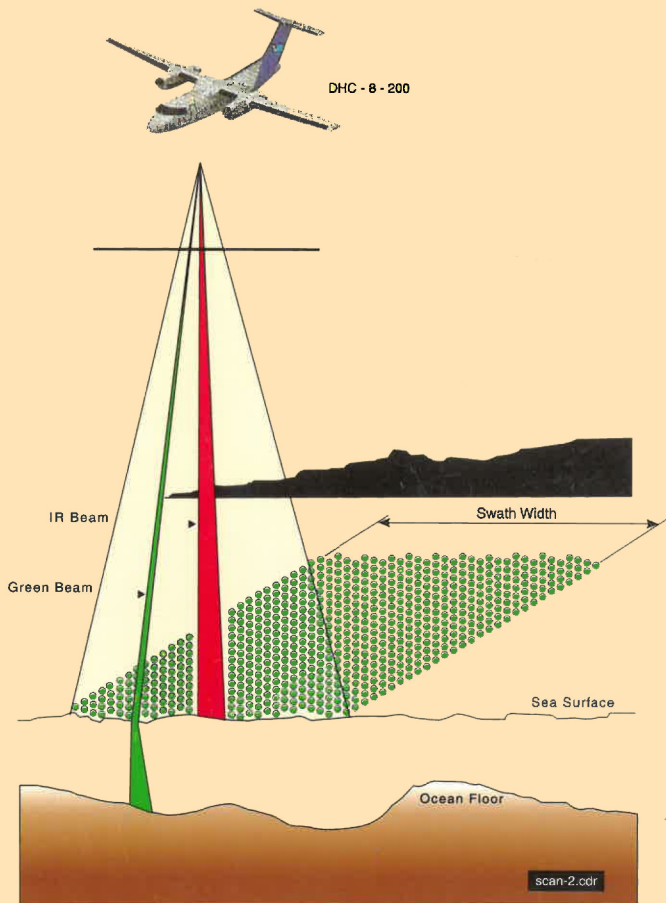




ROPME / PERSGA / IHB WORKSHOP ON HYDROGRAPHIC ACTIVITIES IN THE ROPME SEA AREA AND THE RED SEA

24 - 27 October 1999, Kuwait

Proceedings



**Regional Organisation
for the Protection of the
Marine Environment
&
International
Hydrographic Bureau**

KUWAIT 2000

ROPME/GC-10/027/1

**ROPME / PERSGA / IHB WORKSHOP ON
HYDROGRAPHIC ACTIVITIES IN THE
ROPME SEA AREA AND THE RED SEA**

KUWAIT, 24 - 27 OCTOBER 1999

PROCEEDINGS

Edited by

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Environment (ROPME)**

Kuwait, October 2000

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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

*In the name of God,
the Compassionate, the Merciful*

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Opening Session

INTRODUCTORY STATEMENT OF
John Leech
Director, International Hydrographic Bureau

The IHO hopes that this workshop will be the first of many, jointly sponsored by ROPME and IHO, to encourage regional co-operation in development of hydrographic services.

Definition

Hydrography is defined as; "That branch of applied science which deals with the measurement and description of the physical features of the navigable portion of the Earth's surface and adjoining coastal areas, with special reference to their use for the purpose of navigation".

The hydrographic services provided by the IHO Member States have two principal elements; acquisition of information, and provision of information services. They serve two principal groups of users; navigators, and users of Geographic Information Systems (GIS).

Prevention of shipwrecks and oil spills

The main purpose of hydrographic services is the prevention of shipwrecks through the provision of accurate and comprehensive nautical charts. Nautical charts enable ships to make safe international voyages and approaches to ports through the dangerous rocks and shoals which lie hidden beneath the surface of the sea. Prevention of accidents helps to ensure the safety of life and property, and to protect the marine environment from the often disastrous consequences of such accidents. However, groundings on (or collisions with) uncharted shoals continue to occur (eg: *QE II*, USA, 1992). It is the fundamental business of the hydrographic services to ensure that all dangers to navigation are discovered and reported.

Two other aspects of hydrography are of interest in the context of navigation. One of the principal causes of shipwrecks and pollution of the sea is human error in navigation (eg: *Torrey Canyon*, UK, 1969; *Exxon Valdez*, USA, 1990). Recent advances in GPS and computing systems have given rise to new techniques in electronic navigation, which significantly reduce the incidence of human error in navigation, greatly reducing the risk of groundings and collisions. Electronic hydrographic charts are an essential component of electronic navigation techniques.

Collisions between ships are another major cause of marine pollution (eg: *Agip Abbruzzo*, Italy, 1991; *Orapin Global*, Singapore, 1997). In order to reduce the incidence of collisions there is a trend internationally towards the introduction of maritime traffic control. Successful introduction of marine vessel traffic systems (VTS) requires a good knowledge of the hydrography in the area of interest. This is recognised in the IMO document "Routeing Guidelines". An example of a regional VTS is being established by the littoral states of the Malacca Strait, driven by the need to prevent pollution of the important eco-systems in this busy sea area. Another example is proposed under the PERSGA project for the Gulf of Aden and the Gulf of Suez, funded by GEF.

Response or Prevention?

Internationally much attention is paid to *response* to accidents, especially oil spills resulting from groundings and collisions. However containment of and clean up after such events is very costly, and of limited effect. There is an old proverb, which says, "Prevention is better than cure". Programmes such as hydrographic services, which are aimed at *prevention* of accidents, will be more effective than response programmes in ensuring the protection of the marine environment, and the preservation of dependent industries and communities from the often disastrous economic consequences of such accidents.

The value of hydrography in this context is emphasised by the upcoming revision of the IMO Convention on the Safety of Life at Sea (SOLAS), including the introduction of the new Regulation 9, of which a copy is attached. The importance of this is also mentioned in the UNCED Report, "Agenda 21", Chapter 17, which suggests that States may *promote navigational safety by adequate charting of coasts*.

Hydrography in support of GIS applications

The UN Convention on the Law of the Sea (UNCLOS) also mentions the importance of hydrography, not just for the safe conduct of maritime traffic, but also for the delimitation of maritime boundaries, and the sustainable development of marine resources.

Following the signing of the UNCLOS Convention, nations are beginning to take a much greater interest in the administration and sustainable development of the coastal zone and the EEZ. Emerging demographic projections suggest a significant increase in economic activity within the coastal zone. This will result in much higher demands for high resolution spatial data for the coastal zone and EEZ in digital form.

UN Assembly Resolution A 53/32, concerning the Year of the Oceans, recognises the world wide importance of hydrography.

Hydrographic data are essential to the understanding of marine ecosystems, since seafloor topography, and marine tides and currents are fundamental determinants of ecosystem characteristics. Easy access to these data makes an important contribution to the sustainable development of the national maritime zones and maritime industries. They are invaluable to scientists engaged in all sorts of marine research.

As the information age matures, governments and the community have come to place a much higher value on geographic information than was the case in the past. This is evidenced by the development of national, regional and international spatial data infrastructures.

It is likely that spatial data management will soon be one of the most important activities of national hydrographic organisations, and that GIS will become one of the most important enabling technologies.

It is interesting to note that some major hydrographic initiatives, for example the GEF funded PERSGA project for the Red Sea, are seen by the sponsors to be not only initiatives in improving safety of navigation, but also as contributing significantly to the provision of spatial data to a number of other important coastal zone programmes.

Status of Hydrography in the ROPME Sea Area

Hydrographic surveying and nautical charting of the ROPME Sea Area (RSA) was, for the most part, carried out during the colonial period. Some improvements were made in the 1980s and 90s, but activity was limited due to other national priorities. In the year 1999, much of the RSA is not well surveyed, which increases the risk of marine casualties, and inhibits understanding of the marine environment.

It is the opinion of the IHO that hydrographic services will continue to be an important part of several elements of the national and regional infrastructure (eg: transport, science, foreign affairs, environment programmes, etc.). Hydrographic charts and data services cannot be produced from satellite imagery, and images must be obtained using acoustic or laser technology from ships (or aircraft). This is expensive and time consuming and regional governments should try to budget for provision of these services.

The International Dimension

Hydrography is an inter-national business, since navigation and marine ecosystems operate across national boundaries. A most important aspect of this workshop is that it brings together representatives of all the regional states, providing a good opportunity to renew personal contacts, and to strengthen regional co-operation.

Conclusion

ROPME Member States should be aware of the important benefits, which accrue from investment in hydrographic services. ROPME and IHO should work together to encourage their development in the region. This would accord with the objectives stated in Articles III and IV of the ROPME Convention.

The IHO considers that inter-agency collaboration on this important subject will have positive results.

Draft Regulation 9, SOLAS Chapter V

Regulation 9

Hydrographic Services

- 1 Contracting Governments undertake to arrange for the collection and compilation of hydrographic data and the publication, dissemination and keeping up to date of all nautical information necessary for safe navigation.
- 2 In particular, Contracting Governments undertake to co-operate in carrying out, as far as possible, the following nautical and hydrographic services, in the manner most suitable for the purpose of aiding navigation:
 - i. to ensure that hydrographic surveying is carried out, as far as possible, adequate to the requirements of safe navigation;
 - ii. to prepare and issue (official) nautical charts, sailing directions, lists of lights, tide tables and other (official) nautical publications, where applicable, satisfying the needs of safe navigation;
 - iii. to promulgate notices to mariners in order to keep (official) nautical charts and publications, as far as possible, up to date;
 - iiii. to provide data management arrangements to support these services.
- 3 Contracting Governments undertake to ensure the greatest possible uniformity in charts and nautical publications and to take into account, whenever possible, relevant international resolutions and recommendations.
- 4 Contracting Governments undertake to co-ordinate their activities to the greatest possible degree in order to ensure that hydrographic and nautical information is made available on a world-wide scale as timely, reliably, and unambiguously as possible.

Note: The precise text of this Regulation is still under discussion within IMO, but it is expected to be finalised in the year 2000.

*Refer to the resolutions and recommendations of the International Hydrographic Organisation

Session I

**Presentation from
Member States**

PRESENTATION OF THE STATE OF BAHRAIN

Moh'd A. Al Fayez

Introduction

The State of Bahrain is an independent Arab State situated centrally on the southern shores of the ROPME Sea Area (RSA), with the mainland of Saudi Arabia on the west and the peninsula of Qatar on the east.

Bahrain Statistics

Bahrain is an archipelago of over 33 islands and island groups, which cover a total area of 702 km². It has territorial waters of some 10,000 km², much of which are generally shallow and contain many coral reefs. The main port of Mina Salman is located south of the capital city of Al Manama, on the northern end of Al Bahrain, the largest island. A natural channel leads from the central RSA to this main port.

Bahrain currently has a total of 164,300 merchant tonnage. In addition, 1,500 fishing vessels are registered under Bahraini flag, along with 1,500 pleasure craft.

In 1992 Bahrain became a member of the International Hydrographic Organisation (IHO).

The Hydrographic Section

The Hydrographic authority for Bahrain was established in 1978 as a Section within the Survey Directorate of Ministry of Housing, Municipalities and Environment. The Hydrographic Section is located at Mina Salman (Figure 1).

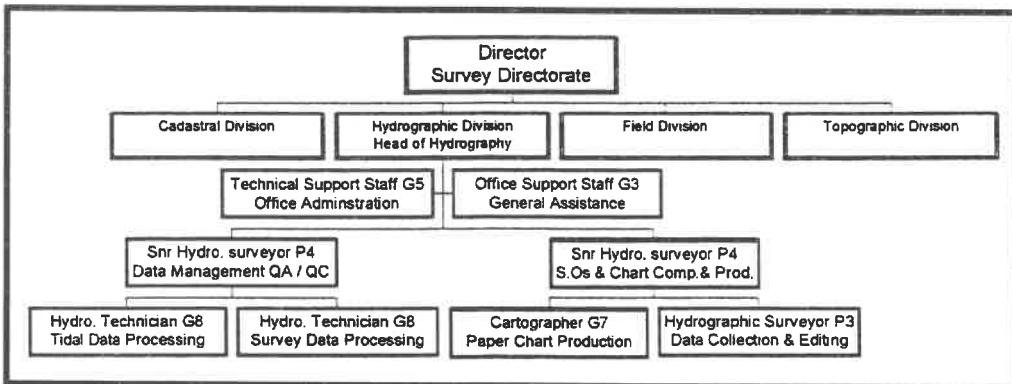
The Hydrographic Section's main duties include traditional bathymetry, tidal analysis and tidal stream measurement within the territorial waters of Bahrain.

The staff of the Hydrographic Section consists of 12 people: 4 professional hydrographic surveyors, 3 hydrographic survey technicians, 1 cartographer, 2 technical support staff and 2 office support staff. The professional hydrographic surveyors have all been educated in the UK (RN Hydrographic School, HMS Drake and Plymouth University) and the survey technicians at International Maritime Academy in Trieste, Italy.

The Section has presently two boats for its activities, both locally designed and primarily used for shallow water bathymetry. However an 18 meter catamaran is

presently being built in Wanganui, New Zealand and is expected to be commissioned September 2000 in Bahrain. This will allow the Hydrographic Section to carry out survey of the northern waters of Bahrain.

Figure (1): Hydrographic Section present organisation Chart



Differential GPS is used for positioning at sea. The Differential link is supplied by MENAS. The on-line software used is Trimble's Hydro package, which shortly will be upgraded to HydroPro in order to cope with the Millennium change and to integrate the on-line software with CARIS HI~S and the database system.

Hydrographic Section Activities

The State of Bahrain Hydrographic Section has surveyed to date some 55% of the Territorial Waters of the country.

Its products include a national chart series of ten published charts, seven of which are published and the remaining three are proposed. Four charts have been adopted into the International Chart Scheme, two having already been published, and the other two being under production. Of the charts the Section has produced, two have already been converted to WGS 84 in accordance with IHO resolutions and the rest will be converted upon reprint.

The Section also publishes annual Tide Tables for the State of Bahrain, has published a Tidal Stream Atlas, and provides a survey service for the private sector and other government bodies (Table (1) & Figure (2)).

During the past 5 years there has been an increased demand for hydrographic data for coastal zone management. From 5 -10 requests per year the Section is now handling 1-2 per week for projects within the coastal zone, primarily

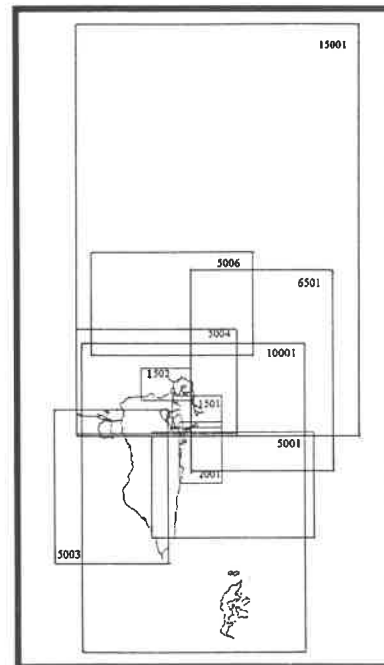
Table (1): Chart and publication catalogue

CHART NO	TITLE	PUBLISHED	SCALE	PRICE
1501 INT7258	Mina Sulman and Approaches	May 1996	1:15,000	6/-
1502	Mina Manama and Approaches	Prop. Dec 99	1:15,000	6/-
2001	Sitra to Umm Jalid	May 1996	1:20,000	6/-
5001	Sitra to Tighaylib	Dec 1994	1:50,000	6/-
5003	Al Baynah As Sagirah to Ra's Al Bar	Feb 1992	1:50,000	6/-
5004	Approaches to Bahrain	Jan 1993	1:50,000	6/-
5006	Hayr Shutayah to Khawr Fasht	Apr 1989	1:50,000	6/-
6501	Outer Approaches to Bahrain	Prop. Mar. 2000	1:65,000	6/-
10001	Khawr Fasht to Janan	Sep. 1997	1:100,000	6/-
15001	North Shoals of Bahrain	Prop. Dec 2003	1:150,000	6/-
P700	Tide Tables	(Annual Updating)		4/-
P701	Tidal Stream Atlas	(Complements P700)		4/-

reclamation. In order to cope with this number of requests the Section has developed a comprehensive database system using Microsoft Access for managing hydrographic data. The latest DB is S-57 compliant database integrated with the CARIS Hydrographic software package that was acquired and implemented earlier this year. Using CARIS the Section will have all its charts as CARIS files in approximately a year. The next step, the CARIS Hydrographic Object Manager (HOM) will be purchased early next year and will enable the Section to start producing ENC data. This is expected to be finished within a year.

The databases held in the Section are:

Figure (2): Chart publication



- Automatic Survey Log containing all information for surveys carried out.
- Tidal data
- Sounding data
- S-57 in-coded data
- Hourly pressure data for water level compensation in tidal analysis
- Hourly wind data

Today, all bathymetric data is collected in digital format. The Section has approximately 95% of all data needed for chart production in some type of digital form and uses a comprehensive pool of networked PCs during its data processing and quality assurance/control.

PRESENTATION OF THE ISLAMIC REPUBLIC OF IRAN

Ahmad Parhizi

Ports and Shipping Organisation is working under the supervision of the Ministry of Road and Transportation.

Ports and Shipping Organisation are responsible for

- Safety of Navigation
- Prevention of Marine Pollution

Bandar Imam Khomeini Port includes

- 37 Berths
- 6 Petrochemical Berths
- 8 Oil Terminal Berths

There is Hydrographic and Dredging Department

Hydrographic Dredging: Boat with Echounder, DGPS, Computer, 4 Hopper Suction Dredger, 3 Cutter Suction, 3 Grab Dredger

We make our Hydrographic Surveys four times a year in some part of the port there is 1 meter of siltation.

KUWAIT HYDROGRAPHIC OFFICE ACTIVITY (K.H.O.)

Nabil Al-Turkait

Kuwait is a member in IMO since 1960. Kuwait Hydrographic Office is under the Technical Department of Transportation Sector of the Ministry of Communications.

The K.H.O. provides support to Government Departments, agencies and contractors on matters concerning navigation aids hydrographic survey, channel dredging, chart production, warning to navigation and marine projects for Kuwait territorial waters.

The K.H.O. has carried out a project for hydrographic survey covering most of Kuwait territorial waters (90% approx.) in 1986).

The final product of the product was series of eleven navigation charts in both languages English and Arabic.

In 1998, a complementary hydrographic survey of the northern area was conducted. The scope of this survey in addition to that is to update all the data collected in 1986 including wrecks, navigational aids, coastline changes, offshore structure, and consequently reproduce the Kuwait Chart Series in full updated information. The project also includes digitising of charts and converting to electronic data according to S-57 (IHO special publication). By the end of this project, Kuwait will establish a database for its future hydrographic services.

Hydrographic activity in Kuwait runs through a Committee with members from MODC (Survey and Naval Dept.), Port Authority, Oil Companies, Pollution and Municipality (Survey Dept.), Coast Guard in addition to Ministry of Communication (Transport Dept.).

Co-ordination between these authorities is very necessary for hydrographic activity. Kuwait is willing to join IHO. The application was made since 1997 and is waiting for final approval in the National Assembly.

We hope finally by our leased survey boat we have trained people in cartography and fulfilled our objectives in updating our charts.

PRESENTATION OF THE STATE OF QATAR

Ali A. Al-Abdulla

Qatar is a peninsular; it is about 11,000 km² and falls in the ROPME Sea Area.

The survey division which falls under the Ministry of Municipal Affairs & Agriculture, it is part of The Land Information Centre and the Survey Division is divided into two parts i.e. Land Survey and Hydrographic Survey.

The Hydrographic Survey consists of a Supervisor, Sr. Surveyor, Asst. Surveyor and three Technicians and are equipped with a boat which is fully equipped with Echo Sounder, GPS and Navigation System to carry out all the surveys along the coast of Qatar.

Up to the present time we have made a coverage of 60% from the north to east coast of the Country and we do carry out special projects such as survey for dredging channels for our Ports (Doha, Umm Saeed and the Ras Lafwan Ports) as well there are other agencies in Qatar such as (QGPC) which carry out most of the Hydrographic surveys with the help of our office to cover their requirements. In the meantime we do produce tidal charts and distribute them to the different agencies in the Country.

A study is in progress at present wherein we will be converting all the digital data available with us to GIS system.

And we are also aiming to have all the data of hydrographic works digitally formatted which we were carrying out for Land and Water Projects.

HYDROGRAPHIC SURVEY IN THE KINGDOM OF SAUDI ARABIA

Abdulrahman M. Al-Shehri

The Kingdom of Saudi Arabia has a large coast area overlooking the Red Sea and the ROPME Sea Area (RSA). The Kingdom's geographic and strategic location makes it more responsible for security and for the safety of navigation in the region. Accordingly, the Ministry of Defence and Aviation established the Military Survey Department (MSD). Part of the MSD mission is to take care of geographic information, data collection and the production of maps and charts of different types and scales.

As part of the MSD organisation, the Hydrographic Survey Wing is operating to collect information as needed for the production of hydrographic charts, maintaining and updating them and ensuring their conformity to international standards and requirement of the Monaco - based International Hydrographic Organisation (IHO).

The Hydrographic Survey Wing involves many sections including the Hydrographic Survey Section, Oceanographic Section, the Navigation Section, and other support sections. The Wing's duties and the responsibilities are briefly stated as follows:

1. Survey the Saudi waters.
2. Producing charts in coordination with technical wings at the Military Survey Department.
3. Charts updating.
4. Extend Hydrographic information support to meet the requirements of military agencies (such as the Navy, Coast guards, and the government sectors) along with the needs of such civilian departments as the Ports Authority, the Meteorology and Environment Protection Department, the National Commission for Wildlife Conservation and Development and others.
5. Oversee and follow-up the conduct of maritime research and development projects on the Kingdom's waters.
6. Extending advisory support on the selection of seafont locations suitable for the construction of seaports.
7. Represent the Kingdom of Saudi Arabia at regional and international conferences and seminars.
8. Represent the Kingdom in the coordination of work with international and regional organizations.
9. Participate in maritime boundary committees.

As the wing has no hydrographic survey vessels in its possession, it has been sending staff for overseas training (in Taiwan, Britain and United States of America). As of

today, the wing has many well-trained hydrographers on its staff who can now build up their own experience and cope well with technological developments in the field.

The Hydrographic Survey Wing is currently studying offers from many international companies specialised in hydrography and oceanography in the context of a long-term plan whose goal is for the Kingdom to have its own hydrographic survey vessels and obtain adequate local manpower and equipment support, build up a national hydrographic geographical database and the production of charts to international hydrographic standards.

It is worth mentioning though, that the Ports Authority, acting on behalf of the government, has conducted hydrographic surveys covering certain areas of the Kingdom's Red Sea expansion and produced 1:150,000 and 1:50,000 charts. As for the Kingdom's RSA waters, no such hydrographic surveys have been conducted yet. Therefore we are still using NIMA and Admiralty charts for this area.

The MSD hydrographic Survey Wing has plenty of information on the Kingdom's islands and coastlines. The wing is always operating in systematic coordination with other government authorities concerned with the Kingdom's hydrographic areas.

Unfortunately, the status of hydrographic survey in the GCC countries is not pleasing, nor is it up to the required level. A quick look at the government departments in charge of this activity in those countries will tell that they are widely different and lacking uniformity as seen Table (1).

Recently there was a workshop organised by ROPME, which brought together hydrographic survey specialists in the ROPME region including Iran. It was noticed that representatives taking part in the workshop were sometimes from the General Directorate for Surveying and Hydrographic Affairs and sometimes from companies interested in hydrographic surveying such as petroleum companies.

ROPME was successful in organising this meeting of hydrographic specialists in the ROPME countries along with representatives from the International Hydrographic Organisation (IHO). The meeting parties discussed the current situation and future prospects and agreed to establish a regional grouping of the ROPME countries, and to the best of my knowledge, the group will hold its first meeting in the Islamic Republic of Iran in July 2000.

I am optimistic that the meeting will mark a turning point and come up with a more positive outlook to hydrographic survey in the region. To make this happen, specialist hydrographers should contribute in a more active role in promoting public awareness and knowledge of their field of speciality. They must also speak their mind on the subject so that governments in the region would agree to take better care of hydrographic survey and become more involved with the world efforts for the safety

of navigation and the safety of life at sea. Each country in the region should contribute to the common effort of ROPME countries for establishing a good image worthy of their historical role as pioneer sea explorers of the world.

This is what I could recall of the brief remarks I had made at the conclusion of the fore-mentioned workshop on hydrographic survey in Kuwait

Table (1): The government departments in charge of hydrographic survey in the GCC countries

Country	Government Authority In Charge of Hydrographic Survey
Kuwait	The Ministry of Communications.
Saudi Arabia	The Military Survey Department / Ministry of Defence and Aviation (coordination is active with 11 other government agencies of concern).
Bahrain	Ministry of Housing.
Qatar	The Geographic Information Centre of the Ministry of Municipalities.
U.A.E	The Military Survey Department of the Ministry of Defence (at an international meeting in Pakistan, the country was represented by military personnel from the UAE Navy / Operations).
Oman	The Royal Navy, Ministry of Defence, is taking charge of this activity, which is obviously more relevant to the field. The country's steps in this area are praiseworthy.

HYDROGRAPHY IN THE UNITED ARAB EMIRATES

Abdulla M. Al Naqbi

Purpose

To give a brief explanation of how the sea surveying and Nautical charts are produced and managed in the United Arab Emirates, to be available for both military and civilian users.

Introduction

Talking about the United Arab Emirates, it is considered to be the second in the area in terms of the length of its coastline after Iran. This coastline extends for a distance of about 275 miles on the ROPME Sea Area, and the UAE occupies 50 miles stretch of the coastline on the Gulf of Oman, which both add to a total length of 325 miles.

Resulting from this critical and very essential information, it was found that, it is very important to have well trained personnel with modern and very advanced softwares and hardwares to manage these bodies of waters.

The need for nautical charts, which perfectly describe the seabed, was raised long time ago in all countries due to its importance. The main users for these charts are navigators and mariners whose task is to run big commercial ships, these charts are also used by coastal engineers, oceanographers, marine biologist and environmental scientists.

Military users are considered one of the primary users of these charts.

As many other countries, we started to depend on the British Admiralty charts. These charts cover most parts of the country with different scales. The information on these charts are mainly gathered and updated by the mariners and commercial ships passing by the area. So, it seemed insufficient to completely cover the area.

In 1997, we started the production of our own charts; this was accomplished with cooperation with some foreign companies. A lidar bathymetric survey was conducted to almost cover the entire country; several charts were published with different scales. Some approaches and Channel Surveys were also accomplished by our hydrographic section using conventional echo sounder technique to produce large-scale charts.

Roles of MSD in Charting

1. Produce and publish paper charts.
2. Produce all charts in digital format.
3. Produce and distribute predicted tide tables.
4. Publish periodic notices to mariners.

Resources of Products

1. Existing data from available old charts.
2. The use of available topographic data.
3. Satellite Imageries and photographs.
4. Data resulting from Seismic Surveys.
5. Data resulting from dredging projects and ports development.
6. Hydrographic data directly collected by :
 - i. LIDAR system.
 - ii. Single beam echo sounder.
 - iii. Multibeam system.

Chart Scales

Three different scale categories are used in our charts: -

1. Large Scale: i.e. 1:7000: 1:10.000
- Used for harbour and approach channels.
2. Medium Scale: i.e. 1:50.000
- Used for coastal navigation.
3. Small Scale: i.e. 1:750.000
- Offshore navigation.

On the Horizon

1. Converting all digital charts to S-57 format.
2. Production of ENC to be used in all ECDIS technology.

Conclusion

UAE Military Survey Department (MSD) which is considered the primary hydrographic organisation in the United Arab Emirates will continue to provide the ultimate services to fulfil all needs for both civilian and military users, by furnishing all essential information related to hydrography and charting.

Session II

General Presentations and Safety of Navigation

INTERNATIONAL DISTRIBUTION OF CHARTS

John Clarke

Introduction

I am grateful to the organisers of this workshop for the invitation to be here today and to have the opportunity to address you. This is an important initiative, which aims to assist in the development of hydrographic infrastructures in each of your countries such that you are in future capable of delivering necessary services. However, unlike perhaps the majority of national responsibilities, those tasked with the support of a nation's hydrographic needs are required, almost from the start, to consider how the data they gather and assess and from which they make navigational products are to be distributed beyond their own shores to ensure, in particular, safety of navigation for SOLAS users.

It would of course be very easy for me today to direct my remarks solely towards issues which dominate the thinking of a Hydrographic Offices (HO) such as my own, but I recognise that for many, though not all of you, these will seem divorced from your own needs and interests. However I will seek to show that while there are differences in emphasis depending on the organisation involved, there are, in reality, common demands upon HOs as organs of government and which are at the heart of the distribution activities of all hydrographic organisations be they small or large.

Aims of a Hydrographic Office

My task here is to elaborate on what I consider are the three aims, which any Hydrographic Office must achieve if it is to carry out its mandate. They are setting up of systems able to deliver data to all mariners in the area of responsibility, ensuring that the data so provided meets defined standards and lastly maintaining the data from all information sources.

National Responsibility for Data Provision

The first of the aims of the HO must be to ensure the availability of data to meet all foreseeable types of need within its area of responsibility. Hydrographic Organisation, as parts of government, does not of course operate in a vacuum. Governments require them to undertake work which meets both national responsibilities as well as other possibly more marginal activities. National governments' responsibilities for hydrography arise principally from Chapter V of the International Convention for the Safety of Life at Sea (SOLAS) which is administered by the International Maritime Organisation. It is Regulation 20 of

the Convention which requires all ships to carry adequate and up to date charts and publications for any voyage. This then may, in simple terms, be described as the principal “customer need” and is the primary driver to which hydrographic offices must respond in carrying out their production and distribution functions.

The aim, must be to ensure the safety of navigation in the waters under national control as well in other areas where a country may, under the arrangements of the International Hydrographic Organisation (IHO), have assumed the responsibility for chart production in response to a local deficit in capacity and resource.

National HOs must, however, have other needs in mind in considering their distribution function. National governments will inevitably make demands, which cover a much wider canvas including the provision of data in inshore areas, meeting the needs of small craft users for pleasure as well as for fishing, the support of marine research to meet a wide variety of needs and the protection of the whole maritime environment including the setting up of zones protected for historical, resource exploitation or environmental reasons. All of these can in their way impact on the distribution capabilities and resource, which must be found by national HOs.

Quality of the Delivered Product

The second aim of the HO is to be able to assure its government that the data it provides is supplied to meet defined standards. As bodies within government, national hydrographic organisations have a considerable interest in the maintenance of the quality of the products they deliver to the user. It is fair to say that the user has in most respects a similar, though possibly less frequently stated interest. Over most of the present century, working within the IHO, member states have attempted, with increasing success particularly over the last twenty years, to standardise the content of charts, with the aim of delivering a quality product constructed to meet the stringent technical standards of the IHO. The work of the Chart Standardisation Committee of the IHO has been fundamental to the success of this work, which has benefited both users and producers. The Technical Resolutions (TRs) of the IHO have provided an agreed set of rules within which chart producing nations can operate ensuring their control of the quality of their products.

Nations have also to keep clearly in mind that the data they collect has to be delivered in the forms required by their diverse customer groups. While charts are primarily planned and the surveys are carried out to meet the SOLAS need, other products must be able to be constructed and delivered to meet what may be seen, from a narrow viewpoint, and to be uneconomic or marginal needs such as those listed above. Increasingly the development of digital databases within HOs is making supply of these products possible, but the levels of investment in skills

and training, which are needed to carry out these tasks to requisite quality standards, should not be underestimated.

Updating the National Database

The third aim of the HO, is the continual updating of the database from which its products are delivered. The integrity of the national database and the maintenance of the outputs from it are essential if governments are to be assured that their maritime interests are being safeguarded. A nautical chart, unlike a land map, is only as good as the extent to which it is kept up to date for those features which have a bearing on user safety. While skilled staff will have been employed in the initial assessment and analysis of the data incorporated in the chart, there is then a similar need to maintain and deliver corrections to the product using both analogue and electronic means. This requires each nation to be able to deliver Notices to Mariners (NtoMs) which are a distillation of material which has to flow into the HO continuously throughout the year, be processed to tight deadlines and be published and distributed quickly. It will be readily appreciated therefore that to enable such delivery, the national HO has to institute and maintain internal systems employing considerable "connections" across the geographical area it serves, accepting information, interrogating data suppliers and searching for material it suspects may be available but which has not reached it.

The ability to carry out this work requires there to be a national consensus as to the status of the national HO at the centre of the information wheel, with its spokes leading to other government departments, ports, national bodies such as lighthouse authorities, environmental protection agencies, oil and gas and other commercial developers, research bodies and local authorities responsible for such things as outfalls. Without the co-operation of these and the resource to handle their information within the context of the national interest, it is impossible for a Hydrographer to guarantee to his Minister the distribution of safe data and products.

From what I have said so far, it will be clear that we wish to ensure as hydrographers that within the waters for which we have national responsibility we are able to provide an official chart which is kept up to date. My government looks to me to state that the product I produce is an adequate product meeting the full range of national requirements, not just today but for the future.

Product Availability and Distribution

One of the main components of the distribution function is the availability of the product. This necessitates the creation of a production flow line which is

responsive to changing levels of demand for issued products so that orders from customer/users can be met expeditiously, either immediately from stock or, if a more “just in time” philosophy is to be used, by printing what is needed. This last approach will probably only really come into its own when Print on Demand systems are able to meet economically the full needs of users with delivery either in electronic or analog form to often demanding deadlines. Until then, HOs will need to maintain chart and publication stocks sufficiently large to meet continuing demand but without imposing an unnecessary correction burden on the HO’s staff.

Customers needs also have to be met where they occur: it is of little use having a corrected chart available in the HO of a country but not in at least the principal ports where the product demands will arise. For most smaller HOs meeting this need will not require the institution of more than a limited network of distributors, though these may range in size from large specialised businesses dealing solely in charts and similar products, to small yacht chandlers for whom charts are a small part of the sales inventory.

But no matter what the number of outlets, the HO will need to exercise close control of the standards being applied to the operation in its name. This calls for comprehensive contractual arrangements with distributors setting out on the one hand the responsibilities of the national HO, and on the other hand of the commercial outlet. Requiring the distributor to carry sufficient stock to meet expected user demand is essential, as is the need to ensure that his staff are trained to undertake the correction of the product before issue.

Meeting the particular needs of government and being able to distribute particularly to naval users will require a separate chain of supply. Naval needs can be both long planned in the case of exercises, but can also arise, frequently with little or no warning, demanding quick supply in larger than normal quantities. No government will wish to find itself so placed that it is unable to respond to such national needs. Such imperatives underline the reality that supply of a nation’s hydrographic products cannot be entrusted solely to the commercial world.

Data Ownership and Liability

You will be aware that since the 1919 London International Hydrographic Conference one of the strengths of the world’s hydrographic community has been the willingness of HOs to engage in the exchange of data for the greater good and safety of chart users. Although until recently this was permitted without financial recompense to data providers, TRs dealing with the exchange of data are framed against the background of increasing awareness of the value to national HOs of the data they have gathered and turned into products. While in reality, the

ownership of the Intellectual Property Rights (IPR) has never been in doubt, the increasingly commercial nature of the world of hydrography has highlighted the need for HOs to control the use of their data either through arrangements with other HOs (Bilateral Arrangements) or through the mechanism of full contractual arrangements with commercial data providers.

Whichever situation pertains, there is however a need for HOs to take this seriously. It will, if properly managed, provide the HO and the national tax payers who fund the collection of survey, with a valuable source of income able to be re-invested in the development of systems and processes, ultimately to improve the ability to meet the full variety of customers needs.

The importance of the question of liability for erroneous information or data has always been an area of which HOs have been aware, and it is arguable that the inception of digital systems has heightened their appreciation of the position. HOs are required to produce products for distribution and sale to standards consistent with the best recognised levels of competence across the IHO's membership. National HOs accept their liability as professional data providers, always accepting that they cannot be liable for the mistakes of others of which they could have no knowledge or which they could not be expected to have foreseen. Many shipping companies and other chart users value the level of assurance provided in officially produced charts and publications.

I have now dealt with the major issues, which surround the delivery of a paper chart by the HO. It is time now, in the remaining part of my presentation, to deal with the issues, which have arisen, in dealing with digital data and product delivery. We must be under no illusion: although the bare bones of paper chart and digital chart delivery systems look alike, they differ in some important ways.

Electronic Charts and their Distribution

Until a relatively short time ago all HOs had only to concern themselves with the provision of chart information in analog form – the paper navigational chart. While the paper chart is still the dominant product of most HOs, the balance of supply is rapidly changing with increasing demand for raster and vector chart data. Some navies are already planning for the paper-less charting environment. New as well as established HOs must therefore ensure that they have distribution capabilities able to meet the challenges of electronic chart delivery. Indeed it may well be that newer HOs will wish to concentrate their distribution arrangements on digital supply rather than paper products. The ability to do this, particularly if skill levels are low, may well depend on either assistance or arrangements with other HOs or commercial producers.

Whichever type of data the new HO decides to provide, the databases it creates must enable supply to meet international specifications. In the case of the Electronic Navigational Chart (ENC) these will meet the IHO's S57 edition 3 product specification as required by the IMO. A significant number of offices are also producing raster data following the UKHO's HCRF data format and it may be that even smaller offices will see the production of raster data for the non-ENC areas of their waters as a good cheap investment.

The difficulties involved in the delivery and distribution of the S57e3 product with its weekly updates should not be underestimated. The specification is highly involved and while it attempts to be unambiguous, skill is required in interpretation. This takes time to achieve, such that consistency of output is possible. A number of options therefore confront the newer HO where investment in the hardware, software and training to make a possibly restricted number of ENCs may be difficult to justify. The first is to have the product made available for distribution by another possibly larger HO under contract. Alternatively they may be made by a contracting commercial company, and there are a number of such companies in the market, in some cases already carrying out such work and able to provide consultancy on how best to achieve the aim of early data distribution.

The fundamental issue, however which cannot be avoided, irrespective of the production route chosen, is how to manage Quality Assurance (QA) in the product. Under the WEND principles (see below), the issuing HO is responsible for the quality of the data it issues. The QA is therefore at the forefront of the debate about how to deliver. It is QA by the national HO which transforms a collection of varied data sets into the digital product, which a government can be assured, meets the appropriate international specifications for content and quality.

The largest HOs have found this a major challenge and have resorted to employing considerable software resources in the form of data format checking programmes as well as visual checks against raster chart images from their paper charts. Where work is being done by an organisation, whether an HO or commercial company, on behalf of another HO, then there will need to be a decision on where QA is to be undertaken: in the issuing HO, with the attendant resource overheads and training requirements, or elsewhere. Given that in either case the liability for the accuracy of the distributed data will lie with the HO which has distributed the data to users under its imprimature, not with the organisation which produced it under contract, it would seem wise for the issuing HO to undertake the QA. The important point is that who makes the chart is not important: what matters are who does the QA on the process output.

WEND Principles

The principles governing the creation of ENC's were produced by the Special Committee on Worldwide Electronic Navigational Chart Data Base (WEND), with the recognition that distribution of the product was a separate issue from that of data base management. In order to form an orderly arrangement, ensuring the availability of their ENC's to users, the northern European nations agreed to the establishment of a Regional Electronic Navigational Chart Centre (RENC) with participating nations signing a Co-operation Arrangement (COA) in September 1996. Their commitment was additionally underlined by their signing of the Helsinki Accord in March 1998. This identifies the RENC as the common instrument for the provision of an integrated, consistent, uniform ENC service to be delivered through a wide network of distributors.

The Northern Europe RENC, known as PRIMAR, is, at the moment, the only organisation which has come into existence to perform this function, though there have been moves, particularly in the Mediterranean and Black Sea Regional Hydrographic Commission to examine other options. The originators of the WEND concept held the view that a number of RENC's would be required, one in each major hydrographic region, with data being transferred between them and so to the user. However, this has so far not happened, although PRIMAR stands ready to co-operate with other RENC's should they be established.

The decision, which each nation is now faced with, is what is the alternative to becoming a co-operating nation supplying data to PRIMAR? In discussing PRIMAR I use it as an example to demonstrate the sort of mechanisms being put in place to establish an ENC Service. This may act as a useful thought process as you, in your individual HOs, collectively or individually, consider how you will take matters forward in your region. I do not wish to make this talk appear to be simply an attempt to have you all join the other ten signatory nations or the other nations, which have begun to attend meetings as observers. Rather I want to point out the advantages, which accrue from the use of such a process. Firstly, it is working strategically with long-term plans, which are agreed by the nations contributing to it. Secondly it has developed production and management support systems which will ensure that only data able to meet the full S57 specification is accepted and passed to users. Its service support systems will allow distributors of its data immediate access to new ENC's and their updates using on-line systems. It will, in addition, give access to text and graphical information about all ENC products and services available from PRIMAR. For those distributors wishing to receive the data in hard form, CD Roms will also be produced.

Of course the operator actually distributing the product, whether the HO or a commercial data provider is no longer in complete control of the depiction of the final data. The software which Original Equipment Manufacturers (OEM) supply

as part of the ship's ECDIS is responsible for the actual display and integrity of the data in use. This is a major change from the paper chart model described above, but the prime responsibility of the HO is still the delivery of a Quality Assured product.

Data integrity in delivery is at the heart of the systems, which PRIMAR will use. Data encryption will protect the data, which HOs have paid to make available from tax payers' funds, in order to ensure a return to the suppliers in line with the sales achieved. The data will also be protected using internal Cyclical Redundancy Checks (CRC) or "checksums" to ensure that what is delivered is complete. This latter check system is an integral part of the S57 system: without it the data will not function in an ECDIS.

Conclusion

My message today has, I hope been clear. Delivery of the services which governments look to HOs to provide can only be achieved within a quality framework. While we understand the provision model for paper charts, the world of digital data has brought changes, which need to be borne in mind. The WEND Principles should underpin the digital operation and delivery systems of an HO. Adherence to these and the assumption of the need for the national HO to QA the national hydrographic data set will provide the best possible delivery to customers of all kinds.

REGIONAL CO-OPERATION AND INTERNATIONAL CHARTING

Peter Cox

Abstract

This paper traces the history and development of International Charting. It provides comment on the current status of International Chart Scheming and looks at issues affecting International Charting today including the impact of the revision of Technical resolution A3.4 and the development of the Electronic Navigational Chart. The arguments for and against the continued validity of the International Chart concept are reviewed. The concepts of paper charting will need to be reconsidered but the paper proposes that there will still be a place for the International chart concept.

Introduction and Brief History

The use of charts for navigation is only a little younger than navigation itself. Admiral Ritchie (1972) told of the first known gridded charts made by Marinus of Tyre in the first century. By the 13th century in Aragon and later by Portugal and Spain in the 14th and 15th centuries a form of chart known as the Portulan chart with its characteristic radiating rhumb lines was being produced. A measure of chart standardisation had begun. This standardisation was built on the needs of the mariners of the day and the foundation of great trading nations and explorers who needed the charts. Ritchie says that:

“Studying the early history of marine cartography one finds little co-operation between nations, but rather a changing pattern of leadership in chart-making dictated by the ascendancy of a number of nations in turn in the fields of marine trade and exploration.”

