

MARINE POSITIONING FOR EXPLORATION OF OFFSHORE RESOURCES

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ABSTRACT

In the area of offshore exploration and exploitation, Government of India is concerned to explore the marine resources not only within the shelf but to extend the activities to slopes and deep sea. Accordingly, various programs for the exploration of marine mineral resources of the oceans have gained momentum in the recent past. This interest has acquired new dimensions of accuracy of Sea-Floor Positioning not only to help in demarcation of marine boundaries and exact location of marine resources but also ultimately for an accurate Sea-floor Mapping by extending the Geodetic control on land to marine environment.

There are many marine positioning systems, viz : short, medium and long range low frequency systems currently available for accurate position fixing. The knowledge gained in recent years using the Navy Navigation Satellite have, under optimal conditions, given an accuracy of about 150-200 m in dynamic mode. Global Positioning System (GPS) receiver developments have revolutionised the 3 D Position fixing techniques and this system combined with the acoustic navigation system will be an invaluable tool for surface as well as sub-surface positioning for the precise deep sea mining operations, as is being planned in Indian Ocean. The paper reviews the requirement of Sea-Floor Positioning depending upon the specific needs and to suggest the possible methods to achieve the higher accuracy at reasonable cost with the help of available equipment, expertise and resources in the country through an inter-institutional participation.

## INTRODUCTION

Recognising the importance of the ocean and its vast economic resources the scientific and technological organisations in the country started giving the major thrust to explore and exploit the living and non-living resources of the Exclusive Economic Zone (EEZ) and deep oceans in tune with the short and long term developmental needs of the country. The key to all these offshore development is a requirement of a range of position fixing systems to locate, relocate map and assess the potential extent of marine resources. When these resources have been located and evaluated it is possible to estimate the value of these resources and begin to delineate the economics of particular given resource. The purpose of the positioning and surveying techniques is not solely assessing the commercial prospects of marine resources but they also provide the accurate location and subsequent relocation of marine resources. Thus the precise position fixing is an essential pre-requisite for exploration and utilisation of various ocean resources.

As we enter a new generation of marine operations scientific and practical interests exist to determine and establish with high accuracy a geodetic control on the ocean surface, subsurface and ocean bottom regardless of remoteness from the coast or depth of water. To serve the practical needs of offshore positioning and mapping marine geodesy has become a common term between interdisciplinary interest involved precise positioning in the ocean. Some of the important areas covered under this interdisciplinary field are presented in Figure-I.

## PRESENT STATUS

During the last two decades National Institute of Oceanography (NIO) has gained experience in operational and experimental marine geodetic surveying applications on the regions extending from Indian coast to Antarctica. Based on these experiences the marine positioning needs for different navigation zones described below are intended to give a resume of national objectives that require supporting marine geodetic applications for exploration and exploitation of marine resources and environmental studies presently undertaken by the Institute. Furthermore, considerably increased interest in demarcating a mining area and extraction of manganese nodules from the Central Indian Ocean Basin, demarcation of over 2 million sq.km EEZ for systematic and cost effective exploration and exploitation of natural resources on and under the sea floor and demarcation of offshore boundaries demands the higher position fixing accuracy. Included is a view of the proposed national project which have special relevance to marine geodetic application for ocean science, offshore engineering and marine operations.

The problem of offshore positioning increases with distance from the land. In the nearshore vicinity the position can be obtained by visual or radio positioning system. Over a longer distance the accuracy of radio positioning deteriorates. It is

therefore reasonable to divide position fixing requirement into different arbitrary navigation zones (Ross et al., 1970).

#### NAVIGATION ZONE

ZONE	RANGE
Line of sight	0-30 km
Coastal	30-150 km
Offshore or Remote	150-1000 km
Deep Sea	1000 + km

The major offshore exploration and exploitation activities in the country (Figs. 2,3) lie on the continental shelf (line of sight and coastal zone). Exploration of hydrocarbon, surficial mineral exploration, bathymetric, geological and geophysical mapping need precise position fixing to locate and repeat the area of interest. The required accuracies are well within the capabilities of positioning system available at present.

