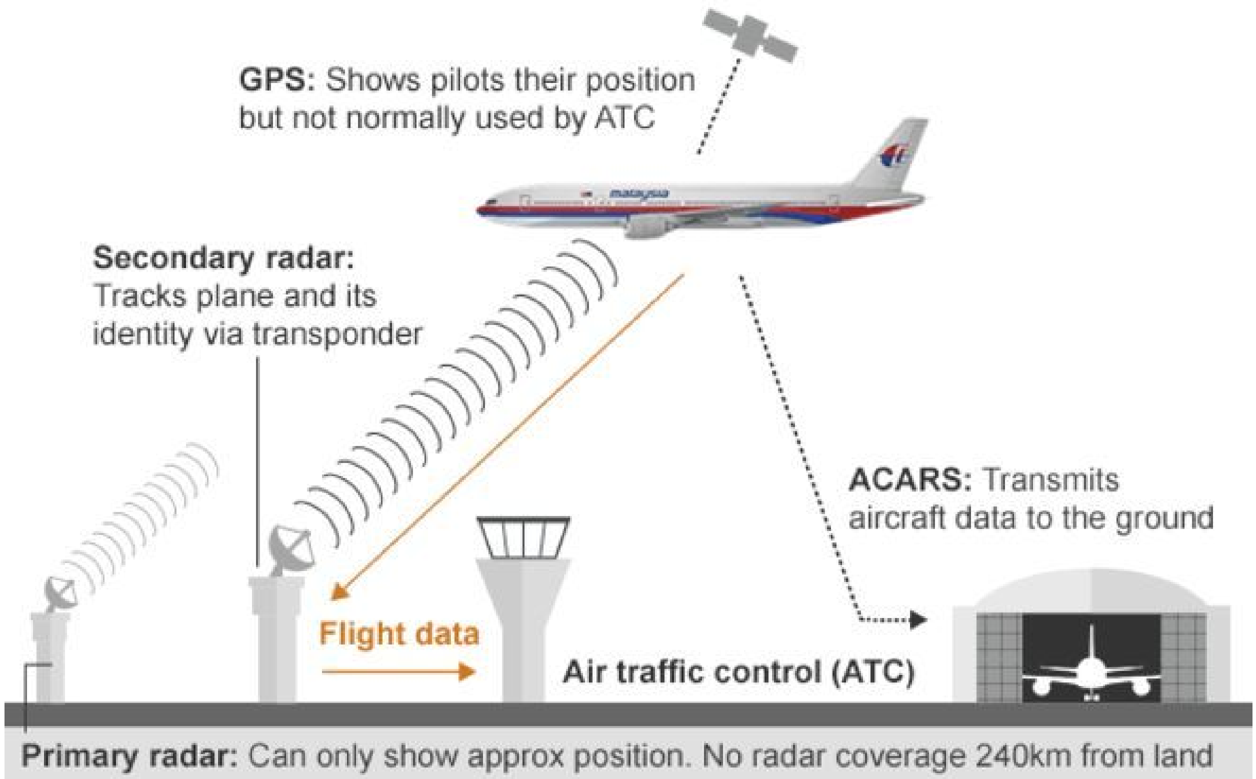

Fig. 3.2 Radar system [8]

Air traffic control - standard international practice is to monitor airspace using two radar systems: primary and secondary.

Primary radar -based on the earliest form of radar developed in the 1930s, detects and measures the approximate position of aircraft using reflected radio signals. It does this whether or not the subject wants to be tracked. **Secondary radar,** which relies on targets being equipped with a transponder, also requests additional information from the aircraft - such as its identity and altitude.

All commercial aircraft are equipped with transponders (an abbreviation of "transmitter responder"), which automatically transmit a unique four-digit code when they receive a radio signal sent by a radar.

The code gives the plane's identity and radar stations go on to establish speed and direction by monitoring successive transmissions. This flight data is then related to air traffic controllers.

However, once an aircraft is more than 240km (150 miles) out to sea, radar coverage fades and the aircrew keeps in touch with air traffic control and other aircraft using **high-frequency radio**.

For India and for the Indian Ocean Region the Air Traffic Control (ATC) service of the Airports Authority of India provides radar navigation for planes.

3.1.3. MoU between AAI and the coast guard

India is a signatory of the International Civil Aviation Organization and the International Maritime Organization. The Indian Coast Guard has been entrusted with the responsibility to carry out search and rescue operations of distressed airplanes in the Indian water. As Aviation industry has grown over the years at a very fast pace, the Airport Authority of India has provided safety measures in all aspects including the search and rescue. However, SAR over the oceans is a difficult task and it requires a vast amount of specialized resources.
As per the IMO and ICAO conventions, standards have been established between aeronautical and maritime and rescue

Following is the list of recently signed MoUs between AAI and coast guard -

- 11th October 2018 → For search and rescue of flights in Chennai Flight Information Region
- 6th February 2019 → Memorandum of Understanding with Airport Authority of India(AAI) is aimed at strengthening mutual interactions, interoperability and validating procedures during conduct of search and rescue operations jointly by the Rescue Coordination Centre (RCC) Kolkata, Airport Authority of India (AAI) and Maritime Rescue Coordination Centre (MRCC) in Port Blair, the PRO of Indian Coast Guard.
- 18th December 2017→ Mumbai FIR covers 12,35,000 sq. NM of airspace with approximately 3000 flights operating daily. The objective of SAR operation is to save precious human lives and property during emergent situations. The very essence of successful Search and Rescue operation is the speed with which it is carried out. This MoU will enable the efficient and speedy Aeronautical SAR operations in Mumbai FIR. It is also aimed at strengthening mutual interactions, interoperability and validating procedures to conduct SAR operations jointly by RCC Mumbai and MRCC Mumbai.[8]

This list may not be exhaustive of all the MoUs between the two parties. However, these can help to design future courses of actions that can be taken in this regard.

3.2. Non - Military submersibles

The predominant technology that can be deployed to trace the last known location of a non - military submersible is the use of Automatic Identification System (AIS) data. Automatic identification systems (AIS) are designed to be capable of providing information about the ship to other ships and to coastal authorities automatically.

International Maritime Organization regulation for carriage of AIS

The regulation requires AIS to be fitted aboard all ships of 300 gross tonnage and upwards engaged on international voyages, cargo ships of 500 gross tonnage and upwards not engaged on international voyages and all passenger ships irrespective of size. The requirement became effective for all ships by 31 December 2004.

Ships fitted with AIS shall maintain AIS in operation at all times except where international agreements, rules or standards provide for the protection of navigational information.

A flag State may exempt ships from carrying AISs when ships will be taken permanently out of service within two years after the implementation date. Performance standards for AIS were adopted in 1998.

The regulation requires that AIS shall:

- provide information - including the ship's identity, type, position, course, speed, navigational status, and other safety-related information - automatically to appropriately equipped shore stations, other ships and aircraft;
- receive automatically such information from similarly fitted ships; · monitor and track ships;

- exchange data with shore-based facilities.[9]

For India the coast guard obtains the AIS data for non - military ships from the Information Management and Analysis Centre (IMAC), Gurgaon.

About IMAC

- The Information Management and Analysis Centre (IMAC) is located in Gurugram.
- It is the main center of the Indian Navy for coastal surveillance and monitoring.
- IMAC is the nodal center of the National Command Control Communications and Intelligence Network (NC3I Network).
- IMAC is a joint initiative of Indian Navy, Coast Guard and Bharat Electronics Ltd. and functions under the National Security Adviser (NSA).

Since IMAC is a joint initiative involving the coast guard, no separate MoU is required to obtain the AIS data for carrying out search and rescue operations in the Indian Ocean Region.

In addition the coast guard must have guidelines that ensure that all non military submersibles in the Indian waters must have devices like Transmitter Buoy or Emergency Pinger along with suitable SONAR sensors. This will be very useful in the pre penultimate step of this process where surrounding submersibles near the distressed vehicle can help the SARS to locate the distressed vehicle. These regulations used here are also applicable for AIS tracking of ships.

3.3. Military submarines

The predominant technology that can be deployed to trace the last known location of a military submarine is the use of Automatic Identification System (AIS) data. This data however must remain secretive and must only be shared with the SAR team after a distress has happened. Therefore, a mechanism must be in place to share the data present at the IMAC to the SAR team of the coast guard as and when required.
Rest all regulations remain the same as in 3.2

4. Modelling

The movement of the platform from the last known position till the actual search operation is initiated and beyond becomes important to plan the entire search operation. The platform has to be monitored till it settles down in a stable position in its final resting location. This monitoring is undertaken using modelling that gets inputs on the oceanographic parameters to estimate the movement of the platform from the last known position. The model provides the framework and based on the platform and oceanographic parameters fed to the model, extensive simulation is undertaken to generate possible movement of the platform.

4.1. Tracking the target object

In this part, we will look into some existing models that can be used for tracking the target object.