Chart standardisation as we know it today grew out of the needs of the chart user in a similar way. But, by contrast, it has been fostered by the principles of co-operation in hydrography, which the International Hydrographic Organisation (IHO) has championed. The growth of international co-operation in hydrography from International Maritime Conference in St Petersburg in 1912 through the development of the International Hydrographic Bureau in 1921 to the first regional hydrographic grouping, the Scandinavian Hydrographic Union, formed in 1929, is documented well elsewhere. The emphasis, which the pioneers in international hydrography brought, has always been focused on co-operation wherever possible. Wars have come and gone but the cordial yet often frank exchanges of views on charting issues have continued from 1921 to this day.

One key facet of international hydrographic co-operation has been the development of the International Chart. The concept of the International Chart series was to provide a worldwide series of charts to common specifications and format suitable for the use of vessels trading between nations. The first Technical Resolution A1 (I) decreed that “ the Conference is unanimous in expressing the wish that all countries, as soon as convenient, adopt the metric system for their nautical publications”. Commodore Kapoor (1976) saw this as the key step, which made it possible to conceive of the development of an international series of charts. It is perhaps significant that the fairly widespread movement among many nations to provide charts in metres in the late 1960’s heralded the first serious attempts at developing a single common series of charts, which could be accepted, contributed to and used by all nations.

Chart Schemes

For those who are not familiar with the processes of chart construction it may be well to rehearse briefly the principles of chart scheming, that is, the arrangement of scales and boundaries of the chart as it appears on paper.

In order to provide a document, which can be used for manual plotting of bearings at sea the chart, must be accommodated on a reasonable sized piece of paper. Various sizes of paper sheet have been used in the past. In the early part of the 19th century it was common for British Admiralty charts to vary in size and even in the shape of the rectangle used to accommodate the chart. The size and shape were arranged to fit best to the area being charted. More recently sizes and shapes have become more standard. A0 is becoming the most common size although there are still variations between nations. The issue of paper size immediately focuses the mind of the chart maker on three key issues:

- What areas of sea and coast do I need to portray on my chart?
- What level of detail is going to be required to navigate safely using my chart?
- What level of overlap between charts is needed to enable a navigator to transfer correctly from one chart to another?

If the paper size is already standard, these questions are resolved by decisions on the scale of the depiction of the detail on the chart, the precise positioning of the chart limits on the detail to be charted, and the precise positioning of the adjacent charts. It must normally be possible to show beacons, lights and other navigational marks commonly used to navigate through an area on the same sheet so that bearings can easily be plotted. Common marks between overlapping charts need to be shown. Even if the Global Positioning System (GPS) is used as the primary position fixing aid, visual marks are still needed to provide manual back-up should the electronic systems fail.

Another major factor in the decision on the best scales and limits for an area is the nature of the source data available to draw the chart. If only small-scale data are available it may be invidious to enlarge this beyond the limits of the positional accuracy with which the data were collected to a chosen chart scale and so the chart scale may have to be compromised to allow for the source data. There are occasions when the user needs plotting space on the chart even when the data are inadequate, but the inadequacy of the data must be clearly shown in such cases.

Charts are normally arranged in decreasing level of detail and therefore descending scale as the user leaves the coast. Larger scales depicting small areas in great detail characterise charts of ports and harbours. The scale decreases in the approaches, and the charts designed for coastal passage some distance offshore tend to be at yet smaller scales. Ocean transit charts are smaller still in scale. Charts are used both for planning voyages and for direct navigation on voyage: smaller scale charts, which may be used for planning, do not therefore exclude all coastal and inshore detail.

Chart scheming is not an exact science. It is almost invariably a compromise between the ideal and what can be achieved given the source material available, the shape of the land and sea in the area in question and the navigational requirements of the area.

Small Scale International Chart Scheme

In 1967 a Committee of six IHO member states (France, Germany, Japan, Netherlands, United States of America and the United Kingdom) was convened to study the development of a truly International Chart. This group began its work by establishing two common scales of ocean charts at 1:10,000,000 and 1:3,500,000. A particular nation would take on the drawing and production of a chart or group of charts. This would usually be where that nation had access to the best available source material. Once drawn, other nations could then request copies of the master information on plastic to enable them to produce their own versions of the charts in their own chart series. The aims were the promotion of a common specification which would be easily understood by chart users worldwide, and economy of effort between nations so that each nation could benefit from the work done by others in the shared generation of the charts in the scheme. The IHO seal was shown on all the charts. The seal of the producer nation was also shown and that of the nation printing the chart from reproduction material was added on a chart "adopted" into that country's national series.

The Committee established two key elements:

- A common specification document for the charts.

- A set of limits to cover the coasts and shipping routes of the world at the two standard scales. The smaller scale 1:10,000,000 scale charts effectively provide total world coverage except for the Arctic and Antarctic regions.

Production of the charts developed during the 1970s, and by 1972, twelve of the charts had been published. The series of 79 charts was completed in 1987. Sixteen nations contributed charts to this series.

The development of common specifications, scales and limits was a significant achievement and demonstrated that international co-operation on a common chart series was achievable. However, the range and complexity of symbols needed to construct such small scale ocean charts was considerably smaller than would be required to construct all the charts necessary at larger scales for a region. This task remained to be tackled and a further commission was set up at the 1972 International Hydrographic Conference to study this and propose a way forward.

The Influence of Regional Hydrographic Commissions

The emerging Regional Hydrographic Commissions of the IHO became a medium by which local regional charting issues could be discussed by the nations on the spot. The work of pioneering the International Chart concept for medium and large-scale charts was taken on in 1972 by the North Sea International Chart Commission (NSICC). This included member nations who were already part of the North Sea Hydrographic Commission together with Canada and the USA who asked to be involved. The NSICC reported on its work to the 1977 International Hydrographic Conference.

There are now 13 regional charting commissions. Ten of these are directly linked to Regional Hydrographic Commissions. Admiral Haslam (1994) reported that in 1991 800 medium and large-scale charts had been planned and 240 of these had been produced. The position in 1998 was that 1583 charts were planned, 583 had been produced, and 291 had been adopted by other member states. This represents a 97% increase in those planned and a 143% increase over those produced in 1991 in only 7 years. The distribution and coverage of the regional charting groups and commissions is shown in Figure (1). The status of the charts at the end of 1998 in each area is shown in the table at Table (1). (The figures are taken from the Annual report of the IHO for 1998).

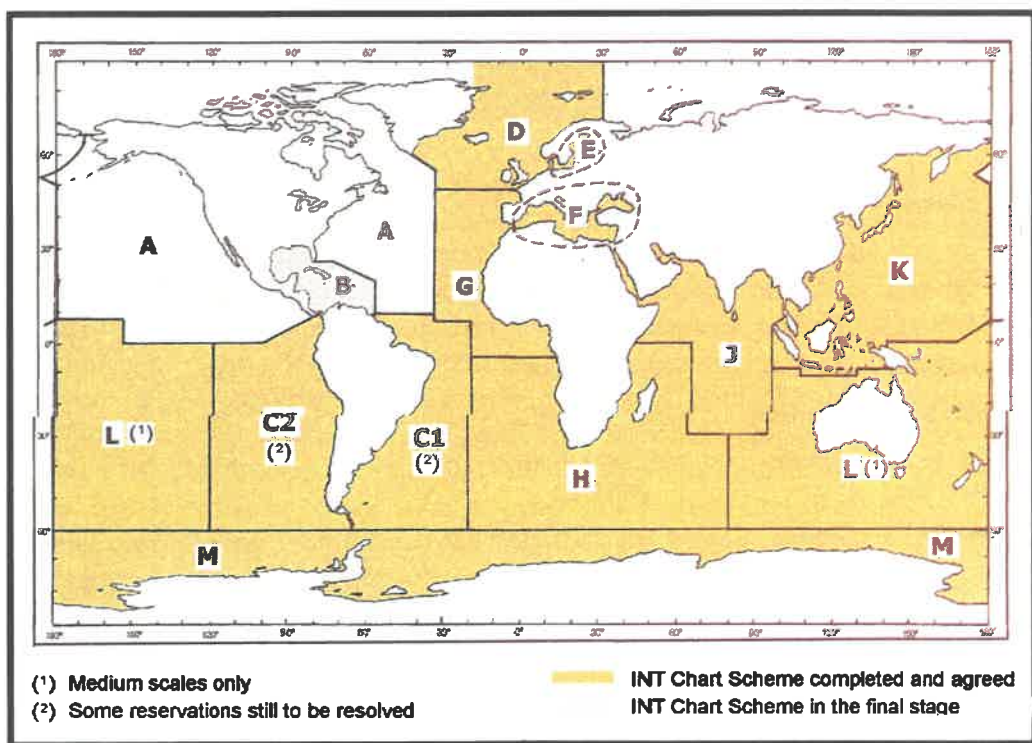
Chart Standardisation

In 1977 the International Hydrographic Conference established the Chart Specifications Committee. This was re-named the Chart Standardisation Committee at the 1982 Conference. Its function was both to seek to promote common standards of format and depiction of detail on charts and to provide a

source of advice on international scheming to support the work of regional charting groups and commissions. One particular task was the formation of a comprehensive set of chart specifications to which all member hydrographic offices of the IHO could subscribe. Chart standardisation is fundamental to the International Chart concept for two reasons:

- Standard symbology allows nations to minimise the differences of depiction and language, which would preclude adoption of charts produced, by one nation by another nation.
- Standardisation of size and colour also makes the production of a chart by one nation and its printing by another possible.

Figure (1): IHO International Charting Regions



Newson (1984) in his paper on chart standardisation reflects on the principles, which inspired the basic approach to developing the specifications. This includes the need for agreement on five fundamental factors:

1. The balance of navigational information included in charts as opposed to other navigational documents. The principle should be that charts should show as much information as can be shown clearly in graphical form.

A similar approach to international chart scheming in charting the Mediterranean and Black Seas has been adopted by the Mediterranean INTCHART Group, co-ordinated by France.

In Region G covering the Eastern Atlantic the initial work concentrated on the smaller scale coastal cover but additional port and approach cover has now been added and some 79 large scales were planned by 1997. A similar scenario pertains in Region H covering Southern Africa where the primary coastal scales are at 1:300,000 and 1:1,000,000 but where there are also a significant number of larger scale charts planned. In Region G there were few existing coastal charts suitable for inclusion in the international series and new charts were schemed from scratch. The Southern Africa scheme has a mixture of approaches but there are many existing charts, which can be used for the international scheme.

In the Caribbean and Gulf of Mexico region the continuous coastal scale cover has been established in advance of the decisions on the ports to be included. In a region such as this it is not really possible in all cases to focus coverage on existing national coverage. In many cases national coverage does not yet exist and the charts available from world charting authorities are often old, unsuitable and do not conform to the standardised symbols and depiction. The only choice is therefore to develop new charts for the series where this applies.

In other regions the primary effort to date has often been focussed on the continuous coastal cover. The work on both the east and west coasts of South America (Regions C1 and C2) has been focused in this way. Some Regions, such as Region L in the South west Pacific Ocean, have no intention at present of progressing beyond this stage preferring to take advantage of the international chart principles only for the coastal cover.

It is good to see that production of the planned charts is continuing and that we can expect to see yet more charts being added to the International Series. It is notable that, with the completion of the south western Atlantic scheme planning in 1996 some of the charts are now being published.

Difficulties in INT Chart Scheming

One of the primary difficulties has been the precise determination of the limits of coastal charts where a change in the limits of a chart at one point has a domino effect on the limits of charts throughout a scheme. The central co-ordination of the scheme with a particular nation acting as the co-ordinator has greatly facilitated the resolution of such problems.

Another issue, which often needs to be resolved, is the allocation of member states to be producers of the charts. In areas where the coastline is fairly linear

this is not usually a problem but it can be very complex in areas characterised by island groups such as the Caribbean Sea. In such cases, an individual coastal chart may straddle several countries' waters and producers must acquire source material from one or more other states in order to complete the charts. Smaller hydrographic offices may lack the capacity to take on the production of a number of international charts. In such instances the co-operative nature of the relations within the IHO come to the fore and other hydrographic offices with more capacity often assist.

Occasionally a country may have difficulties in agreeing to the detail of a chart scheme because of political or other factors outside the purely hydrographic arena. In such cases the advice of the International Hydrographic Bureau to coordinators is always to complete the planning and begin the implementation of as much of the chart scheme as can be implemented without controversy. The area in question can then be left until matters can be resolved at a more propitious time. This can, however, be difficult to put into effect where the domino effect mentioned above has effect.

It would be dishonest to gloss over the fact that there are differences of opinion between member states as to the value of international charting. This is true of the concept itself. Also, the growing development of digital charting has rightly caused some of the fundamental tenets applicable to paper charting to be challenged including the INT chart concept. It has already been stated that some nations question whether it is appropriate for a selection of charts to be made which are then deemed appropriate for international shipping but insufficient for national shipping. One fundamental assumption emerging from the international charting principles is that not all charts published by a given nation are necessary for the navigation of a vessel along established international routes into a major port. The argument hinges on the view that international trading vessels will not normally be coasting inshore but will be transiting well offshore and will carry a pilot, normally from well offshore into the port. Those challenging this view, point out that anyone can buy charts which are internationally available and can legally use those charts. Such purchasers may include yachtsmen and other small craft users who are navigating inshore. If charts published by the host nation are not required then not only the charts but also relevant chart updating information may be missed.

The Influence of Technical Resolution (TR) A3.4 on International Chart Cover

In 1992 many nations began to challenge formally the appropriateness of world charting nations using information from their published charts to provide charts of other countries' waters. The debate continued for a number of years and has resulted in agreement to change the TR A3.4 which formerly allowed this to

happen so that nations wishing to chart other nation's waters must seek a bilateral arrangement or agreement for such charting. The Technical Resolution discourages new compilation of charts in such circumstances and points initially to the international charts as the primary solution to the problem of what charts such nations should seek to adopt into their series in another country's waters. The secondary solution is for nations to adopt selected charts from the host country's national chart series.

The development of such bilateral arrangements is increasingly pointing to the need for a country's full large-scale coverage to be considered for international shipping in the approaches to a particular port. The selection process is therefore more one of selecting which ports need to be included in the international series rather than selecting the individual charts to be used. Interestingly, this approach is one which is being used by those planning digital chart cover for ENC (Electronic Navigational Charts) for their national waters where selected cover of the relatively expensive ENC product is seen as appropriate.

The WEND, ENC and International Charting

Over the last decade much effort has been put into establishing the format and means of producing and distributing officially approved vector electronic charts. This subject has been very well documented elsewhere and it is no place of this paper to rehearse this discussion. The principles established within the IHO for this have been codified under the now well documented WEND or Worldwide Electronic Navigational Chart Database principles. Amongst others these argue for the production of ENCs by national charting authorities who then distribute them through Regional Electronic Chart Co-ordinating Centres (RENCs) such as the one now in place for Northern Europe in Stavanger in Norway.

It is arguable that many of the concepts, which led to the development of international charts in the paper chart era, will be superseded or irrelevant when the use of ENCs is the norm. We may represent the arguments as follows:

- If individual producing nations contribute their ENC products to a Regional Electronic Chart Centre for distribution the concept of a specific series of charts which any nation can adopt into their series as they choose would be superseded.
- The need to keep to a slim easily updated series of charts for use by the mariner would be irrelevant in the days when data can be displayed on a screen at the press of a button and updating charts is equally simple.
- Although some aspects of standardisation are still an issue, such as symbology, some of the aspects of standardisation which have been of concern for paper charts would become irrelevant, for example, paper size.

Standardisation is more an issue for data formats and displays systems than for the precise details on charts.

There is, however, a substantial converse argument. The first point has already been alluded to above. There are also others:

- Many nations producing ENC data have realised that it will not be economic or practical at least initially to produce the data to replace every paper chart. ENCs will tend to be relatively high priced and therefore there is a need to concentrate production and availability on those ports and approaches where the majority of international vessels with a capacity for using ENC data are going to trade. In reality, for several international charting regions the initial analysis of port coverage has already been undertaken.
- A comprehensive set of navigational purpose (or usage) bands has been devised for ENCs to provide for overview, general, coastal, approach and harbour charts. Much of the thinking necessary to apply this in a particular area has already been done in order to prepare international chart schemes.
- Standardisation is not yet a dead issue. The Colours and Symbols Working Group for ENC still concerns itself with issues of standardising symbology for ENC data. There is certainly a need for closer co-operation, even perhaps amalgamation with the Chart Standardisation Committee. Apart from symbols the issues of the colours with which to display information has become increasingly important. As Kerr (1996), points out language is still an important issue, and although ENCs will be produced in English as the international maritime language there is still requirement to symbolise as much as possible to avoid text which is not easily read by all users. There is a powerful argument that, from the user's point of view, there should be as much continuity as possible with the depiction on paper charts in order to minimise the potential misinterpretation of data critical to safety.

Alongside the above discussion, there is also a practical issue that there has to be a transition between the use of paper charts and the use of ENC data on board ship. There will not in the foreseeable future be a point in time when paper charts cease to be used and ENCs or any other form of electronic charts take over. For many vessels paper charts will continue to be used for the rest of their working existence, while, at the same time newer vessels will tend to be built with the capability to operate with electronic chart data. As time progresses paper charts will become less used than electronic chart data and hydrographic offices will tend to build production systems which produce charts from multipurpose databases or will consider producing paper charts from ENCs. At this point there will be new challenges for the standardisation and production of the residual paper charts as well as for the ENCs.

Other new challenges also face us in the era of digital charts. There may be growing pressure, at least for navigation in ports and close inshore, for real time data. Such data might include depth information adjusted for the state of the tide, or more timely information on moving sandbanks. This will also present some interesting challenges for the residual paper chart series mentioned above. There is also likely to be an increasing desire to include information currently covered in navigational publications alongside the electronic chart data. This message is already emerging from the thinking at the Working Group on the Standardisation of Navigational Publications held in Monaco in September 1999. This too will have an impact on the remaining paper chart. Paper charts have increasingly becoming the repository for more and more text notes as regulations and guidance to mariners has become more complex. It is possible that the paper chart could become the source of more general information, which covers a wide area and is best displayed graphically, while the electronic chart database supplies detailed local information. The development of Mariner's Routeing guides is instructive in this.

Conclusions

My aim in this paper has been to outline the development of the International Chart and pick out some of the issues, which have been faced in the past and those which are being faced in the present. The international chart concept has been a major achievement of international co-operation in a century, which has seen more than its fair share of international strife and discord. It is a testimony to the strength of hydrographic co-operation fostered by the IHO and the outstanding foresight of its originators. It will be clear from the above that it is the opinion of the author that the concepts of international charting are far from dead. There will be significant challenges ahead and the close co-ordination of paper and electronic data generation is of paramount importance.

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PROMULGATION OF NAVIGATIONAL WARNINGS UNDER THE GLOBAL MARITIME DISTRESS AND SAFETY SYSTEM

Elroy A. Soluri

Abstract

The Global Maritime Distress and Safety System (GMDSS), adopted in 1988, was developed under the auspices of the International Maritime Organisation (IMO). The GMDSS will improve the dissemination and receipt of Maritime Safety Information (MSI) by vessels at sea and appropriate shore facilities equipped to render search and rescue co-ordination to shipping. Operational service of GMDSS began on 1 February 1992, with full implementation on 1 February 1999. Although there are seven basic categories of MSI within the GMDSS, this paper will focus on the promulgation of long range and coastal navigational warnings, which are co-ordinated through the International Hydrographic Organisation (IHO).

Introduction

Navigational warnings are broadcast to offshore waters through an internationally co-ordinated World Wide Navigational Warning Service (WWNWS). The world ocean, excluding the Polar Seas, is divided into sixteen "NAVAREAs," each of which is assigned to a Co-ordinator (Figure 1). The IHO Commission on the Promulgation of Radio Navigational Warnings (CPRNW), in co-ordination with the IMO, monitors and provides guidance on all WWNWS activities concerning the GMDSS. The membership of this Commission includes the NAVAREA Co-ordinators, several National Co-ordinators and ex-officio representation by the IMO, World Meteorological Organisation (WMO) and the International Mobile Satellite (INMARSAT) Organisation. The essence of this international co-operation is the promotion of safety of life at sea and to prevent disasters in all oceans.

Background

Until the early 1970's, most national systems for the transmission of radio navigational warnings covered only their own coastal waters. Some countries broadcast in English and their own language, while others broadcast only in their national language. Broadcasts were generally unscheduled and reception was restricted to vessels near the coasts. There was some limited interchange of information between countries; however, no formalised system of co-operation and co-ordination existed.

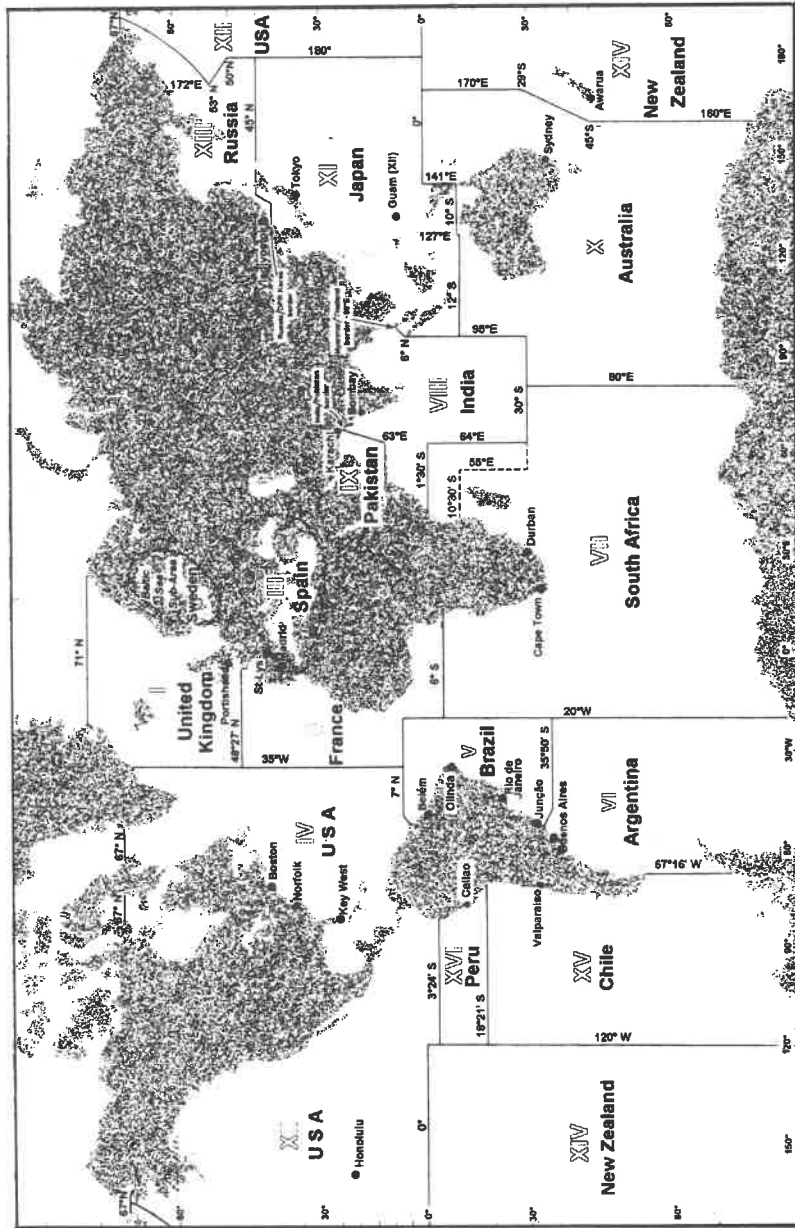


Figure (1) : Geographical Areas for Co-ordinating and Promulgating Navigational Warnings.

In addition to these coastal broadcasts, several national long range warning systems existed. These systems attempted to provide coverage over extensive ocean areas and to incorporate the more important coastal warnings issued by other countries in the area. Some examples are the Commonwealth's NAVSYS, now discontinued, and U.S. HYDROLANT/HYDROPAC navigational warnings' broadcasts. There remained, however, large areas of the world where little, or no, information was available.

The WWNWS was designed to minimise the redundancy of navigational warnings and standardise the formats and content of messages. It also sought efficiencies from new technology available at that time, such as Narrow Band Direct Printing (NBDP), although HF radiotelegraphy (Morse, hand copy) was the primary broadcast mode. HF NBDP or Radio Telex as it is more commonly known is a great improvement over Morse service, but it has inherent deficiencies such as propagation restrictions during solar activity. Clearly, the time had come for a new, modernised broadcast system.

Global Maritime Distress and Safety System

The GMDSS was developed by the IMO to take advantage of modern communication technologies, especially satellite communications. It is an automated system designed to improve the dissemination and receipt of Maritime Safety Information, not only by ships at sea but also by pertinent shore based authorities equipped to render assistance to shipping. After many years of study and debate, the GMDSS was adopted in 1988 and IMO Member Governments began implementation on 1 February 1992. GMDSS reached full compliance in February 1999.

The area in which the vessel operates dictates vessel carriage requirements under the GMDSS. Under the GMDSS, the world's oceans have been divided into four sea areas. Sea Area A1 is within range of at least one VHF coast station (out to about 30 miles); Sea Area A2 is within the coverage of MF/HF coast station (about 200 miles); Sea Area A3 is within the coverage of an Inmarsat geostationary satellite; and, Sea Area A4 is the area of the world not covered by A1, A2, and A3.

Maritime Safety Information under the GMDSS

The categories of Maritime Safety Information (MSI) under the GMDSS were expanded considerably, in keeping with the requirements of world shipping and the capabilities of new technology. It is these new developments that offer the greatest potential benefit and the greatest improvement in safety services for all ships at sea.

There are seven basic categories of MSI within the GMDSS. These are Navigational Warnings, Meteorological Warnings, Ice Reports, Search and Rescue Information, Meteorological Forecasts, Pilotage Service Messages (not in U.S.) and Electronic Navigation System Update Messages. Under the current WWNWS, in order to receive all necessary messages in the above categories, an operator would have to be knowledgeable of the broadcast times and frequencies of the numerous radio stations and take the time to copy each broadcast affecting his vessel.

Under GMDSS, a ship anywhere in the world will be able to receive all the above types of information by just flipping the switch of two small receivers.

Dissemination of MSI within the GMDSS

The dissemination of MSI is an internationally co-ordinated network of broadcasts containing information necessary for safe navigation. It automatically monitors a preset frequency and prints out in English information relevant to that ship. This concept is depicted in Figure (2).

Coastal warnings are generally sent via NAVTEX, or in some NAVAREAs by INMARSAT-C Enhanced Group Call (EGC) SafetyNET in lieu of NAVTEX; long range warnings are sent via Enhanced Group Call (EGC) SafetyNET service.

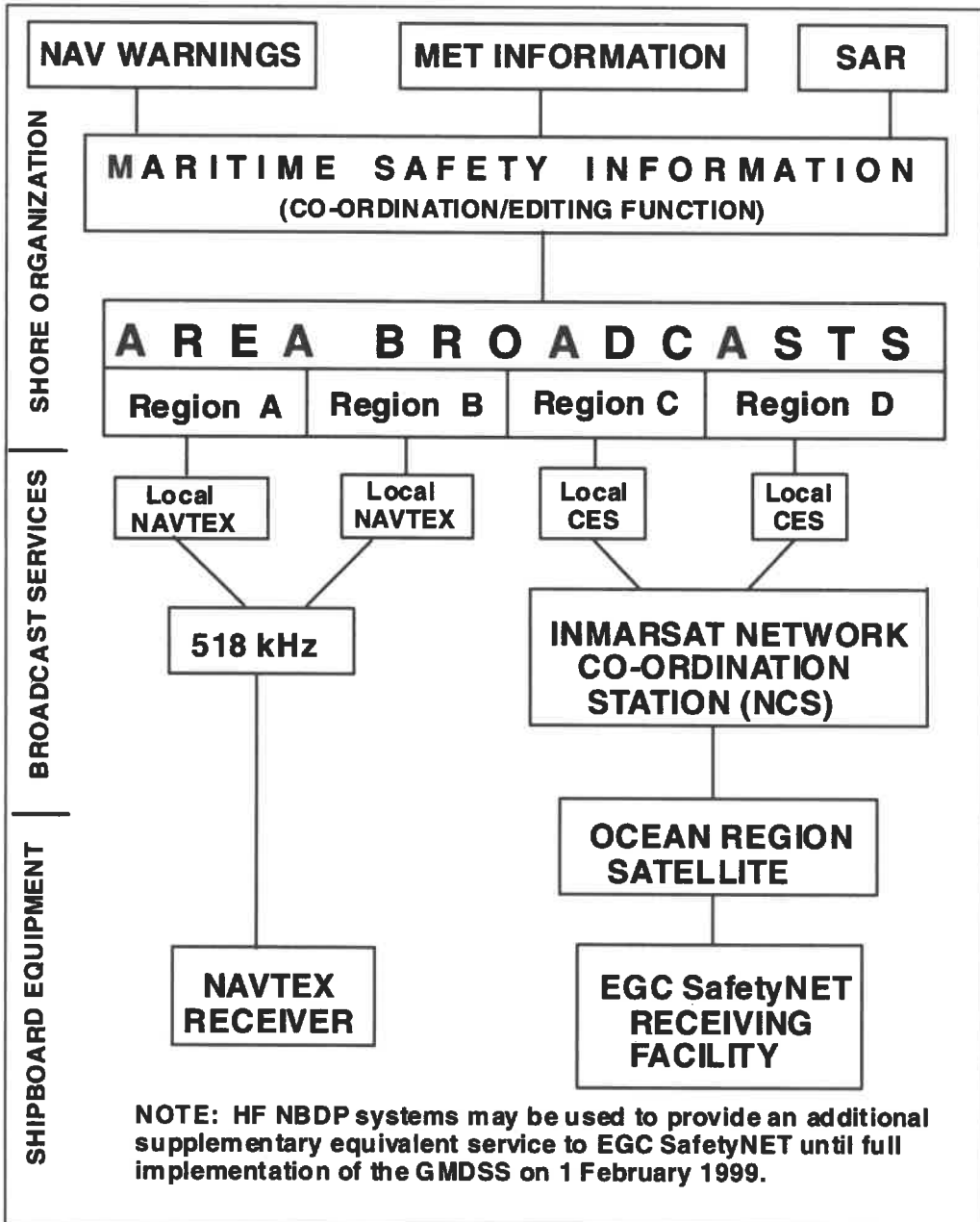
NAVTEX

Coastal MSI out to about 200 nautical miles will be available throughout most of the world on NAVTEX. This is a timeshared, universal broadcast on a frequency of 518 kHz. Broadcast schedules are co-ordinated internationally by the IMO to minimise interference and overlap. Routine messages are normally broadcast six times daily, and urgent messages are broadcast upon receipt, provided that an adjacent station is not transmitting. In most administrations, NAVTEX broadcasts are the responsibility of the National Co-ordinator, for example the Canadian Coast Guard. In addition to coastal warnings, NAVTEX broadcasts may contain the following information: specific Coast Guard District Broadcast Notice to Mariners that affect deep draft vessels in harbour areas and seaward to the line of demarcation between Inland and International Rules of the Road, severe weather warnings, offshore marine weather forecasts, International Ice Patrol reports, etc.

Implementation of NAVTEX services continues throughout the world, and most waters for which this service is suitable are either covered, or are planned to be covered, by NAVTEX. This is not to say that the necessary coverage is yet complete but it does indicate that administrations are aware of the requirement

and are generally taking action to fulfil their obligations under the GMDSS. Latest details of planned and operational NAVTEX services are given in the IMO Master Plan of Shore-Based Facilities for the GMDSS.

Figure (2) : International Maritime Safety Information Service
(Source: IMO A.705 (17)).



It is important to remember, however, that many coastal waters will not generate enough information or have enough international shipping to warrant the establishment of a NAVTEX transmitter. These countries are encouraged to establish communication links with their NAVAREA Co-ordinators to arrange for the broadcast of coastal information through the International SafetyNET Service or by a neighbouring country's NAVTEX Service if the broadcast extends into (i.e., can be received in) their coastal waters. Where such countries do not yet have an organisation for the collection and collation of coastal warning information, the IHO and IMO are available for advice and possible assistance.

SafetyNET EGC

Inmarsat SafetyNET is an international automatic direct printing satellite based service for the promulgation of MSI. It was developed as a safety service system to provide a simple and automated means of receiving MSI (at 600 bits per second) on board ships whether far at sea or in coastal waters. (NOTE: Australia has opted to utilise SafetyNET in lieu of NAVTEX for both long range and coastal warnings). SafetyNET is designed with the capability to provide services within the footprint of geosynchronous maritime communications satellites (approximately 70° North and 70° South). Figure (3) shows the footprints of the satellites in relation to the NAVAREAs. Beyond these latitudes, there is little commercial shipping and if MSI coverage were required, either NAVTEX or a national high frequency service would be provided. With Inmarsat-C EGC, calls may be directed to a given geographical area such as a NAVAREA (fixed) or a region defined by the originator. The service is co-ordinated by a group of Coast Earth Stations, which work directly with each satellite region's Network Co-ordination Station.

To facilitate the registration of Administrations, IMO has approved two Circular Letters. The first outlines the procedures for registering as an MSI Provider in the International SafetyNET Service and strongly encourages Administrations that have an obligation to provide MSI under the GMDSS to make interim arrangements with a CES in a neighbouring Administration. The second Circular Letter is a strong reminder that Administrations which are not or will not provide broadcasts of MSI in coastal areas via NAVTEX are required to issue these warnings via SafetyNET.

The IHO has also urged its Member Administrations to take prompt action and has, like the WMO, recommended that an interim service be established to provide navigational warnings in those NAVAREAs which are not yet able to fully participate in the SafetyNET service. Table (1) is the current status of the provision of MSI via SafetyNET.

NAVAREA warnings fall within the 200 nautical mile limit, it has been estimated that approximately 20% (600 messages per year) of the current NAVAREA traffic will be sent via EGC. This figure may increase once the gaps in NAVTEX coverage are known and to allow for overlapping duplication with messages that traverses the 200 nautical mile border. However, as a general policy, the only NAVTEX messages that will be duplicated via EGC are those which might cause a vessel to reroute before entering the area of NAVTEX coverage, i.e. closure of a port/harbour.

Table (1): Status of MSI Broadcasts via the International SafetyNET Service (as of 15 October 1999)

NAVAREA/ METAREA	NAV Warnings	MET Forecasts & Warnings	Ocean Region For Scheduled Broadcasts
I (UK)	X	X	AOR-E
II (France)	X	X	AOR-E
III (Spain/Greece)	X	X	AOR-E/IOR(MET)
IV (USA)	X	X	AOR-W
V (Brazil)	X	X	AOR-E
VI (Argentina)	X	X	AOR-W
VII (South Africa)	X	X	AOR-E + IOR
VIII (India/Mauritius/La Reunion)	X	X (Note 3)	IOR
IX (Pakistan)	X	X	IOR
X (Australia)	X	X	IOR + POR
XI (Japan/China)	X	X	IOR + POR
XII (USA)	X	X	POR + AOR-W
XIII (Russian Federation)	X	X (Note 4)	POR
XIV (New Zealand)	X	X	POR
XV (Chile)	X	X	AOR-W
XVI (Peru/USA)	X	X	AOR-W

Notes:

1. X = Full Service now available.
2. IMO has decided that routine broadcasts of navigational warnings and meteorological forecasts will be made at scheduled times over a single nominated satellite. Unscheduled broadcasts of severe weather warnings will be made over all satellites, which serve the area concerned.
3. India provides meteorological warnings and forecasts for METAREA VIII north of the equator through LES Arvi (IOR). Mauritius/La Reunion provides meteorological warnings and forecasts for METAREA VIII south of the equator through LES Burum (IOR).
4. South of 60° North, full service provided by Japan.

Depending on the priority precedent imbedded in the message addressing "C" codes, the NAVAREA message is either sent immediately as an unscheduled broadcast or pooled with other traffic and sent on the next scheduled broadcast. NAVAREA broadcasts may remain in effect for a maximum of six weeks. At that time, information that is still valid would have been published as a correction in the Weekly Notice to Mariners or would be reissued as a new message. As proposed by the 37th Session of the IMO Sub-committee on Radio communications, only the primary Inmarsat satellite or satellites are to be used to fully cover a NAVAREA for scheduled broadcasts. For unscheduled broadcasts, all satellites with a footprint covering the relevant area of the message are used. There are currently four Inmarsat satellites: one each for the Pacific Ocean Region (POR) and Indian Ocean Region (IOR), and two for the Atlantic Ocean Region (AOR (East) and (West)). A significant area of overlap is intentionally provided to give ships ample time to switch to the new satellite channel (when entering a new ocean satellite region).

In several NAVAREAs, a dual system whereby all navigational warnings are sent via both satellite and HF still exists. Generally, these are only those navigational warnings that fall outside of the NAVTEX coverage. As of 1 February 1999, all MSI should be broadcast via satellite only.

Navigational Warnings in the World-Wide Navigational Warning Service

As previously mentioned, the WWNWS was also designed to standardise the format and content of navigational warnings. To this end, the CPRNW has nearly completed work on the IMO/IHO/WMO Joint Manual on Maritime Safety Information (MSI).

Radio Navigational Warnings are essentially HAZARD WARNINGS. In accordance with the WWNWS Guidance Document, S-53, section 4.2.1.3, the following subject areas are considered suitable for transmission as NAVAREA warnings. This list is not exhaustive and should be regarded only as a guideline. Furthermore, it presupposes that sufficiently precise information about the item has not previously been disseminated in Notice to Mariners:

- Casualties to lights, fog signals and buoys affecting main shipping lanes.
- The presence of dangerous wrecks in or near main shipping lanes and, if relevant, their marking.
- Establishment of major new aids to navigation or significant changes to existing ones when such establishment or change might be misleading to shipping.
- The presence of large unwieldy tows in congested waters.
- Drifting mines.

- Areas where search and rescue (SAR) and anti-pollution operations are being carried out (for avoidance of such areas).
- The presence of newly discovered rocks, shoals, reefs and wrecks likely to constitute a danger to shipping, and, if relevant, their marking.
- Unexpected alternation or suspension of established routes.
- Cable- or pipe-laying activities, the towing of large submerged objects for research or exploration purposes, the employment of manned or unmanned submersibles, or other underwater operations constituting potential dangers in or near shipping lanes.
- Establishment of offshore structures in or near shipping lanes.
- Significant malfunctioning of radio navigational service and shore-based maritime safety information radio or satellite services.
- Information concerning special operations which might affect the safety of shipping, sometimes over wide areas, e.g. naval exercises, missile firings, space missions, nuclear tests, etc. It is important that where the degree of hazard is known, this information is included in the relevant warning. Whenever possible.
- Such warnings should be originated not less than five days in advance of the scheduled event. The warning should remain in force until the event is completed. NOTE: The IMO Maritime Safety Committee is authorised to review the provisions of this paragraph and, if appropriate, to provide for exemptions from this requirement, under special circumstances.
- Acts of piracy and armed robbery against ships.

Navigational warnings are issued in response to SOLAS V/2.b and carry information, which may have a direct bearing on the safety of life at sea. It is the fundamental nature of navigation warnings that they will often be based on incomplete or unconfirmed information and mariners will need to take this into account when deciding what reliance to place on the information contained therein.

IMO Resolution A.706 (17) requires the use of the English language for NAVAREA and Coastal Warnings of the WWNWS. It must always be remembered that the majority of mariners receiving radio navigational warnings are only professional users of English who do not speak or read it naturally. Warnings therefore must be written so as to be easily understood by all mariners.

In order to achieve maximum impact on the mariner, it is necessary to present information that it is CLEAR, UNAMBIGUOUS and BRIEF. This can be ensured by using structured messages, which present the text in a standard format with key words to emphasise the most important features of the message.

The Manual provides a practical guide for anyone who is concerned with drafting radio navigational warnings or with the issuance of meteorological forecasts and warnings for the high seas under the GMDSS. It is assumed throughout that the navigational warnings are being issued under the auspices of the IHO/IMO World-Wide Navigational Warning Service (WWNWS) and in accordance with the requirements of IMO Resolution A.706 (17). As cited earlier, the WWNWS includes two major international radio warning services as components; namely, NAVAREA warnings and Coastal warnings.

The structure of radio navigational warnings will provide the minimum information, which a mariner requires to avoid danger. This is:

Hazard and Position

It is usual, however, to include sufficient extra detail to allow some freedom of action in the vicinity of the hazard. This means that the message will give enough extra data for the mariner to be able to RECOGNIZE the hazard and ASSESS its effect upon his navigation. In some cases, it will be desirable to include an estimate of the DURATION of the event. e.g. special operations.

The text of any radio navigational warning will need to contain some or all of the STANDARD ELEMENTS defined in the Manual, however, it does not provide specimen texts for every type of event. The principles illustrated in the Manual may be applied in general to drafting messages for every kind of navigational warning and covering all types of hazards. Table (2) is an illustration of specimen text with regards to New, Moved or Re-established Lights from the Manual.

Conclusion

Technology improvements in the area of communications have pushed the IMO, IHO and WMO to provide improved services in the dissemination of MSI. The use of this new methodology and equipment has resulted in the receipt of more timely, comprehensive and vital maritime safety information. The Joint IMO/IHO/WMO Manual on Maritime Safety Information (MSI), provides a practical guide for anyone who is concerned with drafting radio navigational warnings or with the issuance of meteorological forecasts and warnings for the high seas under the GMDSS. This Manual has also been published by the IHO as Appendix 1 to Special Publication S-53, IHO/IMO World-Wide Navigational Warning Service (WWNWS) Guidance Document. Additionally, the guidance/formats specified in the Manual will help reduce the costs incurred by the Information Providers in the promulgation of MSI. It is anticipated that the Manual will be approved for publication as an official IMO document in due course.

Table (2): Illustration for drafting Navigational Warnings for New, Moved or Re-established Lights

Lights-New, Moved or Re-established

B3

Lighthouses, Beacons, Light Vessels		
Key Subject	Remarks	Comments
Flamborough Head Light, Flash Three 20 Seconds 22 Metres 21 Miles Naresboro Light Vessel, Flash Red 5 Seconds 14 Miles	Established 21-14.6n 000-16.3w	New Light.
	Moved 0.3 Miles North To 63-14.8n 022-15.6e	Do not quote former geographical position. Indicate former position by approximate direction and distance.
	Re-Established	For Charted or Listed as Destroyed. See Note A.
NOTES:		
I. Re-Established is only appropriate for lights, which have previously been Charted Or Listed As Destroyed. Navigational Warnings concerning such lights are merely cancelled when the Light is re-established. A new Navigational Warning is only required if the Character or Position is changed. See Table (B2) or above.		
II. Quote accurate Charted position; in Degrees, Minutes and Decimal Minutes (maximum 2 decimal places).		
III. Distances should be quoted in nautical miles and decimals.		

