

POSITION FIXING REQUIREMENTS FOR OCEANOGRAPHY AND MARINE SURVEYS IN INDIA

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ABSTRACT

Oceanographic studies and marine surveys require position fixing of varying accuracy for different tasks. The considerable expenditure involved in ship time and data collection demand a greater accuracy in position fixing. Therefore, an analysis of some of the basic requirements of position fixing vis-a-vis its cost and the cost of data collected is often necessary.

The problems of position fixing at sea increase with distance from the coast, and therefore, the offshore areas of India have been divided into arbitrary navigation zones, i. e., line of sight and coastal (continental shelf), remote (shelf edge to the economic zone) and deep sea (beyond the economic zone). Regional oceanographic surveys of the environment and living resources require an accuracy of ± 1 km which is considered adequate for fishing purposes. However, an accuracy of ± 100 to 200 m for detailed surveys of the environment or fisheries research and bottom trawling may be required in the shelf region. An accuracy of ± 10 m may also be necessary in studies of pollution or harbour development in specific areas. Exploration and exploitation of mineral resources, because of high expenditure involved in this survey, require a far greater accuracy. Regional surveys for oil and other minerals demand position fixing of the range of ± 250 to 500 m, while detailed exploration for oil requires an accuracy of ± 100 m. Even higher accuracies of ± 5 to 25 m is needed for oil drilling, placer mining and submarine pipe laying.

The present offshore activities in the country indicate that accurate position fixing will initially be required largely in the line of sight and coastal zone (the continental shelf). Similarly very accurate position fixing is needed in areas where exploration and exploitation of oil are in progress. Precise position fixing is an essential prerequisite even in the line of sight zone for the exploration and exploitation of heavy mineral placers, marine pollution studies and harbour development. In the remote zone and deep sea position fixing at present is required only for regional reconnaissance programmes, but consideration should be given for development of integrated position fixing systems for exploration and exploitation of deep sea manganese nodules.

INTRODUCTION

The need for position fixing at high seas arose ever since man started sailing. The earlier requirements for navigation were largely in coastal areas for fishing, transport, trade and even for warfare. These were required to take a sailing craft safely to a predetermined destination. Multiple uses of the sea for such tasks as navigation in congested sea routes, exploration and exploitation of minerals, particularly oil, and control of marine pollution, fishing and defence demanded higher accuracy and such needs led to the development of better methods of position fixing.

With the increasing size of the ships and volume of trade, the need for charting the coastal areas more accurately at greater depths became necessary. Increasing demand for living resources led to the identification of fishing grounds in many countries for their better management. More stringent requirements for accurate position fixing arose with the offshore oil exploration and its exploitation.

The problems of position fixing at sea increase with the distance from land. In the vicinity of the coast, fixes can be obtained from shore objects but with the increasing distance from the coast reliance has to be

placed on other methods such as radio positioning. Over longer distances even the accuracy of radio positioning deteriorates. It is, therefore, proposed to divide position fixing requirements into different arbitrary navigation zones (Ross *et al.*, 1970).

NAVIGATION ZONES

1. *The line of sight zone:* Positions in this zone can be determined by optical or microwave methods. The range of the zone is dependant on the height and geometry of the coastal objects in the area. It is, therefore, likely to be of variable width and on a low-lying flat shore (*i.e.* the east coast and the northern and southern extremities of the west coast) may not extend beyond a distance of 15-20 km. However,

where hills and cliffs occur along the coast, as along the Konkan and parts of the Malabar coast (*i.e.* from Bombay to Mangalore and Calicut), the zone may extend to even 50 km. The depths in this area may range upto tens of metres on the wide shelf off Bombay, but where the shelf is narrow, depths may be greater, and at some localities, particularly on the east coast, the zone may extend even beyond the shelf edge. Along the Andaman Nicobar and Lakshadweep coasts, due to the absence of a wide shelf or terrace, the depths increase sharply to more than a thousand metres within this zone.