4.1.1. Searching the lost plane

These are the models used by Team#40860 in searching the lost plane. We use this model to determine the distance the plane has flew after the last time the machine on the ground got its signal to the moment it dropped into the sea. We divide this part into a two-piece and the key difference is whether the plane is flying normally. Here, we define "normally" as it follow the preset flying route but just lost connection to the ground.[18]

Normal Moving Model -

In this part, we denoted $A1$ as the coordinate of the plane where people on the ground got its signal; $A2$ as the coordinate that the plane become uncontrollable. We are aiming to find the possible area of$A2$.

Tr - T is the duration of two signals that should be reported.

$t1$ - $t1$is the time since it took off to the last time ground received its signal.

tm - t is the duration since last time that ground receive the signal to the plane that start being abnormal.

S(t) is the map that contains all the flying coordinates which has an one-to-one relationship to the t.

1. Since we assume that the plane is flying normally in this stage, we can say that $A2$ is a point in map S.

2. Meanwhile, time t is the time that the ground got a signal before t but do not receive the one next to time t. So, we could say that $0 < tm < Tr$.

With these two, we can get the possible area of$A2$.[18]

Abnormal Moving Model -

In this part, we use the point $A2$ as a start point. We denoted $A3$ as the coordinate of the plane where it hit the sea level. We need to figure out the area that the plane may hit the sea level so it can give a smaller area to apply the later models and easier to search.[18]

Td is the total time it cost from the plane acting abnormal to it hit on the sea level.

$Dmax$ is the distance that the fuel in the plane can support it to fly. It will be changed due of different types of plane.

t is the time interval that decide by us. We get this number by divide Td by n which is a constant that means the number of interval we want to cut from the time plane start flying abnormal to the time it hit the sea level.

tn is the time that the plane has flew after it became abnormal. tn has the property that $t1 + t = t2;t2 + t = t3;\ \dots\ ;tn-1 + t = tn$ and $tn = Td$.

S(tn) is the distance that it should fly as planned in time $tn - tn-1$.

$O(xn, yn, zn)$ is the estimated position of the lost plane at time tn.

$O1(xn, yn, 0)$ is the estimated position of the lost plane at time tn in horizontal plane.

$O2(0, yn, zn)$ is the estimated position of the lost plane at time tn in vertical plane.

θn is the angle between the planes actually flying route to its pre-set route in time td in horizontal direction. This parameter has included the try made by the pilots. We set if the plane turn right as the positive angle and $-180° \le \theta n \le 180°$.

γn is the angle between the planes actually flying route to its pre-set route in time td in vertical direction. This parameter has included the try made by the pilots. We set if the plane fly up as the positive angle and$-90° \le \gamma n \le 90°$.

$Hmax$ is the highest height the plane is able to reach. It will be changed based on different types of planes.

Pick a point j that $1 \le j \le n, j \in Z$. We can have the position of the plane in horizontal plane :

$$O1(x_j , y_j , 0) = O1(x_{j-1}, y_{j-1}, 0) + (S(t_j) * \tan(\theta_j) , S(t_j) \cos(\theta_j) , 0) \quad (4.1) \quad [18]$$

$$O2(0, y_j , z_j) = O2(0, y_{j-1}, z_{j-1}) + (0,S(t_j),S(t_j) * \tan(\gamma_j)) \quad (4.2) \quad [18]$$

Adding these two planes together to get the $O(x_n, y_n, z_n)$.

$$O(x_j , y_j , z_j) = \sqrt{(O1(x_j , y_j , 0))^2 + (O2(0, y_j , z_j))^2} \quad (4.3) \quad [18]$$

Finally, since we are talking about searching lost plane, so the plane must dropped into the sea at last. As the same assumption before, we assume that the plane will drop as a free fall when the plane can't keep flying. So, the searching area will be: $O(x_n, y_n, 0)$ [18]

Now we have the plane drop into the sea and we have the region of where the plane might drop. In this section, we are going to discuss the where the plane components are going and generate a map which we call "the Grid Map".[18]

The Grid Map is what we want after we analysis the current. It's a map that is divided into many small squares. We can obtain the possible area of dropping from part 2. And now we slice them into grids. Each grid has its general direction that where the current in it flow. Each grid has its own possibility of existence. Some has higher possibility and some has lower ones.[18]

Analysis of ocean currents

sometimes our grid is smaller than the spacing of the arrows and we want to know the current between them. To resolve this we need to analyse the ocean currents.

Our model of getting the current direction between two currents is quite similar to vector calculation. First, we transform the surrounding factors into vector mode. For example, the following two vectors can be considered as (0,6) and$(3,3\sqrt{3})$.[18]

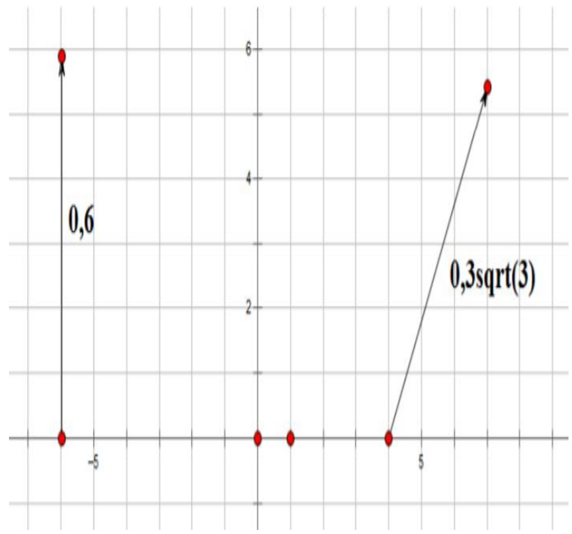

Fig. 4.1 Surrounding vectors [18]

Now we want to know the direction on the original point on the figure. The origin is 4 units away from the right current and 6 units away from the left one. So the ratio of the effect of the two surrounding current to the origin is 6:4 (right: left)

$(0,6) * 0.4 + (3,3\sqrt{3}) * 0.6 = (1.8, 2.4 + 1.8\sqrt{3})$

Since we just want to know the direction, we can transform this into:

$(1.8, 2.4 + 1.8\sqrt{3}) = (3,4 + 3\sqrt{3}) \approx (3,9.2)$ [18]

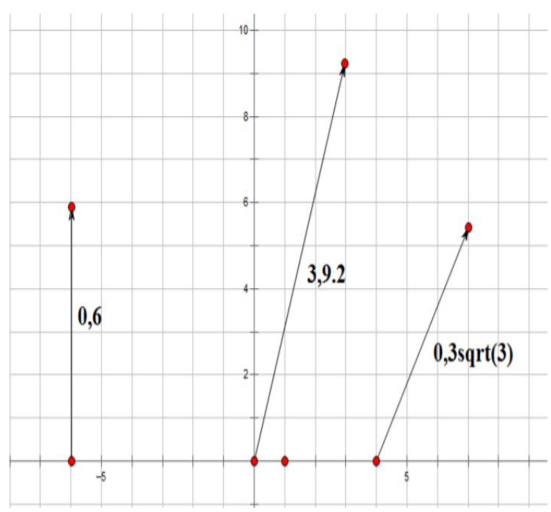

Fig. 4.2 Final vector [18]

Now we have the sketch of the ocean current and have the idea of where the current brought our plane components to. By saying where we mean the possibility of the components go through each grid. In fact, we are going to put two possibility values into each grid, p and q. p is the possibility that there are components existing in the grid, and q is the possibility of the chance we can find it if the component is in the grid. According to experience, q is related to the depth of the water in the tile. The deeper the water is, the smaller the chance is. We are going to apply the Bayesian search theory to our searching method.[18]

4.2. Tracing the target object

Based on depth at which we have to perform the search and recovery operation, the requirements like technology, methods (patterns) change. For smaller depths, we can perform the search operation with the help of divers. For larger depths, we need the help of submersibles and some active positioning systems to trace the target object.

- DISUB - Distressed Submersible
- SARS - Search and Recovery Submersible
- MPP - Most Probable Position

The **search area** is derived in such a way that it normally forms a circle centered on the MPP or datum. The radius of this circle is a function of the DISUB's navigational error, the delivery vehicle's navigational error and the drift of the DISUB due to currents during the elapsed time. By using an extended search radius a safety margin is added on to each search to reduce the chance of missing the search object on the edge of the search area. [11]

4.2.1. Active Search Patterns

There are three search patterns that are employed when the most probable position of the distress can be fixed fairly accurately. All three types would have to be "terrain" modified. That is, the bottom contour would have to be considered in carrying out the search pattern. Therefore these searches have been utilized on one plane only. Thus the SARS would be the first vehicle to undertake a three dimensional search, going into canyons, around outcroppings, over or around guyots and seamounts, etc.[11]

Expanding Spiral -

Although the expanding spiral is theoretically the best search~ there is at present no navigation equipment for following such a path. This equipment could be developed in the near future. The advantage of this plan is that the sweep width to track spacing ratio is varied as the search vehicle travels away from datum. This allows a higher ratio near datum where the probability density function is the highest and a lower ratio near the periphery of the search area where the probability density function is the lowest.S If this were not true it would be justifiable to start the search at the outside limit of the area and search inward.[11]