Session III

**Hydrography,
Contract Work**

POST-PROCESSING IN LASER AIRBORNE BATHYMETRY SYSTEMS

Gavin J. Perry

Abstract

Sounding data acquired by a Laser Airborne Bathymetry System must be Post-Processed to extract accurate depth and position information from the raw sounding data. This paper describes the LADS MkII Post-Processing that takes place on a Ground System.

This Ground System also provides interactive tools to assist the Hydrographic Surveyors in checking, validating and approving the post-processed data. The most important criteria for a post-processing system is to produce the highest accuracy data in the shortest possible time. The LADS MkII Ground System processes and achieves accurate soundings (within IHO SP44 Order 1), corrected to datum, in a time significantly less than the acquisition time.

Introduction

This paper addresses the principles and results of Post-Processing of raw data from Laser Airborne Bathymetry Systems. In particular, this paper addresses the processing aspects of the Laser Airborne Depth Sounding (LADS) System that is mounted in a de Havilland Dash 8-200 aircraft (Figure 1).

Figure (1): LADS Mk II Aircraft: Dash 8-202

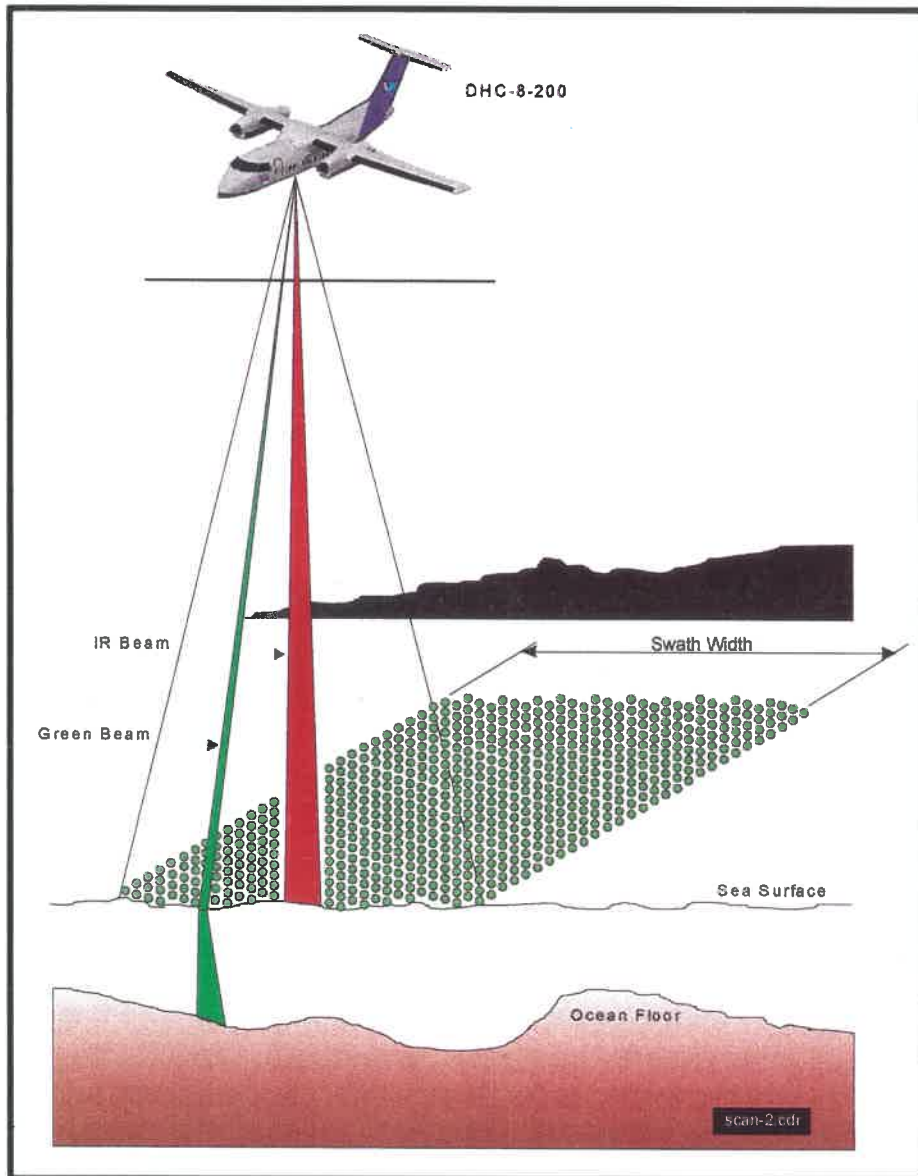


The LADS Airborne System is a state of the art Laser Bathymetry System that has the following performance characteristics:

- 900 soundings per second.
- Depth capability to 70 m.
- High density sounding at either 5 x 5 m, 4 x 4 m, 3 x 3 m, or 2 x 2 m.
- Survey rates as high as one (1) square kilometre per minute.

During a sortie, data is acquired by the Airborne System from an orthogonal grid of soundings that has a normal swath width of 240 m (Figure 2). This data comprises digitised laser sounding signals, position fixes, and laser platform orientation information and supporting system data.

Figure (2): Typical Aircraft Operating Scenario



Post-processing of the acquired laser bathymetry data is necessary to produce final soundings that contain x, y and z data for each acquired laser sounding. Since a typical seven (7) hour LADS MkII laser bathymetry sortie records the raw data for approximately 20 million soundings, the post-processing system must be capable of:

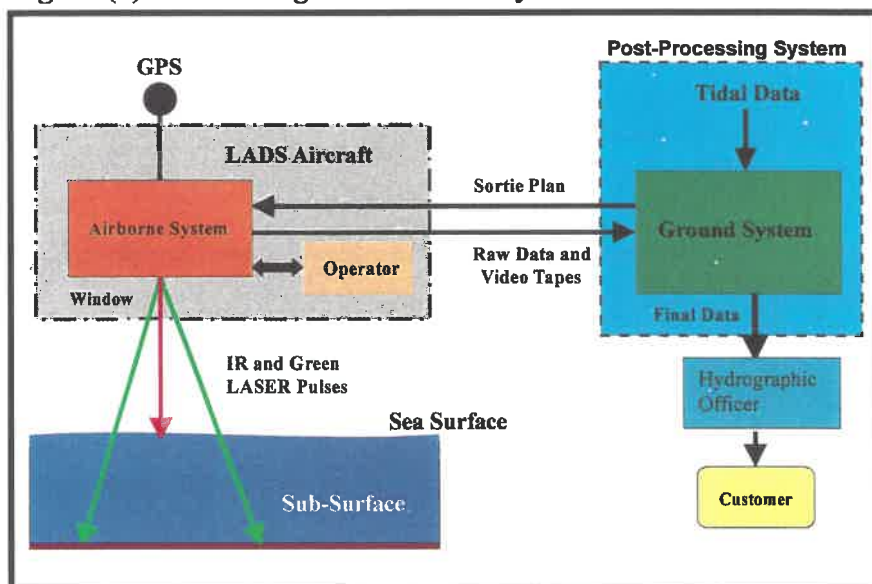
- Promptly processing the data.
- Automatically processing the data to the highest accuracy standard.
- Providing hierarchical visibility to the data for verification by a Hydrographic Surveyor.
- Providing a comprehensive suite of tools for examination, checking and validation by a Hydrographic Surveyor.
- Managing large databases that may contain up to 90 days of acquired laser bathymetry data (approximately 1.3×10^9 soundings).

The most important criteria for post-processing are:

- To produce the highest accuracy data.
- To produce the data in the shortest possible time.

The LADS MkII Ground System meets these important criteria as it can post-process acquired data to IHO Order 1 accuracy, in less time than it takes to acquire the data. (i.e.<1:1 relationship between acquisition time and post-processing time). The relationship between the Airborne System and the post-processing Ground System is shown diagrammatically in Figure (3).

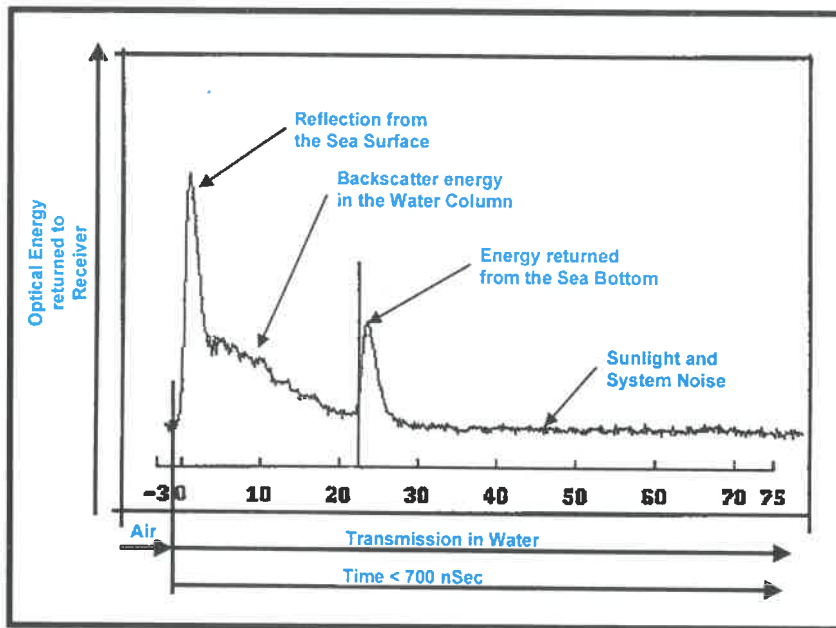
Figure (3): Block Diagram of LADS System



Airborne System Processing

The Airborne System acquires and digitises the returned optical energy for each sounding as well as the basic position data. The elements of each laser signal return are shown in Figure (4), with a laser return signal being recorded for each laser firing (900 firings per second).

Figure (4): Elements of a Laser Return Signal



The laser return signals are received by an optical telescope and photomultiplier system, with the signals being:

- Gain controlled to maintain the wide dynamic range of the optical return signal within the range of the acquisition electronics.
- Digitised at 500 Mhz sampling rate to 8 bits.
- Recorded on Digital Linear Tape (DLT).

The automatic gain control maximises the signal to noise ratio in the optical return signal and:

- Provides for recording the strongest to the weakest optical returns (approx. $10^5:1$).
- Automatically controls the optical receiver gain during the actual reception of the pulse.

- Controls the gain independently for all 48 sounding columns across the swath.

Other Airborne Processing includes:

- Real time processing of data for the operator display, including depth data profiles.
- Real time navigation of the aircraft via an autopilot interface. The LADS MkII aircraft is normally controlled by autopilot to within 1.8 m (One Standard Deviation) of the desired survey track.

Ground System Processing

The data recorded by the Airborne System is passed to the Ground System for processing. The primary purpose of Ground System processing is to extract accurate depths and positions from the data.

However, the Ground System data processing also includes the following aspects:

- Cross-Tie and Benchmark depth comparisons.
- Presentation of depth accuracy statistics.
- Navigation position checks and associated statistical presentations.
- Interactive data displays to facilitate checking and validation by a Hydrographic Surveyor.
- Provision of output data in hardcopy (fairsheet) and digital data formats.

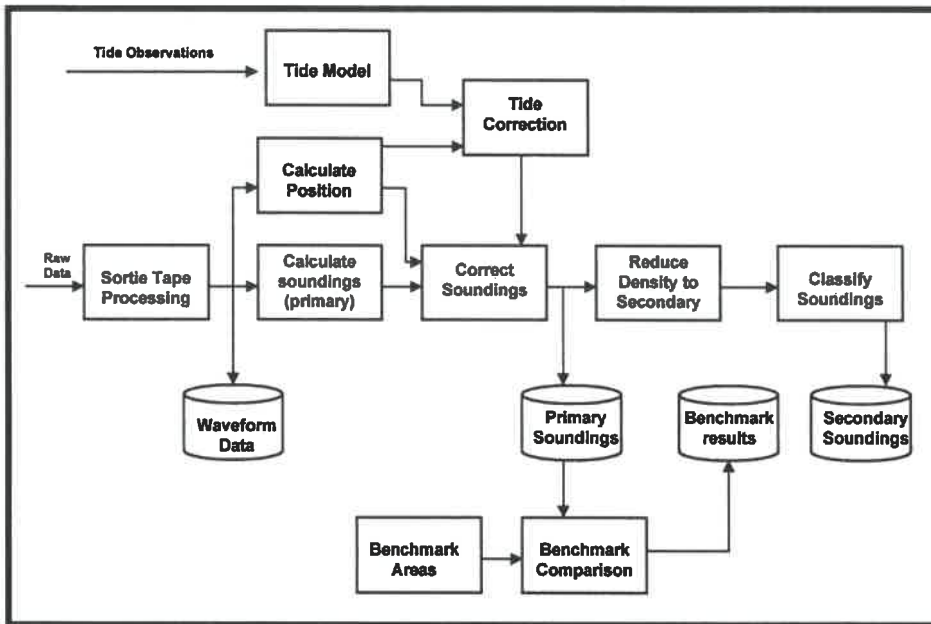
The LADS MKII Ground System also provides facilities for the management of survey planning and assessing progress. The processing operation of the LADS MkII Ground System is highly automated, with operator interaction only necessary to initiate the automated processing of the raw data and to analyse, review and validate the data. The automatic aspects of Ground Processing are shown diagrammatically in Figure (5).

The function of the main aspects of ground processing are described as follows.

Sortie Tape Processing

This function unloads the raw data from the DLT media and commences the automatic processing on a run by run basis.

Figure (5): Ground Processing – Automatic Aspects



Calculate Soundings

This function is the major function, which analyses each return laser waveform to extract surface returns and two possible sub-surface returns.

The algorithms must cope with the large range of possible laser signal returns, examples of that are shown in the diagrams of Figures (6) to (9).

Complex laser signal returns are the result of:

- Rapidly changing and complex bottom conditions, as in reef waters.
- Fish strikes in the water column.
- Shallow water where the bottom and surface returns overlap.
- Deep water and marginal signal detection conditions (near the extinction depth)
- Turbid water and marginal signal detection conditions.

Steps followed in calculating the soundings include:

1. Calculate the Surface Datum
 - Detect available surface reflections.
 - Reject backscatter return signals.

- Model the sea surface datum as a 2D surface.
- Use inertial height to support the datum around and over land. (i.e. islands)

Figure (6): Typical Laser Return Signals

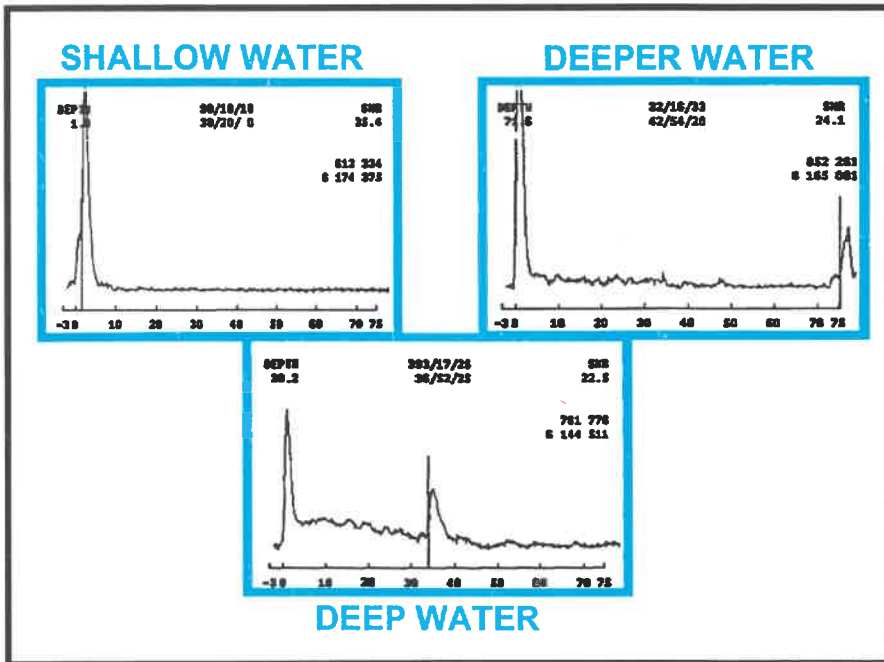


Figure (7): Effects of Laser Return Signals in Calm Water

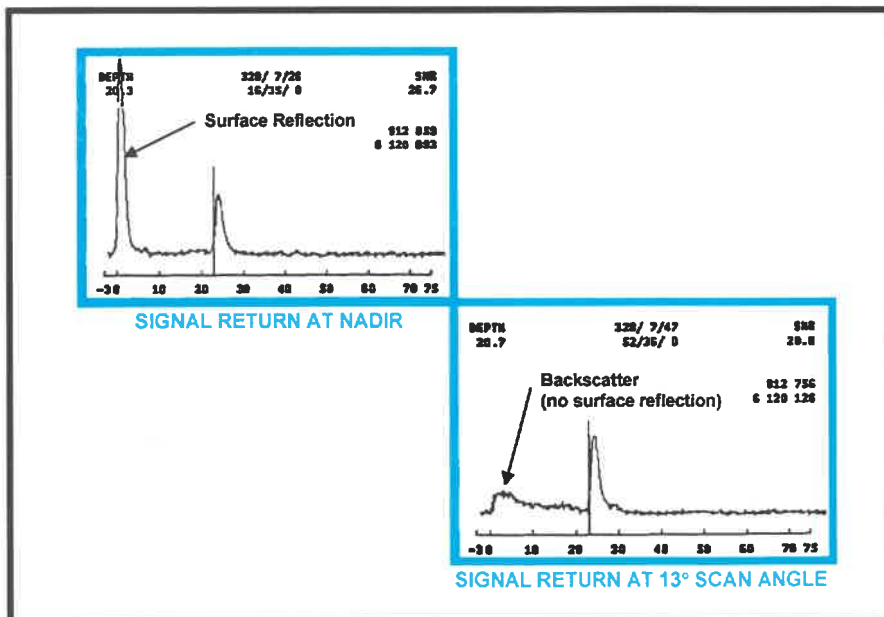


Figure (8): Complex Laser Return Signals

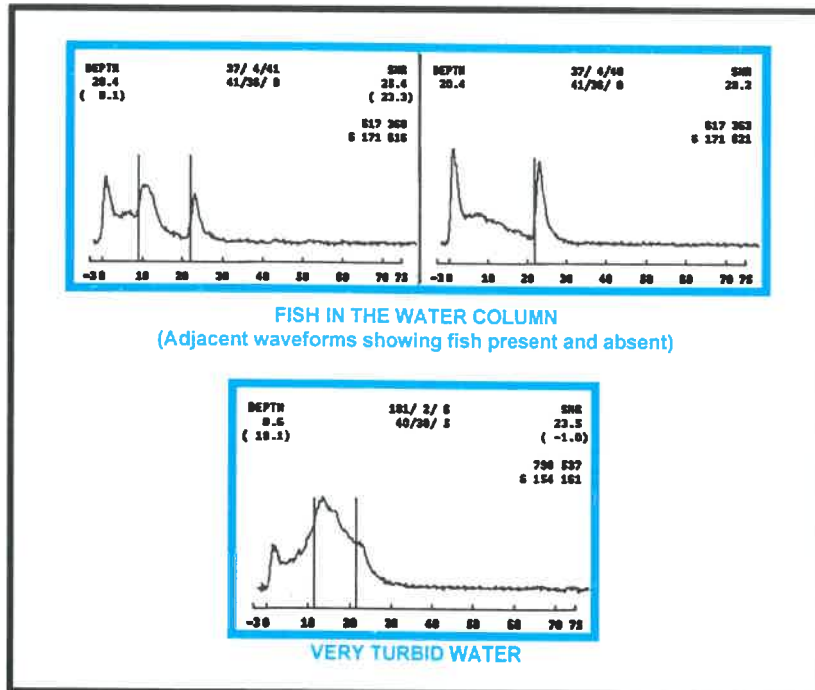
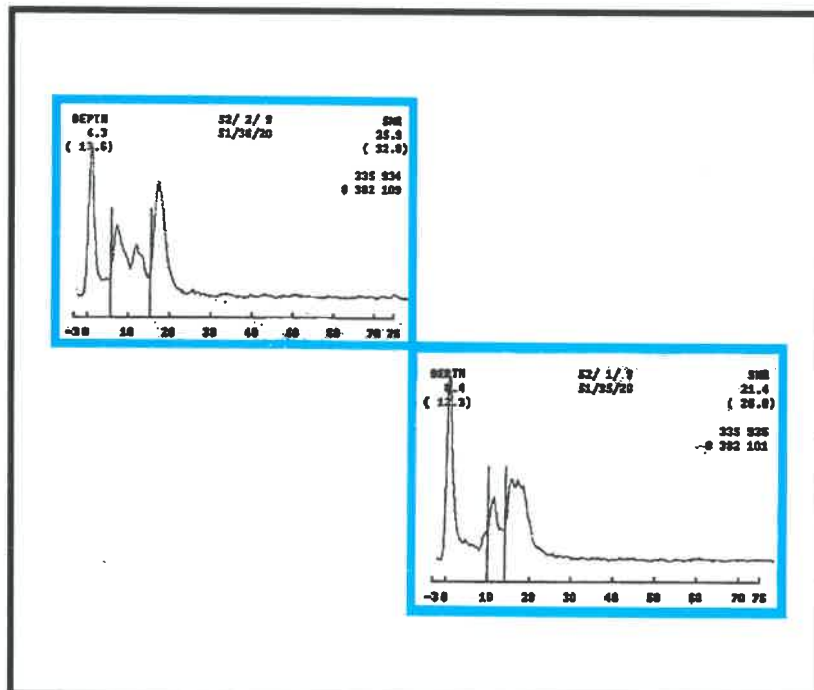


Figure (9): Complex Laser Return Signals in Reef Water



2. Calculate the Sub-surface Returns

- Detect the two most likely bottom returns.
- Classify each return by;
 - signal to noise (S/N) ratio
 - near neighbour confidence
- Correct the slant depth to vertical depth using refraction at the water surface and ray angle.
- Order the two bottom returns into likelihood of shoalest bottom. (with user defined parameters)

Calculate Position

Calculates the position of each sounding on the sea floor using:

- Smoothed track of the aircraft.
- Post corrected DGPS or KGPS corrected fixes.
- Position on bottom calculated considering:
 - real time and corrected GPS fixes
 - antenna offsets
 - aircraft heading, pitch and roll
 - platform pitch, roll and azimuth
 - aircraft height
 - scan angles
 - refractive index
 - sounding depth

All sounding positions are calculated to an operator specified spheroid and grid system. Using accurately positioned IHO targets (2m x 2m x 2m), LADS MkII sounding accuracy has been confirmed within 2.55 m at 95% confidence. Noting that the targets are 2 m x 2 m, this is indicative of a total system positioning accuracy of 1.5 m (Figure 10).

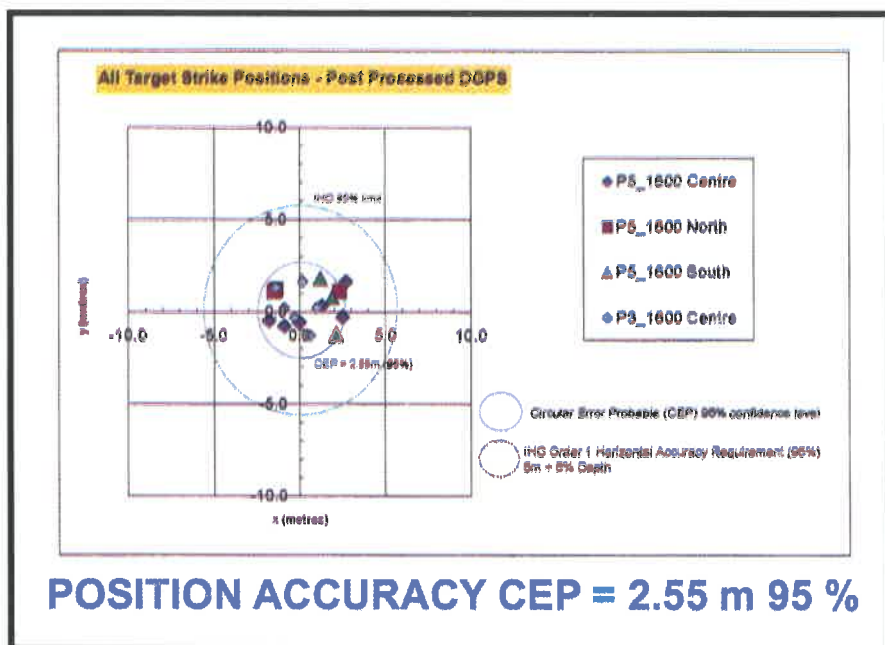
Tide Model and Correction

All soundings are normally corrected to the Lowest Astronomical Tide (LAT) depth datum, which is derived from observed and/or predicted tide models.

LADS MkII generates a tide correction for each sounding based on:

- The assignment of multiple Tidal Areas over the Mission Area.
- Diurnal, Semi-Diurnal, IHO or Admiralty tide models.
- Optional predicted or observed tide stations.
- Tide corrections may be post applied where real time observations are delayed.
- Tide corrections are based on $f(x, y, t)$.

Figure (10): Position Accuracy of Soundings

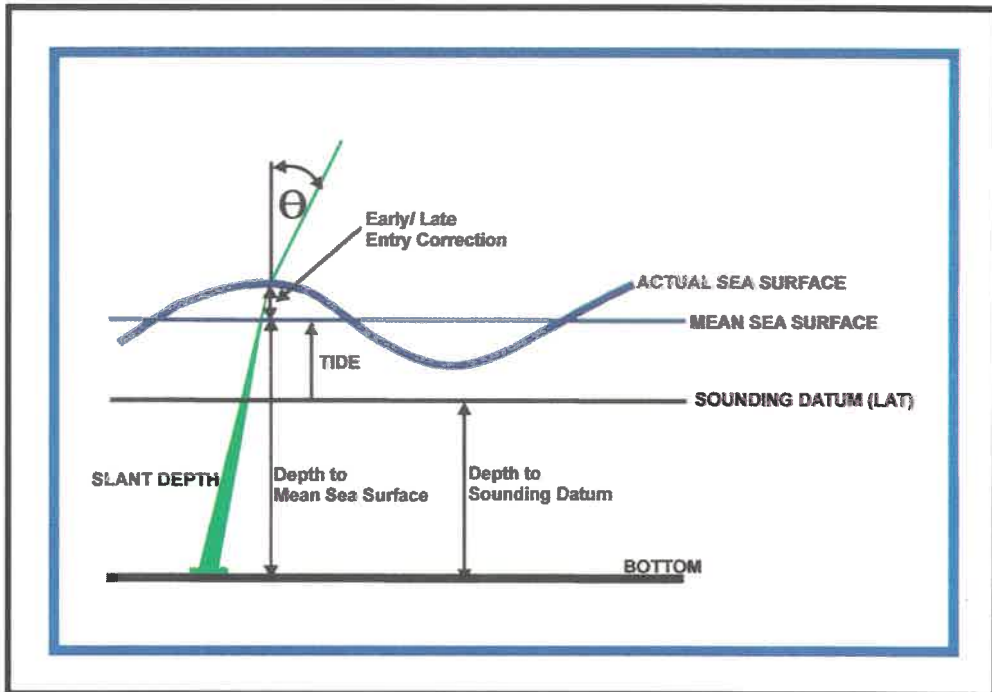


Correct Soundings

The corrections applied to each sounding include:

- Correction for the refraction at the water surface.
- Slant Path correction for optical path lengthening. (A function of beam angle, depth and water turbidity)
- Slant depth corrected to vertical depth.
- Vertical depth corrected to mean sea surface.
- Early/Late entry correction is applied. This accounts for the different propagation times (air versus water) due to a local trough or crest of a wave.
- Depth corrected to the defined Sounding Datum (usually LAT) (Figure 11).

Figure (11): Corrections to Sounding



Reduce Density to Secondary

Primary Soundings are generated by the LADS MkII System at a rate of 900 per second, or approximately 40,000 per square kilometre.

A subset of these soundings is produced by a selection process which selects the significant shoal depths suited to a nominated scale of survey.

This process is particularly aimed at producing a decimated data set suitable for conventional Fairsheet presentation.

These selected soundings are called Secondary Soundings and are:

- Representative shoal soundings.
- The density is dependent on the scale of the survey.
- Each Secondary Point selected is the shoalest sounding within a defined radial range.
- Each Secondary Point retains all the attributes of the Primary Sounding.

This process is included for each survey run as part of the automated post-processing.

Classify Soundings

This process automatically builds, for each sounding, a confidence vector containing confidence coefficients, which assist with the overall assessment and operator validation of the data.

The confidence coefficients include:

- Pulse Confidence (S/N ratio).
 - A measure of the strength of the return signal compared to the background noise.
- Near Neighbour Confidence.
 - A measure of the agreement of the depth with that of the near soundings.
- Surface Datum Accuracy Confidence.
 - A measure of the confidence of the surface datum fit and ultimately of the sea state.
- Swath Coverage Confidence.
 - A measure of the complete coverage of a desired swath width (with overlap). This coefficient quickly indicates “holidays” in the data.

Benchmark Comparison

This function automatically compares the soundings of any processed run with recorded Benchmark Depth Data. This recorded data is generally available for defined, small Benchmark Areas that have normally been surveyed using high accuracy acoustic techniques.

The statistical comparison of surveyed Primary Soundings with the Benchmark Soundings, are recorded as Benchmark Results with the Hydrographic Surveyor subsequently analysing the Benchmark Results as part of the data checking function. The statistical comparison process is part of the automatic post-processing.

Interactive Operator Processing

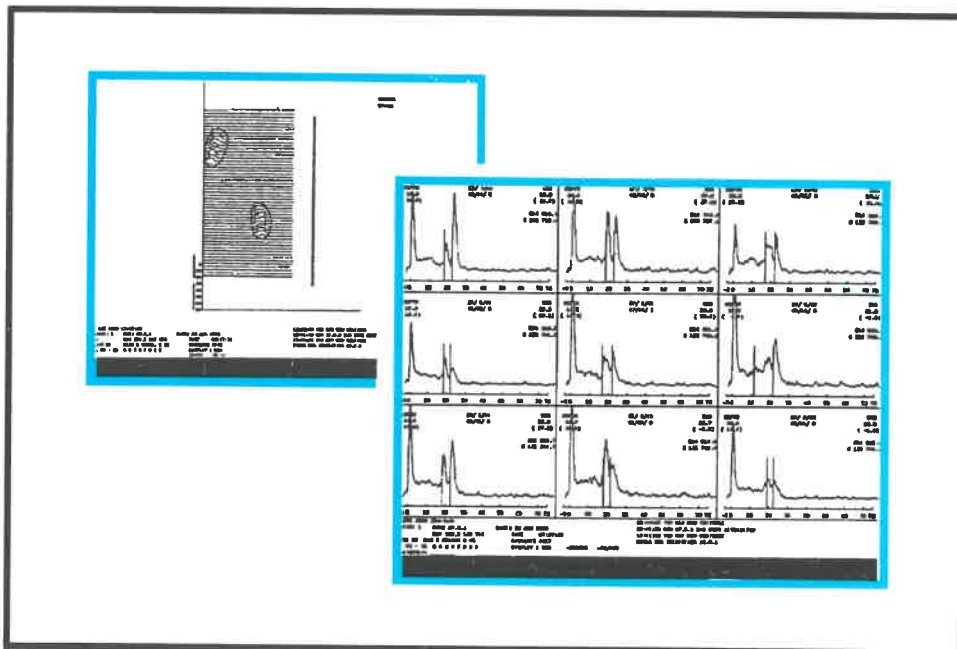
Whilst the automatic data processing phase can promptly process the acquired data to obtain high accuracy soundings, it can not make the final decision as to the quality and suitability of the sounding data for further (say chart) action. The checking, validation and approval process is performed by Hydrographic Surveyors, and to assist them with these tasks a series of interactive displays, tools and data presentations are provided.

These displays and tools include:

- Composite Depth Profile Display.
- Primary Depth Display.
- Secondary Depth Display.
- Waterfall Graphic Depth Display.
- Waveform Display.
- Cross-Tie Results Statistics.
- Benchmark Comparison Statistics.
- Audit Display.

Figure (12) is an example of Waterfall and Waveform displays showing the detection of two wrecks.

Figure (12): Wreck Detection



The Hydrographic Surveyors will review, check and validate the data, with only positively “accepted” data being available to subsequent processes.

The interactive operator processes include:

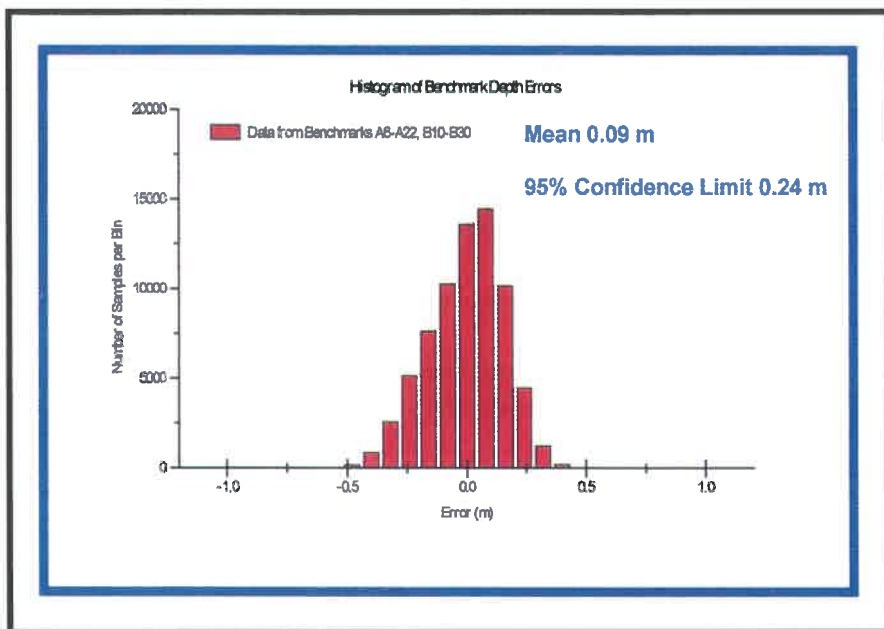
- Review and Validation of data.
- Review of Cross-Tie and Benchmark results.

- Resolution of anomalous soundings due to:
 - fish strikes
 - turbid water
 - wrecks or objects on the bottom
 - potential shoals
 - noise
- Editing as appropriate, including reversal of selected sounding of particular anomalous soundings.
- Assessment and assignment of NBA (No Bottom At) depths.
- Nominating accepted Run Segments.
- Nominating segments for “re-fly”.

All operator activities are fully logged with additional tools providing a full audit path of operator interactive functions. There are no calibration “knobs or functions” required in the LADS MkII system, with system accuracy being independent of operator actions.

Trials undertaken in August 1999, over depth benchmark areas at depths to 30 metres, showed that LADS MkII depth accuracy significantly exceeds IHO Order 1 requirements. In more than 84,500 depth benchmark comparisons, through depths ranging from 6 m to 30 m, it was established that 95% of LADS MkII soundings were within 0.24 m (Figure 13).

Figure (13): LADS MkII Depth Accuracy over Benchmark



As this depth benchmark comparison process assigns any residual errors in the acoustic benchmarks, the tide models and the tide observations to the LADS System, the results above indicate that the LADS MkII system and data processing is very accurate and significantly exceeds the IHO Order 1 requirements.

Output Processes

The fundamental output of the LADS MkII System is high density digital sounding data that contains the following information:

- Depth (z).
- Position (x, y).
- Confidence.
- Appropriate interaction flags.

This digital data is typically on a 5 x 5m or 3 x 3m (operator selectable) grid that covers the nominated area. This data is available in many digital formats, but may also be presented in one or more of the following hardcopy presentations:

- Collector Plots
 - Where all soundings are overlaid on a hardcopy plot that is generally then used for checking purposes.
- Fairsheet Plot
 - Where the Secondary Soundings, colour coded for depth and clashed to suit the selected plot scale, are plotted.
- Colour Contour Plots
 - Where data is exported and displayed as colour contours with or without superimposed depths via separate tools (eg GMT)
- 3D Presentations
 - Where data is exported and displayed as colour 3D presentations with sun highlighting via separate tools (eg Fledermaus)

Summary

LADS MkII data processing has been highly developed during many years of in-service operation and is characterised by:

- A high degree of automation.
- Fast data processing (< 1:1).

- High depth accuracy (<0.24 m at 95%).
- High position accuracy (<2.5 m at 95%).
- High sounding density (5 x 5 m to 2 x 2 m).
- High sounding rate (3.24 million soundings per hour).
- Flexible and extensive post-processing validation tools.

AIRBORNE LASER HYDROGRAPHY : AN INTRODUCTION

Paul E. LaRocque and Geraint R. West

Abstract

A review of the history of Airborne Laser Hydrography (ALH) is presented, with reference to the airborne systems developed over the last three decades. This is followed by a description of the fundamentals of the technique. The typical operational scenario is outlined and the versatility and benefits of the technology highlighted.

Introduction

The development of systems that use lasers for the sounding of depths started not long after the advent of the laser itself. The potential for these systems held great promise in the early years and we can now safely say that the promise has been delivered. There is a tremendous cost and efficiency benefit that can be derived from using these systems in conjunction with conventional techniques, especially in shallow coastal waters. These type of waters represent the most important for shipping and for territorial concerns. The coastal environment is also subject to the most variability from the weather. Hence in one sense, the job is never done: these areas must be surveyed on a periodic basis. ALH systems are well suited for this activity.

History of Airborne Laser Hydrography

Airborne Laser Hydrography (ALH), or Airborne Laser Bathymetry (ALB) as it is also known by, has been an attractive concept ever since the laser itself was invented in the early sixties. The idea of using a laser for underwater detection was confined in the early years to the problem of submarine detection (Ott, 1965; Sorenson, 1966). Hence most of this early work was classified. The first report in the open literature came from the University of Syracuse in 1969 (Hickman, 1969). In the first half of the 1970's, the work in this field concentrated on experimental profiling systems such as by NASA (Kim, 1974) and by the US Navy (Cunningham, 1972) in the USA. In Canada, the Canada Centre for Remote Sensing (CCRS) joined with Optech in profiling efforts (Ryan, 1980) while in Sweden the Defense Research Establishment (FOA) explored this area. In Australia the Weapons Research Establishment (WRE) of the Royal Australian Navy (RAN) developed a profiling system called WRELADS-1 which underwent trials in 1976/77 (Clegg, 1978).

The next step in the evolution was to move beyond the profiling mode and scan

the laser beam. A joint effort by NASA, NOAA, and the US Navy produced a scanning Airborne Oceanographic Lidar (AOL) (Guenther, 1978) which remarkably is still in use today, albeit in a vastly different form from its first configuration. Experience with the AOL led to the HALS (Hydrographic Airborne Laser Sounder) program sponsored by the US Navy, the Defense Mapping Agency (DMA) and NASA (Houck, 1980). In Australia, a scanning system called WRELADS-2 was developed from the experience on WRELADS-1 and it was verified in the late 70's (Penny, 1986). Canada and Sweden cooperated with FOA augmenting the Mark-2 profiling system with a scanning mirror (Steinvall, 1981).

In the eighties, the ALH systems were developed beyond the experimental learning stage and into the operational regime. Optech built the LARSEN-500 system, sponsored by the Canadian Hydrographic Service (CHS) and CCRS (Banic, 1986). It was delivered in 1985 and is still in operation today (Hare, 1994). FOA of Sweden sponsored the development by Optech of a scanning ALH system called FLASH-I, which was delivered in 1988 (Steinvall, 1992). The HALS system was combined with a multi spectral scanner and renamed the Airborne Bathymetric System (ABS) (Harris, 1986). The ABS flew until 1988. Also in 1988, Optech delivered to the US DARPA an airborne lidar for the detection of mines, the ALARMS system (Airborne Laser Radar Mine Sensor). In other parts of the world, China began work on a Blue-green Oceanographic Lidar (BLOL) (Liu, 1990) and in Russia three experimental systems were in use: GOI, Chaika and Makrel-II, (Feigels, 1992).

The late 1980's saw some significant developments. In 1988, the first smooth sheet chart produced by an ALH for navigation was produced for CHS by the LARSEN-500. The same year, the U.S. Army Corps of Engineers (USACE) initiated an operational ALH system to be developed by Optech Inc. The next year, in 1989, a contract was awarded to BHP Engineering and Vision Systems of Australia to build the Laser Airborne Depth Sounder (LADS) for the Royal Australian Navy.

The decade of the nineties began with another order of two ALH systems from the Swedish Department of Defence. Saab Instruments of Sweden was the prime for this order with Optech as the major subcontractor. The Ocean Water Lidar (OWL) system, although not primarily built for hydrography was being flown in the early nineties for this application (Lutomirski, 1994). In 1993, the RAN LADS system was brought into operational use (Setter, 1994). In 1994 the SHOALS system was delivered to the USACE and also began operational surveys (Lillycrop, 1996). In 1995 two HawkEye ALH systems, similar to SHOALS, were delivered to Sweden (Steinvall, 1997).

The more recent years have witnessed significant improvements in ALH

capability. In 1997, the SHOALS system developed the capability of using kinematic GPS with on-the-fly ambiguity resolution, which allowed topographic mapping over land in conjunction with the underwater mapping (Guenther, 1998). A new generation of the LADS system, the Mk II, became operational in 1998 (Sinclair, 1998). The new system has a sounding rate of 900 Hz, and is installed in a Dash 8 aircraft, which can fly at speeds of 175 knots. Also in 1998, the SHOALS system upgraded its sounding rate to 400 Hz and was installed in a Dash 6 (Twin Otter), which can survey at up to 150 knots. These systems now have survey coverage rates in the 15 – 19 nm²/hour.

Current Status

If we restrict the count to only those systems that are primarily for commercial hydrographic purposes, there are six ALH systems currently in operation. In Canada, the LARSEN-500 is owned and operated by Terra Surveys of British Columbia, Canada. In 1995, it was contracted by the UAE for a survey that will be used for their national charting. From Australia, the LADS Mk I system is still in use by the RAN and LADS Mk II is surveying worldwide. Of the two Swedish HawkEye systems, one is still in use by the Swedish Navy; the other has been transitioned to Indonesia for the survey of coastlines. In the United States, the SHOALS system owned by the USACE and operated by John E. Chance and Associates (member of Fugro Group) is surveying throughout the US and in various parts of the world.

In addition to the countries mentioned above which have built their own ALH systems, several other countries have contracted ALH services to use the data in their national charting programs. These nations include Mexico, New Zealand, Norway, Indonesia and the UAE.