2. *Coastal zone:* The coastal zone is defined as the area of the continental shelf, beyond the line of sight zone. The width

Table I. Selected navigation systems

System	Frequency	Approximate accuracy	Approximate range*	Lines of position**	Type of signal
Trisponder	9300-9400 MHz	± 3 m	LOS-80 km	R	Pulse
RPS	9000 MHz	2-20 m	LOS	R	Pulse
Mini Ranger	5450-5400 MHz	± 3 m	LOS-80 km	R	Pulse
Hydrodist (MRB 2)	2800-3200 MHz	2-20 m	LOS	R	CW
Autotape	3000 MHz	2-20 m	LOS	R	CW
Hydrodist (MRB 3)	1300-1350 MHz	2-20 m	LOS	R	CW
Shoran	210-320 MHz	10-50 m	LOS	R	Pulse
XR-Shoran	200-300 MHz 420-450 MHz	± 5 m	250-300 km	R	Pulse
Loran A	1850-1950 kHz	500-10,000 m	1300 km	H	Pulse
Hi-Fix	1700-2000 kHz	5-50 m	250 km	R/H	CW
Raydist	1600-3300 kHz	5-50 m	300 km	Many	CW
Rana	1600-2500 kHz	20 m	150 km	R/H	CW
Lorac	1700-2500 kHz	5-100 m	500 km	H	CW
Pulse 8	100 kHz	50-100 m	800 km	R/H	Pulse
Loran C	100 kHz	50-500 m	2000 km	R/H	Pulse (CW)***
Decca Navigator	70-130 kHz	150-5000 m	550 km	H	CW
Decca Lambda	100-200 kHz	50-400 m	600 km	R/H	CW
Omega	10-14 kHz	2-10 km	Global	R/H	CW

*LOS=Line of Sight (upto 50 km). Ground wave range only for MF/LF systems.

**R=Ranging H=Hyperbolic.

***Loran C uses cycle matching (phase comparison) within pulse envelope.

Modified from Wells (1970).