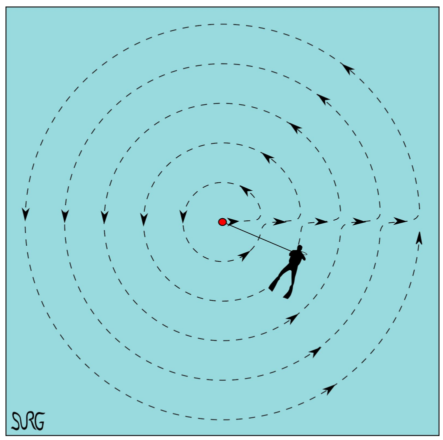

Fig. 4.3 Expanding spiral search [19]

Expanding Square -

The expanding square search (Figure 6.2 is started at the MPP or datum point and expanded outward. It is a relatively easy search to conduct. Normally the pattern is oriented on an axis running due North magnetic, and for subsequent searches the pattern is rotated 45 degrees in a clockwise direction with the area expanded as shown in Figure 6.2. The disadvantage of this system is the constant track spacing everywhere throughout the search.[11]

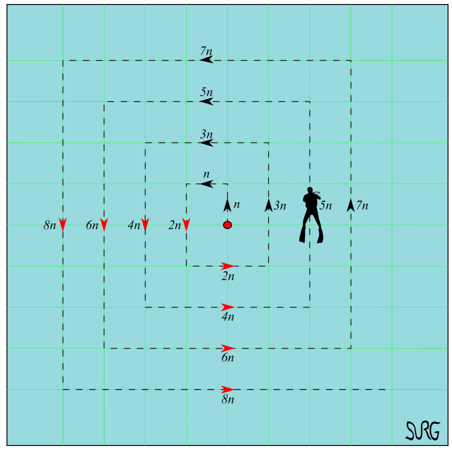

Fig. 4.4 Expanding square search [19]

Sector Search -

The sector search is perhaps the best practical pattern. (Figure 6.3) While easy to conduct, it allows the track spacing near the MPP to be small, while gradually expanding it as the search vehicle proceeds towards the periphery of the area. For a search of this type, the axis would be North magnetic. On subsequent searches the axis should be rotated so that the legs on the second coverage are midway between the ones flown on the first coverage.[11]

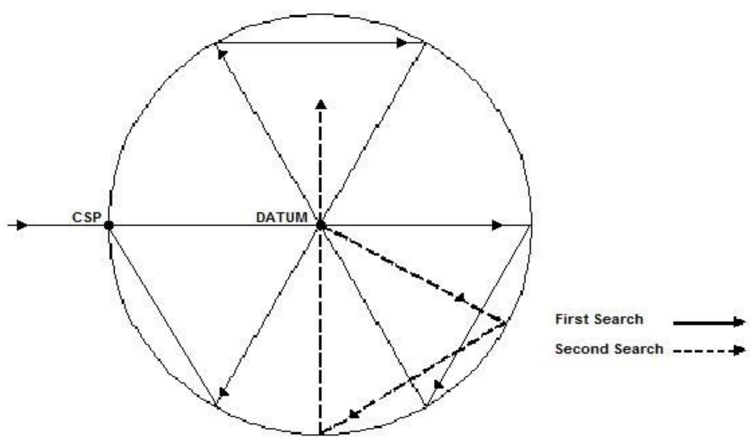

Fig. 4.5 Sector search pattern [19]

5. Ground Information

The inputs on the underwater features are extremely critical to plan the search operation. Availability of inputs on the bathymetry, sediment type and macro underwater features in the search area could be a leg-up, otherwise such survey may have to be undertaken as a prerequisite. Acoustic surveys have their own challenges, particularly in the tropical littoral waters.

5.1 Deep-sea terrain mapping

Accurate information on the seafloor topography is the supporting basis for the search and recovery of underwater objects. Although gravity maps can be used to rapidly invert a topographic map of the seabed, they have low accuracy and cannot meet the needs of deep-sea search and recovery. To map the seafloor topography at depths of several or even tens of kilometers, a large-area walking survey can be performed with a shipborne deep sea multibeam sounding system to obtain relatively accurate data.

Because of the vastness of oceans, shipborne deep-sea multi-beam measurement requires much time and money. Therefore, this method is mainly used along oceanic routes, in areas of high research interest (e.g., abysses, trenches, and cold springs), and in areas rich with oil, gas, and mineral resources (e.g., flammable ice, polymetallic nodules, cobalt-rich crusts, and hydrothermal vents). Therefore, after the scope of an underwater search and recovery is determined, the onboard deep-sea multi-beam sounding system should be used to map the area and obtain a relatively accurate topographic map of the seabed to provide basic terrain data.[1]

5.2 Inputs on ground information

We need to gather information about the parameters that can influence our search and recovery operation before moving on to the surveying part. These are some parameters that can influence -

- Bathymetry
- Salinity
- Sedimentation
- Ocean currents
- Size
- Shape

- Weight of the salvage object
- Windspeed (in some cases)

These parameters may influence the trajectory of the target object in terms of its speed, tolerance, buoyancy forces, direction, drift speed. And these parameters help us to decide our search infrastructure.

5.2.1 Bathymetric Survey

The term bathymetry originally referred to the ocean's depth relative to sea level, although it has now come to mean submarine topography or the shape and depths of underwater terrain. In the same way that topographic maps represent the three-dimensional features of overland terrain, bathymetric maps illustrate the land that lies underwater. Variations in sea-floor relief may be depicted by colour or contour lines called depth contours or isobaths.

This process that involves scanning the ocean floor with multi-beam sonar takes a lot of time.

1. The IOR isn't mapped to the extent it should be and whatever bare mapping that's done, is done by using technology 2 decades old

2.The **General Bathymetric Chart of the Oceans (GEBCO)** is working to map the IOR floor under its Indian Ocean Bathymetric Compilation (IOBC) project.

The major objective of this project is to produce a new bathymetric map and grid of the Indian Ocean (north of -60 degrees S) using data from all available sources, utilizing the contacts generated through GEBCO members and the Scholar's network to access data. The produced map and grid will be constructed from scientific cruise data obtained in both shallow and deep water, combined with hydrographic survey data in shallow water, as required to complete the map area at the highest resolution possible. In areas of sparse acoustic measurements, satellite altimetry will be used to guide interpolation between sounding values.[12]

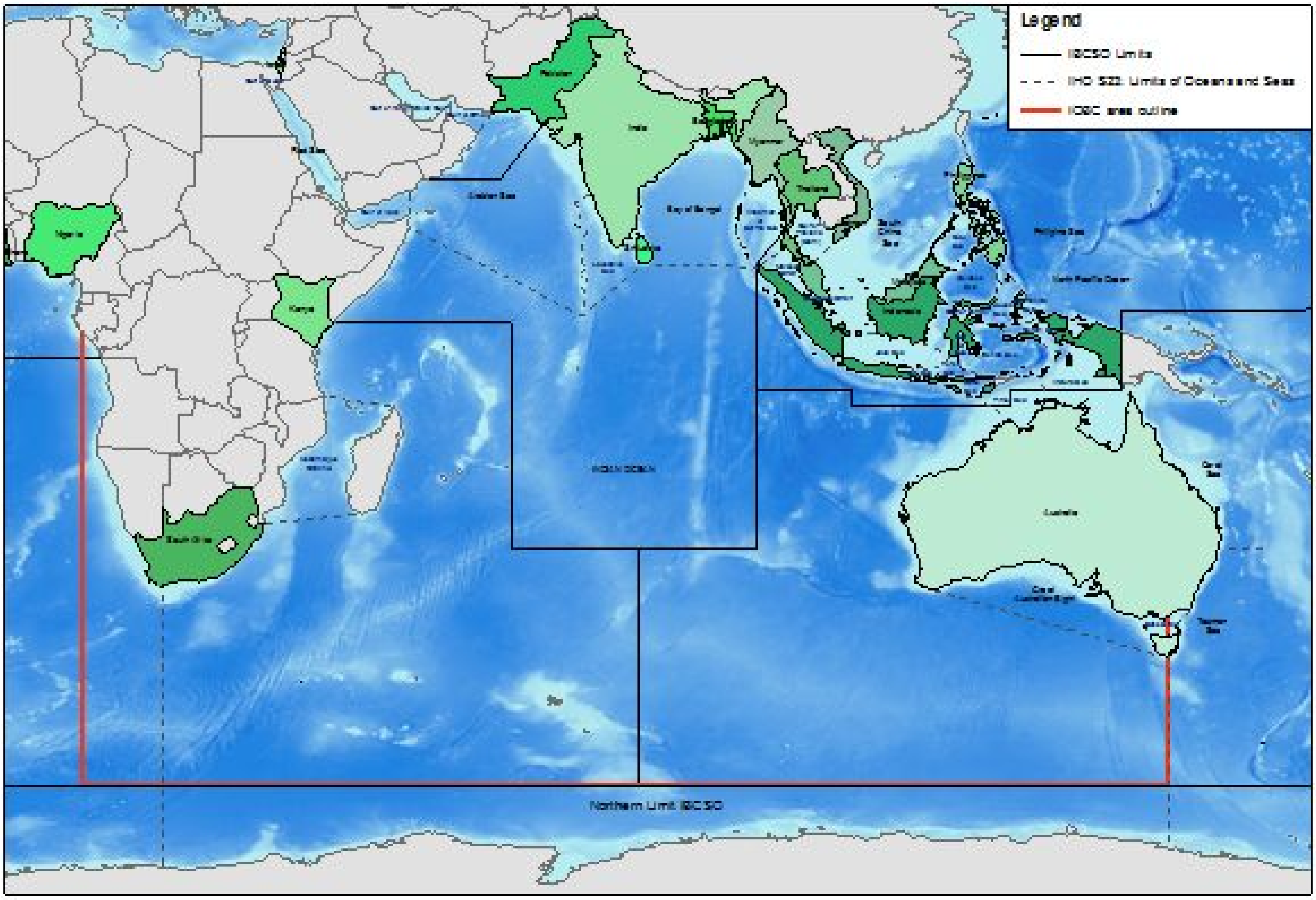

Fig 5.1: Map showing the general limits of IOBC project with home nations of Indian ocean scholars in green [17]

So the coast guard can sign an MoU with GEBCO so that they can use the bathymetric mapping data from this project as and when needed.