Principle of Operation

The basic principle of the ALH system is that the airborne lidar sends two laser wavelengths down to the water surface, as shown in Figure (1). The water depth may be calculated from the time difference of laser returns reflected from the sea surface and seabed. In most systems an infrared channel (1064 nm) is used for surface detection, while bottom detection is from a blue-green channel (532 nm) as shown in Figure (2). It is critical to know where the water surface is located as a reference and in the SHOALS system, there are three separate wavelength channels which can locate the surface on a priority basis (Guenther, 1994). The laser beams are either swept in an arc or in a rectilinear scan across the direction of travel with a swath width typically half of the altitude. The surface sounding density can be varied from as small as 2 x 2 meters up to 5 x 5m spacing and higher. Since the spot size on the surface is typically greater than 2 m this

implies the possibility of complete coverage of the surface of the water at high sounding densities.

Figure (1): Principle of ALH Operation

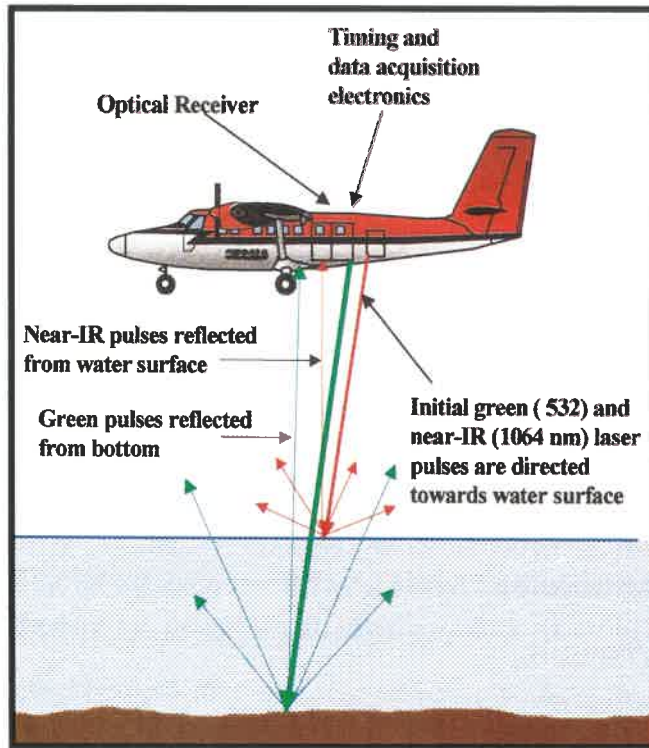
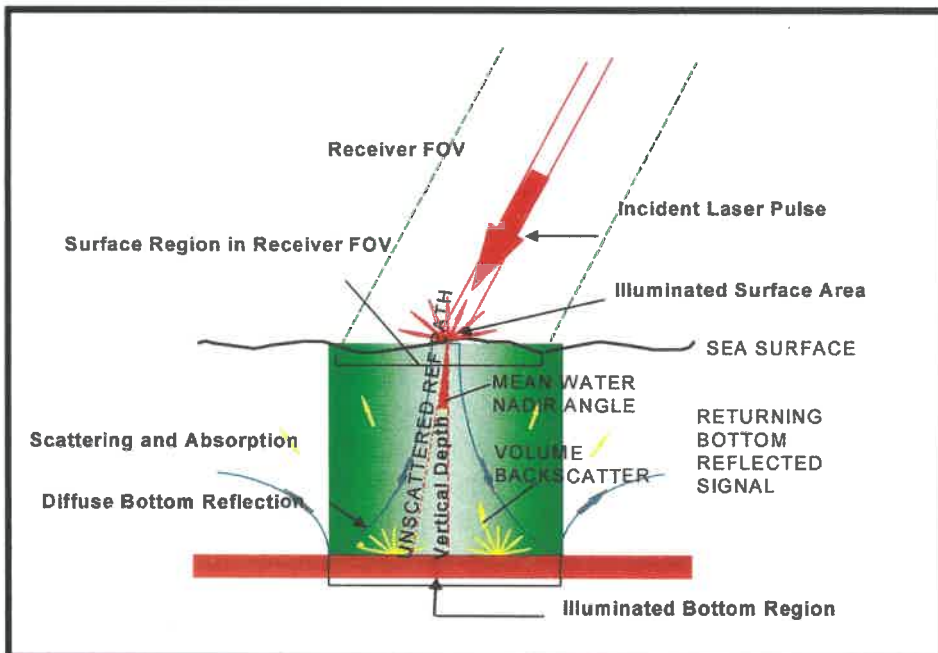


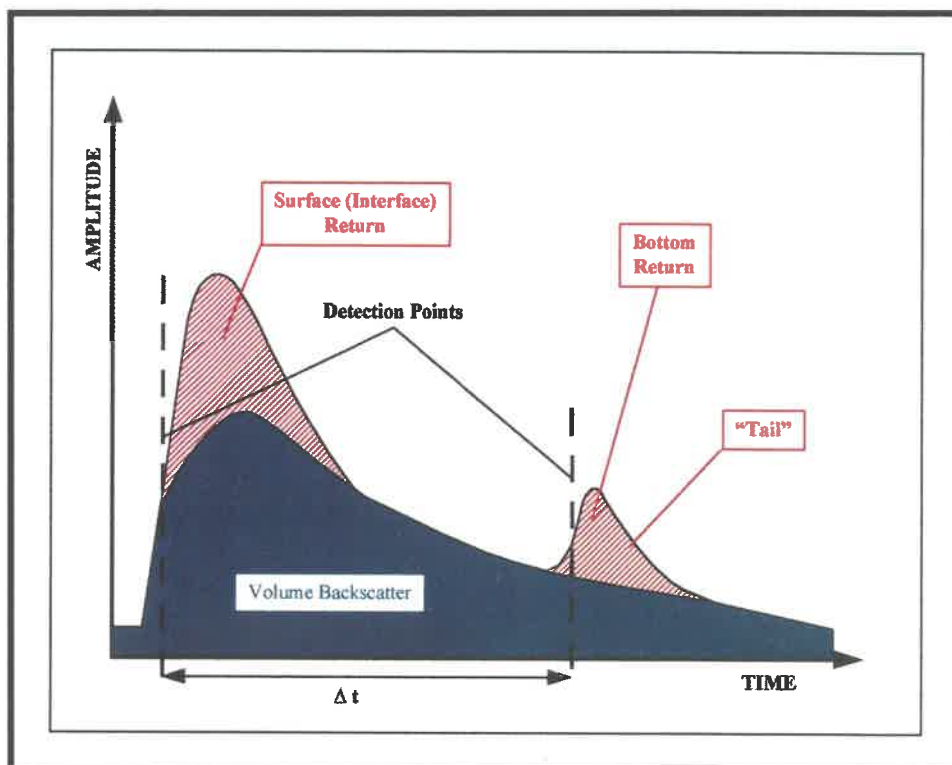
Figure (2): Geometry of Light Penetration



The basic limitation of depth capability is the clarity of the water. Hence the maximum depth measurable by a system is heavily dependent on water turbidity and can vary considerably from just a few meters in very turbid water to several tens of meters in clear water. Water clarity is usually expressed as the diffuse attenuation coefficient K_d , which numerically is the distance over which light intensity diminishes to 1/e of its initial value. Consequently, depth performance of ALH systems is generally expressed as the product $K_d D$, where D is the depth. A more practical predictor of the ALH system is the Secchi Depth. In simple terms, if a 45 cm diameter disc with alternating white and black quadrants is lowered in the water, the depth at which the disc becomes invisible is known as the Secchi Depth. These ALH systems are capable of detecting the bottom to depths up to three times the Secchi Depth.

Although surface detection is usually made with a Raman channel or the infrared channel, the blue-green channel will also detect the surface. Because of this, the generic ALH waveform is of the type shown in Figure (3), with two distinct returns from the air/sea interface and the bottom. The asymmetry of the bottom return is a consequence of the large footprint but, since the detection is measured on the leading “up” ramp of the waveform, it becomes clear why this scattered energy is irrelevant to the depth calculation. Present ALH systems have demonstrated capability to achieve depth accuracy standards at least as accurate as current acoustic systems (Riley, 1995) and because of this, compliance with current IHO Standards can justifiably be claimed.

Figure (3): Generic Lidar Waveform



Operational Scenario

The usual operation of an ALH system is comprised of a few steps. The first is system mobilisation. If the lidar system is not on a dedicated platform then it must be mounted into the airborne platform of choice. If an installation has already been done on a particular aircraft this takes only a few hours. If the platform is new to this type of equipment, then considerably more time must be allowed for the proper approvals. The ALH system must then be ferried to the site of interest. Depending on the distances involved this can be a significant part of the cost.

The most important preparatory step is the site evaluation. It is crucial that the area of interest be examined in advance to determine if the water clarity and the intended depths are within the capability of the system. If the water clarity is too turbid, it is important to know whether this area will clear after a few days or if the water character is a seasonal one. The flexibility of these airborne systems means that it is usually possible to fly somewhere else for surveys while a particular area is clearing for a later time.

Once the system is on site and the area identified as suitable, the next step is mission planning. The desired sounding density and swath widths are pre-programmed along with flight-lines that suitably cover the area. This is all done on a computer environment either from existing electronic charts or from a newly digitised form.

The collection of the data is a straightforward matter. There may or may not be requirements for ground GPS stations depending on the type of survey and its location on the globe. Airborne operation is by a single operator who monitors the data collection from a station similar to what is shown in Figure (4).

Figure (4): Airborne Operator Console



The final step for the production of accurate ALH depths is the post-processing. This is generally done in a dedicated work environment that either follows the airborne system when practical, or the data is sent back to a centralised processing centre.

The Scanning Hydrographic Operational Airborne Lidar Survey (SHOALS) System

The remainder of this paper will discuss the benefits and versatility of ALH with reference to practical examples of projects undertaken by SHOALS, although many of these features are common to other ALH systems in existence. Probably the most versatile Lidar survey system in use anywhere in the world today, it has recently undergone a major upgrade to enable it to operate from either fixed wing aircraft or helicopter. The system was installed in a Twin Otter (Figure 5) during the fall of 1998 and has since completed projects in New Zealand, Hawaii, and the Bahamas in addition to the continental USA. Incorporating a 400Hz laser, it can scan a swath of up to 220m with a selectable spot density of 3 to 15m. Depending on selected scan width and spot density, the system is flown at speeds up to 120 kts.

Figure (5): SHOALS Twin Otter Aircraft



Shallow Water Capability

While Multibeam Echo Sounders (MBES) have revolutionised surveys in medium and deep water, they have suffered from a number of drawbacks in very shallow areas. Most significantly, their swath is greatly decreased in very shallow waters, while ALH swath width remains fixed, irrespective of depth. SHOALS normally employs a swath of 110m with a 4m x 4m spot density; this means that it is able to collect dense data sets in shallow waters that would take conventional acoustic systems many times longer to collect.

Figure (6) is a good example of the detail that is obtainable in shallow water. This data comprises an area of approximately 1000 m x 2000 m and shows two sets of intersecting sandwaves that were detected in general depths of 6.5m during a recent survey in the Bahamas. The vertical scale has been exaggerated to highlight this structure, but the highest of the sandwaves is only 1.1m high while their width varies from 15 – 50 m.

Taking this further, it has also been possible to use SHOALS to delineate smaller area features, including several 'Blue Holes'. The data shown in Figure (8) is from one such case and shows the 'Blue Hole' to be about 40 m in diameter (crest to crest), with general surrounding water depths of about 3 m. The aircraft was flying from bottom-left to top-right, so the data can be directly compared with the in-flight down-look video record, which is collected simultaneously with all SHOALS surveys. In the

Figure (6): Intersecting Sandwave Fields

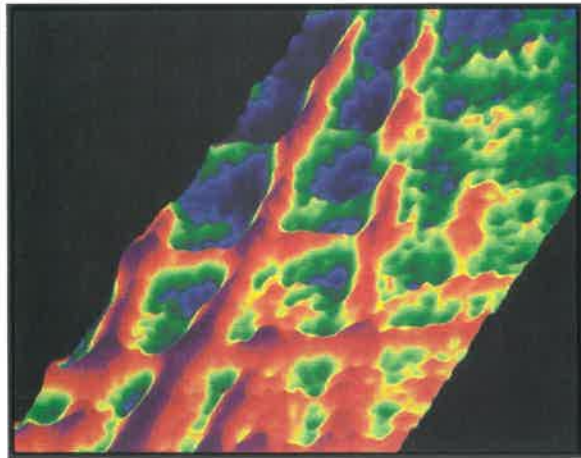
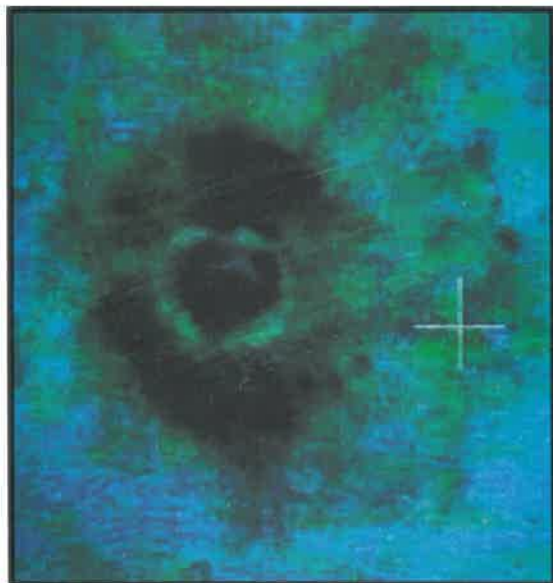


Figure (7): SHOALS Down-look Video of 'Blue Hole'



video, the aircraft is flying from bottom to top, and the lighter right-hand side of the hole's crest is easily correlated with the yellows on the nearest side of the crest in Figure (8). Also visible in Figure (7) are the streaks that run down-slope into the deeper water at the top-right of Figure (8).

The next example shows a wreck detected by SHOALS during a survey in Mexico. Figure (9) clearly shows the vessel on the seabed and about 30m in length, while Figure (10) shows the wreck in 3D view. What is significant about this wreck is that the highest point of was located at a depth of 6.2 m in general depths of 9 m, while much of the body of the wreck had sunken into the sand and protruded less than a meter above the surrounding seabed. It should be clear from this example that lidar has a proven capability to detect small wrecks in very shallow water (West and Lillycrop 1999).

Safety in Hazardous Areas

Delineating and classifying features that are anomalous to the general trend of the seabed is one of the critical elements of any nautical charting survey; however it is a task that often imperils the survey vessel itself. SHOALS is increasingly being used to conduct surveys in areas that are potentially too dangerous for surface vessels to operate it. One such survey was conducted around the rocky

Figure (8): Blue Hole

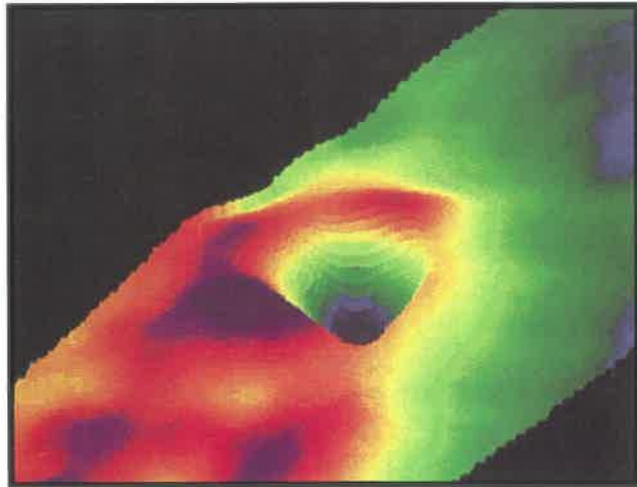
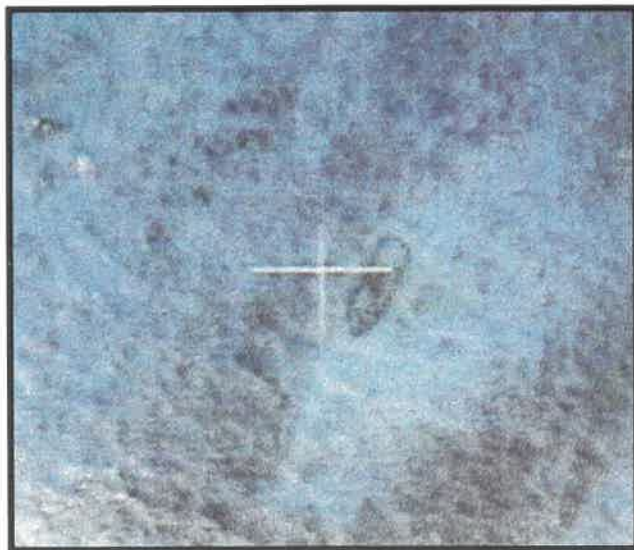


Figure (9): Down-look Video of Wreck



coasts of New Zealand's Sub-Antarctic Islands which are characterised by extreme surf and spray conditions as well as bottom topography which is dominated by isolated pinnacles. Figure (11) shows a typical coastal area composed of both drying and submerged rocks. The drying and breaking rocks are obvious in the photograph, but a submerged pinnacle lies to the bottom-right of the 'doughnut' shaped rock. This particular pinnacle rose from a depth of 15 m to within 7 m of the surface and had a base cross-section diameter of less than 10 m. The challenge was therefore to collect a bathymetric data set in dangerous, uncharted waters and delineate inaccessible coastlines, while also ensuring the safety of survey craft operating around the islands. SHOALS was identified as crucial to such a project (West *et al.*, 1999), able to meet all the inshore requirements while also providing safe clearance for conventional acoustic platforms to work in the deeper water. It was therefore not only used to survey close inshore, but also to sweep many apparently deep areas with the aim of locating any rocks which posed a danger to surface navigation. The results of this survey were then passed to the Surveyor in Charge of the marine survey allowing him to plan ship and launch surveys with complete confidence that all dangers to these assets had been identified.

Rapid Response

Before moving on from the above example, it is important to highlight another reason for its use in this area. The sub-Antarctic island groups of New Zealand are remote and dominated by predominantly foul weather, meaning that a major challenge was to mobilise during an extremely short weather window. The

Figure (10): Wreck, Mexico

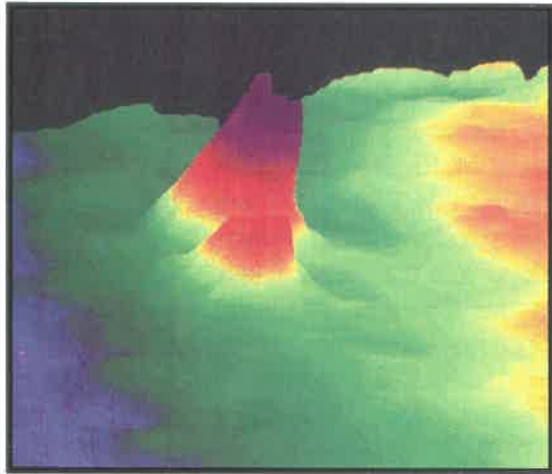
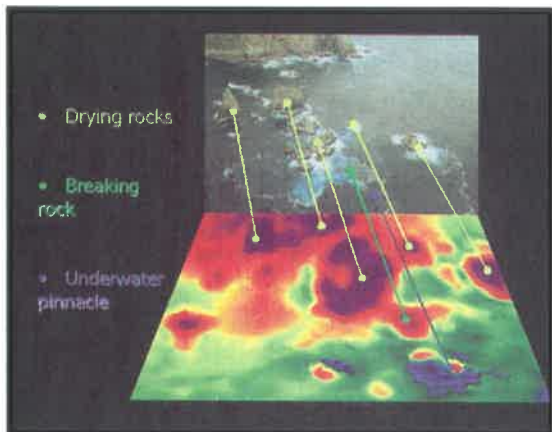
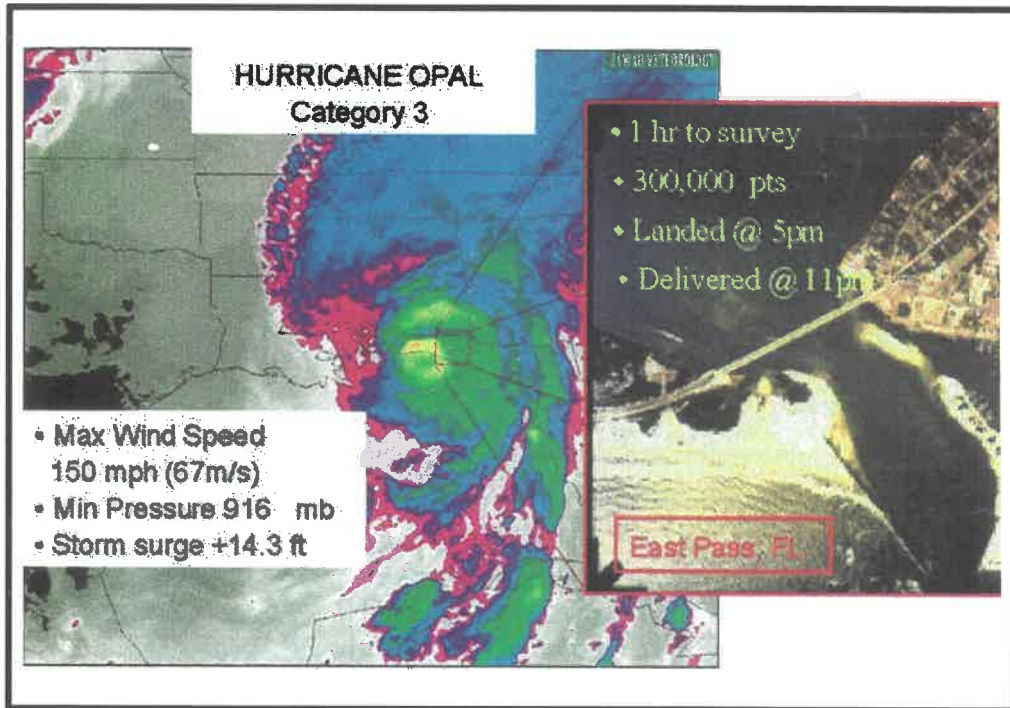


Figure (11): Shallow-water Rock Complex, New Zealand



ability to conduct surveys rapidly also gives it an inherent capability to respond to evolving situations, and SHOALS has now become one of the USACE's primary resources in the aftermath of hurricanes striking the southern USA. For example, in 1995, a Category 3 Hurricane, Opal, struck the Florida panhandle, causing widespread damage and reshaping of coastal features (Irish *et al.* 1996). At the time, SHOALS was engaged in routine surveys in New England but received an immediate call to assess the condition of East Pass Channel at Destin. In response, SHOALS had, by 5 p.m. on the second day after call, flown the survey; maps and volume calculations were generated and delivered less than 6 hours later.

Figure (12): Post-Hurricane survey, Florida 1995

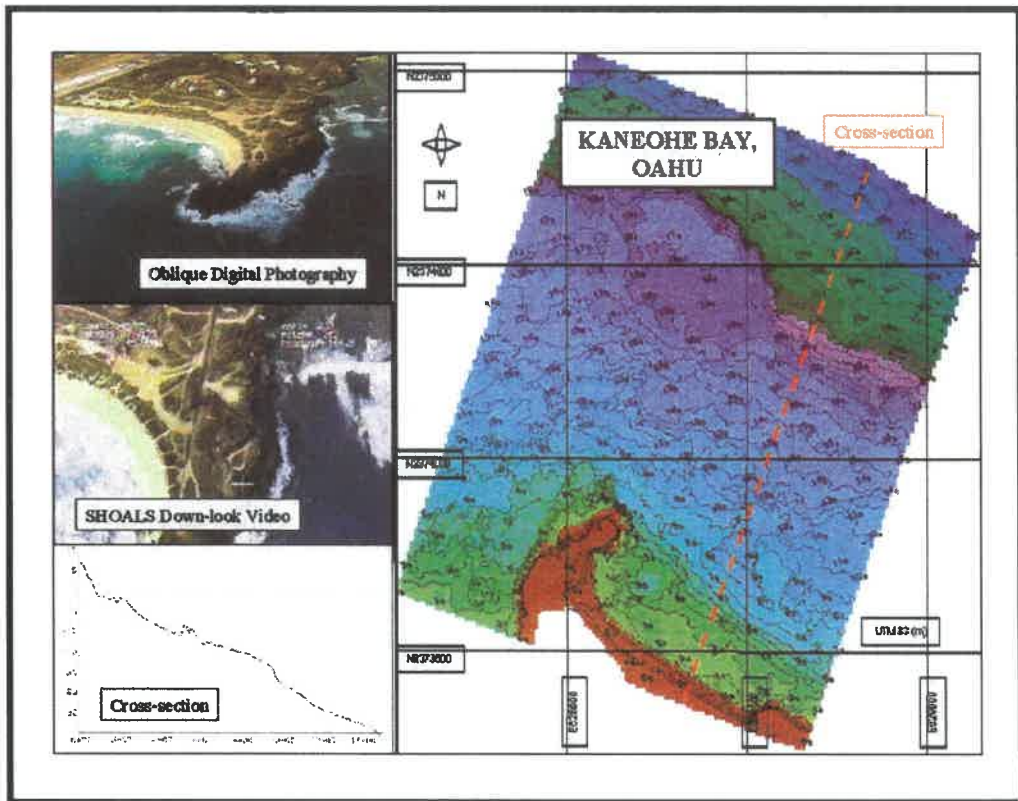


Flexibility

Operating from the air gives the shallow-water surveyor a new flexibility that the ship-borne hydrographers of the past could hardly have imagined. Released from many of the limitations of weather and hazards to a vessel, ALH allows the rapid and safe collection of comprehensive coastal data sets. Part of the SHOALS equipment suite is a down-look video that records imagery of the area directly under the aircraft at all times, while this is often complemented by use of oblique digital photography (Figure 13). The resultant composite of data and imagery is

of immeasurable use to a wide variety of users that is diverse as the warfighter and environmentalist as much as the

Figure (13): Composite Data Product, Hawaii



nautical charting authority. While these tools are standard for SHOALS surveys, there is also the potential to marry ALH with a variety of other technologies. At the most basic level this can be conventional acoustic means and the New Zealand survey illustrates the considerable benefits accruing from combining Lidar capability with conventional acoustic platforms. However, Lidar when merged with other airborne sensors presents new opportunities in fields such as coastal resource management. The USACE has started to move toward an approach that treats sediment, specifically sand, as a regional-scale resource (Parson *et al.*, 1999). Conceptually, this approach appears to make perfect sense; however, it has become viable only as a result of Lidar technology. Because of its ability to rapidly survey entire regions seamlessly across the land/sea interface, SHOALS has become the tool of choice. The key to this has been the development of Kinematic GPS capability, which has effectively given SHOALS the ability to collect data independently of the sea surface. Consequently, all vertical elevations are directly related to the ellipsoid and are not subject to errors introduced by tidal measurements and changing datums. These elevations are

then fused with aerial photography and overlaid in a GIS for presentation and analysis (Figure 14) (Watters and Wiggins, 1999). SHOALS data has also been merged with hyperspectral data in two pilot projects to map sea grass (Lillycrop and Estep 1995).

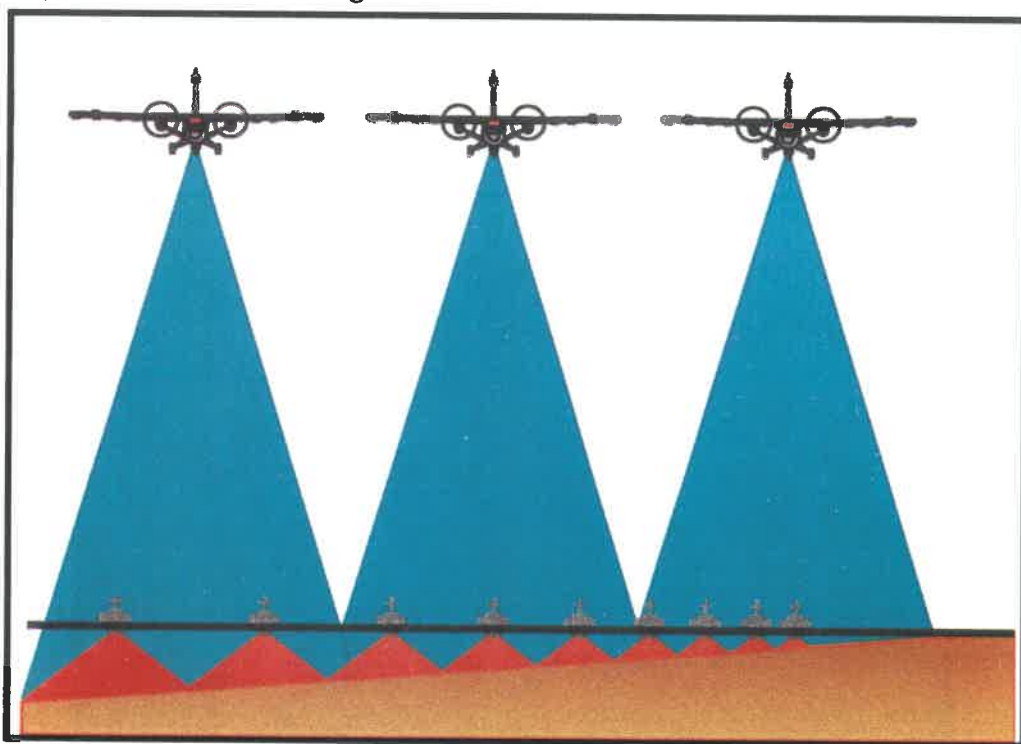
Figure (14): SHOALS Data Merged with Aerial Photography



Cost Effectiveness

LADS, Hawkeye and SHOALS have all reported significant savings over conventional acoustic methods (Sinclair et al 1999), (Axelsson and Alfredsson 1999), (Lillycrop *et al.* 1996). Because of this, ALH is rapidly becoming the tool of choice in clear, shallow waters since it will usually achieve coverage rates several orders higher than current launch methods (Figure 15) at less cost per square mile. Indeed as system capabilities increase, the economics of ALH are likely to become even more irresistible (Axelsson and Alfredsson 1999). However it is important to qualify this since MBES systems rapidly become more effective in deeper water and may also benefit in such areas from 24-hour operations. In summary, though, it is clear that ALH is most economic in areas where MBES systems are least.

Figure (15): ALH Coverage v MBES



Conclusion

The attraction of ALH lies in its capability to augment conventional survey capabilities in a cost-effective manner; operating within relatively clear, shallow water regions, which are among the most costly, hazardous, and time-consuming areas for ship and boat operations. In summary, survey launches suffer from their dependence on a 'Mother' ship or local operating base, slow coverage rates and vulnerability to grounding damage; ALH has the potential to overcome all these disadvantages.

The potential benefits of ALH are considerable and will continue to open up new opportunities in fields as diverse as regional sediment management and war fighting support. Development trends of ALH are already towards, smaller, cheaper and more automated systems that have the potential to be pod-mounted or even flown in Unmanned Airborne Vehicles (UAV). As a consequence, future systems are likely to be cheaper to run and offer even greater degrees of flexibility

Acknowledgements

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of Agreement signed by the Commander, Naval Meteorology and Oceanography Command (COMNAVMETOPCOM) and the USACE in May 1998, its scope was expanded to a Joint ALBTCX (JALBTCX). This incorporates the Naval Oceanographic Office's (NAVOCEANO's) needs and aims to promote the mutual leveraging of knowledge, resources, and expertise with respect to ALB and related technologies. The JALBTCX's missions are to produce quality products using the SHOALS system, promote the commercialisation of lidar bathymetry, and foster the evolution of airborne lidar and complimentary technologies. The JALBTCX is comprised of personnel from the USACE, NAVOCEANO and John E. Chance and Associates. The SHOALS Program is further supported by technical expertise from the National Oceanic and Atmospheric Administration's (NOAA) National Ocean Service (NOS), Kenn Borek Air and Optech, Inc.

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TECHNOLOGY FOR EFFICIENT MAPPING OF PORTS AND PORT ENTRANCES

Freddy Pöhner and Dave Wilson

Abstract

The traditional method of mapping shallow areas such as ports and port entrances is by the use of single beam echosounder. During the recent years, an alternative method has become available, by the use of small, high frequency multibeam echosounders. These instruments are compact and light enough to be mounted in small vessels. The paper demonstrates through modelling as well as through real life data that the multibeam method is sufficiently accurate to fulfil the new version of IHO S-44 requirements for survey accuracy. The paper also discusses the potential of using multibeam acoustic imagery as an alternative to towed sidescan systems for detection of small objects, and for inspection of breakwaters and other man-made underwater constructions.

Introduction

Many harbours and ports have invested in safety systems such as radar based Vessel Traffic Systems, in order to reduce the risk of collisions between vessels, and thus guarantee a safer port. Much less emphasis has so far been put on the need for guaranteeing the safe water depth for visiting ships, except for a few ports that have taken this problem seriously. There are several reasons why a port or an inland waterway authority should establish efficient and accurate mapping of their underwater terrain. The most important ones are:

- Eliminate groundings by providing accurate and up-to date depth information, in combination with accurate positioning services. Obviously the safest ports are the most attractive ones for the shipping business.
- On a routine basis, the harbour basin as well as shallow ship traffic lanes should be inspected for debris and lost pieces of cargo, which may pose a hazard for the ships.
- By establishing more precise water depth information, larger ships can be allowed into port while maintaining full safety against grounding.
- By routine mapping and inspection of the seafloor as well as manmade constructions under water, activities for port maintenance such as dredging and repair work can be specified and checked more precisely, thus reducing maintenance costs.

In the not to distant future, we expect to see ports offering to visiting ships precise and up-to-date depth information in the form of ECDIS charts with high resolution, adjusted for tide level in real time.

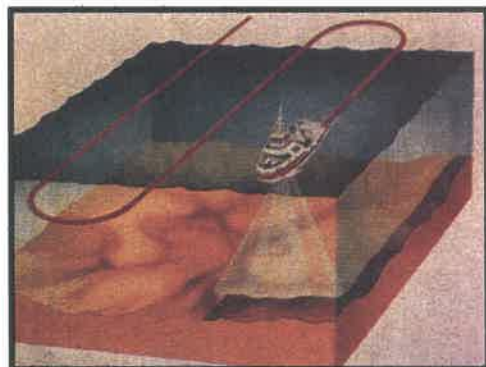
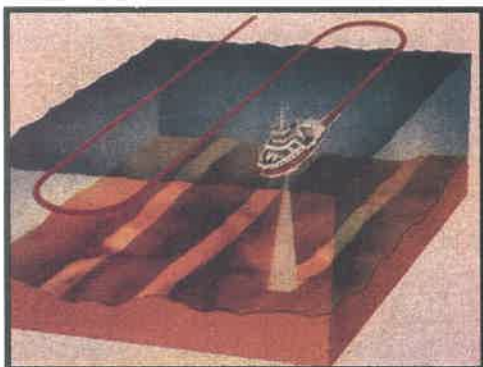
Why not a Single Beam Echosounder?

Most ports are of limited size, and feel intuitively that they can do perfectly well by mapping their waters using conventional equipment such as a low-cost single beam echosounder. However, the International Hydrographic Organisation (IHO) is now in the process of deciding on new and stricter rules for accuracy of seafloor mapping (Regulation S44) (Din *et al.*, 1995). For ports and harbours, and especially for those where the keel clearance is small, the new proposal for S44 regulation calls for 100% coverage of the seafloor during the sounding process, in order to make sure that all potential hazards are mapped.

100% seafloor coverage is not possible or feasible using a single beam echosounder alone (Figure 1a). The alternatives or supplementary technologies available are in practice:

- Mechanical sweeping, which is time consuming and therefore rather expensive.
- Towing sidescan sonar is often impractical in confined areas such as ports. Another problem with sidescan sonars in these environments is multiple acoustic reflexions from ships as well as from quaysides and other constructions, because of the wide acoustic beams of these instruments.
- Compact high frequency multibeam echosounders (Figure 1b), which are described below, are according to the authors view, probably the most viable alternative for the future.

Figure (1a): Single beam echosounding Figure (1b): Multibeam echosounding



Acoustic Principles for Depth Sounding

Conventional Echosounders produces depth soundings by transmitting short pulses of acoustic energy down towards the bottom. Some of the energy hitting the bottom is reflected back so that it can be detected by the echosounder, and the depth under the survey vessel is calculated from the 2-way travel time and the mean speed of sound in the water:

$$d=0.5 * c * T$$

Where T is the 2-way travel time and c is the mean speed of sound in the water column. In this way a vessel with a survey echosounder produces a line of soundings, and a map is constructed by interpolating the depth values between several survey lines.

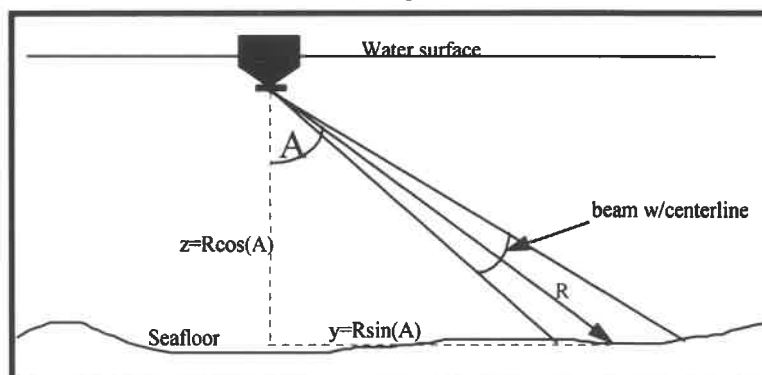
Multibeam echosounders, on the other hand, transmit a pulse of acoustic energy not only vertically, but also in a wide fan. Backscattered energy is received by a multi channel transducer, and several narrow receive beams are formed in different directions in order to analyse and process the received signal (Figure 2). In this manner a high number of depth soundings are generated for each pulse transmission (ping). Each receive beam produces one 2-way travel time (T) and an angle (A), and in the first approximation these measurements are converted into depth sounding values (d) and crosstrack positions (y) of the sounding, by calculating

$$d = 0.5 * c * T * \cos(A)$$

$$y = 0.5 * c * T * \sin(A)$$

These measurements are compensated for the effects of vessel pitching, yawing and rolling by using motion sensors of sufficient accuracy. Also acoustic raybending is compensated for by measuring the sound velocity profile in the water, and modelling the raypath of each beam in the system's computer.

Figure (2): Calculation of soundings in a multibeam echosounder



The system produces a dense pattern of depth soundings that cover a wide swath for each survey line. By adjusting the survey line spacing so that neighbouring swaths are slightly overlapping, the whole area to be mapped is covered by soundings, and virtually no interpolation between soundings is required to generate a detailed bathymetric map.

Not all swath-mapping systems on the market are sufficiently accurate. Multibeam echosounders, which use digital beamforming, are quite robust to different bottom geometries, acoustic reflections from breakwaters and quays etc. On the market there are presently also a number of so called 'swath mapping sonars', without beamformers, but built more like sidescan sonars with split aperture transducers to both sides, to measure angle of arrival as a function of time. This principle is less robust and less accurate in confined waters, due to their wide acoustic beams.

The Simrad EM 3000 Multibeam Echosounder

The Simrad EM 3000 system is a good example of the new generation of multibeam systems which are compact enough to be used on small vessels such as 20 to 30 feet long survey launch.

The system, see Figures (3 a&b), consists of one or two transducers with cable, an electronics unit suited for 19inch rack mount or table mount, and a workstation with software to take care of echosounder operation, survey planning and control, as well as data recording and real time visualisation of the data. The workstation software can even plot maps of the surveyed area in different formats in near real time. With one transducer the EM 3000 produces a fan of 120 beams, covering 130 degrees. This means an effective swath width of typically 4 times the distance from transducer to bottom. For a dual transducer system, the swath width increases to 8-10 times the depth of water, and the number of soundings per ping increases to 240. Dual EM 3000 systems can be set up for 190 degrees coverage, with the purpose of sonar inspection of underwater structures all the way up to the water surface, and also for efficient mapping of canals etc. The working range is from less than 1m of water to approximately 150m depth.

Due to a high maximum pingrate of 25 pings per second, 100% acoustic coverage of the bottom is obtained for all normal survey speeds and water depths. Precise soundings are obtained for the whole swath due to a unique signal processing method, by which interferometric techniques are used inside each beam to locate the points on the bottom which are exactly in the centreline of each beam.