Position fixing requirements

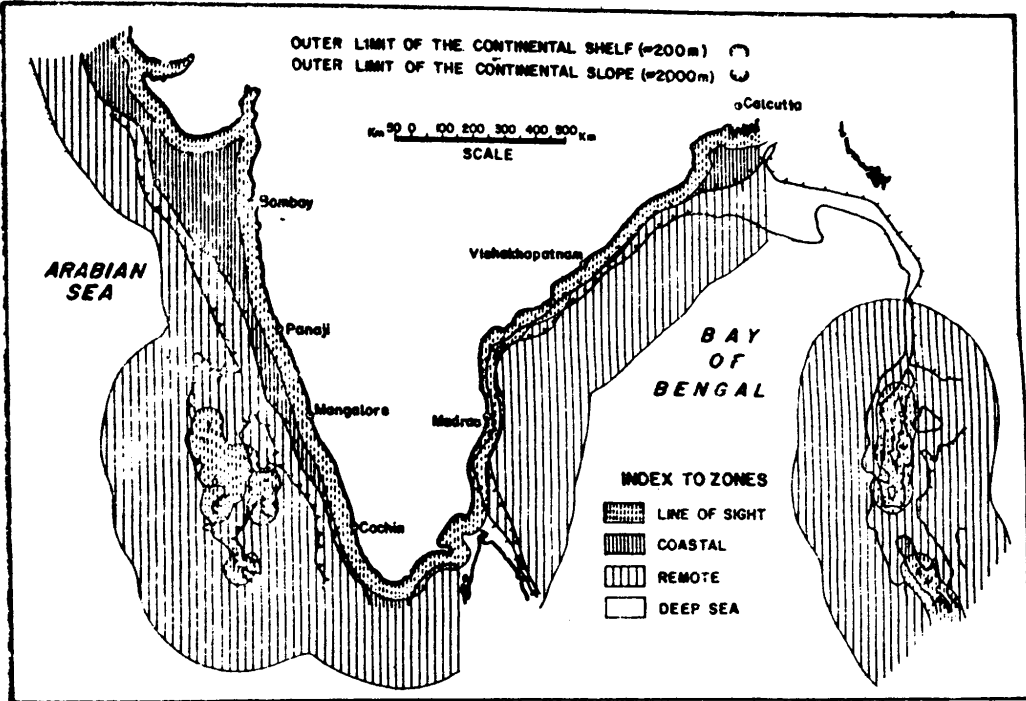


Fig. 1. Map showing the navigation zones in the offshore areas of India

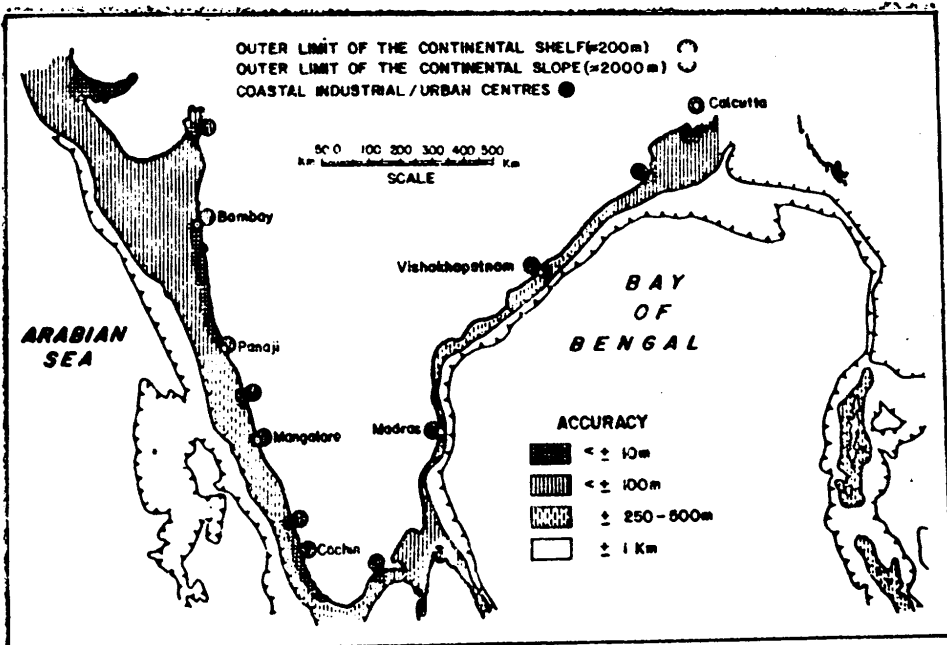


Fig. 2. Map showing the anticipated accuracy requirements in the offshore areas of India

of this zone may range upto more than 200 km off Bombay, but this zone almost overlaps the line of sight zone at places off the east coast, in Andaman and in the Lakshadweep. The shelf break on the western shelf (i.e. north western area off Bombay) is between 80-170 m and at the mouth of the Ganges between 200-500 m. These represent the maximum depths for this zone. The continental shelf (line of sight and the coastal zone) is the area in which currently most of the exploration and exploitation of oil and minerals are taking place and where the needs of accurate position fixing are encountered. Positions in this zone can be determined by radio positioning or satellite navigation systems. The performance of radio positioning systems especially in the tropics is greatly affected by changes in the ionospheric conditions particularly at night and during cloudy and rainy weather. Therefore while choosing a particular system these factors should be taken into account. It is doubtful if a single system will meet all the requirements but a system most suitable for a specific job and period (season) can be identified. However, for many surveys, especially reconnoitry and exploratory, satellite navigation with an EM or preferably Doppler log is considered as adequate.

3. *The remote zone:* The concept of an economic zone extending for a distance of 200 miles from the coast is now widely accepted by many countries. The resources in this area are claimed by the coastal state, and therefore, this zone has assumed great importance. The remote zone covers the area beyond the edge of the continental shelf upto a distance of 200 miles from the coast. The depths in this zone will increase rapidly from about 100 m at the shelf edge to more than 2,000 m beyond the continental slope.