The offshore or remote zone is being explored for environmental, biological and reconnaissance, geological, geophysical studies, site suitability surveys, cable laying, mining of marine resources. At present there is no shore based radio positioning system covering this zone, for exploitation of the resources. Accurate positioning is the need of the day in this region.

In the deep sea zone besides the regional oceanographic surveys the country is putting up the massive efforts to explore and demarcate a mining site for extraction of manganese nodules. This exploration and exploitation program requires integrated position fixing system for determining the accurate surface positioning and surveying/mining vessels and also subsurface positioning of the sample on the seabed. The repeatable fix accuracy should satisfy the needs of deep sea exploration and mining.

#### REQUIREMENTS

The collection of oceanographic data falls broadly into two categories i.e. time variable, and non-time variable data (Wells, 1970). The requirement of accuracy for position fixing for time variable data are not stringent but become stringent for obtaining the non-time variable data. However, the relocation of the position of the time variable data also requires the accurate positioning. The accuracy requirement should form the basis for the reference position in light of three types of accuracy parameters, predictable, repeatable and relative. The definition of these accuracy are defined in Federal Radio Navigation Plan 1986 of USA.

The exploration and exploitation task can be defined in phases, each with a different requirement for positioning and mapping. For example the mining site is preferably chosen in the areas with 30m height variation without vertical discontinuities and with slopes less than 10° (Amann, 1975). The requirements corresponding to these phases are shown in Table I (Zahn and Siapno, 1978).

#### GENERAL OVERVIEW OF THE SYSTEMS

Depending on the task to be undertaken the available positioning systems can be categorised into three major groups.

1. Shore based radio position fixing system
2. Satellite positioning
3. Acoustic position fixing

Shore based radio position fixing systems permit a location to be determined with reference to the position of known radio transmitters. Many of these systems develop to meet the stringent demand of the offshore surveys. There are a variety of radio positioning systems available depending on the specific needs of operation. Such systems either operate using range-range method or hyperbolic lattice method. Where the precise seabed surveys are required for underwater pipelines or offshore platform investigations, the use of underwater acoustic navigation has considerable advantage for locating the towed sensors (Milne, 1980 b). Very high frequency system can provide the accurate position upto the line of sight but one has to compromise the two requirement of range accuracy and repeatability.

For offshore operations far from land the main restraint for surface positioning is coverage V/S accuracy. Except the GPS, the systems providing the long range (global) position coverage normally have a less accuracy. Due to this fact no system is presently available which meets all the requirement of providing precise and continuous position. Omega a very low frequency, long range hyperbolic navigation system has a world wide coverage but its accuracy is limited to 2 km by day and 4 km by night (Ramasayer, 1977). By integrating two or more of these systems, the combination can be more responsive to the offshore and deep sea positioning requirement, and a tool of assuring objectivity. Global positioning system when fully operational will play a very important role. The sea-floor related geodetic positioning requirement need an accuracy requirement of 10 m range which can be met with underwater acoustic system (UAPS) (Pathak et al; 1990).

#### INTEGRATED NAVIGATION SYSTEM (INS)

Integrated Navigation System (INS) is a combination of different navigation systems and sensors with a computer which provides the "best" values of position and velocity. In general a

self contained DRS is used as reference system and all the other navigational aids are used to reduce the errors of the DRS (Ramsayer, 1970, 1974). The corrected DRS can be used to extrapolate the position for some minutes or longer without important loss of accuracy. The noisy control measurements are subtracted from corresponding quantities derived from DRS. The resulting errors are then processed by a filter which estimates the error of the DRS. The estimated errors are then used to correct the DRS. There are different kind of filters which are used. A very effective but also very complex tool is the Kalman Filter. Optimal positions are obtained when all informations are integrated statistically eg. by using Kalman filtering techniques.