Figure (3a): The main units of EM 3000; sonar head and processing unit

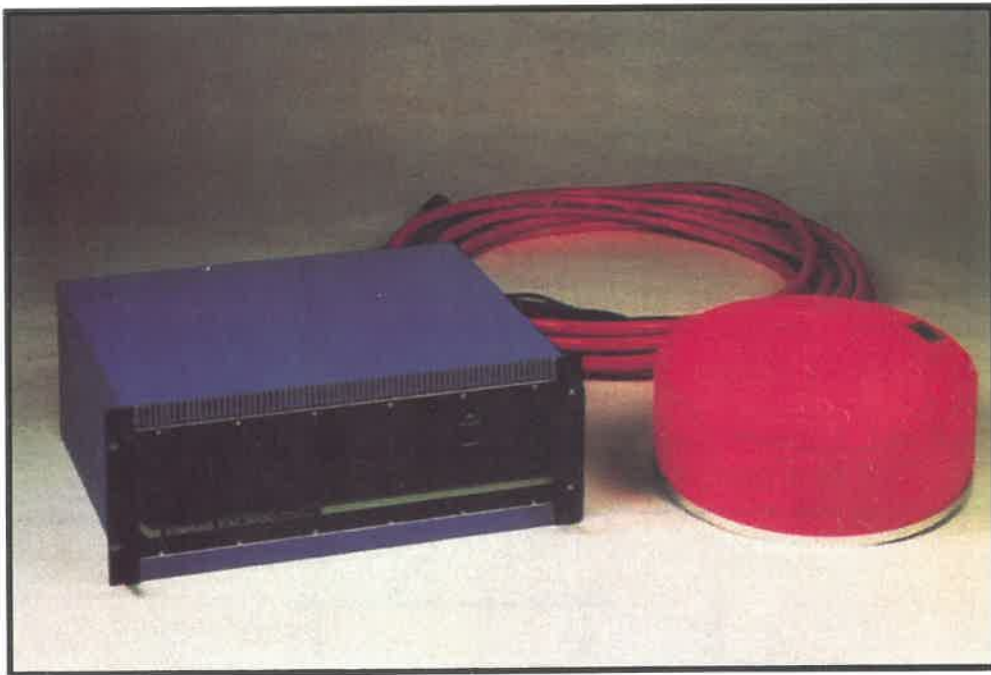
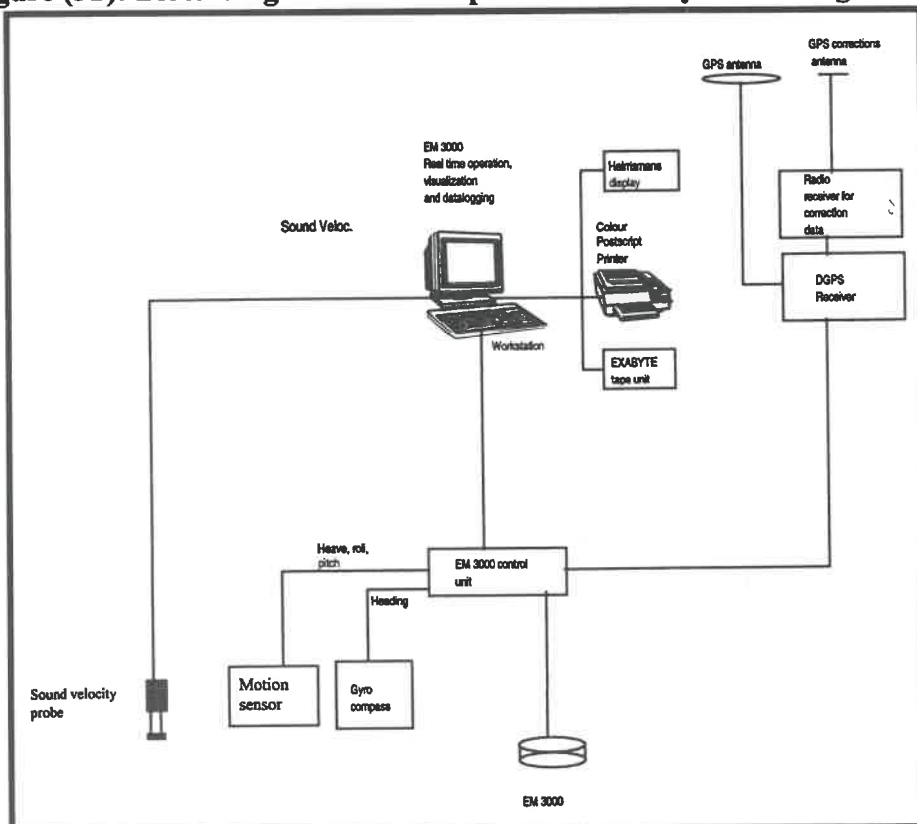


Figure (3b): Block diagram for a complete EM 3000 system configuration

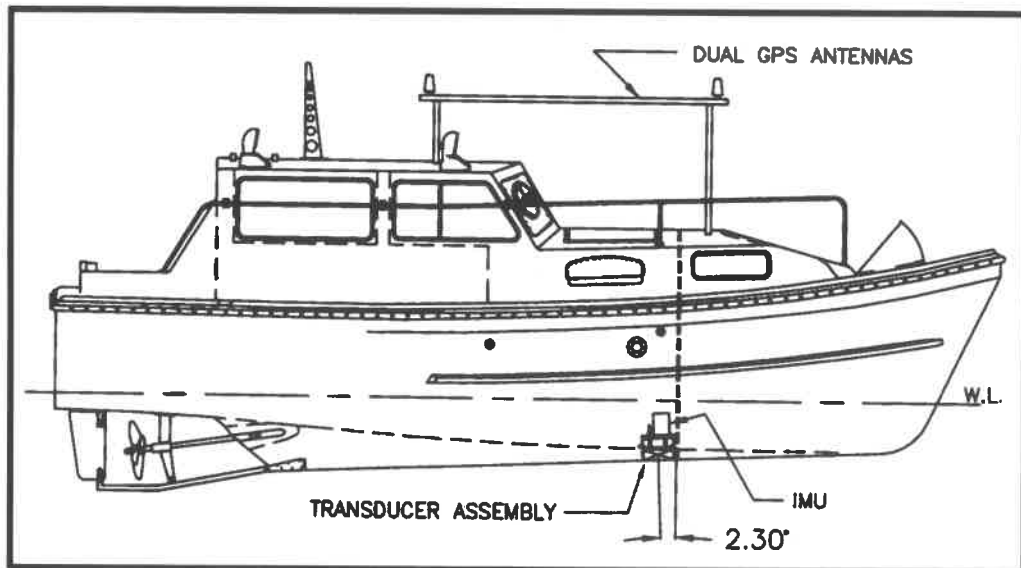


The EM 3000 needs to be interfaced to some external sensors:

- A positioning system, typically DGPS
- A vessel motion sensor
- A gyro compass (sometimes now part of the motion sensor)
- A sound velocity profiler

As an example, Figure (4) illustrates how the new survey launches of the Canadian Hydrographic Services are equipped. For these launches, the EM 3000 transducer is mounted in a fairing in the keel line, and the attitude sensor is mounted directly on top of the transducer.

Figure (4): Launch construction and outfitting for the Canadian Hydrographic Services



For portable use, a robust aluminium rig has been constructed which fits to glass fibre boats up to a size of 40 feet. The rig is strapped to the bow of the vessel, and carries GPS antenna(s) as well as multibeam transducer and motion sensor. Once the rig has been calibrated, it can be easily and quickly moved from one vessel to the next, and the system calibration is preserved. This solution is shown in Figure (5).

Compliance of EM 3000 with the Revised Version of S-44

The relevant part of the revised requirements are in short:

Order	Special	1
Typical application	Harbours and berthing areas with minimum underkeel clearances	Harbours and approach channels, depth up to 100m
100% bottom Search	Compulsory	In selected areas
Horizontal accuracy 95 % confidence level	2m	5m + 5% of depth
Depth accuracy 95% confidence level	25cm for shallowest depth	50cm for shallowest depth
Object detection, cubic features	>1m	>2m for depths to 40m

Bundesanstalt für Gewässerkunde did in 1997 a very thorough test of the EM 3000D system, to find out whether it would be suited for their application, which is surveying of the inland waterways in Germany.

The main conclusions are as follows:

Test	Test conditions	Result	Accuracy obtained
Uncertainty of soundings	Pontoon. Bottom roughness 1mm	Satisfactory	88% of soundings:<5cm 99% of soundings:<10cm
Uncertainty of soundings	River bed Bottom roughness 5 cm	Satisfactory	76% of soundings:<5cm 96% of soundings:<10cm
Uncertainty of soundings	As function of swath width	Satisfactory	Within 8 times water depth 68% of soundings:<5cm
Object location		Satisfactory	Mean pos. error: 11cm

Results for sounding density and efficiency of survey:

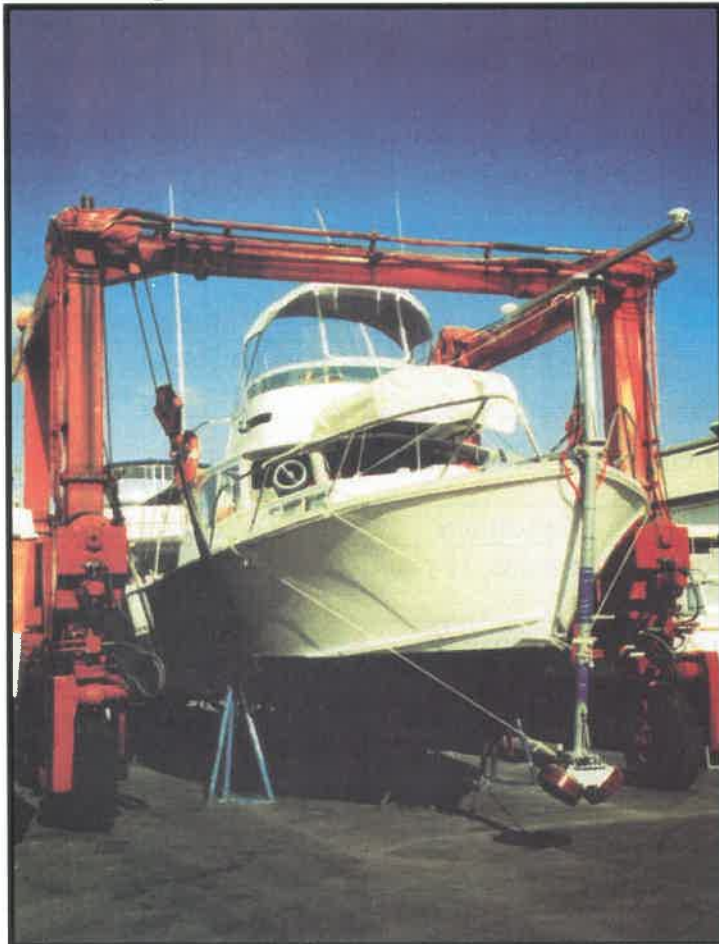
Test	Conditions	Accuracy/result obtained
Sounding density alongtrack	6 knots, 11 pings/sec	27 cm distance between soundings
Sounding density crosstrack	As above	1.5 degrees between soundings
Survey speed	Water depth 5m 8 knots 30% overlap	370.000 m2 per hour

Other results:

Test	Condition	Result
Object detection	Water depth 6m	Very good based upon soundings: Cubic objects min size 0.5m Tubes of diameter 10 cm Shallowest depth accuracy 11 cm Lesser performance with sonar image, Due to too little acoustic contrast
Construction survey	In a lock	Obtained accuracy and geometric model is very good. Some manual cleaning of data required, due to acoustic reflections
Canal survey	Depth 5m Sailing lane 30m	Large increase of productivity, only one survey line required

In essence, the EM 3000D system has satisfactory performance to fulfil the IHO S-44 requirements for special order surveys as well as order 1 surveys, with good margin.

Figure (5): Portable rig for the EM 3000D multibeam, motion sensor & GPS



Acoustic Imaging

In addition to the depth soundings, the Simrad EM 3000 produces a high resolution image of the seafloor, in much the same way as a sidescan sonar. In particular the dual head version of the system is capable of efficient and high quality imaging of the seafloor, object, and underwater constructions. The resolution of the image is one sample for every 5cm, or approximately 20 samples per meter on the bottom, in the crosstrack direction. The acoustic imagery can be used as an additional information when assessing the survey results.

Data Processing

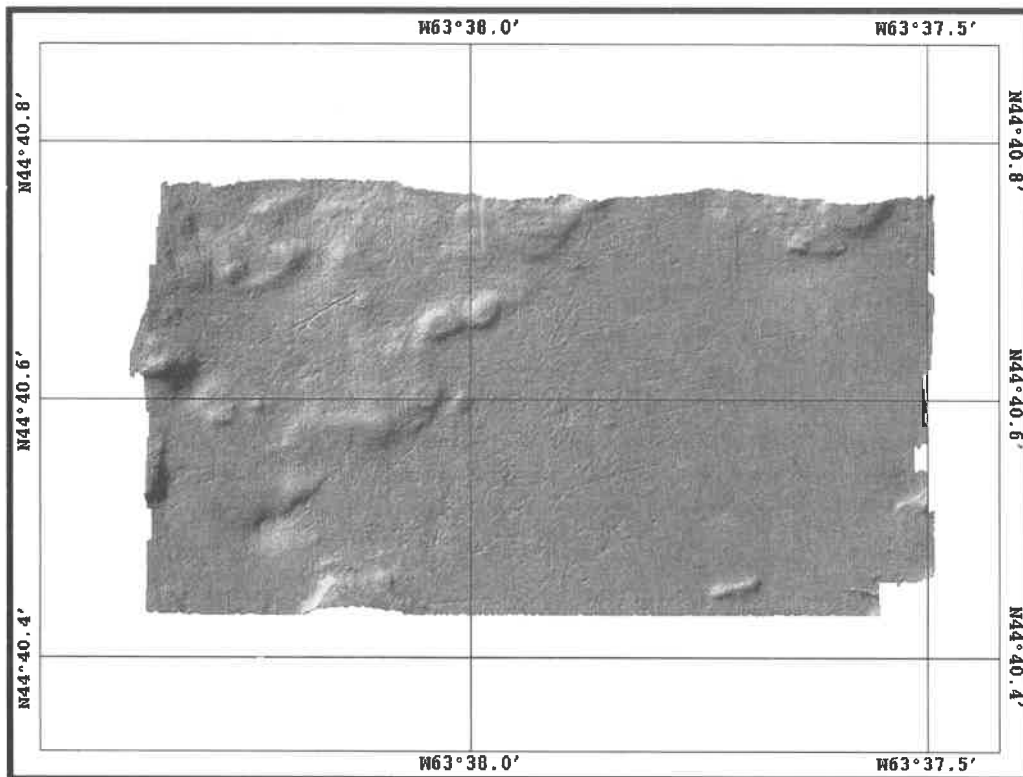
Preliminary maps can be produced by the real-time software, which is resident in the EM 3000 sounder. However, for production of accurate bathymetric maps with full control of the map accuracy, it is necessary to post process the collected sounding data.

The Simrad NEPTUNE software, which has been developed over more than 5 years in co-operation with the Norwegian Hydrographic Services, and also in close contact with the French Hydrographic Services (SHOM), includes the necessary software modules for

- Filtering and editing position data.
- Tide level corrections.
- Consistency analysis by comparing results from crossing or parallel survey lines.
- Applying systematic corrections, including recalculation of data for a different sound velocity profile.
- Statistical analysis with automatic and/or manual editing of soundings, and plotting.
- Export of data to terrain modelling, cartographic system and possibly a translator for ECDIS data format.

Figure (6) shows a typical result of mapping with EM 3000. It is a terrain model for a part of Halifax harbour. While a contour map representation of this terrain (about 20m deep) looks like a normal seafloor map, the shaded relief presentation reveals more bottom details (if the printing process is graceful to us), such as small rocks as well as a number of marks made by dragging anchor chains. The horizontal resolution of this map is 1m.

Figure (6): Typical result of mapping with EM 3000



Figures (7a-b) show near real time processing results of a wreck at about 25m of water depth. In Figure (7a), the terrain model is presented as a shaded relief view, which means that the terrain model is subject to artificial sunlight from the upper left corner, and the shade of grey indicates the local slope angle. In many cases this presentation is more informative than the contour chart type of presentation, as shown in Figure (7b).

Figure (8) shows the processed survey result of a storm barrier. One advantage of using a multibeam system with wide swath coverage, is the capability to map very shallow areas not being under the survey vessel. Note that the shallowest rocks of Figure (8) are only 2 m deep. Contour line interval is here 20cm, and the data are processed with a grid resolution of 30cm.

Powerful yet not so expensive computers make it practical and popular to present results in 3 dimensions, as illustrated in Figure (9). Such presentations visualise very clearly what the underwater terrain really looks like.

Figure (7a): Wreck, shaded relief view **Figure (7b): Same wreck as 7a, contoured**

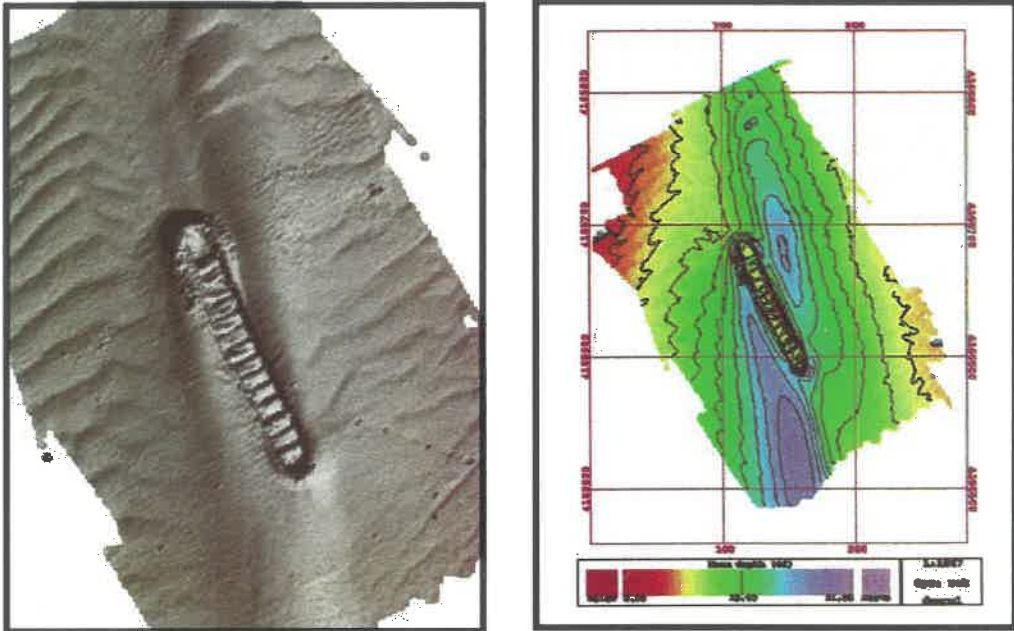


Figure (8): Detailed contour map of a storm barrier

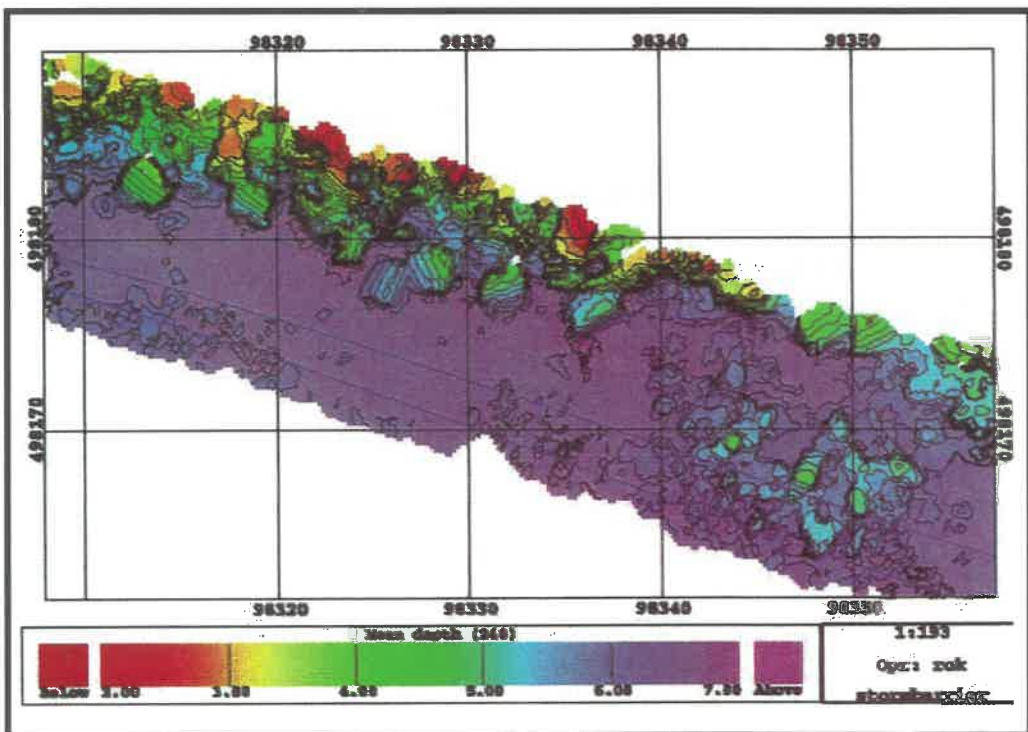
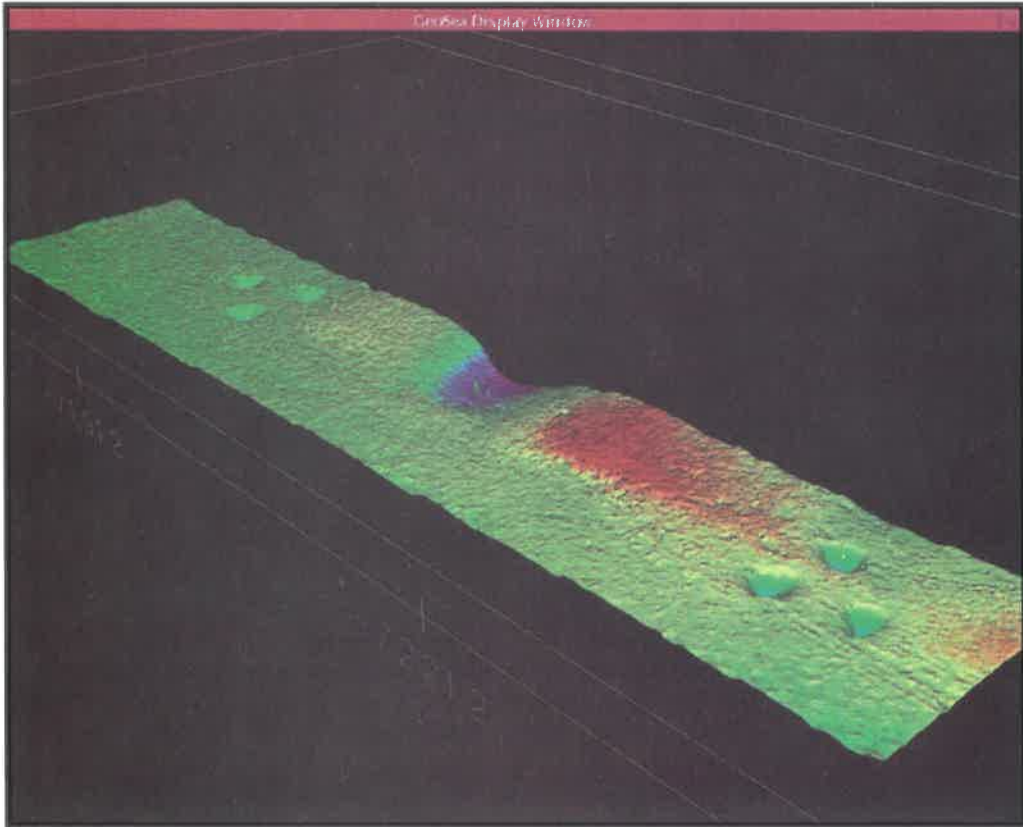


Figure (9): Survey result in 3D



Conclusions

The multibeam seafloor mapping technology makes it for the first time possible to map and reveal all hazards to navigation with high. If taken into use for shallow water areas with significant traffic density such as port entrances, ports, rivers and other inland waterways, it can mean a significant increase in the safety for shipping. For ports, the multibeam technology can be helpful for minimising the cost of dredging. It can also be used for efficient inspection of breakwaters, bridge foundations and other manmade constructions. For surveying of canals and rivers, the increase in efficiency is very substantial, since the survey lines are now parallel to the shoreline. For narrow traffic lanes, one survey line may be sufficient (Both, 1977).

For all these reasons, we expect that seabed mapping and inspection using multibeam systems will become a natural part of the operation of ports as well as inland waterways in the future. The new IHO S44 requirements encourage the use of the new technology, and are further incentives to take the multibeam system technology into use.

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CURRENT NORTH SEA TECHNOLOGY FOR OFFSHORE MAPPING AND INSPECTION OF THE SEABED

Freddy Pøhner

Abstract

Since 1986, when the first multibeam system was taken into use on an experimental basis for offshore oil field and pipeline route surveying, this technology has gradually gained acceptance. Multibeam survey equipment is now the standard tool for seabed mapping in the North Sea area. During the same period the acoustic as well as the data processing technology has experienced a rapid evolution. The paper gives an overview over today's technology for seabed mapping and inspection.

The oil exploration is currently moving towards deeper water. This has given rise to 2 parallel developments: Higher resolution multibeam systems for use from a surface vessel, and an autonomous underwater vehicle equipped with high frequency multibeam. Some examples of results are given.

Introduction

The oil exploration in the North Sea area has extremely difficult working conditions. The ocean bottom topography is in some parts of the area very complex, and the weather conditions are harsh. Especially during the long winter season gale force winds are experienced for long periods of time, the temperature is low, the days are short and the working light is scarce. At the same time the safety regulations of the authorities are very strict. As a consequence, all aspects of the operations are performed with a high level of control. There are needs for precise seafloor maps whenever something is to be put on the bottom, such as fixed structures, cables or pipelines. Until the middle of the 1980's the best technology was to use narrowbeam echosounders compensated for rolling and pitching of the survey vessel in combination with towed sidescan sonars.

In 1986 Simrad launched its EM 100 multibeam echosounder, operated by the Geoconsult survey company on "Geofjord". This produced maps with a degree of detail than what was a previously possible and extensive comparison test with ROV surveys showed that the new technology was indeed trustworthy. By today multibeam seafloor mapping is the standard practice. In some cases the resolution and precision which can be obtained by surveying from a surface vessel is not sufficient for the purpose (1), and multibeam echosounders are now being fitted also to ROVs for the highest precision of surveying.

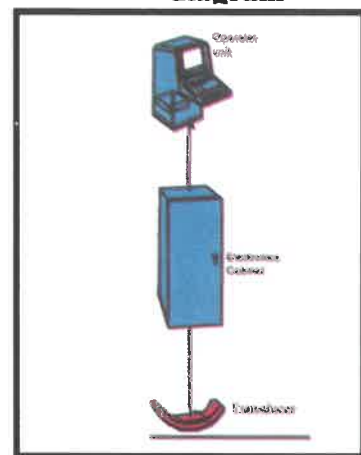
In this paper we will have a closer look at typical multibeam instruments that are in use today, and we will also discuss the use of autonomous vehicles as instrument carrier, a method which is expected to be taken into operational use within short time.

Simrad EM 1000 - The standard survey multibeam system for the North Sea

The EM 1000 system as developed as the next generation based upon EM 100 in 1990/91. It was quickly accepted as a much more efficient tool than EM 100, and is by now the standard instrument for seabed surveys by surface vessels in the North Sea. In the North Sea, a total of 6 systems are presently in operation, by the survey companies Geoconsult, Fugro Geoteam, and Gardline Surveys. As indicated in Figure (1), the basic system comprises 3 units:

- a transducer,
- an electronics cabinet, and
- an operators unit.

Figure (1): EM 1000 block diagram



Positioning data, vessel heading and attitude, and sound velocity profile information is interfaced to the system. The sounding process results in a stream of data presented on the operators display and at the same time output on Ethernet for external data logging and processing. Simrad offers to its range of multibeam systems the MERLIN workstation software for real time data visualisation and registration, and the NEPTUNE software for data cleaning and terrain modelling/map generation (Figure 2a and b).

Figure (2a): Multibeam swath, unstabilised for ships rolling

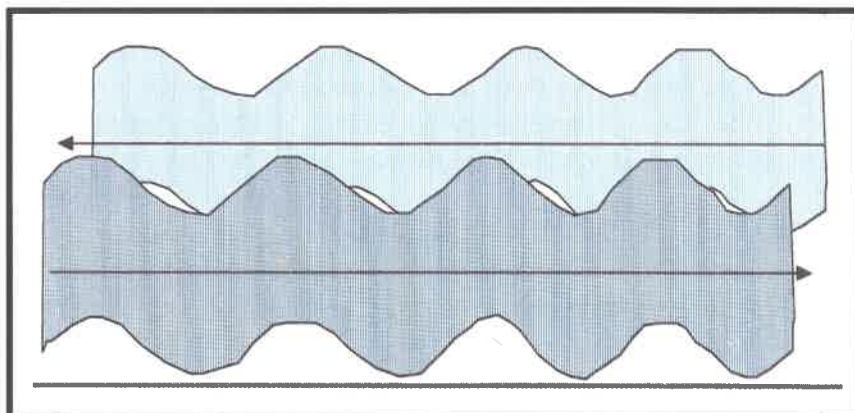
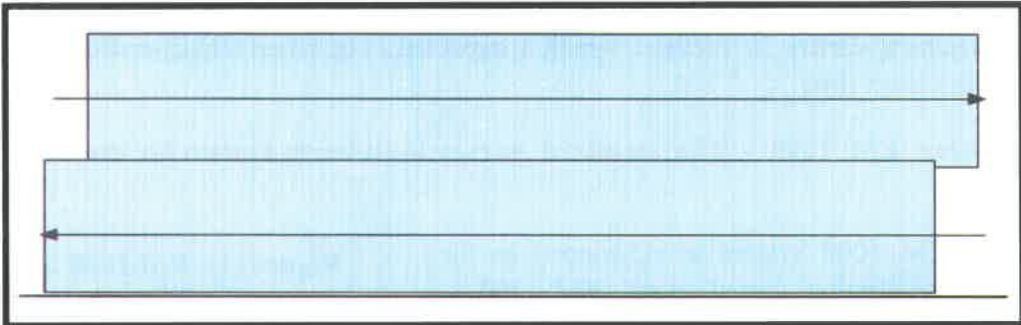


Figure (2b): Multibeam swath, stabilised for ships rolling

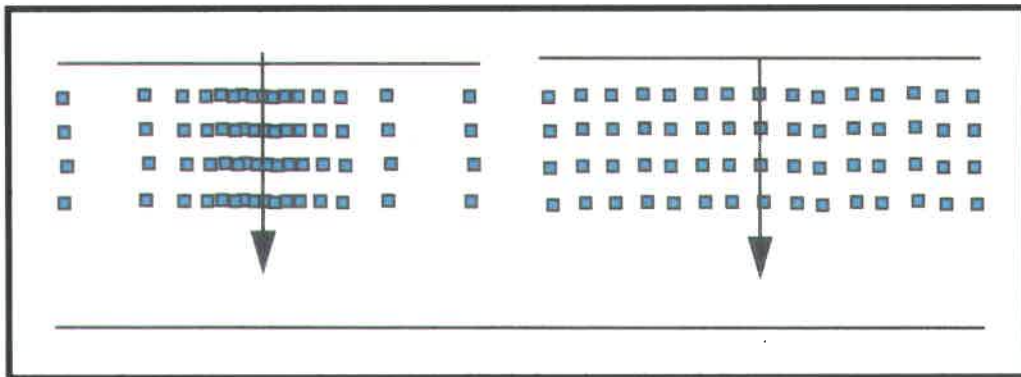


EM 1000 has a wide swath of up to 150 degrees, corresponding to 7.3 times the water depth. The distribution of soundings over the swath can be either the traditional pattern of equal angular spacing between soundings, or what is called equidistant beamspace, Figure (3a and b). With the latter sounding pattern, the distance between soundings on the seafloor is constant over the swath-width. In this way the quality of the gridded terrain model is improved, and the quality is much more uniform over the whole survey area.

Figure (3)

(a): Equiangular beamspace

(b): Equidistant beamspace



When the ship is rolling in the sea, the beamforming is adjusted in real time to maintain the direction of all beams constant relative to the horizontal plane. This helps to increase survey productivity, since the swath which is mapped during each survey line, has a regular, straight shape, and no extra overlap between swaths is necessary to fill gaps in the coverage caused by ship roll.

The transducer for the EM 1000 system is curved, with a radius of 45 cm. This has the advantage that a wide angular swath can be covered uniformly, and that the direction of each beam is independent of the sound velocity at the transducer.

In fact, each EM 1000 transducer is calibrated at the factory, so that all beam angles are corrected to their exact, nominal values.

The maximum range, which can be mapped with EM 1000, is dependent upon the bottom backscatter strength as well as the attenuation factor for sound in the water and the noise level of the ship. As a rule of thumb one can assume that it will work to a maximum water depth of 1000m, and a maximum swath width of 1000m.

One of the key issues of multibeam swath mapping is the system's accuracy of sounding, and in particular the accuracy of the oblique soundings. The EM 1000 system has implemented an improved version of the bottom detection algorithm for EM 100, making use of amplitude detection (centre of gravity) for those beams which hit the bottom nearly perpendicularly, and phase detection for oblique beams. The phase detection algorithm, which makes use of a split aperture of the array transducer, gives superior accuracy over competing systems in the oblique case.

Moving to deeper waters - Simrad EM 300 multibeam system

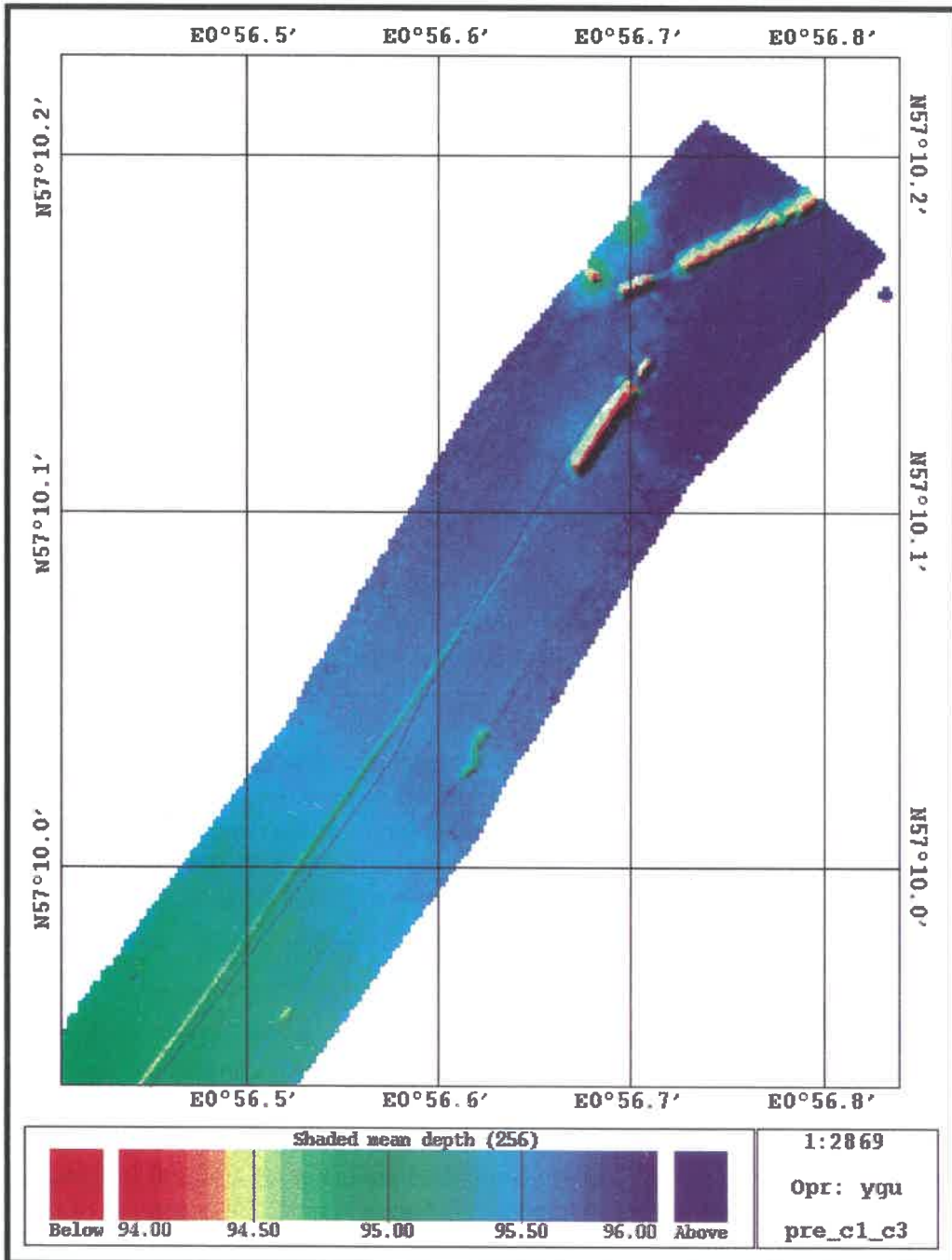
The oil exploration in the North Sea has gradually moved from shallower to deeper waters. While many of the early oil fields are at about 100m depth, the more recent ones are at about 400m, and the activity is now expanding into the Vøring plateau, which is considerably deeper. Large areas are deeper than 1000m, and the interest is now for potential oil exploration down to more than 2000m.

This makes it necessary to establish acceptable technology for mapping of the seabed in this depth range. The oil companies request the same map quality for these deeper areas than they presently have for 3 - 400m depth using EM 1000. The lowest cost of mapping and the highest efficiency is obtained by using a hullmounted multibeam echosounder. The Simrad EM 300 was developed to fill these needs. The lower frequency of 30 kHz gives added range capability, to a maximum of 5-6000m Figure (4).

Compared to EM 1000, the EM 300 transducer arrays were designed for narrower beam-widths and thus smaller acoustic footprints and better resolution of the final map. While EM 1000 operates with 3-degree beam-width for each beam, the basic EM 300 has transmit and receive beams of 2 degrees, optionally 1 degree. During 1997, 3 survey companies are installing EM 300 systems for North Sea surveying. One of these is a 2-degree system, the others are of the 1 degree version. With a 1 degree beam-width, the resolution capability of this system at a depth of 1000m is equivalent to that of EM 1000 at 330m, thus

fulfilling the requests from the oil companies for mapping resolution to that depth.

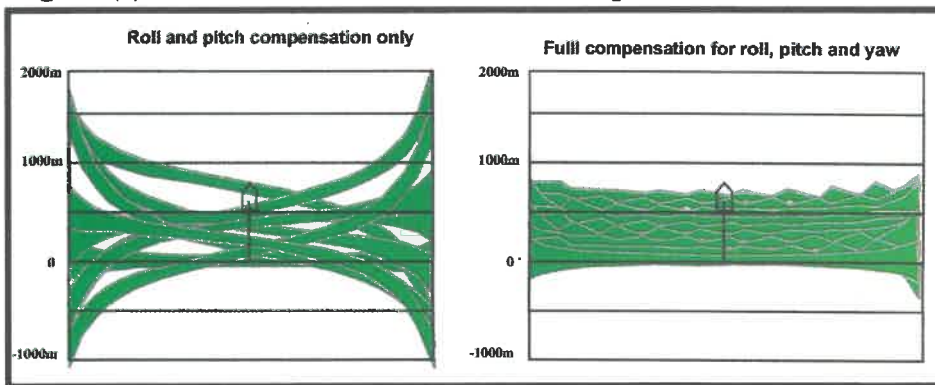
Figure (4): Near real-time result from EM 3000, end section of a 12" pipeline, with umbilical



EM 300 is the first multibeam to implement full stabilisation of the sounding pattern for both ships pitching, rolling, and yawing. For deeper waters, where the swath width is large, the impact of even small changes of vessels heading is significant. The result is gaps in the total seafloor coverage, and thus several spots where the maps can only be generated by interpolation, because of the lack of real data.

Figure (5) illustrates how the seafloor coverage improves radically when yaw stabilisation is applied to the multibeam system, in addition to roll and pitch compensation. The simulated case is for ± 5 degrees of pitching, ± 6 degrees of yawing, and ± 8 degrees of rolling.

Figure (5): Effect of EM 300 full motion compensation



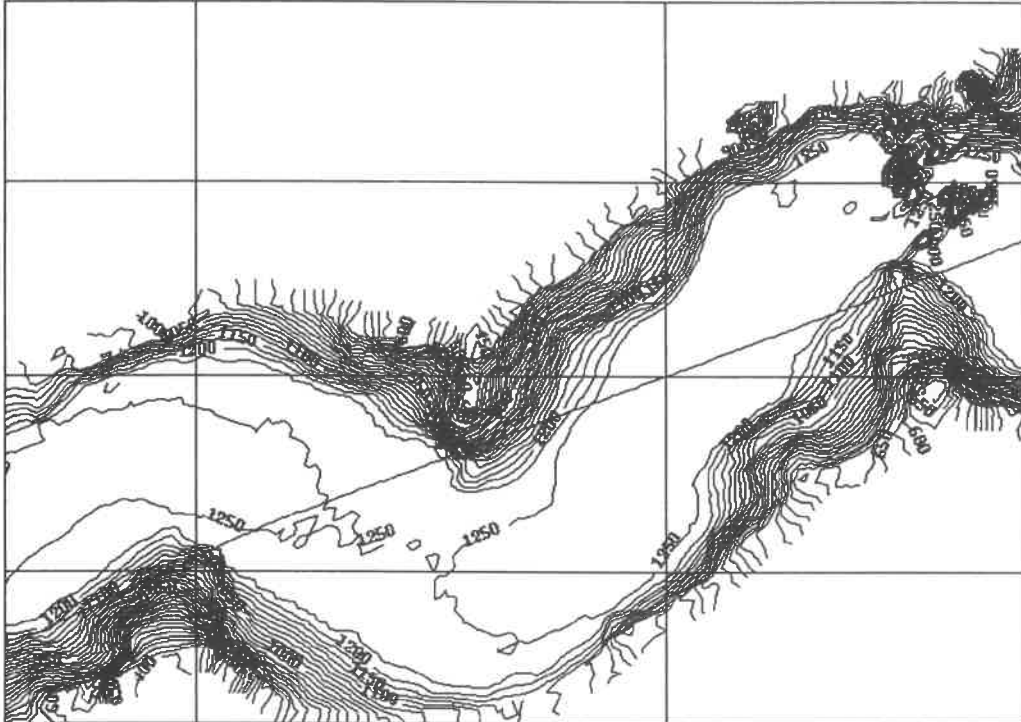
EM 300 is quite new, the first systems are made operational during the late spring and summer of 1997. Figure (6) is the result of a test of the system in one of the deep fjords in Norway.

High resolution mapping and inspection - EM 3000

As already pointed out, in some cases the resolution and accuracy which is achievable by using a multibeam system mounted in a surface survey vessel is not sufficient, and one has to get the sensor system closer to the bottom. In the North Sea region, the dominant instrument carrier for such detailed surveys has been and still is the ROV, using dGPS and acoustic positioning to determine its position, and a high precision pressure sensor to determine its depth. Initially it was equipped with a high frequency single beam echosounder. RESON introduced the first multibeam for ROV surveying with its SEABAT 9001 system, and this quickly took over as the standard ROV mapping sensor. In 1986 SIMRAD launched its EM 3000 system, which is a 300 kHz, compact multibeam system for shallow water and for ROV use. This system offers better range capability than the SEABAT, due to lower frequency and digital signal processing. Also the accuracy for oblique beams is better, the number of pings

per second is higher, and the swath width is larger. EM 3000 comes in a ruggedised version with 1500m depth rating of its transducer. The first results obtained with EM 3000 on ROV's are very encouraging, and it seems that this system will set the standard for high resolution ROV based seabed mapping in the North Sea Region in the future.

Figure (6): Example of seafloor map produced by EM 300



HUGIN - Autonomous vehicle for seabed mapping and inspection

The survey speed of ROVs becomes quite low when the water depth increases, due to the drag of the umbilical cable system. This means that ROV surveys become very expensive. This fact is the main motivation for the HUGIN development program, during which the goal is to develop working technology and system solutions for untethered, underwater vehicles to be used for detailed surveying. So far, the HUGIN 1 vehicle has been tested successfully, for water depths to 600m and with a battery capacity for 6 hours operation.

Positioning of the HUGIN UUV is by use of SIMRAD HIPAP in combination with dGPS, and the main sonar sensor is SIMRAD EM 3000 (Figure 7). The survey speed is 4 knots, independent upon water depth. During the next phase of

development, a 2000m version of the system will be built, with extended endurance to 36 hours.