6. Underwater search operations

6.1. Acoustic positioning systems

Acoustic (Hydroacoustic) position reference systems are used extensively within the Dynamic Positioning (DP) community. A clear understanding of the capabilities and limitations of these systems is required by all involved in the procurement, engineering and operation of DP vessels. The increase in the number of DP vessels working in close proximity and the increased water depths are just two of the factors driving the development of acoustic positioning systems.

6.1.1 Types of Active Positioning Systems -

The distance between acoustic baselines is generally used to define an acoustic positioning system – that is the distance between the active sensing elements. Three primary types of acoustic positioning systems are usually defined in this way. [10]

Baseline lengths -

Type of Acoustic Positioning System	Baseline length
Ultrashort Baseline	<10cm (4”)
Short Baseline	20m to 50m (60’ to 160’)
Long Baseline	100m to 6,000m+ (350’ to 20,000’)

Table. 6.1 Acoustic Positioning Systems [10]

Ultrashort Baseline -

This system measures phase comparison on an arriving “ping” between individual elements within a multi-element (≥3) transducer. This phase comparison is used to determine the bearing from the USBL transceiver to a beacon. If a time of flight interrogation technique is used (Transponder or Responder), a range to that beacon will also be available from the USBL system. An USBL system can work in pinger, responder, or transponder mode. Any range and bearing (position) derived from a USBL system is with respect to the transceiver mounted to the vessel and as such a USBL system needs a Vertical Reference Unit (VRU), a Gyro, and possibly a surface navigation system to provide a position that is seafloor (earth) referenced.[10]

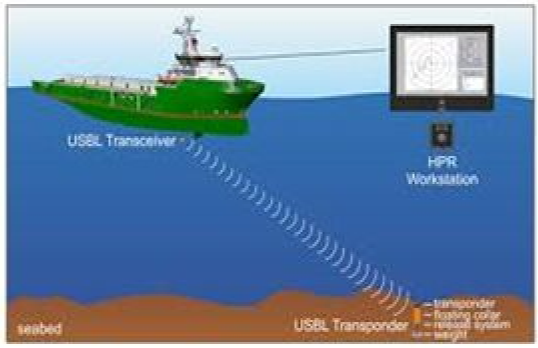

Fig. 6.4 ULTRASHORT BASELINE [19]

Short Baseline -

Short baseline systems derive a bearing to a beacon from multiple (≥3) surface mounted transceivers. This bearing is derived from the detection of the relative "time of arrival" as a ping passes each of the transceivers. If a time of flight interrogation technique is used (Transponder or Responder) a range to that beacon will also be available from the SBL system. A SBL system can work in pinger, responder or transponder mode. Any range and bearing (position) derived from a SBL system is with respect to the transceivers mounted on the vessel and as such a SBL system needs a Vertical Reference Unit (VRU), a Gyro, and possibly a surface navigation system to provide a position that is seafloor (earth) referenced. [10]

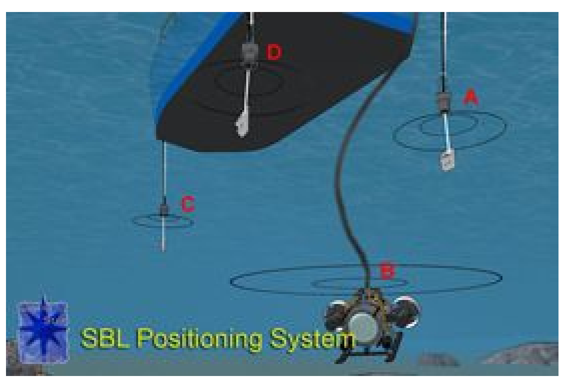

Fig. 6.5 SHORT BASELINE [19]

Long Baseline -

Long Baseline systems derive a position with respect to a seafloor deployed array (grid) of transponders. The position is generated from using 3 or more time of flight ranges to/from the seafloor stations (“range/range”). A LBL system can work in responder or transponder mode. Any range/range position derived from a LBL system is with respect to relative or absolute seafloor coordinates. As such a LBL system does not require a VRU or GYRO. [10]

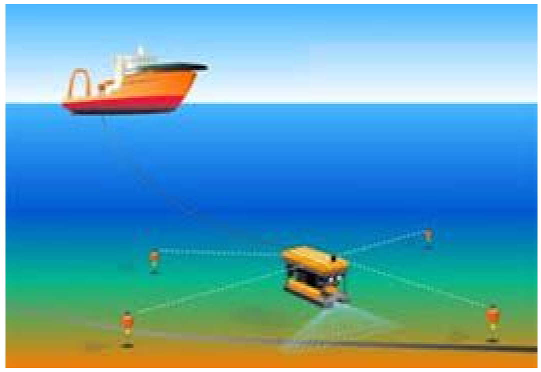

Fig. 6.6 LONG BASELINE [19]

Combined Systems -

These systems combine the benefits from all of the above systems and provide very reliable and redundant positions. With these benefits come more complex systems. [10] Combined systems come in many varieties:

- Long and Ultrashort Baseline (L/USBL)
- Long and Short Baseline (L/SBL)
- Short and Ultrashort Baseline (S/USBL)
- Long, Short, Ultrashort Baseline (L/S/USBL)

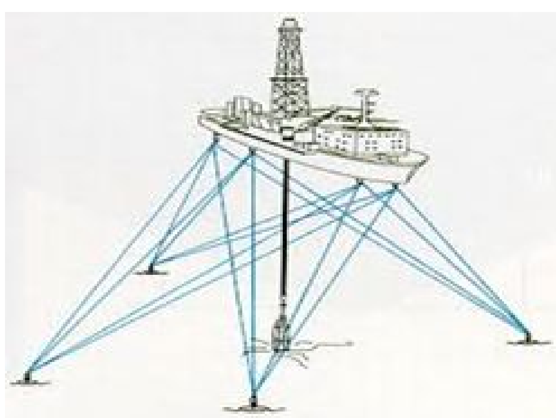

Fig. 6.7 COMBINED SYSTEMS [19]

6.2. Shipborne sound signal search

A shipboard sonar system can be used to search for the signals of underwater objects carrying acoustic beams. Once an aircraft black box enters the water, the water-sensitive switch on the carrying beacon activates the beacon to transmit a sound wave frequency of 37.5 kHz to the surrounding seawater through a metal shell. The sound source level is about 160 dB, the theoretical maximum action distance is 4000–6000 m, and the beacon can last for 30 days. Specialized search and recovery vessels are usually equipped with sonar systems capable of locating 37.5 kHz acoustic beacons. If the surface search vessel does not detect the signal within 30 days, then the battery charge is gradually depleted, and the acoustic signal weakens until it stops working altogether. At this point, the corresponding acoustic positioning method is also no longer applicable.[1]

6.3 Near-sea-bottom scan search

Although a shipborne deep-sea multibeam sounding system can detect a wide range of deep seabed terrains, its detection accuracy is limited, and it cannot search for small objects on the seafloor. A large-scale search of deep-sea salvage objects mainly relies on underwater vehicles such as the deep tow system and AUVs to carry sonar with side-scanning functions (e.g., side-scan sonar and sounding side-scan sonar).