The positions in this zone can be determined by long range radio positioning systems or satellite navigation systems.

4. *The deep sea:* The deep sea is the area beyond the remote zone and covers the abyssal areas of the ocean. The depths in this area will be more than 2,000 m. For position fixing in this area, a greater re-

lance has to be placed on satellite navigation system and perhaps in appropriate areas on radio positioning.

POSITION FIXING REQUIREMENTS FOR DIFFERENT OCEANOGRAPHIC STUDIES AND SURVEYS

The collection of oceanographic data falls broadly into two categories, i.e., time variable and non-time variable data (Wells, 1970). The data collected during geological and geophysical surveys including those for oil and mineral exploration and exploitation are nontime variable whereas the data collected for exploration and exploitation of living resources (marine biological, physical and chemical) and environmental (chemical and physical oceanography) are time variable. The requirements of accuracy for position fixing for time variable data are not stringent, but these become considerably stringent for obtaining the non-time variable data. However, if the same position is sought to be occupied for collection of time variable data, the requirements for position fixing also become stringent. Increasing expenditure on the collection of data for the exploitation of resources, especially oil, has usually led to a greater demand for accuracy in position fixing.

Environmental studies

(Physical and Chemical Oceanography)

Physical oceanographic studies in the country, and particularly those at the NIO involve determination of seasonal and spatial variation of mixed layer and thermocline characteristics, water mass structure, mixing, circulation, upwelling, light penetration and sound propagation with a view to develop prediction models for these parameters. Investigations also include heat budget studies for developing models for predicting sea surface temperatures. Chemical oceanographic work involves the determination of seasonal and spatial variations in the nutrients and trace elements in sea water and to assess the interactions of inorganic and organic constituents with a view to identify the potentially fertile regions of biological and geochemical productivity.

Position fixing requirements

Table II. Accuracy requirements

Work/Task	Surveys	Application/Exploitation
Environment	Regional oceanic surveys ± 1 km	Pollution studies ± 10 m
	Detailed surveys on shelf ± 100 m	Waste disposal ± 250 m
	Mooring and recovery of buoy systems	
	Position fixing repeatable within the range of acoustic releases, i. e., 3-4 km	
Living Resources	Regional surveys ± 1 km	Midwater trawling, shrimping and gill net operations ± 1 km
	Fisheries research and surveys on shelf ± 200 m	Fish farming ± 100 m Bottom trawling, location of pots and traps ± 50 m
Non-living resources	Regional surveys ± 250 to 500	Detailed surveys for oil ± 10 to ± 25 m
	Surveys for oil ± 100 m	Oil drilling ± 25 m
	Surficial geological mapping ± 500 m	Pipe laying ± 1 to 3 m
	Gravity research ± 50 m	Detailed surveys for placers ± 5 to 25 m.
		Placer mining ± 5 m
		Exploration for manganese nodules in deep sea with positioning for samplers at sea bottom ± 1 km
Others		Man in the sea ± 20 m
		Cable laying ± 1 to 100 m
		Implantation of gear ± 5 m
		Rescue and salvage ± 25 m
		Retrieval of treasure ± 25 m

Compiled with modifications from Putzke (1969) and Cohen (1969).

The primary objective is to study the variations of these parameters over a wide oceanic area. The data are collected by research vessels and these are utilised to describe circulation patterns in the sea. However, where time variable parameters are to be recorded over a long period at a particular location, moored buoys with instrument packages are used. In the ship, the accurate determination of each position occupied is required while in the moored buoys accuracy of position to enable retrieval of the moored instrument package is required. In the case of ship-borne

surveys an accuracy of ± 1 km is acceptable. The location of a moored package on the sea floor requires navigational accuracy at first to delineate the features of interest which may vary from a few hundred metres to several kilometres, and then to release and retrieve the package. Precise location of the instrument package within the area of interest is of primary importance rather than the actual positioning of the ship. The recovery of the equipment requires positioning repeatable to within the range of the radio beacon and acoustic releases which vary from 1-3 km

and the same is considered adequate for many operations.