Figure (7): The HUGIN 1 UUV in a launch situation

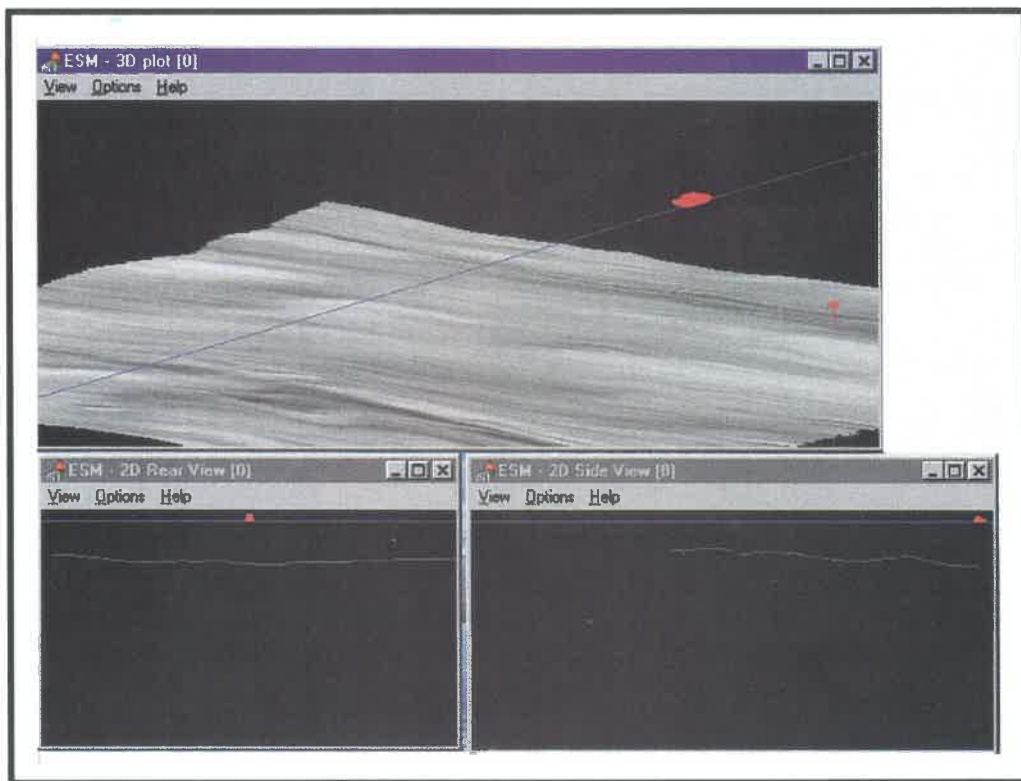


Advances in data processing

With the modern, high speed workstations that are available today, the data processing capacity has increased to a level which is sufficient to support the needs for cleaning and editing multibeam data, and for chart compilation.

While the capability to visualise multibeam data in near real time has become standard for the 2D case, a novelty is the capability to display the seabed terrain in 3 dimensions as the data is collected. This is expected to open for new applications, by which the seabed information is used in a more operational role, to give an operator steering guidance for the control of towed bodies, to control precisely the setting of anchors or other structures, to aid diving operations, etc.

Figure (8): A real time 3D view of a vehicle and a towed object over a seafloor (EM 1000 seafloor data)



Conclusions

An atmosphere of collaboration and common objectives between oil companies, offshore operators, research institutions and electronics industry in the North Sea region has proved to be effective for the development of novel concepts and

systems solutions for mapping and inspection of the seabed, the main objectives being reduction of cost and improved control and documentation.

One striking technology trend, which is the main topic of this paper, is the increased use of beamforming, swath-mapping sonars: the so-called multibeam echosounders. In spite of higher equipment cost than earlier, conventional instrumentation, the survey companies have selected these instruments because they reduce the overall survey cost, and they produce better and more reproducible results.

Although operating conditions and governmental regulations are different in other parts of the world where offshore oil and gas fields are explored, it may well be that the technological solutions which have been developed in the North Sea area may be applied beneficially also elsewhere.

Acknowledgments

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ADVANCED GPS POSITIONING TECHNIQUES

Michael W. Trimble

Introduction

Since the first release of commercially available RTK systems, many advances have been made in receiver technology, antenna design and RTK algorithms. In terms of marine survey applications, RTK systems are required to initialise and generate centimeter level positions in highly dynamic and often noisy environments.

Early generations of RTK systems were only capable of outputting positions every second (1Hz). One of the most important considerations with early RTK systems was the latency, or age of data, associated with each position output by the receiver. Typically this was 2.2 seconds with earlier RTK receivers. When integrating the position data into a real-time navigation software system such as Trimble's HYDRO™ software, the latency associated with each position was important to know when determining the vessel's position at any moment in time. As the latency of a position value can vary with changing satellite constellations, setting a constant latency value in the real-time software is often not enough to guarantee the correct determination of the vessel's position.

To determine the accurate latency of each position output by the receiver, the 1 Pulse per Second (1PPS) timing strobe and associated time tag was used by HYDRO to calculate the latency of each position. HYDRO would then determine the "time of applicability" of the RTK position, which would then be used to determine the estimated or dead-reckoned position of the vessel at the current moment in time.

New generation RTK systems and real-time navigation software from Trimble allows RTK to be used more efficiently in the determination of tide, long period swell and centimeter-level accurate positions. This paper describes the results obtained with a MS750 RTK system and HYDROpro Navigation software to determine tide and high frequency swell (heave) in real-time.

New Generation RTK Systems

The performance of an RTK system can be measured with the following parameters:

- Cost
- Size / weight / ergonomics

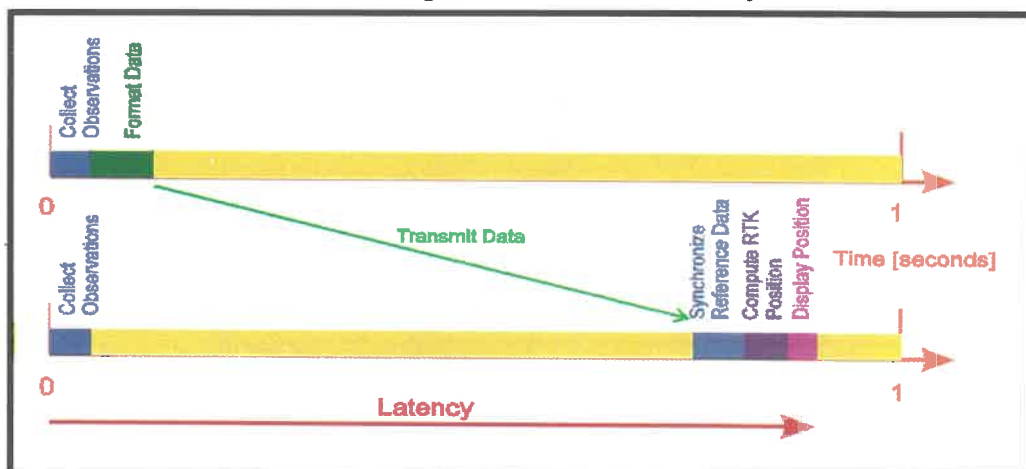
- Operating range
- Initialisation time and solution reliability
- Solution latency and update rate

The cost, size and weight of RTK systems have decreased appreciably over the last 5 years, with advances in technology, production and design. Operating range refers to the distance between the reference station and mobile receivers. As the separation distance between the reference and mobile receivers increases, satellite and atmospheric errors experienced by both receivers becomes appreciably different. An increase in distance equates to degradation in the system's positional accuracy. GPS manufacturers typically quote a maximum operating range of about 10 - 15km.

Initialisation time and solution reliability are a function of the algorithms used to determine the carrier phase ambiguities and minimise noisy observations caused by multipath for example. RTK systems determine centimeter-level accuracy by tracking the carrier phase observable from 5 or more GPS satellites simultaneously. An initialisation process is used to determine the whole number of integer wavelengths and the partial wavelength between the GPS satellite and the receiver (often called carrier phase ambiguity). All Trimble RTK systems use a technique called On-The-Fly (OTF) initialisation to determine the carrier phase ambiguities while the rover receiver is in motion. This initialisation typically takes 30-60 seconds to complete.

Solution latency refers to the time difference between when the position was valid and when it was output or displayed. Solution latency is predominately related to the time required to format and transmit corrections from the reference station to the mobile (Figure 1). Transmission delays are typically 0.5 – 1.0 seconds with a UHF radio at 4800 baud.

Figure (1): Factors contributing to RTK solution latency.



For dynamic environments such as marine surveying, we are interested in where we are now, not where we were 2.2 seconds ago. Update rate refers to how often a position is generated. In a dynamic environment, the more positions that are determined per second, the smoother our trajectory is represented.

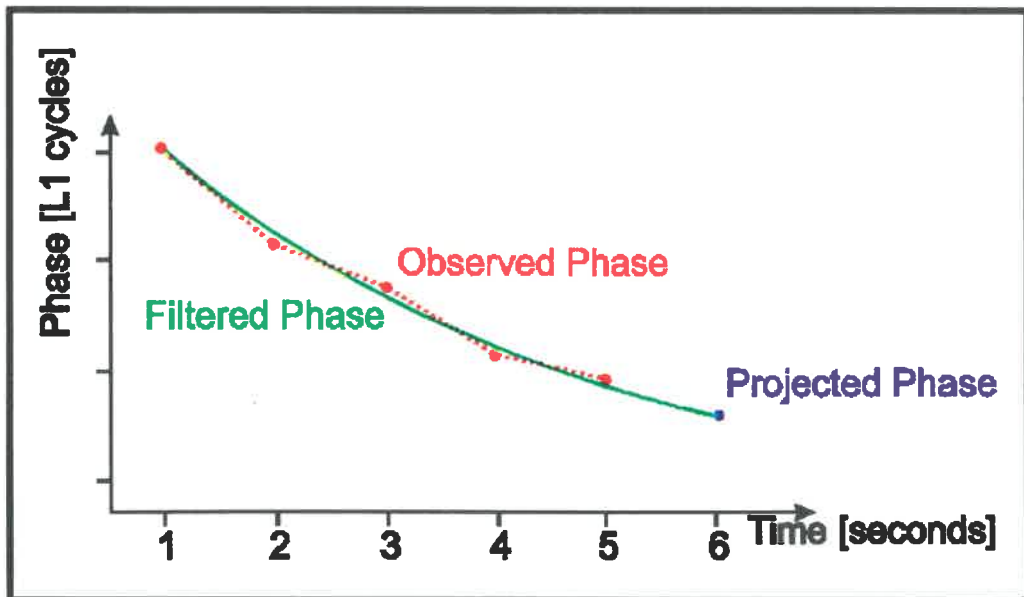
Ideally for marine survey applications, we want an RTK system that provides high output rates with low latency while still maintaining centimeter-level accuracy.

Low Latency Positioning

Trimble's new MS750 marine RTK system offers various positioning modes. One particular mode addresses the problem of solution latency. The MS750 is able to generate centimeter level accurate positions up to 20 times a second (20 Hz), with 20-millisecond latency.

This is achieved by the mobile receiver estimating the reference station carrier phase measurements a short time into the future. The reference station carrier phase measurements are highly predictable over a few seconds. Rather than waiting for the carrier phase corrections to be sent via the radio link before computing a position, a history of the reference station measurements is used to estimate to the current epoch (Figure 2). Each position is computed using the mobiles observed carrier phase measurement and the projected reference station carrier phase measurements.

Figure (2): Simulated carrier phase projection process.



The trade off for a low latency solution is degradation in accuracy – typically 3 – 5 centimeters. However, an increase in data link delay leads to an increase in the uncertainty of the low latency RTK position solution, not an increase in solution latency.

The advantage of the low latency technique is that the reference data need only be sent once a second while the mobile can generate projected reference station observations at a user selected rate. For example, a mobile MS750 receiver can be configured to output low latency positions at 1, 2, 5, 10 or 20Hz (times a second) while the solution latency is typically 20 – 30 milliseconds.

Software - HYDROpro

To be able to best utilise the latest features of a high update rate, low latency RTK system, you need to have a real-time data acquisition and guidance software package that can utilise the information in a constructive manner.

Trimble's latest generation real-time navigation software, HYDROpro, has been developed to take advantage of the latest features that RTK technology has to offer to the hydrographic / marine survey market. HYDROpro has the ability to interface to a wide range of sensors simultaneously and accurately timestamp and log the data to an Access database. The most critical part of a real-time data acquisition system is accurately time stamping each individual data record, no matter the input frequency. Coupled with this is the determination of the data's latency or "time of applicability". HYDROpro uses various time mechanisms to determine the latency or age of each "data stream". The user can nominate a constant latency value that may have been published by the equipment manufacturer. Alternatively, if a GPS timing source is available (1PPS or NMEA ZDA) and the incoming data record has a GPS timestamp associated with it, a latency value can be determined for each incoming record.

All of Trimble's marine GPS receivers can be used with HYDROpro. In the case of the MS750, HYDROpro can be used to configure the receiver from within the software. The user need only connect the MS750 to the serial port on the PC, as receiver settings can be controlled from within HYDROpro. Once configured, the MS750 can provide HYDROpro with a number of "services" or data streams. Most of the data services are computed by the MS750 such as position, GPS time, GPS status, solution quality etc, but HYDROpro can also use the incoming position data to create a derived data services such as tide.

RTK Tide Determination

As in the HYDRO software, tide is determined using the centimeter-level accurate height component of the GPS position output by the receiver. The RTK

reference station is located on a control point whose coordinates are accurately known on the WGS84 and local datums. The carrier phase corrections are then transmitted to the mobile receiver via a suitable radio link (typically UHF) at a minimum of once a second. The mobile receiver then computes a WGS84 low latency position up to 20 times a second.

The WGS84 height is then used to determine the tide. The tide value is calculated as follows:

Tide Correction = GPS Height – Antenna Height – Datum Separation

For the tide value to be calculated, the datum separation must be known. The datum separation is the vertical separation between the WGS84 datum and the zero value of the local tide datum. This separation is generally established using conventional survey techniques. The accuracy of this value will depend on how far the mobile is from the reference receiver. The WGS84 and local tide datum are usually not parallel, but the rate of change is usually no more than a few centimeters over the range of the RTK system (10–15 kilometers).

A tide value is computed by HYDROpro for each GPS position input into the software. This instantaneous value will contain unwanted artifacts due to vessel motion – such as heave, pitch and roll of the GPS antenna. Previously HYDRO used the derived tide value to account for tide and long period swell. A derived tide value was calculated and logged every position update (maximum once a second).

Most users are interested to determine the tide only. They do not want vessel motion artifacts included in the tide value. To overcome this problem, HYDROpro filters the incoming GPS height data used in the tide calculation. The first filter removes any unwanted GPS heights based on the status of the solution. Generally this filter is set to remove any GPS heights that are not based on a fixed integer solution (highest precision solution type). The second filter is an average mechanism that can be used to smooth ‘noise’ in the tide value generated by vessel motion. The user defines a sample period from which an average tide value is generated and logged to the database. For example, if a MS750 receiver is generating 20 positions a second and the sample period set to 1 minute, providing all the positions were fixed integer solutions, the derived tide value would be based on the average of 1200 GPS positions.

Figure (3) details a comparison over a 2-hour period between tide values recorded at a tide station and tide derived from a RTK system. The filter period for the RTK generated tide was set to 60 seconds. The average difference

between the two tide profiles is 0.03 m. This difference accounts for factors such as; accuracy of the GPS height value (0.02 – 0.03m.), vessel motion, accuracy of the datum separation value entered into the software and the mobile / reference range.

Figure (3): Comparison between derived RTK tide and observed tide.

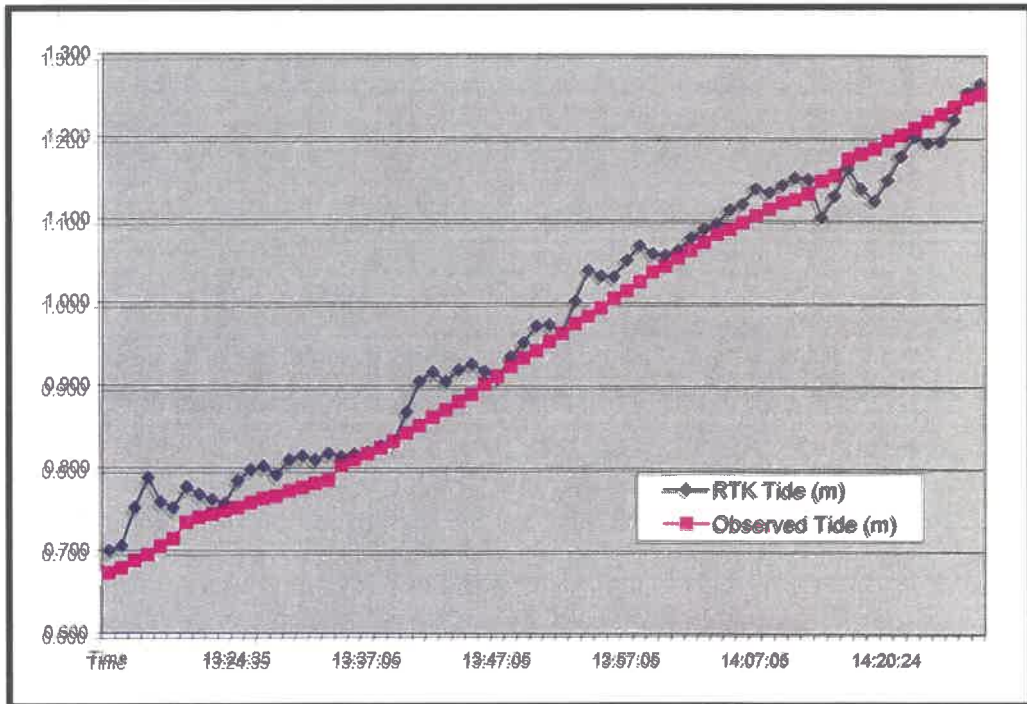


Figure (4) details the difference between the derived RTK tide value and observed tide value every time the observed tide was recorded (1 minute intervals).

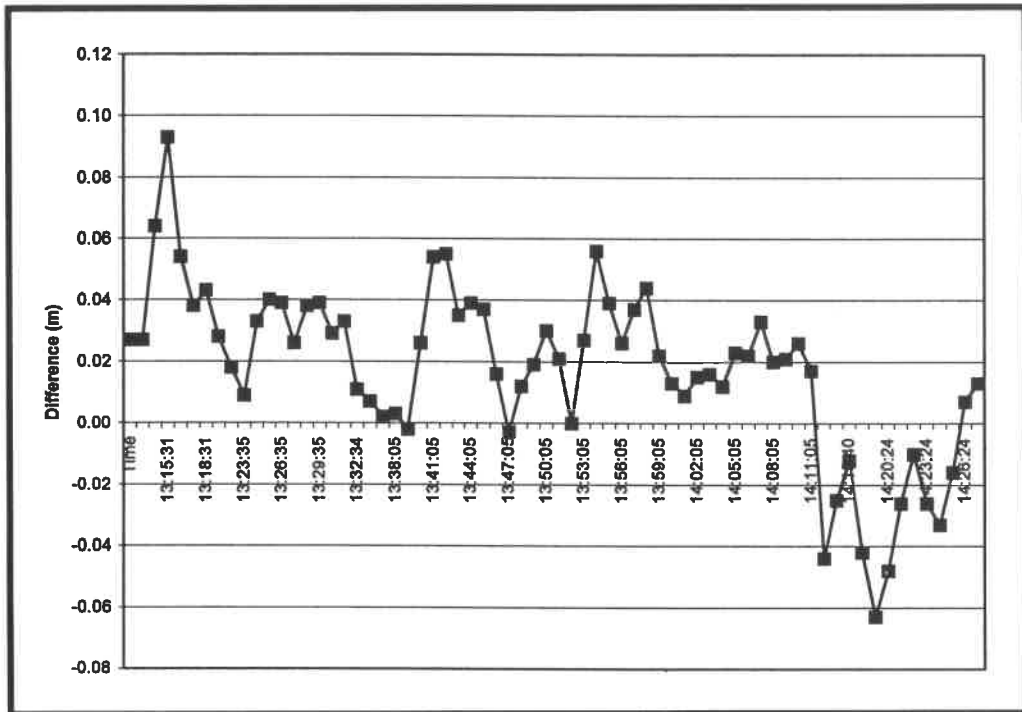
High Frequency Swell Compensation

Previous generations of RTK systems were only capable of data output rates of 1 second with a minimum latency of 2.2 seconds. During processing, the calculated RTK tide value applied to reduce a depth contained elements of vessel motion. This system was used to correct depth data for tide and long period swell. Previous trials [Walker, 1996] showed that the system was capable of correcting for low frequency swells with periods greater than 5 seconds. Vertical movement caused by high frequency swell was still required to be measured using a heave compensator.

The standard motion compensator contains accelerometers that measure a vessels motion in various directions. Heave is measured as the vertical motion from a

zero datum. Motion compensators such as the TSS DMS-10, are capable of output rates of up to 50Hz (50 times a second).

Figure (4): Difference between derived RTK tide and observed tide.

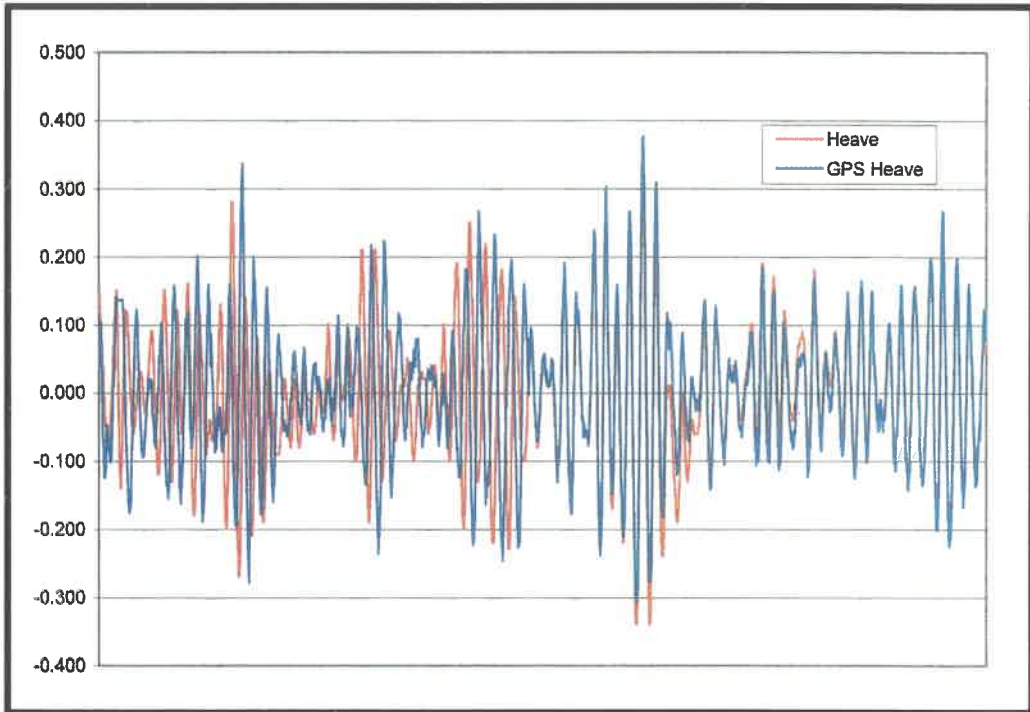


With the 20Hz output capability of the MS750, there is now the ability to compare RTK heights generated 20 times a second with heave data from a heave compensator.

By disabling the average filter in the RTK tide calculation in HYDROpro, the tide value logged to the database contains tide and vessel motion artifacts such as heave, pitch and roll. Of these three motions, we know that heave will have the largest effect in terms of the vertical location of the GPS antenna at any given moment.

Figure (5) shows a comparison between the heave from a TSS DMS-10 and RTK tide data generated 20 times a second. The RTK tide data has been normalised so that all that is displayed is vessel motion – heave in this case. The ‘RTK tide’ in this data will still contain effects from pitch and roll, but we are unable to remove these effects from the data. If an inexpensive pitch/roll device, such as the AGI MD900-TW, was interfaced during the trials the data would be corrected for these effects. The period of the heave is about 2 seconds with a maximum range of $\pm 0.30\text{m}$. The RTK “derived” heave is generally within $\pm 0.05\text{m}$.

Figure (5): Comparison between RTK derived heave and observed heave (DMS-10). Time span is 3 minutes.



Generally the MS750 in low latency mode is able to monitor the real-time vertical motion of the vessel to within $\pm 0.05\text{m}$. Factors affecting the accuracy of the derived RTK tide and heave will be an increase in pitch and roll of the vessel. For example, if the GPS antenna is 3.56m above the water line on the vessel, a roll or pitch of 10° at the time the carrier phase is observed equates to a change in height of 0.05 m.

Another Application of RTK

Docking System

Safely and precisely docking ferries, tankers and other large vessels has always been an important task. If not done correctly then a docking procedure could result in damage to the dock, vessel or worse yet, the environment or life. In order to safely dock a vessel, a pilot relies on accurate and timely information on the vessels position and velocity in relation to the dock along with environmental information. RTK GPS is ideally suited to this application. It should be noted that there are certain parameters that are the same in both the conventional and GPS systems. These are the need for environmental information such as the current speed and direction, wind speed and direction, and tidal height along with how

and where the information is displayed. This paper will examine only the positioning issues related to each method.

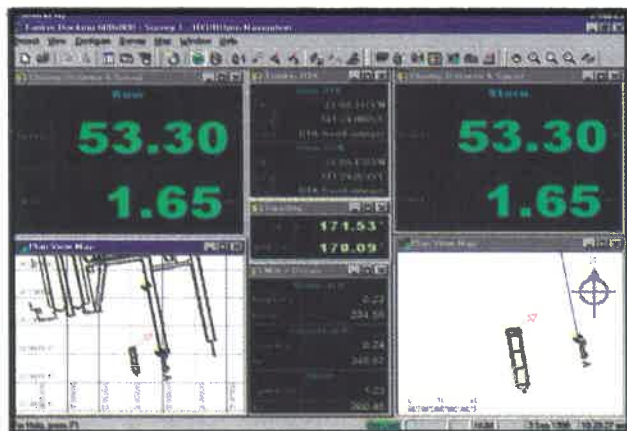
Conventional Methods

Conventional methods rely on lasers, which emit pulses of light, from the shore to the side of the vessel, which is docking. By measuring the time it takes for the pulse to reflect off the side of the vessel and be received back at the laser, the distance of the vessel away from the dock can be measured.

GPS Docking System

GPS is able to overcome all of these installation and operational limitations with a simple and affordable solution. The first point to note is that all of the positioning information is determined by sensors (GPS Receivers) onboard the vessel that is docking. Apart from a radio link transmitting RTK GPS corrections, there is no reliance on equipment mounted on the dock. Having the positioning information 'connected' to the vessel that is docking, the basic system of two GPS receivers can be used on any size vessel docking at any berth in the port. This means that the port doesn't need to invest in additional sensors for larger or smaller sized vessels. Tied in with this is that the GPS antennas can be mounted anywhere on the vessel if a rudimentary survey of the vessel exists.

Given that the GPS system is providing position, heading and velocity information about two fixed points on the vessel, if a survey to determine the relationship between the two antenna locations and shape of the vessel is carried out, then the system can calculate closing velocities and distances for any point on the vessel. Also, the problems associated with visibility, tide, and approach angles are eliminated.



As GPS is able to provide 3D positions, the GPS based system is able to provide the actual position of the vessel not just the distance away from the wharf of two points on the vessel. This solves the need for longitudinal information.

Also, the GPS sensors that are providing the accurate heading and velocity information are able to provide accurate navigation information while underway.

The seamless navigation features of these receivers allow automatic transition from code phase differential (DGPS) to carrier phase RTK. This means that the one system can provide DGPS accurate corrections using MSK beacon signals while entering the harbour and then automatically switch to centimetre accurate RTK operation for the docking operation.



RTK Compass

Having accurate information on the heading of a vessel is important for a number of reasons. For navigation, courses are followed using heading information and for surveying, the heading of a vessel must be known so that the positions of various offsets onboard can be determined. The two currently used conventional methods of determining heading are using either a magnetic compass or a gyrocompass.

The Magnetic Compass

The magnetic compass has been in use since the 14th century as a direction finder. However the magnetic compass has the following limitations that see it now used only for back up should the gyro compass fail

Firstly the magnetic compass is influenced by magnetic fields. By calibrating, or *swinging*, a magnetic compass the errors introduced by the magnetic surroundings can be determined and a table compiled that lists corrections. However if the magnetic signature of the vessel or object that the compass is installed upon changes so to does the errors introduced, hence a recalibration

would be required. Also the values from magnetic compasses can lead or lag the actual heading in turns, and during periods of acceleration or deceleration. Also the magnetic compass is not suitable for use at extreme latitudes. This is due to the fact that the earth's magnetic vector is three dimensional, and past high latitudes the vertical component of the vector starts to become greater than the horizontal.

The Gyro Compass

These limitations ultimately led to the invention of the gyrocompasses. Gyrocompasses have been in use for over 100 years now and are the directional reference used in any application that requires accurate heading information. Not only is the Gyro compasses able to overcome all of the limitations mentioned above but it also indicates true north instead of magnetic north, thus there is no need to correct for local variations in the earth's magnetic field. However, the gyrocompass suffers from gyroscopic procession, which means it must be periodically reset to the magnetic compass.

GPS Compass

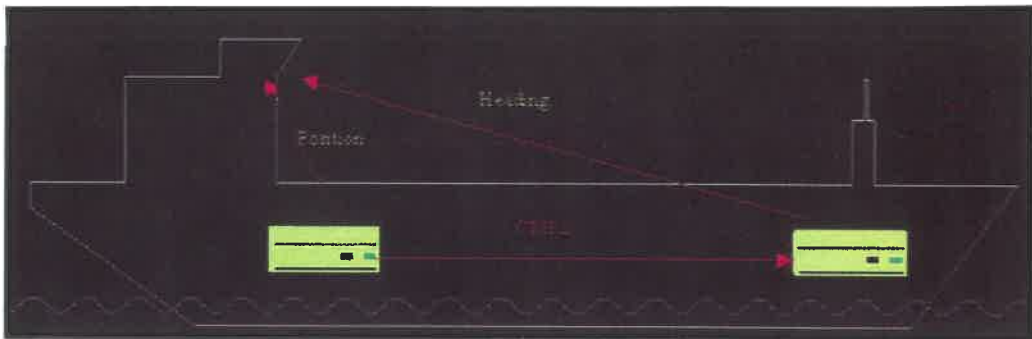
The GPS compass is able to overcome all of the aforementioned errors that exist in both the magnetic and gyrocompass. The GPS compass determines heading by the same method that conventional RTK surveying is done, it solves a carrier phase vector between 2 GPS antennas. Just as conventional RTK uses a base station transmitting corrections to a rover receiver so that the 3D vector between the two can be solved, the GPS compass does the same however the base receiver is moving along with the rover.

Installing and calibrating the system is relatively straightforward. Two antennas are mounted and 'surveyed in' on the vessel. For best results, and to eliminate any errors associated with the vessel pitch and roll the base line between the antennas should be parallel to the vessels centre line. One receiver is then configured as the Base and this receiver sends corrections to the Rover. The Rover is then able to determine the:

- base line length between the two antennas, and
- the true heading between the two antennas.

This system is able to operate without any type of GPS corrections being transmitted via radios from one GPS receiver to the other. If DGPS corrections are available then the GPS sensors are able to provide accurate navigation information while underway, thus the one system fills several needs.

The following figure shows how the GPS compass is configured. Note that the Radio providing the RTCM corrections is only need if DGPS positions are required. If accurate heading information is all that is required then this radio is not needed.



NAVAREA IX

Muhammad Riaz PN

General

Navarea IX is one of the 16 areas established through the Worldwide Navigational Warning Service (WWNWS). It includes parts of Arabian Sea, ROPME Sea Area and Red Sea. The 16 littoral states bordering Navarea IX are Bahrain, Djibouti, Egypt, Ethiopia, Iran, Iraq, Jordan, Kuwait, Oman, Pakistan, Qatar, Saudi Arabia, Somalia, Sudan, UAE and Yemen. Pakistan having a better set up of Hydrography in the area got the responsibility of co-ordination of Navarea IX in 1976. Hydrographer Pakistan Navy is the Navarea IX Coordinator. Since taking over this responsibility, Pakistan Navy has been meeting all requirements satisfactorily to ensure safety of mariners at sea.

Source of Information

Headquarters Navarea IX receives information relating to navigational hazards by MENAS, Port authorities, National Co-ordinators, Nautical Authorities and Master of Ships etc. After receipt, the information are plotted, scrutinised and promulgated to mariners at sea within the minimum time.

Promulgation of Navigational Information

There are four main methods of distributing navigational warning by Navarea IX Co-ordinator. They are:

- I. Radio Navigation Warnings.
- II. Navigational Warnings on International Safety Net
- III. NAVTEX
- IV. Weekly and Annual Summary of Notices of Mariners

I. Radio Navigational Warning

Since 1976, navigational warnings for Navarea IX are broadcast through Karachi Naval Station, Karachi Wireless on Radio telegraphy using H.F daily at 0400 UTC (GMT) and 1200 UTC. These warnings are repeated at routine times as messages so long as they remain in force. The frequency, type, powers and times of transmissions are contained in Annual Summary of Pakistan Notices to Mariners and Admiralty List of Radio Signals Volume 5 (NP-285).

II. MSI on International Safety Net

Maritime Safety Information (MSI) originated by Navarea IX Co-ordinator are transmitted on INMARSAT through Perth LES daily at about 0800 UTC. Urgent information is passed to ships at any time.

III. NAVTEX

NAVTEX is an international automated direct printing service for promulgating navigational and meteorological warnings and urgent information to ships and fulfils an integral role in the GMDSS developed by IMO. To broadcast National and Met warnings through this system, Pakistan has recently established NAVTEX Coast Radio Station at Karachi and now it is fully operational. Navigational warnings are broadcast every four hours on 518 KHZ. Weather messages are transmitted at 0630 and 1830 UTC. Details are given in Admiralty List of Radio Signals Volume 5(NP 285, 1999 Edition).

IV. Notices to Mariners

Navarea IX Co-ordinator issues a Weekly Edition (serially numbered) and an Annual Edition of Notices to Mariners. A weekly Edition is issued in four sections:

Section I	Notices to Mariners
Section II	Reprints of Navarea IX and Coastal Warning
Section III	Corrections of Sailing Directions
Section IV	Marine Information

In addition, Annual Summary of Notices to Mariners containing Permanent and Temporary & Preliminary Notices is issued regularly.

Session IV

**Electronic
Cartography**



MONITORING AND MANAGEMENT OF THE EXCLUSIVE ECONOMIC ZONE

Terje Lund Henriksen

Abstract

Under the UNCLOS agreement the rights and responsibility of maritime nations have been extended within their claim of The Exclusive Economic Zones (EEZ).

Before a nation can be sure of enjoying the benefit of its Coastal Zone, it must establish a Monitoring and Management Control System over the area. This is a expensive and complex task which require extensive planning and organisation.

Introduction

Well managed and administered EEZ generally provide substantial economic returns to the nation concerned. However, law enforcement, preservation of the marine environment, safety of navigation, fisheries management, search and rescue services etc., all require extensive planning and organisation. Hence the equipping and running of these services in accordance with the requirement of UNCLOS is a complex yet rewarding task.

Historical Background

With the discovery of the American Continent in 1492 and the rapid increasing in shipping, it became necessary to define the seaward limits of sovereignty for the coastal states. Without any specific international treaty (such things were not known), territorial limits were for several centuries, a distance of 1 marine league (about 5 km) from the low water mark, probably because that was for a long time the practical range of the artillery. A formal definition of territorial waters did not come before until 1876, this was year of the trial at the Central Criminal Court in London of the German master of the Franconia, accused for manslaughter when arrested at sea 2 nautical miles off Dover for having run down the coaster Strathclyde. This led, in 1878, to the passing of the Territorial Waters Jurisdiction Act, by which English courts were empowered to arrest and try persons, whether British citizen or not, for crime committed on the high seas within the territorial waters of the Crown, which was defined as 1 marine league from the coast. After the I world war, largely because of disputes over fishing rights, Iceland and some other nations laid claim to waters extending up to 12 nautical miles from shore. A conference on the Law of the Sea was held at Geneva in 1958 in an effort to resolve these disputes, but it failed to reach agreement. Various nations continued to claim various zones off their shores

over which they wished to exercise exclusive rights. Many such claims were reason to "fishing wars" and other disputes. To resolve this potentially dangerous situation, a further conference was convened by the United Nations in 1982, and it was the agreement reached as the United Nations Convention on the Law Of the Sea (UNCLOS) which gave an internationally agreed legal framework to the concept of territorial waters.

Offshore Zones

Under UNCLOS 1982, a nation's waters can be divided into six distinct zones. The first of these, called Inland Waters (IW), is of course not an offshore zone, but was included in the agreement to encompass all navigable waters. The other zones are the Archipelagic Waters (AW), the Territorial Sea (TS), the Contiguous Zone (CZ), the Exclusive Economic Zone (EEZ), and the Continental Shelf (CS).

Inland Waters

Inland Waters are defined as being within the baselines from which the territorial sea is measured. The baseline is normally the low water line, although straight lines can be drawn across the mouths of bays, estuaries and other indentations in the coast. IWs are an integral part of the territory of the state within whose baseline they lie, and this state exercises full sovereignty over them. Law enforcement and the maintenance of order are normally the responsibility of internal law enforcement agencies. Since most ports are located within IWs, their administration may involve many other tasks such as immigration and contraband control, customs inspection, health checks, navigation services, search, and rescue services and others.

Archipelagic Waters

Some states comprised of a group of islands and the waters separating these islands are referred to as Archipelagic Waters (AW). They have a status similar to that of IWs, except that the ships of other nations have the right of innocent passage through them. The maintenance of law and order therefore becomes a matter of international concern, although the tasks involved are similar to those applying to IWs. The extent of AWs is largely a question of the geographic arrangement of the islands involved.

Territorial Waters

The Territorial Sea (TS) can be extended to a distance of 12 nautical miles from the baseline. The area within their limit is also part of the sovereign territory of the state. No other state has an automatic right to the resources in another

nation's TS, but foreign vessels do have the right of innocent passage. The requirements for law enforcement and administrative control are the same as for IWs.

Contiguous Zone

The Contiguous Zone (CZ) can be extended for a further 12 nautical miles beyond the TS, that is to say to a total distance of 24 nautical miles from the baseline. In this zone the rights and responsibilities of a nation change as compared with those within IWs. The zone is not part of the territory of the state, but the state is permitted to extend its jurisdiction to cover the zone for the purpose of customs, fiscal legislation, immigration and public health. The CZ can therefore be used to carry out operations for the prevention of smuggling, drug and weapons trafficking, illegal immigration and similar acts defined as illegal in the state concerned. In return for this right, the operational forces (which may include fast reaction forces) are required to extend protection against illegal acts to the nationals and property of other nations on innocent passage through the zone.

Exclusive Economic Zone

The introduction of the Exclusive Economic Zone (EEZ) represented a radical change from traditional views, not so much because an EEZ can be extended to a distance of 200 nautical miles from the baseline, but because it reserves exclusive rights to the control of the zone to the coastal state. While the recognition of an EEZ gives the claiming nation the rights to enforce regulations for full environmental protection (in addition to control of fish stocks), it also entails (in addition to law enforcement and control operations) criminal and accident investigations on offshore installations, the enforcement of pollution regulations, the provision of substantial disaster and fire fighting forces and the operation of long range search and rescue services. Nations laying claim to an EEZ must realise that if fish stocks are to be managed effectively, surveillance and the enforcement of regulations can be very demanding. If the zone covers rich fishing grounds, the permanent presence of an effective patrol force is essential.

Continental Shelf

The most extensive claim, which can be made under UNCLOS 1982, relates to the Continental Shelf (CS), with a limit of 350 nautical miles from the baseline. Under this claim coastal states can exercise exclusive control over the resources of the seabed and all other benefits of the zone. The claim to a CS therefore gives a state control over potentially very substantial assets, but at the same time also imposes on it very substantial responsibilities. The responsibilities must be met under all conditions to uphold the claim, whereas the benefits may not

materialise for some time, if ever. Tentative evidence of offshore oil deposits, for instance, may or may not develop into a profitable industry. It may or may not prove economic in the near term to exploit mineral resources such as manganese nodules and phosphate crusts. Power generation from wind, waves, currents and differences in sea temperature with depth could earn very large revenues, because the energy is free and practically inexhaustible, but with present technology the production costs are too high to compete with traditional forms of power generation. The picture could however change rapidly as the result of a technical breakthrough, or through depletion of reserves in oil, gas and coal, or if heavy fiscal penalties were to be imposed on the use of these fossil fuels, as proposed by increasingly influential environmental groups. The decision by a state to claim the CS is therefore not to be taken lightly but should be based on an objective balance of immediate costs against existing and potential future benefits. The time scale on which this balance is struck depends on the financial reserves or borrowing power of the state. Where zones or waters claimed by nations meet, as for example in the English Channel or the ROPME Sea Area, they are divided by a "median line" agreed between the nations concerned.

The Normal Baseline

The general definition of the normal baseline is the basic element from which the territorial sea and other maritime zones are determined, it is the low water line along the continental shore and around islands, including the outer limits of permanent harbour works, the low water line around certain low tied elevations, and seaward low water line of atoll reefs and fringing reefs around islands.

Straight baselines

The purpose of authorising the use of straight baselines is to allow the coastal State, at its discretion, to enclose those waters that, as a result of their close interrelationship with the land, have the character of internal waters. By using straight baselines, a State may also eliminate complex patterns, including enclaves, in its territorial sea, that would otherwise result from the use of normal. Properly drawn straight baselines do not result in extending the limits of the territorial sea significantly seaward from those that would result from the use of normal baselines.

Basepoints

Basepoints for all straight baselines must be located on land territory and situated on or landward of the low water line. No straight baseline segment may be drawn to a basepoint located on the land territory of another State. Use of low tide elevations as basepoints in a system of straight baselines. The only those low tide elevations which have had built on them lighthouses or similar installations may

be used as basepoints for establishing straight baselines. Other low tide elevations may not be used as basepoints unless the drawing of baselines to and from them has received general international recognition.

The Obligations Involved

Many maritime nations have now claimed jurisdiction over different offshore areas under UNCLOS 1982. As outlined above, in doing so they accept the responsibilities appropriate to the area claimed. It is thus clear that a nation can only seek to enjoy the benefits from the claimed zone (either directly or by licensing foreign investors), if it carries out the tasks essential for the proper maintenance of the zone. In this context "maintenance" includes such matters as the enforcement of law and order and the preservation of public property to conserve and protect it for future generations. It may be helpful to examine these obligations in greater detail, thus providing some indication of the wide range of equipment and services needed.

Offshore Law Enforcement

The formulation of a comprehensive resource management and law enforcement regime is a complex matter. Policing arrangements must be based on the nature, extent and peculiarities of the area concerned, on the range and intensity of activities within it, and on the possible impact from common or conflicting interests with adjacent countries. In most cases, policing will involve the enforcement of national and international laws and of international treaties.