6.3.1 Side-scan sonar

Side-scan sonar transmits a sound wave signal and receives the reflected echo signal to form an acoustic image of the state of the sea bottom, including the position, current status, and height of the target object (Dong et al., 2009). Compared with other subsea detection technologies, side-scan sonar has the advantages of image visualization, high resolution, and large coverage. Side-scan sonar on an underwater vehicle can reach a distance of tens of meters from the sea bottom. At low speeds, high quality side-scan sonar images can be obtained, and even pipelines a dozen centimeters wide can be distinguished. Recently, some deep-tow side-scan sonar systems have been operated at high speeds, and high-resolution underwater images were obtained. This shows that side-scan sonar is particularly suitable for searching seabed targets.[2]

7. Underwater recovery operation

In general, a successful deep-sea recovery requires the cooperation of various types of underwater equipment to exploit their respective advantages. For example, in 1966, the US Navy's CURV I ROV cooperated with the Alvin HOV to recover a hydrogen bomb that was lost at a depth of 914 m near Spain. After the US Challenger space shuttle explosion in 1986, manned and unmanned submersibles cooperated to recover 50 T of waste film and debris over a period of 6 months. This provided a reliable basis for an analysis of the Challenger space shuttle accident. In 1989, the former Soviet Union's Komsomol's nuclear submarine sank to a depth of 1860 m, and manned and unmanned submersibles again cooperated to sample seabed sediment, measure the radioactive dose, and seal submarine rafts.[1]

The use of deep-sea ROVs/HOVs to salvage objects maximizes their advantages in large-scale operations, and their manipulators can be used flexibly. However, deep-sea ROVs/HOVs are large-scale deep-sea equipment. They have complex systems, require a special technical maintenance and protection team, and have a high diving cost. This makes them mainly suitable for accidents with significant social impact, such as the salvage of aircraft black boxes and debris. They are rarely used to salvage other lost objects.[1]

Operational ROVs and HOVs are deep-sea heavy equipment that carry robots and can perform underwater operations. The existing deep-sea recovery and salvage system mainly depends on operational ROVs and HOVs.

7.1 Choice of SARS

Once the location of the distressed vehicle is found and the surveying of the seafloor is done, the next step of the rescue process could involve the use of a search and rescue submersible that can be sent to the distressed location. The choice for the same can depend upon-

- Manned instead of unmanned SARS to avoid entanglements in the distressed area
- Should have a fast descent and should be capable of powering down to the sea bed instead of the use of negative buoyancy.
- Should have endurance of upto 10-12 hours to stay underwater and that's why the use of fuel cells instead of conventional cells is recommended
- Should have a good speed of search

- Good navigation system
- Should have good visibility

The Deep Submergence Rescue Vehicle (DSRV) present in Mumbai and Visakhapatnam is the best choice that can be used in the IOR for this purpose.

The DSRV which is present with the navy has performed underwater mating with bottomed submarine at a depth of 3000ft. It is then capable of opening its hatches and then submarine hatches and then carrying out transfer of personnel from submarine to DSRV. The DSRV has also successfully dived 666 meters which is record for deepest submergence for manned vehicles in Indian waters.

The Coast Guard must make regulations to acquire it from the navy as and when required.

Fig. 7.1 DSRV - Mumbai [23]

7.2 Typical recovery process

First, the operational ROV/HOV needs to carry an USBL beacon. After it arrives at the position of the salvage object, it places the USBL beacon next to the object, and video is shot at multiple angles. Even when the location of the object has been obtained in advance, the deep-sea navigation accuracy is limited, and the underwater visible range is only 5-8 m. Thus, the operational ROV/HOV may take a long time to find the salvage object. If a 3D real-time imaging sonar is installed on the ROV/HOV, the search time can be greatly reduced. For example, Echoscope’s 3D real-time imaging sonar utilizes phased array technology to generate 16, 000 simultaneous beams to form 3D sonar images and visualize the entire scene in real time. Its maximum range is 120 m, which is a qualitative leap compared to underwater visibility. If the salvage object is lightweight, such as an aircraft black box, it can be directly grabbed by the deep-sea ROV/HOV and carried back to the surface. If the salvage object is too heavy, then ropes or steel cables are required. In this case, the deepsea ROV/HOV mainly performs work such as traction and hooking. Scientific vessels are usually equipped with geological winches, conductivity–temperature–depth (CTD) winches, and so on. The geological winch can bear a load of up to 1 T. The CTD winch can bear a lower weight of several hundred kilograms. If an object weighing several tons needs to be recovered, then composite buoyant fiber ropes may be needed. The rope diameter is determined according to the weight of the salvage object and the breaking force of the rope.[1]

7.3 New type of deep-sea recovery system

Based on the design idea and working mode of TV-grab in oceanographic studies, this paper proposes a new type of deep-sea recovery system that does not rely on any operational underwater vehicles and presents the recovery process. The new deepsea recovery system combines underwater optical imaging, mechanical docking/grasping, acoustic imaging and positioning, and propeller driving to provide low-cost and rapid deep-sea recovery.

7.3.1. TV - grab

TV-grab is a visual grab sampler that combines the continuous observation of seabed images with a grab sampler (Zhang et al., 2005; Geng et al., 2009; Cheng et al., 2011), as shown in Figure. 7.1 .

Figure. 7.2 TV-grab.[1]

7.3.2. New underwater recovery technologies

The new deep-sea recovery system combines a seabed optical camera, mechanical alignment and grabbing, acoustic imaging and positioning, and propeller drive for rapid deep-sea recovery on the seabed.

7.4. Recovery process

The new deep-sea recovery system can only be used when the position of the salvage object on the seabed is determined. Figure. 7.2 shows the flowchart for deep-sea recovery with the new system.

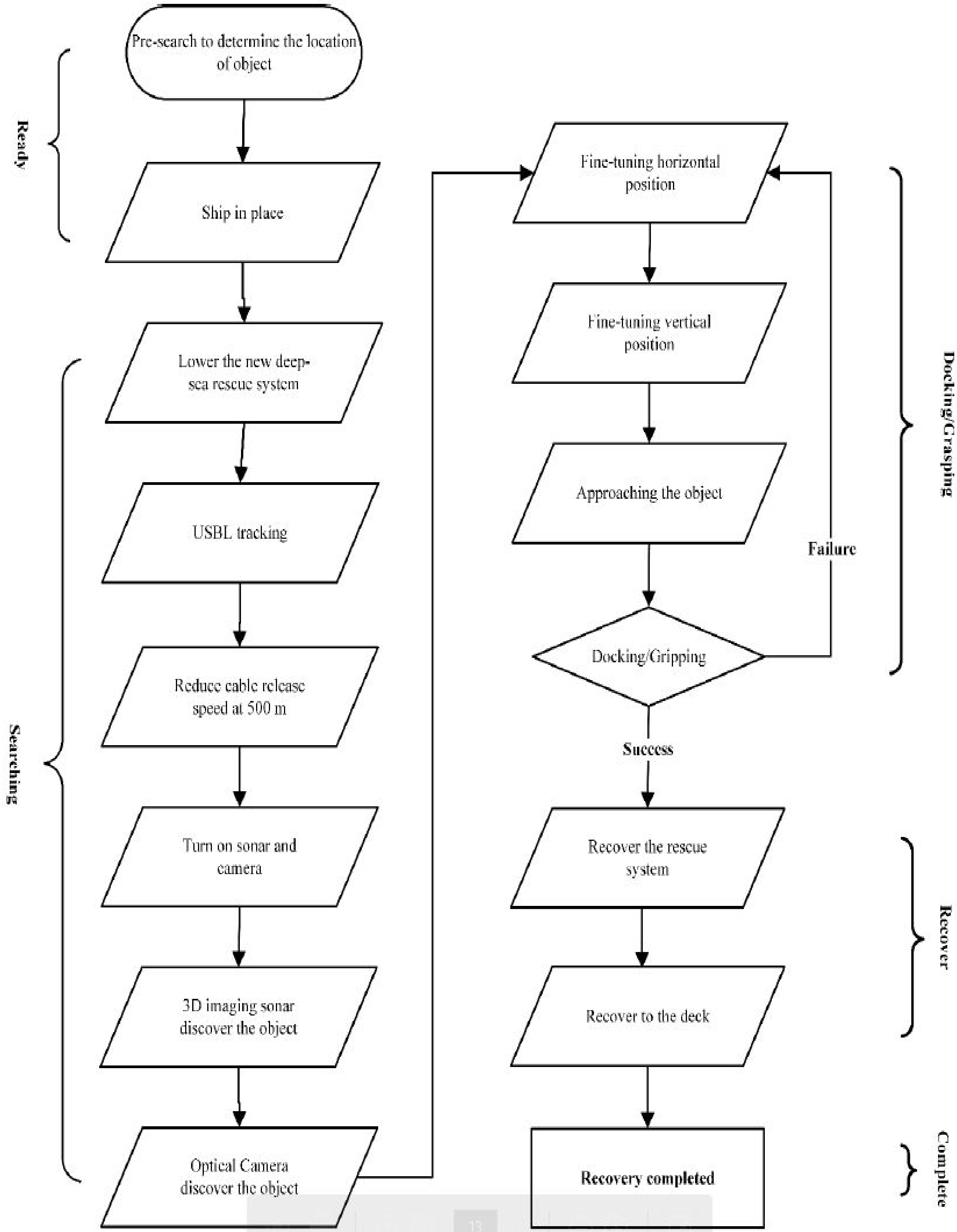

Figure. 7.3. Recovery flowchart with the new deep-sea recovery system. [1]

In addition to better equipment for deep-sea recovery, recovery methods and operating techniques also need to be developed. The entire recovery system needs many people to work together, especially after the recovery system enters the water. Specific control personnel should master the system's performance and know how to use it properly. Recovery personnel should work closely with the ship's driving department to improve the recovery efficiency and avoid accidents.