Static error budget	-	15-35 m
Speed and course	-	40-400 m
Roll and Pitch	-	10-30 m
Antenna height	-	5-90 m
Geometry	-	45-400 m

The advantages and estimated accuracy (in good coverage area) of integration of some of the candidate systems operational in this region are presented in Table 2 and 3.

#### INTEGRATION OF THE DRS WITH NNSS AND OMEGA

The INS smooths the short term propagation anomalies of omega. To reduce the influence of long term errors of omega an updating of the integrated inertial/omega system by the NNSS will be more effective. In this case the positions which can be found by the NNSS can be introduced to the adjustment with precision. The position errors of integrated inertial/omega are roughly estimated 500 m to 1 km. In the ocean the accuracy depends essentially on the stability of the current of water in time. If it is stable for a longer time, we can expect that the adjustment of the measured data increases the accuracy, even if the speed vector is measured with log and gyro compass. The magnovax 1105 omega NAV has been used during surveys and it was found that the DR errors may be minimised by using omega positions from which the speed component deduced.

#### GLOBAL POSITIONING SYSTEM (GPS)

The GPS is a satellite based radio navigation system. The system will provide extremely accurate three dimensional position and velocity information to users anywhere in the world and thus will provide the most offshore positioning problem (Senus, 1984; Grunthal, 1984). The two characteristics which will make the GPS particularly useful are its availability and accuracy. As a result of U.S. Government policy the accuracy of GPS is expected to be 100 m in civil users set and 10 m in military sets.

Increased accuracy can be obtained by using GPS in the differential mode. However, due to the fact that the area of interest for deep sea mining is far from any fixed shore location, differential techniques of limited use in the deep sea mining activities in the Indian Ocean. Except for applications requiring underwater operation or sub meter precision GPS will provide accurate position for all activities.

There is a requirement for more accurate relative position for increased use of seafloor to enable detailed surveying and bottom sampling. In the case of detailed sampling and mining, the requirement is for the positioning of the sampler or the mining head on a bottom feature rather than the positioning of the surface ship. If the deep tow equipment is used in deep sea surveying the requirement for positioning the deep tow is much more stringent than the positioning of towing ship. As a result of available accuracy of GPS positioning, the acoustic arrays can be established much faster than previously. Due to US Department of Defence Policy of degrading the accuracy to 100 m, the increased use of sea floor for position locating functions using acoustic transponder system tied to a appropriate global coordinate system will fulfil the requirement. For many underwater location and navigation requirements in the deep ocean the acoustic method will be a principal solution. It is true that India at present does not have requirement to date for ocean floor surveys at an accuracy of 1-10 cm but in the near future we may require these submeter accuracy for the tasks presented in Table 4.

#### SUB-SURFACE POSITIONING

Detailed surveying with reference to an array of bottom moored acoustic transponders is the only practical method of accurately determining the surface and sub-surface positions beyond the line of sight. The first step in utilising a transponder array for navigation is to determine the relative positions of the transponder as accurately as possible by any one of the following methods :

- a) Acoustic marker positions from accurately known surface positions
- b) Acoustic marker positions from cloverleaf and baseline crossings
- c) Ship manoeuvres and acoustic marker positions from an iterative least squares fitting procedure

In the line crossing method, to determine the relative position and azimuth of one transponder from another any one of the parameters is determined first. When the ship passes through the plane of the transponders of slant range comes to a minimum at the point of closest approach (Fig. 4). This minimum is converted into a distance. In this method, there is an initial assumption of depth and it affects the accuracy of the final co-ordinates.

The improved method to solve three dimensional co-ordinates is intersection (Mourad, 1977). Various sets of three dimensional positions will be taken with different set of ship's position (Fig. 5). A least square method is used to solve the three dimensional co-ordinates for the velocity of sound profile and curved travel path of the signal. The intersection method is widely applied during deep sea mining surveys. Once the co-ordinates of the transponders are established, the position of the survey ship is determined in relation to the transponder.