The safeguarding of national interests, which would include:

- The prevention of maritime terrorism and piracy.
- The control of emigration and immigration.
- The exercise of customs controls and the collection of excise duties, and in particular the prevention of smuggling and the trafficking in drugs and arms.
- Hydrographic Service.
- Preventing the illegal occupation of offshore islands, platforms and other structures, The policing of maritime traffic.
- Navigation Aids.
- Search and Rescue.
- Fisheries Protection.
- Exploration and Exploitation Control.
- Pollution Control/Monitoring.
- Environment Control/Monitoring.

Command and Control Systems

Of prime importance for effective offshore policing is an organisation designed for this purpose, with a clear chain of command and with immediate access to all ministries, departments and agencies involved, through permanent or on call representatives. Whatever form the organisation takes, it must be supported by a dedicated system with integrated facilities for command, control, information collection and distribution. It must have facilities to analyse and interpret data effectively. The command and control system should incorporate facilities for the display of surface and air dispositions, as well as data on force readiness levels, equipment status and details of activities such as offshore exploration and fishing. For example, a prerequisite for good fisheries management is a continuous flow of information on who is fishing where, how, for what and in what quantities. This is the basis of continuous stock assessment from which conservation measures such as net mesh sizes, closed areas and quotas can be decided. Command centres should be at the same location as, or near to, national defence centres, with permanent links between them. If some operations are carried out jointly with neighbouring states, appropriate links and procedures for consultation and action must be established. The entire organisation and its equipment, from headquarters to the smallest local station, should be exercised frequently, to ensure that all operate smoothly and efficiently.

Radar and other sensors feeding information into the command and control system should have integral equipment for recording time, date and position so that, in the event of a contravention of regulations, indisputable evidence can be presented by the prosecution against the offender. Operations against smugglers, terrorists and pirates.

Operations to prevent the importing of undesirable commodities, including drugs and weapons, will probably involve the use of high speed vessel. In many areas smugglers are now equipped with powerful weapons and capable craft; the police forces must be sufficiently well equipped to deal with the illegal threat. The same applies to operations against terrorists, insurgents and pirates. These threats vary so widely that no general equipment list can be given, but the principle of establishing rapid intervention forces able to deal with the worst foreseeable threat applies. Depending on the terrain, equipment needed may include helicopters, hovercraft and submersibles. The forces required to deal with contraband on merchant ships, passenger liners and small vessels can have a lower profile but may need to be more numerous and must be well equipped.

Fisheries Protection

Adequate forces must be available to protect fishing fleets and to enforce claims to exclusive fishing rights. It will generally also be necessary to have research

vessels to monitor fish stocks and to provide a factual basis for the imposition of fishing limits.

Exploration and Exploitation Controls

Similar requirements apply to the exploration for and the exploitation of mineral resources, especially of oil and gas, diamonds and precious metals. In recent years there has been an upsurge of interests in locating wrecks and recovering their contents, for their intrinsic or historical value. All such operations must be properly planned, supervised and protected.

Hydrographic Service

The introduction of EEZ requires a large amount of expertise and resources within the field of hydrographic and oceanographic surveying for the purpose to supply the required services to meet the objectives of Management and Control.

Navigation Aids

Within the claimed zone there must be adequate provisions for the safe conduct of maritime traffic, in accordance with international agreements and national or local regulations. This involves the creation of the entire infrastructure of navigation aids and services, from radar area surveillance systems to channel marker buoys, reliable meteorological services, the dredging of channels, marking of hazards, and so on. There must also be means to ensure that maritime traffic complies with the rules of navigation. The provision of proper charts will call for hydrographic surveys and for studies of tidal and ocean currents. Essential information must be distributed in Notices to Mariners.

Environmental Protection and Monitoring

The protection of the environment to preserve it for the future is an important obligation. The work involved can be very extensive. It is both necessary and difficult to police the discharge of pollutants from ships. The risk of a major pollution vary from area to area, but everywhere there have to be contingency plans to meet the worst case, and adequate means to deal with disasters.

Marine Pollution Control

The pollution of the marine environment by effluents originating from the land can be very severe in some areas, but its control is best left to the land based authorities. At sea pollution is either deliberate (for instance the discharge of tank cleaning solutions, garbage and dirty ballast), or accidental. In both cases, early detection is essential to minimise the cost of clean up operations. The quickest

means of detection is through the use of modern electronic sensors (infra red, ultraviolet, etc.) from aircraft or satellites. Remote sensing from satellites requires hired down links and earth stations, or data links with the satellite organisation data distribution centre, plus interpretation facilities. Such a system can be very cost effective for large sea areas. Smaller areas can be patrolled by suitably equipped aircraft. Satellite services and patrol aircraft can provide valuable inputs to local weather forecasting. For combating pollution, properly trained teams will need dispersants and spraying equipment, containment booms and recovery equipment, plus the means for rapid transport to site. It is advisable to establish links with independent expert assessors, to validate and scale claims for damages.

Marine Traffic Policing

Marine traffic continues to grow, and with it the need for improved traffic control, because collisions, grounding and other accidents in any area may not only inflict long term damage to the environment, but may also drive trade to other areas. In addition to providing the navigation aids, it may also be necessary to carry out detailed hydrographic surveys, which call for special vessels and equipment. In busy areas, traffic routing and traffic separation measures may have to be established in the interests of safety. It may be desirable to introduce shore based Vessel Traffic Surveillance (VTS). VTS may be needed near ports, in Sealanes and hazardous areas. The service is based on the use of high definition radar's, automatic tracking and processing systems and radio direction finding equipment.

Search and rescue services

The importance of saving lives and property at sea is reflected in the very comprehensive regulations which govern the services that have to be provided, such as Safety Of Life At Sea (SOLAS) regulations. Shore based services include constant radio monitoring, high speed rescue craft and fire fighting equipment, but may extend to rescue helicopters, medical and similar services. Search And Rescue (SAR) operations are now widely Convention of 1979 under the auspices of the International Maritime Organisation (IMO). Land based SAR services are geared to integrate with shipborne SOLAS equipment. It is worth noting that a major revision of SAR regulations is envisaged to take account of the latest technical developments in materials and equipment. The IMO introduced the Global Maritime Distress and Safety System (GMDSS) in 1997. Land based SAR arrangements must include highly efficient co-ordination facilities, full time monitoring services of radio distress frequencies, and of course the means to offer help at short notice and at high speed, which means the provision of life craft and helicopters on constant stand by. If there are offshore platforms in the

zone, the SAR organisation must also be equipped to deal with emergency calls from them.

Administrative Principles

There must be close co-operation between all the national government departments and agencies involved in the administration of an offshore zone, to ensure that the offshore legislation, regulations and implementation policies reflect the common national interest. Close co-operation is also essential for efficiency, by avoiding duplication of effort and wastage. Where possible, good relations should be fostered with neighbouring countries, with a view to concluding agreements between groups of nations to share policing tasks, such as operations against smugglers. Such incidents as major oil spills often demand international co-operation in any case. Rights to offshore territorial waters should only be claimed if there is the ability and the will to uphold them. Ability involves not only the necessary equipment, but also the training of personnel to use it effectively. The will to uphold claims must be backed by the implementation of enforceable laws and regulations. The effective administration of offshore zones requires a variety of forces; these may be military (such as navies and air forces), semi military (such as coastguards and customs services), and civil (such as medical backing, research, meteorology and navigation services). The extent to which national defence forces are involved in policing and surveillance depends largely on the preferences of individual nations. Whatever the balance between civil and military involvement, the costs of policing offshore zones are best offset against the revenue derived from the zone, such as licensing fees, tariffs and commercial returns, to supplement the operational and procurement budgets of the agencies involved. Cost effectiveness must be stressed, because the cost of even very modest maritime surveillance and control can quickly absorb the economic benefits of the resources they are designed to protect. Modern equipment, although high in capital cost, considerably reduces manpower needs and therefore operating costs. Experience shows that the degree of compliance with local regulations, for example those governing fishing, is generally high and the aim should be to establish organisations, which are virtually self-regulating. On the other hand, it is best to establish the strongest possible forces against terrorists, smugglers and pirates, because risks to life and property can reduce the trade through high insurance rates and by discouraging tourism.

Equipment requirements

Some of the equipment needed for offshore administration (communications systems, lifeboats, oil dispersant sprays, etc.) may already be available, while it may be possible to upgrade other equipment (radar's, hydrographic survey vessels, light buoys, environmental monitoring buoys etc.). It is possible only to

give a general overview of the equipment, which may be required. The equipment purchased for upholding law and order offshore enjoys the advantage that it need not meet full military requirements. Ships and aircraft for offshore surveillance, survey and patrol, for instance, need not be equipped to their full capacity and are therefore less expensive. Prudence suggests, however, that they should be of a design, which permits rapid conversion to defence task in an emergency. Economies can often be achieved by empowering a main contractor to undertake a "package" or "turnkey project", whereby the contractor assumes full responsibility for the whole project, which can include the co-ordination of equipment, selection, integration, delivery, installation and commissioning. Training, spare parts supply and many operational services may form part of such contracts. Experienced specialists are required to prepare the equipment specifications and the conditions of the contract in full detail. The following is a very brief summary of the systems and equipment necessary to run an EEZ efficiently.

Command and control system

For controlling immigration, drugs and smuggling, the main requirement is an efficient command, control, communications and intelligence system. Backed by such a system, the essential components for interdiction operations are equipment for detection, identification and response. Effective detection requires both aerial and surface surveillance, supported by dedicated communications between all surveillance teams and a shore based HQ. The equipment used should include radar and modern electro optical devices such as stabilised binoculars, infra red sensors, image intensifiers and image processors with appropriate links (by radio or satellite) for sending real time pictures to HQ, where they can be compared against other electronic images in a database for quick reliable identification. Another need is for Electronic Support Measures (ESM) equipment, including scanners to monitor the Civil Broadcast (CB) band. Allied with these must be recording equipment with automatic time, date and location notation, as reliable evidence of any incident for use in any possible subsequent enquiries or legal proceedings.

Patrol vessels

Effective response calls for quiet running fuel efficient ships whose size, construction and complement are optimised for specific tasks. Reliable charts and navigation equipment (Differential Global Positioning System) is also needed for use in confined waters against high speed craft often used by smugglers.

The patrol vessels need modern contraband detection equipment (chemical sniffers, x-ray units, metal detectors, etc.) and effective communications links with their operations centre.

Aircraft and avionic equipment

The specification for air surveillance equipment depends on local needs. For example relatively inexpensive airborne search radar can be obtained to detect normal coastal traffic, fishing and sailing vessels, but costs rise steeply if the radar is required to have Anti Submarine Warfare (ASW) capability or is required to detect small smuggling and raiding craft, such as dinghies. Whatever airborne surveillance equipment is decided on, it is vital that all systems be integrated into an airframe by a small authority or main contractor, on the basis of a clear and detailed specification.

Search and rescue systems

The effectiveness of search and rescue (SAR) work is critically dependent on good equipment and an efficient organisation. A comprehensive Medium Frequency and Very High Frequency (MF/VHF) Direction Finding (DF) Line-of-bearing network can be established and tuned to international distress frequencies. Information can be displayed in regional and district operations rooms from unmanned DF coast stations remotely controlled by land lines. MF/DF is particularly important for incidents occurring a long way offshore. A constant watch needs to be maintained on all international distress bands for ships fitted with Emergency Position Indicating Radio Beacons (EPIRBs). The voice distress frequency (2182 kHz) also needs to be monitored continuously. Channel 16 on VHF is the most frequently used distress frequency. Lifeboats and rescue craft with a lifesaving capacity of 80 men are used widely. All lifeboats should be fitted with speed-lines for the transfer of personnel, at sea as well as with I-band radar and radio equipment to cover all distress frequencies, with receivers for homing in on the distress call. Simple, fully waterproofed hand held communications equipment is considered essential. An example of the equipment fit considered essential for a non-military SAR helicopter is as follows:

Radio navigation and communications equipment includes weather, search and navigation radar, automatic direction finder, transponder and encoding altimeter, radio altimeters with voice advisory system, VHF/UHF and VHF/FM homers, R-Nav area navigation system, VHF Omni-directional Radio (VOR), Independent Landing System (ILS) and marker beacon receivers, doppler equipment, HF/SSB radio, VHF and VHF/FM marine band radio, Distance Measuring Equipment (DME), cockpit voice recorder, pilot and passenger intercom system, and a public address (loudhailer) system.

Safety and survival equipment includes auxiliary popout flotation equipment, helirafts, an air-droppable liferaft with survival pack, an Automatically Deployable, Emergency Locator Transmitter (ADELT), sonar underwater locator

beacons (including one fitted to the cockpit voice recorder), crew lifejackets fitted with Search And Rescue Beacon Equipment (SARBE) incorporating a voice radio transmitter, mini flares and day/night pyrotechnic products, passenger lifejackets, first-aid kits, fire extinguishers, oxygen breathing apparatus, a sea anchor releasable from the cockpit, hull lifelines, high-visibility fuselage markings, cabin emergency lights, emergency exit lighting and appropriate safety instruction placards.

Special SAR equipment includes a stabilisation and auto-hover system, a rescue hoist and hoisting harness, a Forward-Looking Infra-Red (FLIR) camera, additional first aid and rescue equipment.

Marine traffic control system

For the operation of a marine traffic control scheme, radar's may be dictated by the geography of the area. At head direction finders to assist primary identification, and possibly spotter aircraft for positive identification. Graphic displays of the area of jurisdiction should be available through a computer system with facilities for selective data displays and for zooming in and out. A hard copy printer provides evidence against offenders, together with radar, video and VHF voice control channel recordings. For marine traffic control it is considered essential to have accurate radar ranging facilities and narrow beam widths, to ensure reliable track transfer and correct correlation when more than one remote station is needed for coverage of the control area. Human override is helpful. The mandatory fitting of identification transponders on all vessels would considerably simplify traffic control operations.

Marine Environmental Monitoring System

A Marine Environmental Monitoring System is a heterogeneous information network used in oceanographic and meteorological monitoring and forecasting. It will also contain elements and tools to facilitate communication in the heterogeneous network. The system consist of the following modules:

Data acquisition

Data storage, analysis and presentation
Environmental modelling and forecasting
Distribution of data, forecasts and user relevant information.

Satellite Monitoring

The frequency of coverage, fast turnaround time and the ability to acquire high resolution imagery under variety weather conditions, make remote sensing a

useful tool in providing timely and cost effective detecting and monitoring of Environmental Changes, Ocean Colour, Oil Spill and Vessels Traffic Surveillance.

Resource Protection

Patrols to prevent the poaching of resources, of which fish is currently the most common, usually involve the use of long endurance ocean patrol vessels and supporting surveillance aircraft. Both require good radar equipment both should be equipped with video recorders (with time, date and location recording) to identify lawbreakers.

Fishery Protection

The requirements for fishery protection are largely the same as those described for customs control, anti smuggling and anti drugs operations. Economies can be achieved by partial integration with naval patrol work.

Navigation Systems

Navigation and pilotage aids are changing in response to the improvements in the navigation aids carried on ships. For instance, light vessels are being replaced by automatic navigation buoys. Working on the same principle, light houses may no longer need to be manned. There is also less need for lights to have a range of 30 nautical miles. The introduction of Differential Global Positioning System (DGPS) has precipitated a review of radio navigation aids. With the increase in the size of ships and consequently recorded depth needs to be improved and safe channels must be marked more clearly with additional light buoys. Acetylene lights can be replaced by lights powered by solar panels. To cut costs further, research is being undertaken into a wide range of subjects, including more efficient solarcells, tidal and wave motion power units, wind power generators and electro chemical fuel cells. Other areas to be explored are high intensity lights of low power consumption and inherently coloured lights (as opposed to the use of coloured filters for inherently white light), new types of battery and the use of lasers. (Laser beacons could offer substantial economies, but will require the mandatory fitting of suitable receivers on board ships).

Hydrographic Survey Vessel

The vessel should be capable of undertaking activities within the traditional disciplines of hydrographic and oceanographic surveys and research, including:

- Hydrographic surveys down to a depth 5.000 m.
- Sea bottom obstacle investigations.

- Sea bottom sediment investigations down to a depth of 3.000 m.
- Sea current surveys.
- Deployment of surface, sub-surface and bottom sensors and instrumentation.
- Measurement of conductivity, temperature, salinity, sound velocity in the water column, etc.
- Near surface sound velocity measurements.
- Water sampling.
- Current measurements.
- Deployment and retrieval of oceanographic data buoys.

Digital Charting System

In line with today's general requirements, there should be two main chart products, namely Electronic Navigational Charts (ENC) and Paper Charts. Briefly, Electronic Navigational Charts (ENC) based on vector data will rapidly replace paper charts as the primary voyage-planning tool for mariners. Electronic Chart Display and Information Systems (ECDIS) S-52 standard, will be the planning and "navigation" tool installed onboard the ships that utilise ENCs. The production system must offer the capability to generate ENC data, and to distribute these data to end users or other hydrographic institutions. The system will produce Electronic Navigational Charts coded according to International Hydrographic Organisation: IHO Transfer Standard for Digital Hydrographic Data, Publication S-57 Edition 3.0, Monaco 1996. As for Paper Charts they shall be produced directly from the Marine Information database System via the Edit and Plot System. The edit and plot system is to produce paper charts according to the M-4 and INT 1 standard, from data exported from a database which has a data model covering the S-57 Edition 3, and which also holds the required additional information to support paper chart production.

Pollution control equipment

The main pollutant is oil. The best way to detect oil slicks is from the air, while the best way to deal with them is with small vessels fitted with dispersant spray booms. Pollution surveillance by air can be undertaken by aircraft fitted with sideways looking radar (SLAR), which is effective out to 25 km on both sides of the flight path, in all weathers, for initial detection. The aircraft can then fly to and over the slick for visual inspection, infrared linescan (IRLS) and ultraviolet linescan (UVLS) recording for detailed assessment. The UVLS determines the hydrocarbon content of the spillage. The effectiveness of the system can be enhanced by illuminating the slick with lasers. The IRLS provides the best information on the extent and thickness of the slick. All details should be photographed and recorded on video tape with time, date and location data superimposed. The ERS1 satellite is also being used for pollution detection.

Ocean Geographic Information Systems (GIS)

GIS is an organised collection of computer hardware, software, digital geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyse and display all forms of graphically referenced information.

Beyond computer mapping, GIS allows complex spatial analyses of data, the attributes of, which are stored in a database. Attributes are characteristics of a geographic feature described by numbers, characters, images and CAD drawings, typically stored in a tabular format and linked to the feature by a user assigned identifier.

It is database derived mapping

GPS is a system of satellites and receiving devices used to compute positions on the earth. GPS is used in navigation and its precision supports surveying, both cadastral and nautical. GPS positioning points provide location input into GIS.

Remote Sensing acquires information about an object without contacting it physically. Methods include Aerial photography, radar, and satellite imaging. Although not traditionally considered a remote sensing device, side-scan sonar and multibeam echosounder are primary data collection devices in sea-floor mapping and are part of the instrumented universe that captures critical data for use in the GIS.

The value of GIS is the fusion of a variety of data types, complex spatial query ability and reusability of data. Spatial data can be used for a variety of applications of scientific studies without having to re-map an area for each study.

The application of GIS to ocean/coastal science. GIS supports the management, processing, visualisation and explanation of ocean mapped data for:

Seafloor mapping

High volumes of bathymetry data can be captured, edited, stored and visualised to create interactive bathymetry maps. Geologic sampling can be stored with their GPS points and these can be viewed as a point surface and interpolated to create a seafloor geology map. These two data sources can be merged to map the terrain of the sea floor and visualised in 3D. By using animation tools linked to GIS, "flying" through the seafloor is possible. Seafloor mapping is used in petroleum exploration and production, near shore mining, facility siting and management of pipelines and cables, and for navigation. These maps serve as the base map for other ocean related GIS projects.

Navigational Charting

Chart production utilising GIS saves resources by benefiting from the reuse of a built spatial database; built once and updated as needed. Aids to navigation, captured as points with their attributes and navigational sea-lanes mapped as lines or polygons, are geo-referenced and merged with the seafloor base map to create navigational charts. Digital navigational charts are not only used for paper chart production, but for interactive analysis of chart data; and these charts are the foundation for Electronic Charting Display Information Systems (ECDIS). ECDIS are on-board electronic navigational charts.

Interactive navigational charts allow the user to query navigation aid attributes or highlight all navigation aids that fall in a selected bathymetric zone within a designated area, such as navigational high risk areas. Large scale maps can be made of approaches and port facilities and GIS allows to move through varying scales of data. Satellite imagery can also be georeferenced and merged to navigational charts.

Coastal Management

Data collected on fisheries habitats and historical catches can be mapped to digital navigation charts for resource mapping for recreational and/or commercial fishing. Siting of aqua-culture projects in the coastal zone can use merged GIS data regarding shoreline, geomorphology, salinity of estuaries environment biological habitats, managed lands and ownership boundaries to select the most appropriate conditions water quality and degradation of habitats can be mapped along with net ban enforcement zones.

Habitat zones for sea mammals, nesting sites for sea-turtles, etc. can all be interactively captured using GIS. Protection strategies can utilise these habitat maps. This includes, for example, creating policies on set-back line zoning in coastal environmental.

Information about individual species can be mapped as point data and merged with habitat polygons to view individual species and the habitat they occupy Species count can be visualised either on the map or captured in the attribute tables

Disaster Response

GIS can be used in oil spill and hurricane planning and response as well as search and rescue operations. For oil spills, GIS can be used in contingency planning, response and cleanup, and damage assessment. Environmental Sensitivity Index (ESI) maps delineate protection plans for the shoreline, based on the

geomorphology and its sensitivity to a variety of oil types. Also mapped in ESI are species and habitats of the area. During a disaster, the spill itself is interactively mapped either with trajectory model input into the GIS, through GPS, or by using human reporting. The GIS allow the merging of ESI and the spill polygon to determine affected shoreline lengths. Response strategies can be mapped and a historical record can be kept of boom deployment, etc.

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A BRIEF NOTE ON MENAS OPERATION

Andrew Hawkins and Philip Jewell

The major thrust of this presentation will be on the recently operational DGPS service and Radio Navigation Manager. The purpose of this presentation is to explain what MENAS does, the service MENAS provides in the area and the resources channelled into the support of hydrography and safety of shipping.

MENAS is the acronym for Middle East Navigation Aids Service created in 1950 as an independent not for profit organisation, registered in London. MENAS has a board of directors made up from representatives of shipping companies namely BP, Shell, Emirates National Oil Company, Kuwait Oil Tanker Company, United Arab Shipping, P & O and Mobil.

MENAS operate and maintain more than 500 aids to navigation, including lighthouses, buoys, racons and beacons throughout the region - from Masirah to the northern end of the RSA.

Amongst our other roles are:

- Promulgation of maritime safety information and navigation warnings by way of navtex.
- Also our monthly notice to mariners, which include such specialist information as rig lists.
- This and other relevant hydrographic information is circulated to all interested parties.

MENAS is not a high profile organisation, nor does it seek to be, it fulfils a fundamentally important role in endeavouring to ensure the safe passage of shipping in the approaches to and within the inner ROPME Sea Area (RSA). It provides modern state of the art navigation systems and has, over the past 4 years, carried out a root and branch examination to ensure the service is relevant, up to date and cost effective.

It is paid for by shipping companies whose vessels trade in the region. This enables MENAS, to be immediately responsive to the needs of the mariner and to provide its service at minimum cost.

MENAS maintains some 500 or so aids to navigation in support of the mariners needs from traditional floating and shore based lights, radio and radar beacons, to the most advanced satellite based navigational system. Extensive use is made of solar power and the latest wind generated technology, and remote monitoring techniques are transforming the management and control of the service provided.

As part of its commitment to safety, MENAS maintains a purpose built light tender, Relume, which with the very latest in positioning systems and a comprehensive workshop and technical facilities, can cope with all types of floating aids wherever they may be. All but 5-year overhauls of buoyage - can be completed by Relume on station.

A small support base is located in Bahrain with appropriate operational, maintenance and administrative back-up. An equally small team of highly skilled and experienced professionals underpin this support and their services are also freely available throughout the area to assist port/harbour authorities should any independent advice on matters of navigational safety or nav aids be required.

MENAS' independence keeps it highly focused, its purpose is to serve the maritime users of the RSA. By being integrated, the service is highly cost effective and throughout the region's several thousand miles of coastline, and six traffic separation schemes, MENAS provides continuity by an overlapping, consistent and dependable service, maintaining the highest integrity of navigation aids through a continuous regime of inspections, servicing and remote monitoring techniques. MENAS unencrypted DGPS service for example, brings benefits to all classes of mariner and might add other unrelated areas.

This presentation is to provide some background as to MENAS radio navigation service the operation of it and how MENAS got there. The system is fully tested, and has been up and running for over two years.

MENAS is a not for profit company and the DGPS chain is unencrypted / free to air, which has resulted in some interesting peripheral users - rumour has it that certain taxi firms in Dubai benefit from the service! so what makes this area so different and why is the MENAS DGPS so important in the region? For a start, it is one of the busiest waterways in the world and the MENAS DGPS provides positional accuracy down to one metre for those using it and less than three quarters /metre for 65% of the time. This, of course, depends on satellite health.

The sub metre accuracy with over 99.7% reliability, is an excellent service to the mariner and more than adequate for the position-fixing requirement of the hydrographer. Even more so perhaps when considering the sheer importance of the region to the world economy.

The littoral states (Bahrain, Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates) produce some 26% of the world's oil and hold 65% of its reserves (US Dept of Energy).

Given that much of the oil is transported on vessels through this sea area, it doesn't take much imagination to realise that the potential for catastrophe is

huge. Pollution, environmental disaster and the cost of human life would be tremendous, which is why a tested, tried and trusted safety system is essential because of the following facts and figures:

- The area has the largest tanker traffic in the world.
- It is also one of the busiest waterways in the world.
- In 1965 there were about 1200 tanker and cargo vessel movements.
- In 1996 approximately 25,000 vessels used its waters; more than 2,000 a month.
- At its narrowest point the Strait of Hormuz is just 27 nautical miles wide with shipping channels for inbound and outbound tanker traffic only 2 miles wide.

The first MENAS DGPS station was commissioned in 1997. Since its inception MENAS has been dedicated to navigational safety in nearly all of the RSA and that's why way back in the 1960's MENAS installed what was then the most efficient and cost effective navigation system available - the Decca Navigator Chain. At the time, it was one of the most modern systems in the world but, by the 1990's, despite several updates, newer technology had overtaken it, both in accuracy and expense. So, in 1994, the decision was taken to develop and install a freely available and unencrypted differential global positioning system for the area with the aim of providing shipping with the most advanced and accurate service available in a single, integrated, low - cost system. That meant designing a unique system in a unique part of the world and one, which would provide:

- Accurate position fixing in confined waters where freedom of manoeuvre is restricted.
- Key positioning input for emerging integrated systems (particularly for use with electronic charting and within vessel traffic systems) and to contribute to the 'Standard Fit' of equipment for voyages worldwide.
- Real time regional monitoring for GPS.
- Position - fixing for high speed vessels (over 30 knots) requiring the highest levels of navigational accuracy.

The main advantages of satellite technology are the fact that it has much better accuracy and integrity over land based systems. Using information from satellites can obtain a much more precise fix on a vessel position than traditional terrestrial systems.

Differential GPS is different because it has such extremely high levels of accuracy by using reference stations to detect satellite errors and transmit correction signals.

Once the decision had been taken to examine the possibility of installing a DGPS system, a special project management team is formulated, consisting of some of the most able and knowledgeable experts in the area. These included:

- A project manager with 19 year's experience in managing large scale projects.
- The radio officer from MENAS' light tender vessel with 25 years specialist knowledge of the region and its unique radio propagation characteristics.
- A field engineer who grew up developing aircraft and marine navigational systems with Decca before taking on the maintenance of the MENAS Decca Navigational Chain.

This briefing was to find a system, which would provide high quality, cost-effective performance across the area, whilst using no more stations than were absolutely necessary. That meant exploiting available technology to the full. Unlike other regions, MENAS started from green fields, or more like desert sites, with no marine radio beacons infrastructure in existence.

As a starting point, MENAS visited the Swedish National Maritime Administration (lighthouse authority) to look at its system and learn from the group's experiences. Sweden has a similar geographic area and had already established seven operational / trial DGPS stations - a valuable trip.

During December 1994 and January 1995, a feasibility study and trials were undertaken to assess DGPS coverage predictions for the intended area. These were carried out by Professor David Last, Head of the Radio Navigation Group at the University of Wales, Bangor and a renowned expert in the field.

The aim of the feasibility study and trial was to evaluate the effectiveness of the marine radio beacon method for use in our area wide DGPS service. Professor Last's first step towards the feasibility study was to develop a computer model to assist locating marine radio beacon transmitter sites (reference stations) with appropriate overlaps to provide full inner RSA coverage. The model included ground loss, noise and interference and an extensive ground conductivity database. It was important to try and contain sites in locations where main services were already available, although obviously MENAS has to be prepared to look elsewhere as well. Not only to take into account technical reasons for sites being a success or not, but also whether various authorities were happy to give MENAS the go ahead for the project.

Reference stations for DGPS should ideally be built on accessible sites supported by good communications and services - but because of prevailing conditions MENAS had to build four high-powered stations rather than the usual practice of a relatively large number of low-powered radio beacons, this however helped to keep costs down and reduced environmental impact.

With the feasibility trial MENAS had to look at the civil engineering aspects and the provision of equipment, plus find an appropriate site - something which was not without its share of problems, not least finding a site and losing it to other national developments.

This challenge had its compensations, as MENAS had to do some quick thinking and it gave the ability to accurately estimate the costs of preparing a site and all the civil engineering requirements. This was a valuable lesson, which MENAS were able to use when setting up other sites.

For the study and trials key considerations were:

- The need to estimate signal conditions point-by-point at intervals of approximately 10 kms throughout the area around the planned DGPS station.
- Estimate the level of atmospheric noise and interference from other stations.
- Quality of reception available.

The results of this survey programme were used to validate the planning process and to provide MENAS personnel with experience in constructing, operating and using a Radiobeacon DGPS system.

Subsequently, the same station and ship's installation were employed to measure the strength of the ground wave signals received east of the Qatar peninsula. From the results, the attenuation of land paths across the peninsular was calculated and the ground conductivity of the terrain, (which is typical of conductivity in many areas in the region) was determined.

During Relume's voyages ranges of 205nm were noted with accuracy of less than three metres being experienced 98% of the time. When MENAS carried out a similar exercise through Qatar, UAE and northern Oman to Didamar (or Quoin) Island ranges of over 3300 nm were achieved. With such great results, the feasibility trial and study recommended that MENAS press ahead with the DGPS system without delay and the MENAS board gave the go ahead.

For the study and trials key considerations were:

- The need to estimate signal conditions point-by-point at intervals of approximately 10 kms throughout the RSA and its approaches around a planned DGPS station.
- Estimate levels of atmospheric noise and interference from other stations.
- Quality of reception available.

The planned system: the coverage planning model was first used to evaluate a set

of Radiobeacon locations and power levels initially proposed. Subsequently, it showed the effects of adjusting the power levels of these stations and of operating transmitters on a series of alternative sites. The coverage and performance of many combinations of stations were investigated, taking into account both day and night conditions, and atmospheric noise levels at various seasons of the year. In addition, the models allowed the designers to explore the degree of overlapping coverage, investigating the performance of the system if, and when, each beacon was temporarily out of service for maintenance. The coverage contour encloses all waters of the area, at every point the following criteria are met:

- Ground wave field strength exceeds 10uv/m (+20 dbuv/m).
- During night fading, field strength exceeds 10uv/m 95% of the time.
- The signal to noise ratio is at least 10db with respect to the atmospheric noise level for 95% of the time.

Following preliminary system planning, a trial station was established at Sitra, Bahrain in late 1994. The station transmitted on 298kHz and carried rtdm104 standard DGPS data modulated at 100bps. Its signals were monitored at locations throughout the area by the MENAS Lt Relume using Trimble Navigation Receivers. Readings were taken of field strength, atmospheric noise and quality and consistency of reception.

DGPS fixes were compared with those from a Racal Skyfix installation. A Rohde & Schwarz precision field strength measuring system was installed on the vessel and used to make accurate measurements of the field strength of the Bahrain signal at ranges from 2 to 400 km; the results correspond closely with the models predictions for a beacon of 2.3w erp. The system was also employed to identify suitable frequencies for the planned stations, helping determine the identities of potential interfering stations. The results of this survey programme were used to validate the planning process and to provide MENAS personnel with experience in constructing, operating and using a Radiobeacon DGPS system.

Subsequently, the same station and ship's installation were employed to measure the strength of the ground wave signals received east of the Qatar peninsula. From the results, the attenuation of land paths across the peninsula was calculated and the ground conductivity of the terrain, (which is typical of conductivity in many areas of the region) was determined. During Relume's voyages ranges of 205 nm were noted with accuracy's of less than three metres being experienced 98% of the time.

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with the DGPS system without delay and the MENAS board gave the go ahead. Once those trials had been completed MENAS was able to see at a glance the benefits of satellite-based DGPS.

The results of all the trials produced a system, which provides:

- Coverage contour enclosing all waters of the inner RSA and its approaches.
- Provides excellent service under all atmospheric conditions.
- Service reliability of over 99.7 per cent, measured over one year.
- A warning alert within 10 seconds in case of malfunction.
- Overlapping coverage of beacon areas allows downtime without compromising the service.
- Continuous monitoring of all stations with out-of-hours problem alert system.
- Instant access via laptop computer for the duty engineers for urgent maintenance.
- Minimal impact on the landscape.

Having decided to go ahead with the project, the next task was to put it out to tender. Several companies were considered but when it came to finding a manufacturer which could produce the system MENAS signed up Sagem SA, part of the French Sagem Group, a world leader in the design and manufacture of navigation, defence, communications and electronics systems.

The company is well known for producing leading edge technology navigation systems and in July 1996 a contract was signed with Sagem to provide and install DGPS as a turnkey project, including receivers, modulators, MF transmitters and antennae, and computers on all sites and in the control centre.

Although MENAS prepared the sites, built the infrastructure and arranged for the supply of the necessary services the work was carried out alongside Sagem sub-contractors. Stations were chosen at strategic sites in Bahrain, Kuwait, Ras Al Khaimah and Abu Dhabi. Together this meant that all the waters from the northern Oman coast, through the Strait of Hormuz up to the Kuwait/Iraq border would be covered. This was a crucial stage of the project and MENAS co-operated as closely as possible with the various authorities on using sites which would neither conflict with local interests or disturb environmentally sensitive areas.

Ras Al Khaimah was the first station to be commissioned and it was declared operational on April 25 1997 - despite problems with heavy rain and a last minute change of site! Engineers from Sagem, its associated company Nautel, and MENAS worked together to install and test the site ready for the big day. The Ras Al Khaimah installation was so successful that the initial feedback from vessels using the area was excellent - one vessel reported receiving the DGPS signal from this site all the way to Kuwait, which is a distance of over 500 km.

This station was used to comprehensively test the remote control centre at our Bahrain base.

Kuwait although being the smallest site turned out to be a challenge for the antennae contractor. Being on a beach with limited space, the guy wires supporting the aerial had to be redesigned so that the anchor blocks would be inside the security fence, but at the same time still provide the same environmental specifications. Also, being on the beach, the radials lying seaward were changed to stainless steel and the ends attached to concrete anchor blocks, which were positioned well below the low water mark.

Once the Ras Al Khaimah site was complete, MENAS was able to close down its Decca Navigator Chain covering the southern RSA, and it was able to start converting the existing Decca green station at Munayyif in Abu Dhabi for the new DGPS station.

The Munayyif site would prove the most demanding right from the start. Before any work could start, the Decca infrastructure had to be removed, apart from the aerial base block and earth mat, which would be reused. As this site is in the middle of the desert no grid power was available, so new generators had to be used. Due to the remoteness of the site, the generators were redesigned so they could run for 40 days continuously without oil changes in temperatures exceeding 50°C in the shade. As the only station not on main power Munayyif also had problems with the generators and the ups system but these were overcome at last in November 1997 - finally completing the operational status of the whole system.

The Radiobeacon DGPS service described in this paper allows MENAS to provide an IMO standard service of high reliability throughout the area. Whereas such DGPS systems operating in Europe and elsewhere employ large numbers of relatively low powered existing Radiobeacons to which the DGPS service has been added, the design of this system took into account the need to build new Radiobeacons and to maintain them on remote sites. As a result, just four stations are employed, albeit with the unusually high (though certainly not unique) nominal range of 250 nm.

So, innovation is one of MENAS watchwords and advanced monitoring and control techniques are key to this ongoing project, helping to provide considerable savings in cost and manpower and at the same time increase efficiency levels.

In Bahrain, bespoke software was installed at the DGPS control centre to allow the team to control and monitor the performance of all four unmanned reference stations around the clock and, from that control centre, engineers can also verify the strength and accuracy of the receiving signal at all times. It provides a

complete and continuous performance log, so the DGPS team can see the accuracy of each reference station and the system as a whole. By duplication of all key equipment at the stations, from air conditioning to modems, the system provides a fail-safe operation. If anything does malfunction, engineers are alerted and can shut down the faulty unit immediately while at the same time activating the duplicate from the control centre. Round-the-clock emergency cover is provided when the control centre is not manned. The duty engineer is alerted by a pager when an alarm occurs, he then uses a laptop PC to access the system.

The MENAS DGPS project was developed, installed and operational in just three years thanks to a combination of thorough research, testing and making the most of worldwide expertise. MENAS co-operated closely with the various authorities, with suppliers and engineers and, wherever possible made use of existing installations. MENAS believe that was a considerable achievement, especially given the unique, exacting and difficult environment of the ROPME Region.

DGPS proved so successful in such a short time that MENAS was awarded a prestigious searade award commendation for the implementation of DGPS. These are the maritime industry's premier awards and are designed to symbolise the ongoing effort to improve maritime standards. This is a true indication of MENAS contribution to navigational safety in the area. The cost of the project was US\$2.8 million but it is unencrypted and freely available to all ship owners, large or small. For the user, it is a simple system to use, receivers are inexpensive to install and most vessels will already have them.

Conclusions

For some years MENAS aim has been to increase operational efficiency, drive down costs and make judicious use of modern technology, MENAS has been successful in keeping its charges as low as possible, without compromising standards. All monies collected are reinvested for the benefit of the mariner.

In summary, MENAS approaches the millennium, lean and fit reflecting the significant changes that have transformed this unique company to meet the needs and demands of today's mariners. The accurate charts navigation aids are not an optional extra, they are part of that essential maritime infrastructure for any region. They assist the safe and expeditious passage of all vessels. MENAS is proud to deliver reliable, efficient and cost effective aids to navigation service. Whilst MENAS' purpose is to assist the mariner by provision of an integrated system of aids to navigation, MENAS feel that there is much synergy between the respective organisations today. If the master of a vessel can accurately pinpoint the position from the interaction of precise charting and relevant aids there is less chance of a casualty which can only be to everyone's advantage.

REGIONAL ENC COOPERATION AND BUILDING INTEGRATED MARITIME INFRASTRUCTURES AND SERVICES – THE DIGITAL MARKETPLACE

Robert Sandvik

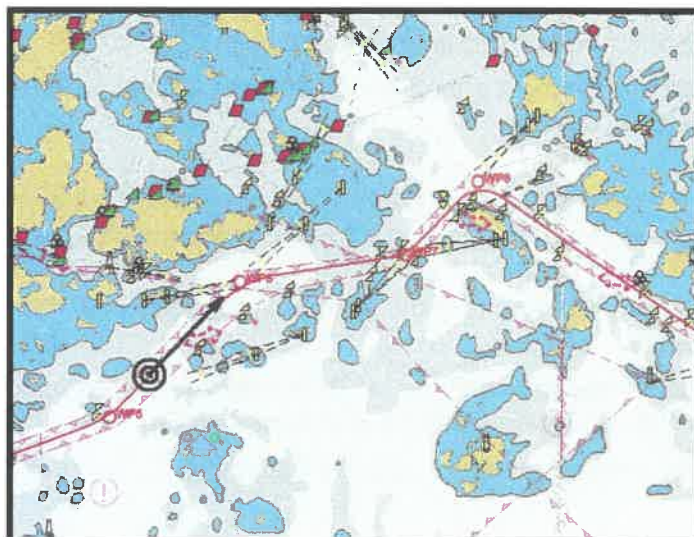
Abstract

PRIMAR is a joint venture co-operation in Europe to integrate and provide a consistent ENC distribution service world-wide. This paper presents how the co-operation is organised and managed between the European Hydrographic Offices. It also presents an overview of the ENC services available from PRIMAR using both on-line telecommunication services and CD-ROM. It also provides an overview of the future development of integrated maritime infrastructures supporting ENCs and other marine and maritime information.

Regional Model for Co-operation

The International Hydrographic Organisation (IHO) established a working group in the early 90's to carefully look at how the hydrographic community should co-operate to promote the Electronic Navigational Charts (ENC) to meet the future market requirement from the distribution chain and the end-users. The working group developed the WEND (Worldwide Electronic Navigational Chart Database) principles which describes a model for information exchange, responsibility and management of a regional co-operation between national Hydrographic Offices and a Regional ENC Co-ordinator (RENC) to provide a global ENC service (Figure 1).

Figure (1): ENC from the ECHO project



The Hydrographic Offices (HO) of northern Europe agreed to the establishment of the RENC as a collaborative arrangement, operated on their behalf, jointly by the Electronic Chart Centre (ECC) and the United Kingdom Hydrographic Office (UKHO). The constitution, organisation and management structure of the European RENC derives from the application of the IHO WEND principles. Among the first activities was the development of an agreement known as the *Arrangement on Co-operation* (COA) within the Northern European RENC and its member states. To date the following countries are signatories: Denmark, France, Finland, Germany, Netherlands, Norway, Poland, Portugal, Sweden and UK. Several other Hydrographic Offices in Europe and other parts of the world have expressed interest in the European RENC and have provided valuable contributions to the development of the existing position. Greece, Spain and Turkey attended the last RENC Advisory Committee meeting as observers. Bilateral discussions are in progress with nations in other parts of the world.

From 1 February 1999 the European ENC Co-ordinating Centre adopted the name PRIMAR™ as a brand name to denote both the organisation and its service.

PRIMAR - Organisation and Co-operation

Primar is operated as a Joint Venture between the Norwegian and United Kingdom governments. It is operated by the two government controlled institutions ECC (Electronic Chart Centre) in Norway and the UK Hydrographic Office. The Joint Venture operators have defined the following *mission statement* for PRIMAR:

- To act on behalf of contributing national Hydrographic Offices, as their common instrument, to assemble their national official hydrographic vector data into a consistent, uniform ENC service and to make it widely available to contribute to the safety of navigation, the protection of the environment and the effective operation of maritime activities.
- To co-operate with RENCs established in other geographical areas to establish a worldwide ENC service.