8. Search and Recovery Organization Structure

8.1. Mission Organization

The SAR coordinator mandates SAR mission organization, assigning the responsibilities and inter-relationships of the SMC, OSC and SRUs for any mission.The following figure shows the typical SAR mission Organisation.

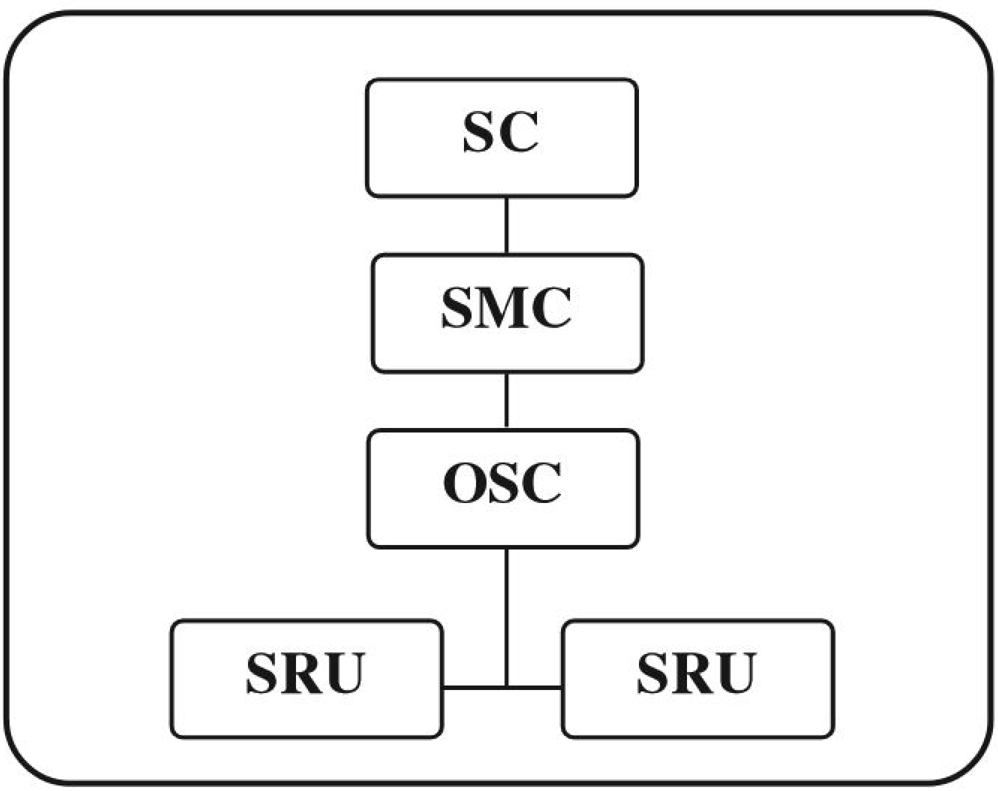

Fig. 8.1. SAR Mission Organization. [13]

8.1.1. SAR Coordinator (SC)

The SAR Coordinator (SC) is the top level SAR manager who has overall responsibility for establishing, staffing, equipping and managing SAR systems with thorough coordination and using the available SAR resources. The SAR Coordinator is not normally involved in the conduct of the SAR operations. The SAR Coordinator should ensure that the MRCC/MRSC/MRSSC is familiar with the capabilities of all the facilities available for SAR in its SRR. Collectively, these facilities are the means by which the MRCC/ MRSC/MRSSC conducts its operations. Some of these facilities will be immediately suitable for use. Others may have to be enhanced by changing organisational relationships or supplying extra equipment and training. If the facilities available in certain parts of Indian SRR cannot provide adequate assistance, arrangements should be made to provide additional facilities. The major duties of the SAR Coordinator include the following:

(a) Identification of SRU/SAR resources that may be used within the area.

(b) Establishing close liaison and agreements with other services/agencies/ organisations having SAR potential.

(c) Liaison with SAR authorities of neighbouring nations and ensure mutual cooperation and coordination.

(d) Preparation and distribution of current, comprehensive area SAR plans.

(e) Coordination of' SAR resources within the region of responsibility and MRSC for the areas where MRCC cannot exercise direct and effective coordination.

(f) Conduct SAR, assign SMC and SRUs until assistance is no longer required or rescue has been affected.

(g) Coordination of SAR training and developing SAR policies.

(h) Suspend SAR cases when there is no longer reasonable chance of success and report results to parent operating command.

(j) Provide appropriate legal and funding support.[13]

8.1.2 SAR Mission Coordinator (SMC)

An SMC should be designated for each specific SAR operation. Every mission is conducted under guidance of SMC and for the duration of that particular mission. While the overall responsibility of the mission is with the SAR Coordinator (SC), the SMC plans, coordinates including transit of SAR facilities to the scene and controls SAR missions with the available resources for the time assigned till conclusion of each mission. The SMC must use good judgment to modify, combine or bypass SAR stages and adopt the procedures to cope with unique, unusual or with the development of the ongoing SAR mission. SMC should use readily available facilities and request additional units when required during the operation.

The SMC should be thoroughly familiar with SAR plans and competently gather information about distress situations, develop accurate and workable action plan and dispatch SRUs for effective conduct of SAR missions. The guidelines for SMC duties include the following:

(a) Obtain, evaluate and convey all data regarding person or unit in distress to OSC and SRUs.

(b) A certain type of emergency, equipment carried by the distressed / missing craft.

(c) Obtain and update prevailing environmental conditions.

(d) Ascertain movement and location of vessels in the area for alerting traffic in search areas.

(e) Maintain radio watch on appropriate frequencies for enabling communication with SAR facilities and designate frequencies for on scene communication.

(f) Plot search area and decide methods / search facilities to be used.

(g) Develop search action plan, allocate search area, designate OSC and dispatch SAR facilities.

(h) Coordinate operations with adjacent MRCC when appropriate

(j) Arrange briefing/debriefing of personnel involved in a SAR mission.

(k) Evaluate reports and modify search action plan as necessary.

(l) Arrange logistics/supplies including accommodation for personnel and fuelling for aircraft.

(m) SMC to inform progress of all proceedings to SAR Co-ordinator and respective administrative authority.

(n) Recommend/decide on abandoning/suspension of search.

(p) Release SAR facilities when no longer required.

(q) Notify accident investigation authorities and parent organisation regarding the incident.

(r) Prepare final report on results of the operation.

(s) Intimate search result to the next of kin of person in distress.

(t) Press management [13]

8.1.3. On Scene Coordinator (OSC)

The On Scene Coordinator (OSC) is designated by the SMC when two or more SAR units are working together on the same mission to enable better coordination of the activities amongst the participating units on the scene. The OSC may be the person in charge of the SRU, ship or aircraft participating in the search or someone at another nearby facility capable of handling OSC duties. However, if an OSC is not designated, the first SRU to arrive at the scene will normally assume the functions of OSC to advise SMC, until the SMC directs the unit/person to be relieved by another. The OSC retains responsibilities from the time of designation until relief or mission is completed. An OSC need not be a SRU. An advance-staging base with all facilities may also serve as an OSC to relieve SRU of that burden.

The OSC should be the most eligible unit for conduct of SAR mission considering the proficiency in coordination of SAR capability, communications facilities and the endurance. Frequent changes of OSC should be avoided to enable continuous and proper coordination on scene. To provide continuity of command, any SRU arriving on scene who is senior to the OSC should not normally assume command unless ordered to do so by the SMC. The duties of OSC include the following:

(a) Assume operational authority of SMC coordinate operations and control of all SAR facilities on scene.

(b) Ensure adequate manning and equipment for the SAR mission.

(c) Receive and familiarise search action plan from SMC.

(d) Modify search plan based on prevailing environmental conditions.

(e) Consult and advise SMC regarding any changes to the plan.

(f) Provide relevant information to other SRUs on scene.

(g) Advise SMC for relieving any SRU on scene and request for dispatch & suitable relief to maintain OSC resources.

(h) Implement search action plan promulgated by SMC.

(j) Monitor performance of other units participating in the search.

(k) Coordinate safety of flight for SAR aircraft.

(l) Develop and implement a rescue plan if required.

(m) Consolidate reports obtained from other SRUs and dispatch to SMC.[13]

8.1.4 Aircraft Coordinator (ACO)

The SMC shall designate an area for aerial search with height of the airspace required and intimate the same to the relevant FIC for promulgation. He shall intimate the same to the OSC as well as the ACO for safe flying. When two or more SAR facilities including aircraft are working together on the same mission, SMC designates one unit as Aircraft Coordinator (ACO) for coordinating air traffic, in addition to the OSC. Preferably, OSC and ACO should be different units. If it is not practicable, then OSC itself acts as ACO. The OSC may designate this responsibility to another unit also, with SMC concurrence. ACO is responsible to SMC and coordinates closely with OSC. However, the overall charge remains with SMC/OSC. The primary concern of ACO is the flight safety of SAR aircraft.