The optional range of the transponders depend on the velocity structures of the sea, transmitting power frequency of water depth. In order to cover a large mining area with a detailed survey, a great number of transponders are required or alternately the transponders must be moved frequently. The position of the transponders is linked to a surface positioning systems. The Acoustic Positioning system is particularly useful for detecting the displacement of position of a mining ship.

#### CONCEPTUAL FRAMEWORK

It is probably true to say that no single positioning system can guarantee the absolute accuracy to meet the requirement of ocean science, technology and offshore industry. It will not be possible to apply the system as is used for surface positioning, at the seabed to meet the underwater positioning demand. Examining our present and future needs regarding positioning and establishment of geodetic control, it can be said that when we wish to measure changes in position to the greatest possible accuracy it is more pertinent to do so from the seabed which is few hundreds of meters away than from a series of radio stations that could be several hundreds of kms away. In the case of the offshore operations which have no access to the air water interface, the only means for position fixing is acoustic techniques. The definition of the term marine geodesy and its inter-disciplinary fields has been defined by SAXENA (1977, 1984).

The above consideration led to formulate the national objectives that require supporting marine application and investigate the marine geodesy needs and opportunities on the ocean bottom. Some of the potential area where inter-institutional participation can achieve the position accuracy needs to satisfy the economic requirement are - demarcation of EEZ, positioning and height determination, topographic mapping of the sea bottom, remote sensing etc. Similar projects are being undertaken by the various institutions in the different parts of the world. To provide nation with a capacity to extend the geodetic applications to the deep oceans in order to provide means of related offshore development objectives such a project is to be formulated and implemented. The inter institutional joint venture do have potential to address specific needs of exploration activities of marine raw material such as manganese nodules, mineral muds phosphorite nodules, alluvial deposits and sulfide deposits.

## CONCLUSION

An Acoustic Navigation System integrated with GPS will be an invaluable tool for position fixing in offshore and deep sea region. When fully operational the GPS will bring great benefits for underwater positioning. Most of offshore and deep sea positioning, coupled with GPS and underwater acoustic positioning system will have resolution of a few meters. With the integration of these systems the technological limitations for long deployment of acoustic transponders for exceeding two years will also be solved. The demarcation of EEZ provides a very important expansion in jurisdiction over resources for the country and the mapping program is an important first step in developing these resources. Based on the overview given here, it is necessary to assess the proposed technological framework in which the inter-institutional participation mechanism must be set to achieve the optimum benefit from technological changes and keeping pace with offshore technology.

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TABLE 1

Phase	Area coverage	Required accuracy in position	Reference system	Map scale	Allowable depth error
General survey	Global regional	4-40 km	Absolute surface	1:10 M	-
General prospecting	regional	400 m	Absolute surface	1:250000	50 m
Preliminary	150x400 m	400 m	Absolute surface	1:200000	4 m
Evaluation	100x150 km	2000 m	Absolute surface	1:120000	4 m
Detail	20x20 km	25 m	relative	1:25000	1 m
Mining	Ship position	400 m	relative surface bottom	-	-

TABLE 2

## ADVANTAGE OF INTEGRATION

<u>Candidate system</u>	<u>Integration</u>
NNSS, Speed log and compass	. Automatic Dead reckoning . Improvement of accuracy depending upon accuracy of DR inputs.
NNSS, Omega, speed log and compass	. Determines set and drift. . Bound DR errors.
NNSS and Inertial	. The precise inertial, enhance, survey accuracy.
NNSS and Decca	. Extends accurate Decca coverage by providing lane resolution.