According to Ross *et al.* (1970), studies in dynamic oceanography require mathematical formulation of the frictional processes occurring in the oceans. The problems of circulation particularly in the field of 10⁵ m are reasonably well studied by oceanographic surveys and the small scale structures (less than 10 m) are also amenable to laboratory modelling. However, studies of circulation patterns in the intermediate states 10⁴ - 10⁶ m are becoming increasingly important as these affect the inshore circulation patterns and particularly the diffusion of effluents in nearshore areas. It is in these shallow coastal areas that accurate positioning, perhaps of the order of about ± 10 m, may be required. These areas are largely in the vicinity of the large industrial/urban centres and are within the line of sight zone.

Living resources

(Biological Oceanography and Fisheries etc.)

Meaningful interpretation of biological oceanographic data requires physical and chemical oceanographic data and usually these are collected together. The position fixing requirements for physical and chemical oceanographic work also satisfy the requirements for biological work. The present programmes of NIQ include the study of biological productivity potentials of coastal and shelf regions of India at various trophic levels. In addition, sizeable programmes for fish farming and aquaculture are also being initiated in the Institute and elsewhere in the country.

For the exploration of living resources, the need for accurate positioning is felt during exploratory fishing. While charting new fishing grounds it is very necessary to return to the same area. Studies in the US have shown (Polhemus, 1972) that about 30 per cent of the dollar-value of the catch in the northern US waters, are obtained using methods requiring 50 m accuracy and another 30 per cent using methods needing 350 m accuracy. The accuracy needed to satisfy the economic requirements of the fisheries in coastal region is based on the accuracy of navigational needs to support

certain fishing methods. Four specific accuracy requirements have been identified (Blood, 1973), beginning with an accuracy of 50 yards for bottom trawling to less restrictive 0.5 nautical mile accuracy for mid water trawling, shrimping and gill net operations. A study of the Norwegian Government (1961) also indicated that fishermen needed 50 m navigational accuracy for bottom fishing, and using such an accuracy the trawlers would improve their annual catch by 18 per cent. Bottom fishing extends upto the edge of the continental shelf. It may, however, be pointed out that these requirements of accuracy for fishing may largely be for areas where fishing grounds have already been charted and where extensive fishing is being carried out and there is a significant potential for increasing the catch. The existing mechanised fishing operations in our shelf are largely confined to shallow depth. However, with the expansion of fishing fleet and the extension of fishing to deeper areas, similar accurate positioning will be required in our shelf region also.

A study of the fishery potential of the offshore areas of India shows that the northwestern continental shelf is one of the richest in the country. Virbhadra Rao (1973) has shown from the compiled data for a decade that high annual catches are landed from the regions off Gujarat and Kutch. Gulland (1971) indicates that the demersal resource potential of the western shelf north of 15° is over 1.2 million tonnes a year while only a fraction of this potential is being exploited at present. The average landings of all crustaceans in Maharashtra and Gujarat from 1959 to 1968 is about 45,000 tonnes annually (Jhingran, 1974) which is equivalent to all the landings of other areas put together. With the expansion in fishing, better positioning will be required in rich fishery areas of the north western and south western shelf of the country. A detailed study of the demersal fishery potential of the various areas and the likely increase in the fish catch with better positioning methods would be useful.

However, for introducing future improvements in navigational facilities for fishing, due consideration should be given not only

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to cover areas rich in fishery resources but also for the development of relatively cheaper aids for position fixing to be used by the trawlers.

Non-living resources

The general requirement for position fixing for geological and geophysical surveys include a sufficiently accurate positioning to decipher features particularly those which are of economic interest. The basic need in a mineral or oil exploration programme is "repeatability", so that a geologist/geophysicist can return to the area of interest.