The ACO may be a fixed wing aircraft, helicopter, ship or a fixed structure such as an offshore platform/appropriate shore based unit. The SMC is to consider the availability of the radio, radar equipment, trained personnel and capabilities of the facilities involved before delegating the responsibility to ACO. The duties of ACO are as follows:

(a) Maintain flight safety.

(b) Maintain safe horizontal and vertical separation between the aircraft in the area and transit.

(c) Ensure common pressure settings on altimeters.

(d) Determine aircraft entry and departure points, altitudes.

(e) Ensure frequency used is in accordance with the COMPLAN.

(f) Coordinate communications and ensure minimum radio traffic between other SRUs and aircraft.

(g) Coordinate with adjacent airfields / ATS / Area Control.

(h) Advise SMC/OSC on the weather implications on scene.

(j) Prioritize / allocate task and direct the aircraft as per SAR plan.

(k) Monitor and report SMC/OSC on search area coverage.

(l) Identify emerging task on scene and direct aircraft accordingly.

(m) Coordinate and supervise effectiveness of search with respect to changing factors on scene.

(n) Coordinate aircraft refuelling.

(p) Render SITREPS of SAR aircraft to SMC/OSC.[13]

8.1.5. Search and Rescue Units (SRUs)

The Search and Rescue Units (SRUs) are used as a resource for performing search, rescue or similar operations. It may have SAR as primary duty or it may be available for SAR missions made available by the parent agency not having primary SAR duty. It is composed of trained personnel proficient in SAR skills and equipment suitable for the expeditious and efficient conduct of the operation. The unit can be an aircraft or a ship. Normally SRUs having SAR as primary duty are used first. In Indian context, the Indian Coast Guard assets are used as the primary SRUs.

The identified SRUs of the resource agencies must have rapid and reliable means of communication with OSC / SMC and the distressed persons. The SRU must have supplies and survival equipment adapted to the manner of delivery and in waterproof, buoyant and strong containers with label & self explanatory symbols. They are also to have at disposal maps, charts and plotting equipment and information relevant to area in which it is likely to operate.

If the SRUs are alone on the scene, it performs the OSC duties and keeps SMC advised. Facilities selected as SRUs should be able to reach the scene of distress quickly and in particular be suitable for one or more of the following operations:

(a) Provide assistance to prevent or reduce the severity of the accident 1and hardship of the survivor.

(b) Conduct the search in the area designated as per the SAR action plans and reports to the OSC the area searched.

(c) Advise OSC on sighting of survivors with position and current environmental conditions.

(d) Signal to survivors and keep them in sight and effect rescue if within capabilities. If rescue is not possible, advise OSC on accurate position of the survivor and depart area.

(e) Deliver supplies and survival equipment to the scene.

(f) Rescue of Survivors.

(g) Provide food, medical or other initial needs of survivors.

(h) Transfer survivor to place of safety.

(j) Advice OSC on sighting of wreckage, debris, life boat/rafts, oil slick, dye marker, flare, smoke or any other unusual object facilitating further in the SAR operations.

(k) Advise OSC on interception of any radio, radar or emergency signal with position and time whenever possible.[13]

8.2. Maritime Rescue Coordination Centre in ISRR

The ISRR is divided into three areas with Maritime Rescue Coordination Centres (MRCCs) located at Mumbai, Chennai and Port Blair.There are 10 Maritime Rescue Sub Centres (MRSCs) and 3 Maritime Rescue Sub Sub Centres (MRSSCs) operating under these MRCCs.The Maritime Rescue Coordination Centre (MRCC) is a facility responsible for promoting efficient organization of SAR services, and for coordinating the conduct of SAR operation within the SRR. The MRCC only coordinates and does not necessarily provide SAR facilities in the applicable SRR.In order to enable MRCCs to exercise direct and effective control over SAR facilities in an area within its SRR, Maritime Rescue Sub Centres (MRSC) and Maritime Rescue Sub Sub Centres (MRSSC) are established.The SRR of neighboring countries namely Pakistan, Maldives, Sri Lanka, Seychelles, Mauritius, Indonesia, Malaysia, Myanmar and Bangladesh share the boundary with Indian SRR. These SRRs are established in cooperation with the neighboring nations which are internationally recognised.

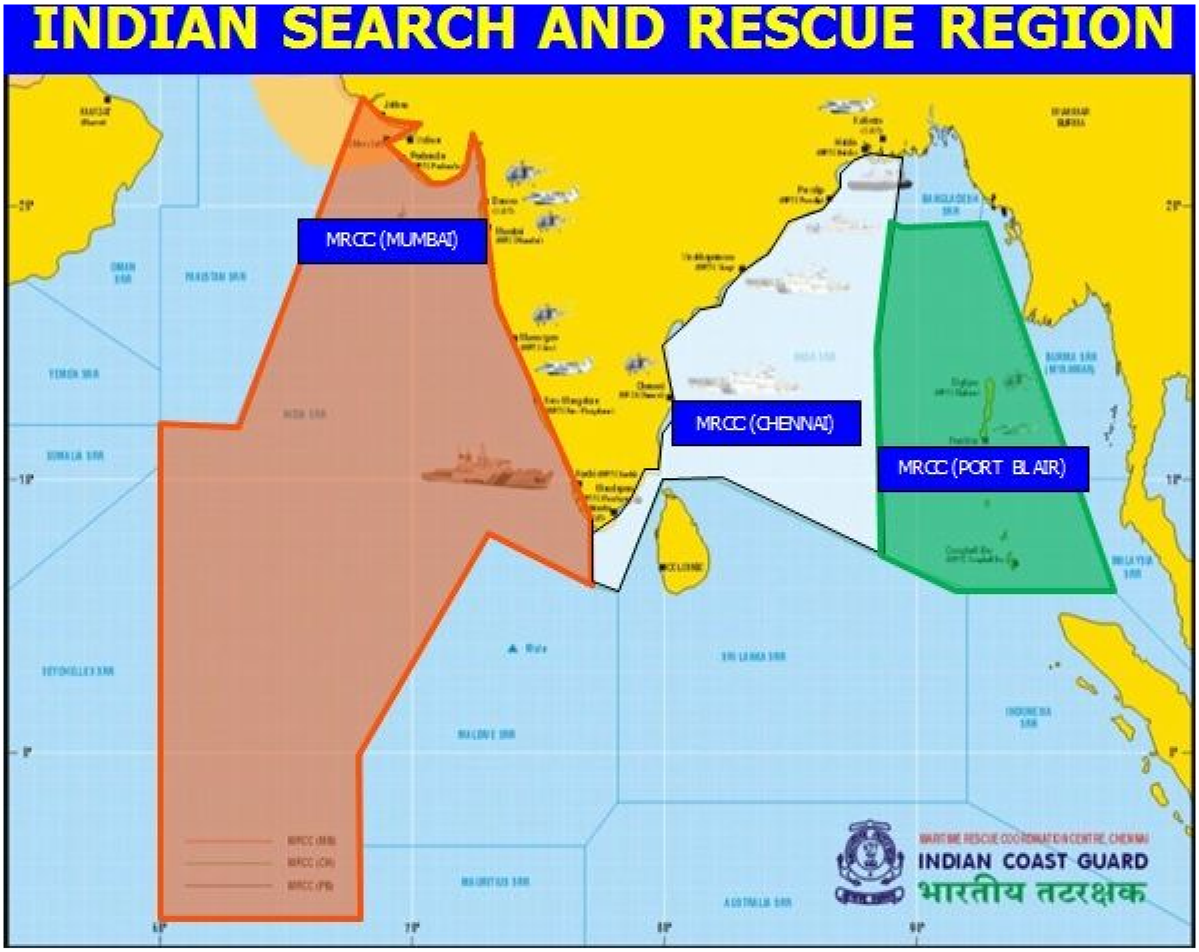

Fig. 8.2. The Indian Search and Rescue Region. [14]

MRCCs perform administrative and operational duties. Administrative duties are concerned with maintaining the MRCC in a continuous state of preparedness. The Officerin-charge MRCC carries out the duties of the MRCC Chief. The operational duties are concerned with the efficient conduct of a SAR operation or exercise and are thus of a temporary character. They are the responsibility of the SMC and are functions, which may be performed by the MRCC chief or by other trained staff of the MRCC. It may include temporary personnel from the other military services also, for facilitating the coordination of specific incidents, if need arises. The MRCC is prepared to undertake and continue operational duties throughout twenty four hours of the day.

(a) MRCC/MRSC Chief. The MRCC/MRSC Chief is the senior most Officer in the MRCC/MRSC organisation. He makes appropriate preparations, plans and arrangements as well as oversee & the daily operations of the MRCC, to ensure that when an incident occurs the SAR operation can be promptly performed.