TABLE 3  
INTEGRATED SYSTEM ACCURACIES

<u>SYSTEM</u>	<u>ESTIMATE RMS ACCURACY</u>
Single channel, NNSS, Omega compass, speed log.	900 m
Dual Channel NNSS, Inertial	90 m
Dual Channel NNSS, Decca	105 m

TABLE 4  
FUTURE TASKS AND ACCURACY REQUIREMENT

	<u>TASK</u>	<u>ACCURACY</u>	<u>RANGE</u>
1.	3-D Seismic survey	10 cm	10 km
2.	Missile firing evaluation	10 m	10,000 km
3.	Radio active Waste disposal	10 m	10 km
4.	Geodynamic-spreading centres, transform faults, slump zones	1-10 cm	10 km
5.	Geodynamics-subdivision, interplate motion, interplate deformation	1-10 cm	1000 km

Modified from seafloored referenced positioning, panel on ocean bottom positioning NRC (1983).

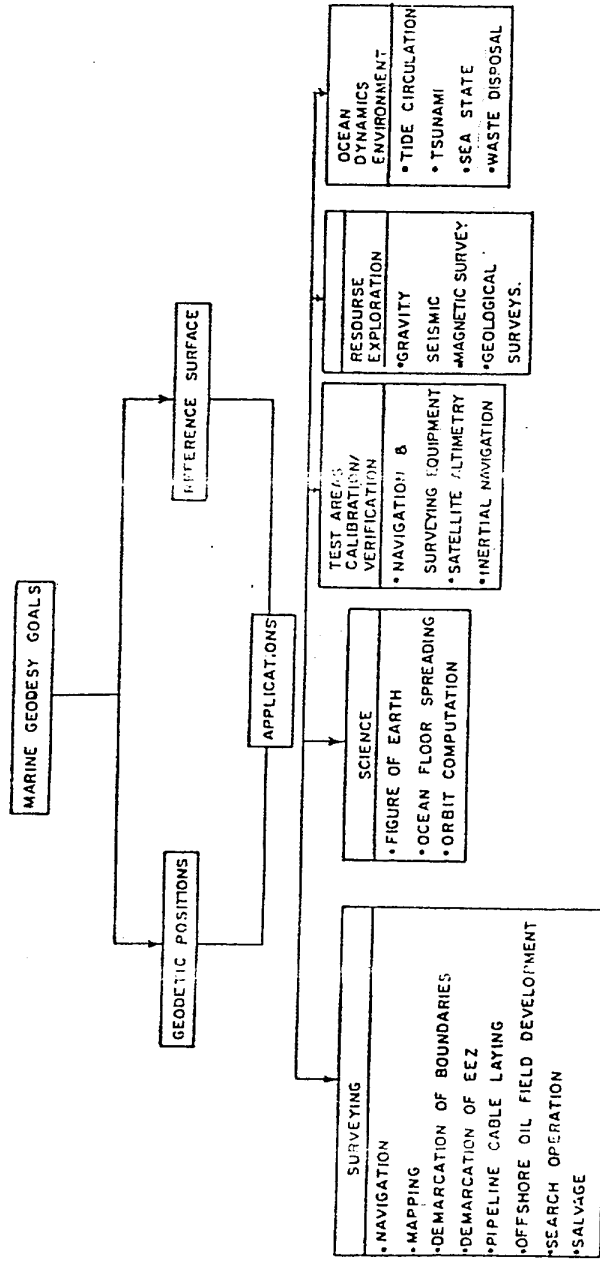


Fig 1

line of sight  
 coastal  
 remote  
 deep sea

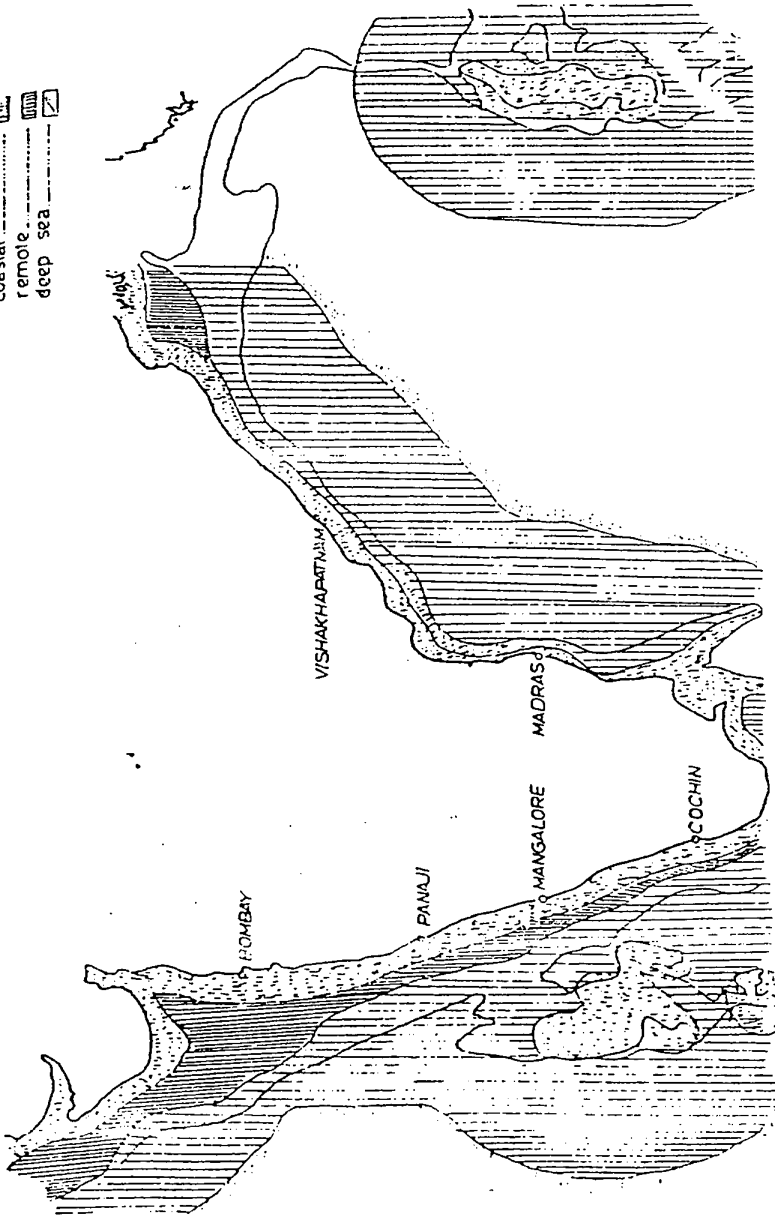


Fig. 2



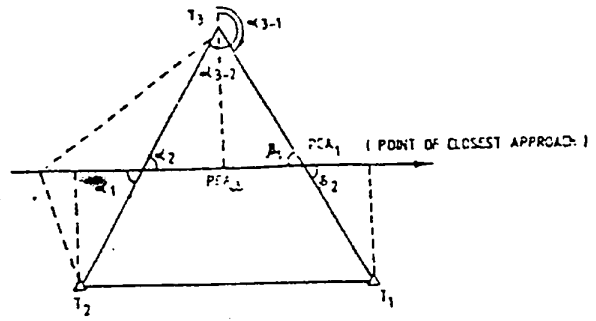


Fig 4

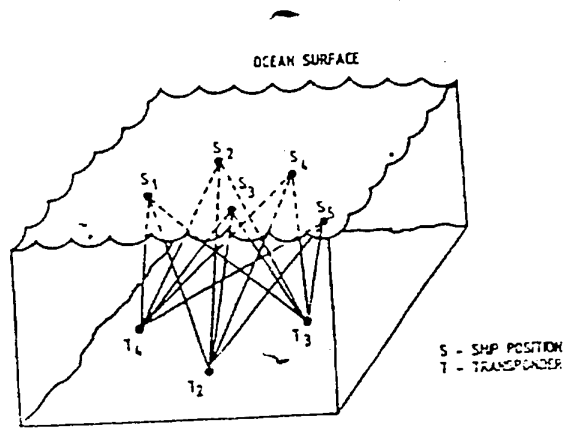


Fig 5