The accuracy requirements for geological and geophysical surveys are dependent on the nature of the survey *i.e.*, regional reconnaissance, exploratory or a detailed survey. However, normally all geological and geophysical surveys at first require reconnaissance of large areas and these are carried out on a small scale. The basic maps required from mineral and oil exploration are (i) topographic and bathymetric maps, (ii) bottom sediment and surficial geological maps, and (iii) the sub-surface geological and geophysical maps. For these different scales were adopted by different countries, but nevertheless a uniformity is now emerging. The United States (Tracey, 1969) has adopted a scale of 1:1 million for reconnaissance mapping of the continental margin and also recommended that this may be considered for the universal coverage. For detailed mapping of offshore areas, the US has adopted the scale of 1:250,000 and has also drawn a programme for covering the entire continental margin of USA on this scale for a period of 15-20 years. In France, offshore geological maps are being prepared on a scale of 1:1 million; and for geological, structural and surficial sediment maps a scale of 1:250,000 is used. For the former a Clark Ellipsoidal and for the latter a Lambert Conformal Conical projections are used. In the United Kingdom, the Universal Transverse Mercator Projection with a scale of 1:100,000 for acquisition of data and 1:250,000 for publication have been adopted (Day, 1973). In India, scales of 1:1 million and 1:250,000 have been agreed to for regional and detailed mapping of offshore areas. The known oil fields and the poten-

tial oil bearing areas on the western shelf off Bombay have been recently surveyed on a scale of 1:125,000 on a Universal Transverse Mercator projection. Some detailed surveys in the nearshore areas off Bombay have been carried out on scales of 1:10,000. It is generally agreed that accuracies of ± 250 to 500 m will be sufficient for regional surveys (Table II).

The half width of a geophysical anomaly is approximately equal to the depth of the source of the anomaly below the sensing head. The accuracy requirements therefore, depend on the depth of water and the nature of the crust forming the ocean bottom. An accuracy of one fifth of the depth of water below the sensing head will always meet this requirement. If deep tow equipment is used in surveying, the requirement of positioning for the deep tow is obviously much more stringent than that of the towing ship or of a ship taking surface measurements. A similar accuracy will be required for sampling the deep sea mineral deposits. An accurate determination of ship's velocity is essential for good surface ship gravity measurements. The correction required for the ship's motion is directly proportional to the speed of the ship, the sine of the course and the cosine of the latitude; and on an east west course, the speed is important. For two-ship seismic refraction work it is necessary to determine the range between the shooting and receiving ship up to at least 1 per cent. Recording the arrival times of the direct water wave will provide this accuracy only if the velocity of sound in water is also known. For seismic reflection surveys, the distance between shot points must be accurately known to permit stacking the data to enhance the signal-to-noise ratio. Accuracy is also necessary in interpreting the magnetic anomaly bands caused by magnetic reversals.

A greater accuracy for oil exploration (± 100 m) will be required in the shelf areas where the potential for oil is high or from where production has already begun. For the present these areas appear to be largely the extension of the proven oil fields and sedimentary basins on land to offshore areas. The basins according to the present indications where higher accuracies will

be required, are the northern part of the western shelf and some of the well known sedimentary basins on the eastern shelf.

There is an urgent need for more accurate position fixing over small areas around proved mineral and oil bearing areas for detailed surveys and bottom sampling of the sea bed. In some of the areas on the western shelf where promising structures have already been delineated, accurate position fixing is required for positioning drilling rigs for exploratory and later on for production drilling (± 25 m). With the completion of the exploration and coming to the exploitation stage, the position fixing requires a much greater accuracy for surveys and for laying pipelines (± 25 to 1 m). In the case of sampling, the requirement is for the positioning of the sampler on a bottom feature rather than the positioning of the surface ship. This type of position fixing is important in the deeper areas rather than in shallow depths on the continental shelf where the position of the sampler with respect to the ship may not vary much.