(b) MRCC / MRSC Staff. The MRCC/ MRSC staff consists of personnel who are capable of planning and coordinating SAR operations. They mainly include GMDSS operator, communicator and plotter.[14]

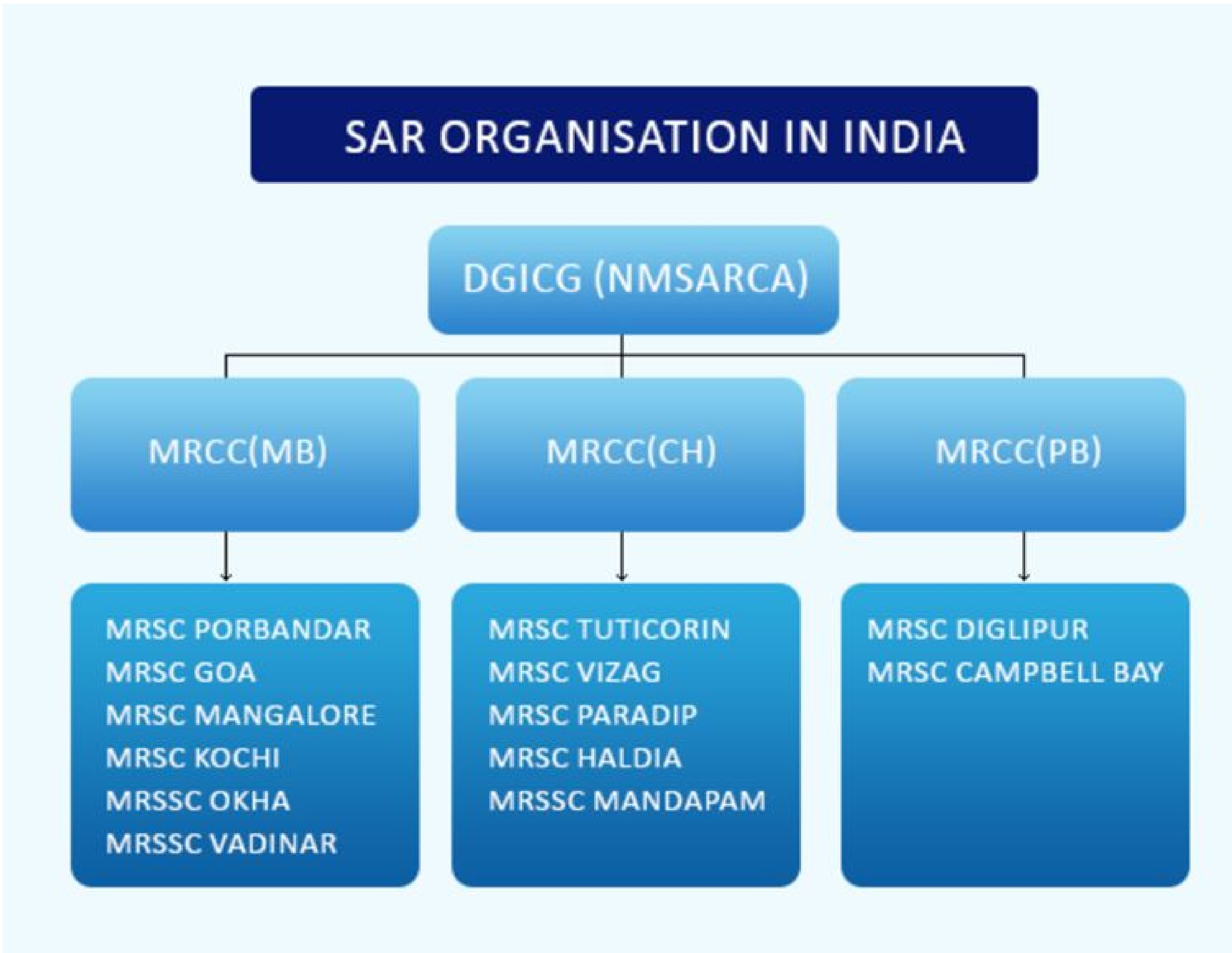

Fig. 8.3. SAR organization in India. [14]

8.3. National SAR Board

To coordinate national SAR objectives in accordance to the provisions of the international conventions, The National Search and Rescue Board was constituted with following composition vide Ministry of Shipping, GOI, resolution number SW- MIC/ 27/ 77/MD/AG dated 28 Jan 2002 with the Director General Coast Guard as the National Maritime Search and Rescue Coordinating Authority (NMSARCA). This board was formed subsequent to India's accession to SAR 79 Convention in May 2002. The formed subsequent to India's accession to Convention in May 2002. The Constitution of the national SAR Board is as follows :

(a)	Director General of Coast Guard	Chairman
(b)	Representative of DG (Shipping)	Member
(c)	Representative of Indian Navy	Member
(d)	Representative of Indian Air Force	Member
(e)	Chief Hydrographer, Government of India	Member
(f)	Representative of-Airports Authority of India	Member
(g)	Representative of Department of Telecommunication	Member
(h)	Representative of Department of Space	Member
(j)	Representative of Central Board of Customs and Excise	Member
(k)	Representative of Meteorological Department	Member
(l)	Representative of Major Ports (To be nominated by Ministry of Shipping)	Member
(m)	Representative of Shipping industry (To be nominated by Ministry of Shipping)	Member
(n)	Representative of three Coastal States (On rotational basis-every two years in alphabetical order)	Member
(p)	Representative of fishing community (To be nominated by Ministry of Agriculture and Department of Animal Husbandry and Dairy)	Member
(q)	Representative of Sailing Vessels Operators (To be nominated by Ministry of Shipping)	Member
(r)	Representative of Directorate of Civil Aviation (Nominated by Ministry of Shipping)	Member
(s)	Representative of Immigration (Nominated by Ministry of Shipping)	Member

Table. 8.1. The National SAR Board. [14]

The terms and reference of the National SAR Board are as follows.

(a) Formulation and promulgation of National SAR plan including its review and updating.

(b) Define functions to perform by participating agencies.

(c) Coordinate measures to be adapted by participating agencies and formulation of contingency plan.[13]

9. Conclusion

A precondition for the recovery of underwater objects is to accurately obtain their position. The search and recovery area needs to be determined, and the salvage object needs to be found before the acoustic beacon is exhausted. If the sound beacon fails, underwater vehicles such as a deep-tow/AUV carrying side-scan sonar or bathymetric side-scan sonar need to be used to reach the seafloor and scan for the salvage objects.

Once the underwater position of the salvage object is accurately determined, an ROV/HOV is often used for recovery and salvage. However, there are many difficulties with the practical application of the existing deep-sea recovery system based on ROVs/HOVs. Based on the design idea and working mode of the TV-grab in oceanographic studies, this paper proposes a new type of deep-sea recovery system that does not rely on any vehicles operated underwater and presents the recovery process. The new deep-sea recovery system combines underwater optical imaging, mechanical docking/grasping, acoustic imaging and positioning, and propeller driving for low-cost and rapid deep-sea recovery. It can be used to salvage not only aircraft black boxes but also lost AUVs, ROVs, and landers.

We need to pay some attention to mathematical models for tracking the target object because that will decrease our search area with limited accuracy and precision. Decrease in the search area will minimize our efforts and save a lot of investment, time..

Also, it’s important to focus on comparing the technologies capable of doing a certain job and then choosing a mechanism to complete a given step in the process of search and recovery. A proper regulation and framework with the required MoUs with different organizations must be in place so that the organization conducting the search and rescue operation can conduct the process smoothly and efficiently.

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Glossary

1. **Acoustic :** the branch of physics concerned with the properties of sound.
2. **Altimetry :** the measurement of height or altitude.
3. **Bathyscaphe :** A bathyscaphe is a free-diving self-propelled deep-sea submersible, consisting of a crew cabin similar to a bathysphere, but suspended below a float rather than from a surface cable, as in the classic bathysphere design.
4. **Bathysphere :** A manned spherical chamber for deep-sea observation, lowered by cable from a ship.
5. **Beacon :** A fire or light set up in a high or prominent position as a warning, signal
6. **Echoscope :** Instrument for displaying echoes by means of ultrasonic pulses.
7. **Hydrographic :** Relating to the charting of bodies of water
8. **Interoperability :** The ability of computer systems or software to exchange and make use of information
9. **Isobaths :** An imaginary line or a line on a map or chart that connects all points having the same depth below a water surface (as of an ocean, sea, or lake)
10. **Navigation channels :** A passage in a stretch of water where the sea or river bed has been deepened to allow access to large vessels.
11. **Pinger :** A device that transmits short high-pitched signals at brief intervals for purposes of detection, measurement, or identification.
12. **polymetallic nodules :** Also called manganese nodules, they are rock concretions on the sea bottom formed of concentric layers of iron and manganese hydroxides around a core
13. **Signal pulse length :** The pulse duration (pulse width) is the time measured across a pulse, often at its full width half maximum (FWHM)
14. **Signal pulse repetition :** It is the number of pulses of a repeating signal in a specific time unit, normally measured in pulses per second.
15. **Transceiver :** It is a device that is able to both transmit and receive information through a transmission medium.
16. **Transducer :** A transducer is a device that converts energy from one form to another. Usually a transducer converts a signal in one form of energy to a signal in another.
17. **Transponder :** It is a device that, upon receiving a signal, emits a different signal in response.
18. **Underwater glider :** It is a type of autonomous underwater vehicle that employs variable-buoyancy propulsion instead of traditional propellers or thrusters.