In the inshore zone the sampling interval for detailed exploration for heavy mineral placers may be as little as 10-50 m

(Table III). The onshore and offshore mineral placers vary considerably in area and in size may range from tens of metres to hundreds of metres. Such a feature necessitate the collection of samples at close spacing and some explorations may require an accuracy of ± 2 m (Brown, 1971). India has large onshore deposits of heavy mineral placer chiefly on the west coast of India. The sampling and survey of some of the offshore deposits (Prabhakar Rao, 1968; Siddiquie *et al.*, 1975) has given encouraging results and a detailed exploration of the entire offshore tract is long over due. The offshore placer deposits are not likely to extend beyond a distance of about 50 km from the shore. Their exploration, therefore, will be largely confined to the line of sight zone.

The reserves of manganese on land are limited in India. Moreover, the country imports large quantities of copper, nickel and cobalt. It is expected that large scale commercial mining of the manganese nodules will be feasible in the near future. The rising demands for the country's industry for these metals in the future will have to be met from the oceans. Our country, therefore has considerable interest in the

Table III. Line and drill hole spacing-placers

		Scout drilling		Developmental Drilling
		Line space	Interval	
Diamonds	— S. W. Africa	100/500 m	10 m	50 m × 10 m
Tin	— Thailand	400 m	200 m	
	— Indonesia	500 m	100 m	50 m × 50 m
	— Malaysia	360 m	120 m	120 m × 60 m
Gold	— Alaska	300 m	60 m	
	— California	150 m	30 m	30 m × 15 m
Platinum	— Alaska	300 m	30 m	150 m × 15 m
Rutile	— Queensland	300 m	12 m	150 m × 12 m
Ilmenite	— West Aust.	300 m	30 m	150 m × 15 m
Magnetite	— Desert Mt. Utah	120 m	120 m	120 m × 60 m

After Bourret (1970)

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development of suitable surveying techniques for the manganese nodules in the deep sea. The development of systems with a capability of precise location of the surface vessel at sea and the samplers at the bottom would be of immense value.

NAVIGATION REQUIREMENTS FOR DIFFERENT ZONES

At present, the major offshore exploration and exploitation activities in the country lie in the continental shelf, i.e., in the line of sight and the coastal zone. It is in these areas accurate position fixing for oil exploration and exploitation, surficial mineral exploration and geological mapping will be required. At present fishing is also concentrated in this zone. However, for this position fixing of a lesser accuracy will be needed. Though some types of fishing may require accurate position fixing, it would be necessary to weigh the economic factors, i.e., the present annual catch and the likely increase in catch in relation to the investments in accurate position fixing systems. The present data indicate that on the north-western shelf the potential fishing areas are located in the region of high accuracy requirements for oil. Hence the requirements of the two for the purposes of position fixing could be combined. The installation of radio positioning chains to cover the entire continental shelf should receive a high priority while the precise accuracy requirements for the oil industry could be met by installing high accuracy radio positioning chains in the operational area. These chains, besides catering to the needs for living and non-living resources, will also meet the other requirements of environmental studies and shipping. In the line of sight zone, accurate

position fixing will be required locally for the exploration and exploitation of heavy mineral placers and for the studies on marine pollution and harbour development. These can possibly be managed by portable chains in the vicinity of the areas of operation.

In the remote zone, position fixing will be required for environmental studies (physical and chemical oceanography) for assessing living resources potential (biological oceanography) and for reconnaissance geological and geophysical surveys to assess the non-living resources potential. At present very little fishing is being carried out in the remote zone by the Indian vessels. The requirements of position fixing for the remote zone may not have a priority and for the present satellite navigation would be adequate for many surveys though long range radio positioning systems may become necessary in the future.

In the deep sea zone, besides the regional oceanographic surveys, the exploration for manganese nodules will be of special interest. Oceanographic surveys in this zone can be carried out by satellite navigation system. Exploration and exploitation of manganese nodules in future may require integrated position fixing systems for determining positions of stations as also for an accurate positioning of bottom samplers on the sea bed.

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