The Joint Venture operation is fully defined in a Memorandum of Understanding (MoU) between the two Participants and has the following objectives:

- To establish the infrastructure and operate the systems necessary to establish the ENC service.
- To ensure the long-term viability of ENC services to customers and thus to protect the rights and interests of the co-operating HOs.
- To achieve the aims set out in the Mission Statement.

- To provide the staff and assets necessary to jointly operate PRIMAR and its services.
- To operate PRIMAR as a non-profit making governmental organisation.
- To develop and implement a suitable Business and Marketing Strategy Plan and an Annual Management Plan.
- To establish, with HOs, arrangements covering the supply of suitable ENC data to PRIMAR, the reimbursement of those HOs through royalty payments and the extent of liability associated with the data.

The Primar Management Structure

The organisation and management structure is as follows:

- The Directing Board (DB). Consisting of the Director General of the NMA (Norwegian Mapping Authority) and the Hydrographer of the UKHO (representing the Joint Venture Participants), together with the Hydrographers of Denmark and France (elected by and representing the Co-operating HOs). This body meets at least four times per year.
- The Advisory Committee (AC). The co-operating HOs contribute to the management of PRIMAR through the mechanism of an Advisory Committee comprising all co-operating Hydrographers or their representatives. It provides assistance, advice and guidance to the Directing Board on the development and operation of PRIMAR. This body meets twice per year.

Although not part of the management structure, there is also a Technical Experts Group that is aimed at resolving the technical problems linked to the data flow between the HOs and PRIMAR and at facilitating the exchange of technical expertise and knowledge. It is made up of representatives from PRIMAR and the HOs. At the last AC Meeting it was decided that a Marketing Experts Group should also be established. They work on issues related to the pricing, sales and marketing of the co-operated ENC service.

PRIMAR - The European ENC Co-ordinating Centre

General

PRIMAR operates from a single office in Stavanger, Norway and is manned by staff provided by the UKHO and the ECC. It is managed by a four-member corporate team led by the General Manager who is responsible to the Directing Board for the leadership and overall management of the PRIMAR Office,

including the formulation of policies, plans and budgets, the determination of medium and long-term operational strategy, and the approval of all plans and initiatives underway within the organisation. The UKHO and NMA provide funding on all operational costs on a 50/50 basis.

Legal Status

The UKHO/NMA Joint Venture (JV) has not established a legal entity, rather it is an inter-governmental co-operation, and the two Participants will therefore be liable to any third party suffering damages as a result of actions or any other circumstance for which the Joint Venture is responsible. The JV has been entered into the Norwegian Register of Organisations.

ENC Production and Management Systems

The ENC production and management system is based upon the *SevenCs ENC Tool Suite*. Independent quality control software is provided by *dKart Inspector* and *Dxaminer* together with *ENC Analyser*.

Liability and Copyright

PRIMAR is working closely with the North Sea Hydrographic Commission Working Group on Copyright to ensure that the rights of HOs are secured when their data are marketed.

PRIMAR will constantly review the question of liability in relation to its services, production processes and other activities.

Relationship with the IHO

PRIMAR will develop its own relationship with the IHO (as distinct from the UKHO and ECC). PRIMAR staff participates in working groups and committee activities as required ensuring that it remains in the forefront of relevant developments and debate.

Requirements for Maritime Infrastructure Services

Market feedback clearly shows that new infrastructures and distribution channels will develop to provide an efficient and economic ENC service. The ENC or its updates are not physical products like a paper chart. It is of course possible to store the ENC on a physical medium like a CD-ROM, but since it is a digital

- Services must be a combination of «push-technology» to make important or user selected information automatically available, and «pull-technology» where information is made available for access. Focus is to avoid information jamming where end-users are overwhelmed with new information, which is not immediately required for their voyage or specific operations.
- Services and data must be secured with authentication of the end-users and the service provider on all supported carriers, and protected to prevent misuse of the ENC products.
- Services must be reliable, cost effective and with high quality
- Technology must be based on well proven international standards and cost effective operation.

PRIMAR provides an operational ENC service, which meets these requirements. They will in the future be amended to support more telecommunication carriers and distribution services.

PRIMAR ENC Information

ENC Information

- The ENC will be fully compliant with IHO publication S57 Edition 3 and its associated ENC Product Specification.
- The ENC will fulfil all the requirements of the IMO performance standard for legal acceptance as adequate for navigation under the SOLAS requirements for the carriage of charts.
- The ENC will be based on the data of the appropriate national hydrographic authority, which will select the source material to be used to populate each navigational purpose category and is responsible for the production and verification of the ENC data.
- New Editions or re-issues of the ENC data will be made available whenever initiated by the appropriate HO. (The data will be produced by national Hydrographic Offices or by the RENC and distributed by PRIMAR in accordance with the requirements of S57 Edition 3)
- Updates to ENCs will be added to the PRIMAR database for all changes issued by the authoritative national Hydrographic Office. These will also be fully compliant with the internationally approved data transfer standard as detailed in the IHO publication S57 Edition 3.0 and its associated Product Specification.
- The ENC updates will fulfil all the requirements of the IMO performance standard for legal acceptance as adequate for navigation under the SOLAS requirements for the maintenance of navigational products fully up to date.

In view of their legal liability, HOs are responsible for all aspects of the quality of their ENC's and of the updates provided to PRIMAR. The HO's therefore verify and validate their own data.

PRIMAR also validates all data it receives, using a variety of software validation tools, and ensures the consistency of adjoining data sets. PRIMAR, on detecting errors or anomalies in the incoming data, does not amend the data itself but sends all queries back to the HO, requesting that the HO should examine the problem and, if agreed, supply a new data set.

The validation of data remains a major task for the PRIMAR Data management Team. It must be remembered that this is the first time that so much S57ed. 3.0 data, from so many sources, has been brought under a single quality control system. Errors have been found in both the data and the validation software as part of this work there is continual dialogue with the QC software manufacturers to improve the validation tools.

Initially, not all HO's have a capability to produce EN and /or ER profiles themselves. In such cases, in accordance with the COA, and in agreement with a HO, PRIMAR may produce ENC's or ER's of that HO's waters. PRIMAR therefore has the ability to process data from three different streams:

- EN and ER produced by a HO.
- EN produced by a HO, ER produced by PRIMAR.
- EN and ER produced by PRIMAR on behalf of the HO. (if requested by the HO and only if resources are available)

PRIMAR ENC Services

PRIMAR commenced 1 October 1999 its official ENC service as defined in the PRIMAR Service Definitions. The service meets all requirements to provide ENC information required for ECDIS operation. All the ENC information is also provided in accordance with the PRIMAR Security Interface. Information about the Service Definitions are available from PRIMAR on request. The ENC service is provided on both a CD-ROM and on-line telecommunication. PRIMAR has also developed a separate *Product List* containing the navigational status and coverage for all ENC's available from PRIMAR. The CD-ROM service consists of:

- ENC base data will be supplied on a base CD, together with all updates which are issued weekly on an accumulative update CD will bring it up-to-date to the most recent corrections at the time of supply.
- New editions or re-issues of cells will be distributed on the weekly update CD until they have been incorporated into the next base data CD.

- New versions of the base data CD will be produced occasionally or as required to incorporate all updates and new cells produced.

The following service will be provided when ENC base data is made available by telecommunications:

- ENC base data will be available globally and 24 hours a day for immediate on-line download, together with all updates to bring it up-to-date to the most recent corrections at the time of supply.
- New editions or re-issues of ENC base data will be made available for on-line access as soon as they are officially released by PRIMAR.
- Only the latest edition of a base ENC will be made available for on-line access. This includes also any re-issues applied to that edition of the base cell.
- A copy of the PRIMAR Product List is always available for download and contains the navigational status and coverage for all ENCs available from PRIMAR at the time of the request.
- The on-line service contains several qualifiers to request specific items (e.g. individual updates) or all of the items (e.g. all updates). The message protocol is defined in the Primar Service Documents.

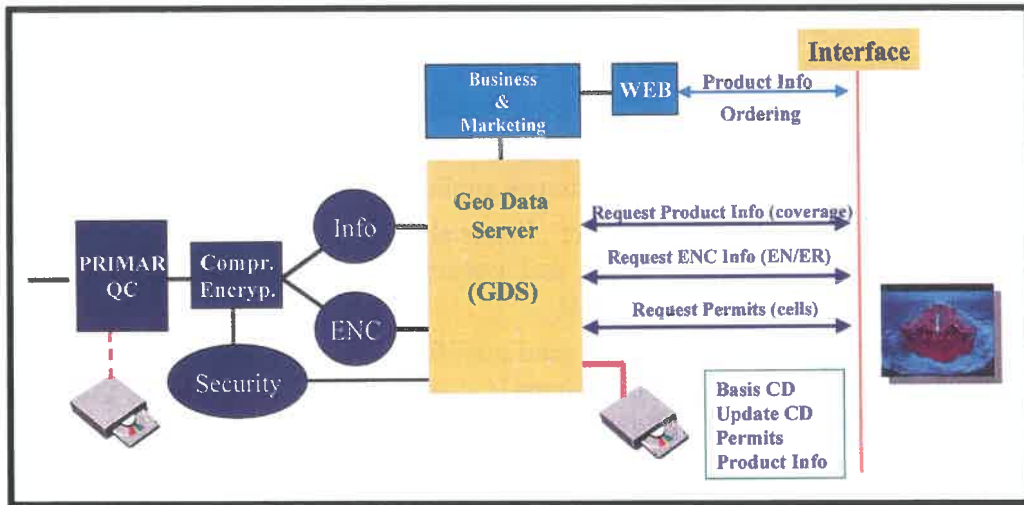
Figure (4) provides an overview of the systems developed by the ECC for the operation and provision of the PRIMAR ENC services. All ENC information is stored safely when it passes validation. Upon import into the Geodata Distribution Server (GDS), security information is applied to all the ENC data. This includes issuing a digital certificate with the PRIMAR public key, digital signatures of all the ENC information in accordance with the international Digital Signature Standard. All ENC information is finally also encrypted. The Security Interface is available from PRIMAR upon request. The GDS has functionality to automatically handle on-line requests using the HTTP and TCP/IP protocols for :

- Download of the PRIMAR Product List for e.g. individual ENC cells, geographic areas or for all ENCs available.
- Download of individual ENC base cells or user specified range of cells.
- Download of individual ENC update messages or user specified range of update messages.
- Download of Cell Permits (decryption keys) as for registered users as specified in the Primar Security Interface.

These services are now available operationally from PRIMAR, but are being amended to also support other types of communication protocols and to make more user tailored services available. Free sample software demonstrating the security and on-line aspects is available from the PRIMAR web-site.

The GDS is also used to automatically produce the weekly and accumulative update CD issued by PRIMAR. The GDS software is also interconnected with a business system which provides a web- interface to distributors to automatically and simplify the registration of new customers and new orders. The GDS will automatically enable access to new customers and also distribute new User Permits (decryption keys) as a response to new orders from distributors.

Figure (4): Overview of the systems developed by the ECC



Conclusion

The European PRIMAR co-operation is a good example for how the IHO WEND principles can be achieved operationally. Whether it is a physical or virtual RENC operation, some regional co-ordination will be required for the exchange and distribution of information. PRIMAR has worked hard over several years and gained valuable experience in the areas of ENC production and validation, distribution, GIS technology, distributor conditions and distribution networks which will be of valuable importance to any nation producing ENCs or ready to disseminate its ENC products. PRIMAR is interested in extending its co-operation and provide support to any other nation working within the IHO WEND model.

PRIMAR can also provide an easy and interim solution for providing the ENC into the market. We have all the systems in place for an operational service with sufficient security to safeguard the commercial interests of the HOs. The distribution model, systems and services are now operational, and the real challenge is to expedite the production of official ENC information to meet the requirements of type approved ECDIS systems which will be released shortly into the shipping market.

INTRODUCTION TO GIS

Max Falká

The HIS-CPS solution (Summary)

The HIS-CPS solution is based on well-known and approved ESRI cots software products like SDE, ArcView, and Arc/Info. The HIS application handles data input, data management and viewing, editing, quality control, production of Electronic Nautical Charts on the S57 format. CPS handles the production of paper charts.

Strong aspects of the HIS - CPS solution

- Increased safety at sea by quality assured workflow.
- Powerful quality checks for legally binding data.
- ONE seamless database.
- Long transactions and history management.
- Database inside relational database management system for integrity and security:
- Same data format and software as market leading land based GIS --> integration possible.
- Client - server solution.
- Application built on World Wide market leader software from ESRI Inc.
- Windows look-and-feel.

HIS has a module for export of data on the S57 format, including selected S52 symbology. CPS has a new Hydro extension, which can handle the specific demands for cartographic production of sea charts.

Some comments about the S57 v.3.0 specifications

S57 specifies both object model and data format. It is possible to have data, which follows the S57 object model, but still using some other data format, like SDE or Arc/Info. ARC/INFO 7.2 includes converters to and from the S57 binary files, creating ARC/INFO covers, which contain S57 objects. This is what we are using in HIS.

T-Kartor see advantages to storing data in SDE rather than in the S57 file format, since this makes the data available also for other applications (such as Map Objects or ArcView applications for web publishing), and since there are tools

readily available to convert SDE data to other standard file. The S57 file format is more of a closed world. SDE also gives the advantage of one common, seamless database, which can be used by virtually any number of clients. It is also a great advantage to have the data safely stored inside a relational database management system, with all its security and integrity mechanisms. The important thing for the Hydrographic offices is that it is possible to export ENC files on the S57 format, which we can do.

It is worth noticing that the Hydrographic Offices must produce specific ENC files. There are additional S57 specifications, which apply to the ENC files, like mandatory meta data and formats for base cells and revision cells (updates). In other words: there is more to ENC production than just being able to extract data on a certain file format. HIS has a production line, which allows the user to select arbitrary data-sets from the SDE database and export them into ENC files. This production line automates the meta data handling and the creation of revision files.

Depth Data Processing

Depth data processing is not included in the HIS. Maritime Administrations in general have other systems for depth data processing. HIS can read the processed output from these systems and enter significant soundings (those which are shown on charts) into SDE. It may be of interest to know that several Hydrographic Offices are considering using SDE also to store all depth data (raw and processed). There have been benchmarks with very good results.

The Hydrographic Information System (HIS)

HIS is an open solution of functionality for Maritime Administrations/Port Administrations, Coast Guard organisations and/or Military Navies. All organisations like to find the most cost-effective alternative. Depending on the customers present situation/status and the goals with the HIS investment there are a couple of different cost-effective solutions available.

HIS and its modules

HIS is modularised and some of the modules are specific to the Swedish and Finnish Offices, such as importers and workflow control. The system has been designed to handle very large amounts of data. The total coastline of Sweden and Finland is more than 4000 kilometres, including a complex archipelago and a lot of shallow waters in the classification of "brown waters". There are several hundred thousands islands in the archipelago. HIS stores all Hydrographic data and information you find on the charts. The full HIS is a high-end system for customers which handle very large amounts of data.

Customers, who handle smaller amounts of data, require a scaled down version of the system, containing selected modules. The really “light” version of the system would include primarily the ENC production line from HIS, and would use CPS as the chart production module. The light version would not use SDE, but would keep the data in Arc/Info coverage’s. The choice of system solution depends on the customer's requirements. It is possible to start small and to expand later on. The key issue demonstrated in the HIS project is that that ESRI products can be successfully applied to manage Hydrographic Data.

To give a price indication, the following information are required:

- In what formats does you store the data today?
- Which quantities of data do we talk about?
- What are the specific goals with the investment (Priorities)?
- How many seats can we expect?
- Do you know any time schedule?

T-Kartor Sweden AB expertise

T-Kartor Sweden AB has an outstanding knowledge in the HIS and CPS software. Also T-Kartor have a deep understanding for IHO (International Hydrographic Organisation) standards like the S57 ed. 3.0 for ENC. T-Kartor have been working with these issues since 1996 and the knowledge of Maritime Administration's operations makes T-Kartor a professional partner in the work of refinement and optimisation of the organisation.

T-Kartor Sweden AB expertise offer

- Professional requirement analysis of customer needs.
- Customised solution using HIS - CPS module system.

Introduction HIS White Paper

The Hydrographic Information System for the Finnish and Swedish Maritime Administrations is a single system for capturing, managing and controlling the quality of Hydrographic data. Information management, data edit, quality control and Electronic Navigational Chart production are some core capabilities of the HIS.

The quality of the data is a main concern of Hydrographic organisations. Starting with the capture of data or importing from existing systems, HIS manages the flow of the data, capturing quality information that is essential to verifying the acceptability of a dataset. Typical source data would be nav aids, soundings,

depth contours, controlled areas, other vector data and raster data. Standard processes guarantee quality control of data to be used for charts, List of lights, Notice to Mariners and ENC.

The Hydrographic data is stored in SDE for Oracle. SDE allows efficient management, search and retrieval of geographic data inside a relational database management system (RDBMS). The RDBMS provides the data integrity and security required by the Maritime administrations.

Data can be input via direct connections to other Hydrographic systems, digitised or manually entered. The HIS registers the new data and tags it so that data history is instantly recallable. HIS data management includes meta data management, multiple scales management and history management. The goal is to keep a high level of data tractability through all aspects of data processing.

HIS has a client-server architecture, where NT clients are connected to a UNIX or NT server. The client-server set-up allows sharing of data-sets, workflow control, and supervisor distribution of tasks to technicians, centralised data achieving and optimised client data processing. SDE and Oracle on the server store the master database from which clients extract Hydrographic data for updates or ENC production, or to which the clients place newly input and validated data-sets. ArcView GIS on the clients provides tools for Hydrographic data editing, viewing, querying, importing and output.

Intellectual Rights:

The ownership of the Hydrographic Information System belongs to the Finnish and Swedish Maritime Administrations. This documentation is a partial direct extract of the HIS system documentation. The HIS system documentation is compiled by the system suppliers i.e. Novo Meridian / Finland and T-Kartor / Sweden. This is a limited submission of the documentation to the ROPME member states. The HIS system are now available throw out the whole world. T-Kartor Sweden AB is the worldwide reseller of the system and represents the system owner in these matters.

System Overview

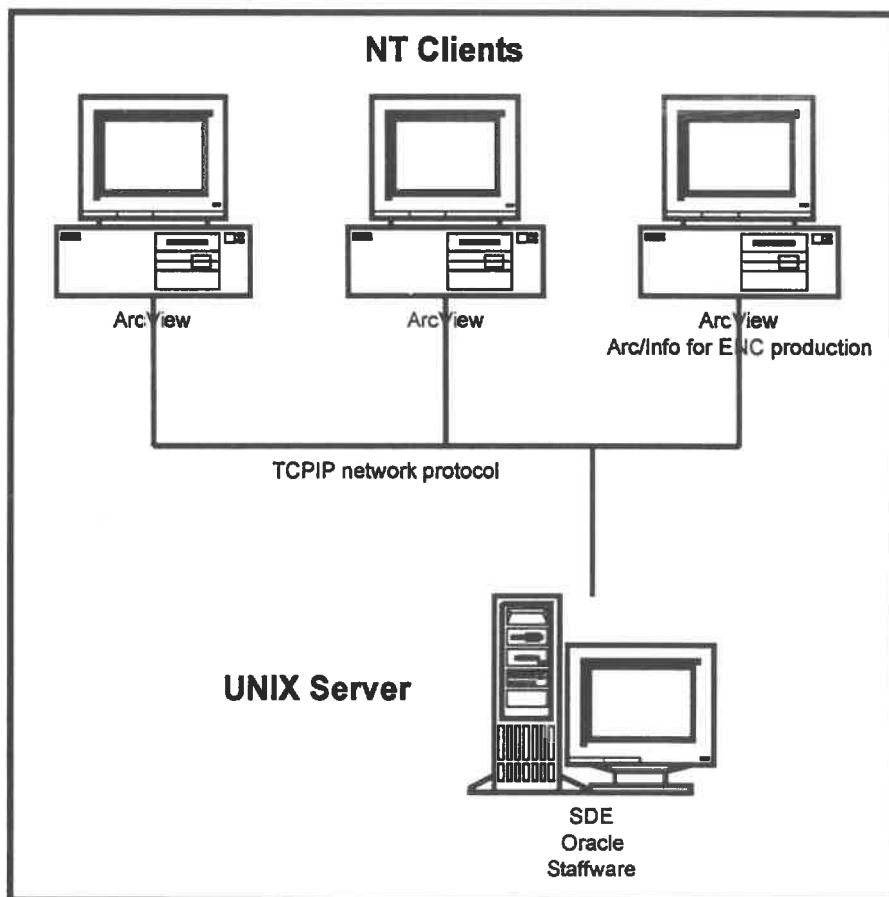
Client-Server Architecture

HIS has a client-server architecture, where NT-clients are connected to a UNIX or NT server (Figure 1). The client-server set-up allows sharing of data-sets, workflow control, and supervisor distribution of tasks to technicians, centralised data archiving and optimised client data processing. SDE and Oracle on the server store the master database from which clients extract Hydrographic data for

updates or ENC production, or to which the clients place newly input and validated data-sets. Staffware, commercial software for workflow management, handles system workflow control. ArcView on the clients provides tools for Hydrographic data editing, viewing, querying, importing and output.

HIS for the Finnish and Swedish Maritime administrations is designed for up to 80 simultaneous client users (50 viewers and 30 operators).

Figure (1): The Client Server Architecture of HIS



Components of the system

The system is primarily based on hardware from Digital and software from ESRI.

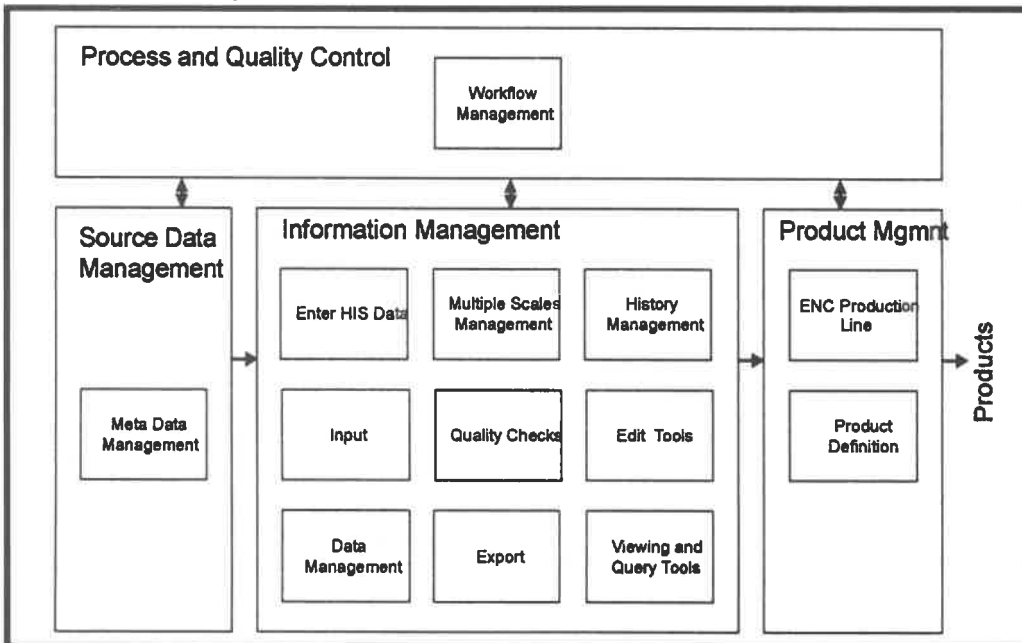
The Hydrographic data is stored in SDE for Oracle. SDE allows for efficient management, search and retrieval of geographic data inside a relational database management system (RDBMS). The RDBMS provides the data integrity and security required by the Maritime Administrations.

	Hardware	Software	Comments
Server	UNIX workstation. Digital Alpha server	SDE 3.0.2 for Oracle	The system can run on any RDBMS supported by SDE.
Client:	NT workstation (min 64 MB)	Staffware 5.2B2	One license for each client. ESRI extensions DBase and Dialog Designer are required to run the HIS. One license for each client running ENC production
		ArcView GIS 3.1	
		ARC/INFO 7.2.1	
		Staffware Client WindowsNT version 2.1B4	

Functionality

HIS contains 13 sub-systems. Data can be input via direct connections to other Hydrographic systems (Figure 2), imported through custom designed importers, digitised or manually entered. HIS registers the new data and tags it so that data history is instantly recallable. HIS data management includes meta data management, multiple scales management and history management. The goal is to keep a high level of data tractability through all aspects of data processing.

Figure (2): Sub-systems of HIS



HIS Users

HIS contains three different user definitions:

- Operating system (WindowsNT) login.
- Database (SDE) login.
- Workflow (Staffware) login.

These definitions and logins are totally independent things from the application point of View. Login to the database does not automatically cause login to the workflow (and vice versa). HIS does not contain automatically login functionality (except workflow login when a job is created), user action (password is always needed. HIS does not save passwords to any files to be used in next logging. It is recommended that the user use same login name for all three purposes.

Security and user groups

This section discusses *data security*. Backup, recovery after hardware failures and similar issues are not handled in this part. Refer to HIS System Administrator's manual for these other security related issues. Data security in HIS is implemented at *user group* and object class level. User groups, which are described in the next section, are implemented each software component of HIS (Unix Server, Oracle, NT Client, etc.). Refer to the HIS System Administrators manual for more detailed information about how the groups are created, modified and deleted, and how the users are assigned to and retracted from groups.

HIS support security at the *object class* level. There could be some other possible security implementations, which are discussed later. Security is implemented in Oracle through access GRANTs, in Staffware (workflow software) through Staffware user groups and in workstation and File Server through Windows NT user groups.

Batch Processing

HIS does not support batch processing. It is possible to use ReachOut -emulation software to use other workstation(s) from one client workstation.

HIS Workflow

HIS workflow management, or process control, is the computer-assisted management of Hydrographic data processing through the execution of ArcView software. The order of execution is controlled by a computerised representation of the business processes. This computerised representation is implemented in

Staffware, which is a commercial workflow system specially customised to work with ArcView.

All tasks that involve modifications to the main and scale databases, as well as all ENC production is under workflow control. Job types, pre-defined sequences of steps (processes), have been defined for these tasks. Jobs are instances of job types, and ongoing jobs can be monitored and managed through the Staffware work queue. Work queue management is provided for individual users, user groups and supervisors. On the client side, the workflow steps are implemented as process extensions, which are loaded and unloaded to provide the functionality the operator needs inside each process. The client application also manages the job workspace, where data is securely kept during the duration of the job.

ArcView is the framework for HIS. For each process of a job type HIS provides to user the necessary tools and rules to accomplish the particular process. The order in which these processes are done is crucial to maintaining the quality of the data. To help ArcView create such a controlled environment, Staffware workflow software is used. The division between ArcView and Staffware is that Staffware moves a job through the correct processes and people. ArcView check the conditions to start and finish the processes and also offer correct tools and rules to complete the job.

Jobtype

Jobtype is a full description of a job. It is a predefined workflow to handle a specific assignment or job. In Staffware terminology jobtype is a procedure. HIS provides three predefined job types:

- ENTER - Enter new data.
- ENC - ENC production line.
- MULTISCA - Multi Scale management.

The workflow administrator (swadmin) defines Job types in Staffware using the Graphical Workflow Definer. Jobtype consists of a complete set of processes and decision steps that define the entire job. Jobtypes are stored on the Staffware database on the server.

Job

Job is an instance of job type. A job is composed of a pre-defined sequence of processes necessary to accomplish an HIS activity, such as entering data into the system, or to produce ENC output files. In Staffware terminology job is a *case*.

An operator during the job registration defines jobs. Jobs which modify the HIS

database (enter and multiscale jobs) are associated with source data via a unique job ID (see document about meta data management). This ID is generated by the UID server and used by HIS to track and monitor the job.

Jobs are stored in a job workspace located in the file server. The workspace is copied to local disk when operator is working with the job. A job ends when the last process of the job is finished and the operator indicates the completion of the processing. Usually a job will not finish until all the data has been successfully input or output.

Process

Processes are the building blocks of an HIS job. A process is a systematic approach to perform a certain task or to achieve a specific purpose.

Client Application

System structure

The Hydrographic Information System (HIS) is designed for flexibility and modularity. The building blocks of the HIS client application are presented below.

User View

HIS has a graphical user interface (GUI) built from ArcView. The technical components of the GUI are described in the next section. The user can work with user utilities or jobs. There are three kinds of job types defined for HIS: ENTER jobs, MULTISCALE jobs, and ENC PRODUCTION jobs. Each job type is workflow controlled and composed by a number of pre-defined steps, processes. The jobs are described in more detail in section 3.

The GUI changes depending on what the user is doing. There is the project GUI that contains the user utilities, such as managing the meta data. There is also the View GUI which contains basic View and query functions, but where additional functionality is added, when the user enters a certain job process, thus enabling tools which are allowed only in that process (e.g. editing tools in edit processes).

Technical View

The application is built from extensions. An extension is a collection of system functionality, which can be loaded and unloaded at will. The extensions can be thought of as system modules. A scripts or group of scripts make up a logical function to execute a certain task. One script always belongs to one extension.

Data Dictionary Tables

The Data Dictionary tables are *class*, *attrib*, *codes*, *rel*, *access* and *method*. In the field descriptions below, key field (must be unique) is marked with asterisk (*). This field is used also as dictionary key, which is described later. If the field is HIS-specific (defined in the HIS GeoCASE initialisation file), it is marked with (°). DBName is the field name in the tables. The width of the table is the width in GeoCASE.

DD Class table

The Class table is used for getting the information about the object classes and their types. The format of the Class table is described below:

Explanation	DBName	Type	Wid.	Comments
Schema	schema	String	10	Value is either "MAINDB", "METADB" or "SUPPORTDB". This is the Computedby field in GeoCASE.
Name	name *	String	10	Object class unique name.
Screen text	enscrtxt	String	30	Name in English
Description	endesc	String	80	Longer description in English
Finnish screen text	fiscrtxt°	String	30	
Finnish description	fidesc°	String	80	
Swedish screen text	sescrtxt°	String	30	
Swedish description	sedesc°	String	80	
Type of table	classtype	String	30	Value is either "basic", "mother" or "component".
Spatial Layer	isspatial	Boolean	1	
Has generic attribute	havegen	Boolean	1	The GeoCASE field "usean" is used.
Layer Number	layernum	String	10	Layer number is not used in HIS application.
Layer features	features	String	20	Feature types supported for the layer. Used in 'sdelayer' command.
Label fields	labelflds	String	-	Label fields are the most descriptive fields of the class.

DD Attribute table

The Attribute table is used for attribute information for each object class. The format of the DD attribute table is described below.

Explanation	DBName	Type	Wid.	Comments
Name	attrname*	string	10	
Class name	clsname	string	10	
SQL Type	sqltype	string	20	
Width of the attribute	width	string	4	
Number Scale	scale	number	-	
Screen text	enscrtxt	string	30	
Description	endesc	string	80	
Finnish screen text	fiscrtxt°	string	30	
Finnish description	fidesc°	string	80	
Swedish screen text	sescrtxt°	string	30	
Swedish description	sedesc°	string	80	
Code List	codelist	string	30	
Key	iskey	boolean	1	
Mandatory	ismand	boolean		
Unique	isunique	boolean	1	
Validation	validat	string	250	
Default Value	defval	string	250	
Hidden	ishidden	boolean	1	1 when the attribute is not meant to be shown. Used for link fields
Is Static	isstatic	boolean	1	1 when the attribute is not editable by the user.

DD Relation table

The Relation table is used for finding relations (links) between object classes. The format of the DD relation table is described below:

Explanation	DBName	Type	Wid.	Comments
From class	fromcls	string	10	
Name of the relation	name *	string	10	
To class	tocls	string	10	
From attrib. (link)	fromattr	string	10	
To attribute (link)	toattr	string	10	
Screen text	enscrtxt	string	30	
Description	endesc	string	80	
Finnish screen text	fiscrtxt	string	30	
Finnish description	fidesc	string	80	
Swedish screen text	sescrtxt	string	30	
Swedish description	sedesc	string	80	
To-many relation?	ismany	boolean	1	
Mandatory?	ismand	boolean	1	
Part of Key?	isporkey	boolean	1	Part of key relation means that the on of the attributes in class's key is another object's unique id. This is used for composite and link table relations.
Type of relation	typofrel	-	-	Not used

DD Code list table

The Codelist table is used for creating lookup tables for attribute values. The code list table includes the code list names that exists. The format of the codelist table is described below

Explanation	DBName	Type	Wid.	Comments
Code list	codelist	string	30	This is the name of the codelist.
Code text	code	string	30	Name of a codelist value.
Value	entext	number	30	English name
Finnish code text	fitext	string	30	
Swedish code text	setext	string	30	

DD Method Table

The method table is used for storing some integrity checks. The format of the DD method table is described below.

Explanation	DBName	Type	Wid.	Comments
Class name	clsname	string	10	
Name	attrname*	string	10	
English screen text	enscrtxt	string	30	
English description	endesc	string	80	
Finnish screen text	fiscrtxt	string	30	
Finnish description	fidesc	string	80	
Swedish screen text	sescrtxt	string	30	
Swedish description	sedesc	string	80	
Is the method mandatory?	ismand	boolean	1	
Validation for field	validat	string	250	
Method parameters	methparams	string	30	Not used

DD Access table

The access table is used to store access rights to database tables. The format of the access table is described below.

Explanation	DBName	Type	Wid.	Comments Sample
Schema	schema	String	10	Value is either "MAINDB", "METADB" or "SUPPORTDB". This is the "Computedby" field in GeoCASE.
Name	name*	String	10	Object class unique namefwayarea.
Access list	sclass	String	64 ¹	Security access list for the object, e.g. SELECT:VIEWER; INSERT, UPDATE, DELETE:OPERATOR

Data Dictionary Usage

The Data Dictionary is used internally for:

- Finding a list of objects and their types in HIS database.
- Displaying the attributes of different kind of objects.
- Finding the default values of the attributes when editing and storing into the database.
- Validating the values of attributes in editing and storing into the database
- Finding the codelists of the attributes.
- Finding the relationships from one object to other related objects, and the type of the relationship.
- Validating the values of attributes within an object.

National versions of Data Dictionary

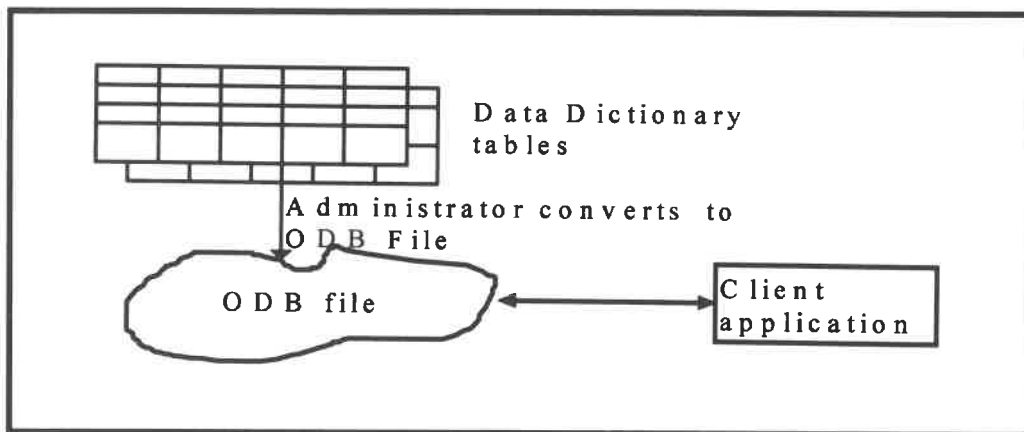
Only one model of the database is used in HIS. Because of that, a mechanism for handling national variations in attributes is needed. The solution has been to add the country code in front of the attribute, for example, FI_Maintaining_authority, where FI_ is the country code for Finland and SE_ for Sweden. Also two fields in GeoCASE are used: HideSWE and HideFIN. The data dictionary creation script notices the national variation.

¹ The default width in GeoCASE for Security Class field is 5 characters. The field width has been extended in hisdb.ini file.

If there is a common attribute but the codelists differ, the attribute has to be changed to national and separate codelists are created for both attributes. National attributes cannot be mandatory, and they cannot have CHECK constraint without allowing NULL (e.g. The constraint must be something like: “(<field> IS NULL) OR (<field> > 0)). The correct version of screen texts and descriptions are selected based on the selected language.

Data Dictionary Implementation

The Data Dictionary implementation is a collection of Avenue *dictionaries* (Avenue Object classes, a kind of hash tables). The Data Dictionary is stored as one dictionary to object tag *dd* in ArcView project. Some DD dictionaries are dictionaries that contain other dictionaries (which can contain dictionaries). The runtime Data Dictionary is read from the text tables, converted to dictionaries and stored to ODB files for faster loading. The Data Dictionary is used in so many places of the HIS application that it is acceptable to keep it in the memory.



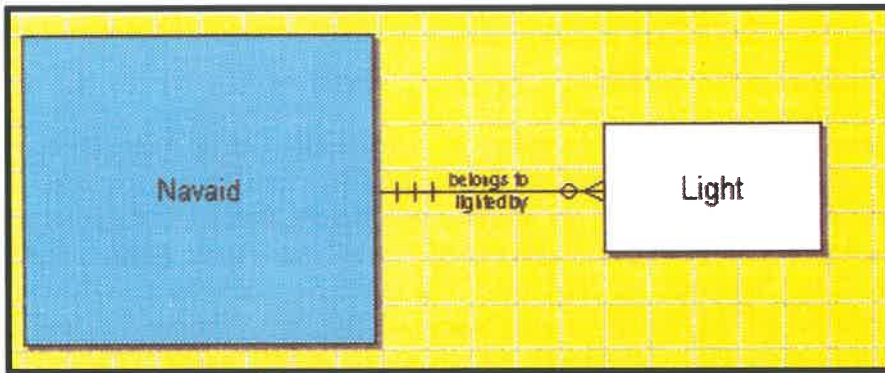
Database Integrity

HIS has strong support for data integrity. Integrity rules have been implemented on many levels: in the database, in the data dictionary, and in a set of integrity rules in the application. This section deals with integrity rules implemented inside the database. These rules apply to data when it is committed to the SDE database.

The database integrity rules are set when the database is initially created. The rules are defined in the GeoCASE database model. GeoCASE supports referential integrity between tables, validation for attribute and basic validation for field values within a table (if there are dependencies within fields in a table).

Referential integrity

Referential integrity is implemented with Oracles FOREIGN KEY ON DELETE CASCADE constraint. It is used with link tables and mother-component -tables (Navaid). An example is Navaid and its relation to component table light.



The relation from Light to Navaid is Part-of-key relation (three tics on the light side). Similar constraint is added to all link fields, which means that if an object from either side of the relation is deleted the links are deleted, too.

Attribute validation

Field validation is a CHECK-clause, which is written, in the attribute's validation field. It is copied to attribute creation script.

Validation within a table

Validation within a is identified by starting the validation name with "test" and "method" for the attribute is set. Validation within a table is implemented as Oracle table check.

Long Transactions

Due to the length of time that may be required to perform complex edits of spatial features in the SDE database, it is necessary to prevent users from copying out features for edit that have already been copied out for editing by another user, but have not yet been returned to the database. By placing locks on the features that are being edited, the system can prevent a second user from checking them out and making edits to an out-of-date version of the feature, or from posting an out-of-date version over the top of someone else's changes

Long transactions are handled on an individual feature basis. Therefore when a user decides to work on a certain area in different layers, all the features which

intersect that area are locked from being modified by other users. Only feature locks are supported. Areas without features cannot be locked for editing and this situation should be handled by the system supervisor.

Object Locking

In a given database there can exist three different types of objects. These need to be considered individually for locking:

- ? *Simple Spatial Features*: These are handled as described above. When the particular feature is locked, the feature id and the layer of the feature is added to the lock table along with other fields describing the lock. When the feature is unlocked, this entry is deleted.
- ? *Non-Spatial Features*: These involve locking non-spatial objects that have no direct relations to spatial features. This is done similarly by storing the feature's unique id, and table name into the lock table.
- ? *Composite Objects*: These are objects that are made up of several different components, either spatial or non-spatial. For these objects, the parent or main object is always a spatial feature. Therefore by locking the feature the same way as you would for a simple spatial feature you would automatically disallow any modification of all the related components.
- ? *Shared Geometry Features*: These are objects that share always the geometry with an object in the same object class or another shared object class. When shared geometry objects are locked, the lock must be extended to next shared geometry object (buffer objects). This is described more detailed later.

Check-out

Checkout means lock and extract selected and related features in the database to the users workspace. It is normally followed by Edit and Commit. Checkout locks features, not areas. It is an administrative task to keep track of that two operators are not working on the same area editing the same object classes. The Job rough polygon can be used for this purpose. Check-Out is based on Selection Set, i.e. the user must select the feature objects in a DBTheme prior to the checkout.

The active object class(es) and object classes having shared geometry with the selected object class will be locked for editing for the user. Composite objects (Navaid) are locked by locking the parent object. If the user is planning to edit the relation or related (attribute relation) object, the related object(s) must be selected for editing, too. There is no automatic locking of related object(s) or relation(s). Locked features are extracted to edit data set (workspace). An extra column, edit status, is created to shapefiles to indicate if feature is buffer feature

(indicating that it cannot be edited) or not. The same column is used in editing to indicate if the feature is new, modified or deleted.

Features having shared geometry with features selected for editing will be locked from all users including the active user (the user who checks-out the features). These features which no one is allowed to edit are so called buffer features. In the editing they can be used for binding the features to the "outside world". The buffer features ensure that the connection to features in the "outside world" is not lost.

Check-In

Check-In enters HIS feature and meta data into the database. If the data was previously checked-out from the database, Check-In is the final step of a *long transaction* (editing) where data is checked back in again. Check-In is used in the commit extension.

Commit itself is a *short transaction*. It is an atomic operation, which means that either all data or no data goes into the database. If commit fails, no data will be stored to database. The result of commit is unsuccessful or successful. The commit fails, if SDE transaction was not successful. Successful commit of feature data will update the MultiScale Transfer Queue and stores information about the added modified or deleted features to SUPPORTDB.COMMFEAT table. Commit reads data from shapefiles in the users workspace (data set). Commit has the following steps:

1. *Sort the Vtabs.*

Because of the mandatory relations, the object classes must be stored to the database in such an order that the object class which has mandatory relation to some other object class (like from Light to Navaid), must be stored after that another object class. The Vtabs to be stored to database are sorted based on the amount of mandatory relations they have from other object classes. The more they have mandatory relations from other object classes, the earlier they are stored to database.

2. *Start the short transaction.*

The short transaction (SDEConnection. BeginTrans) is started before any modifications to the database are done.

3. *Deleting deleted features.*

When an object is deleted during an edit session, its edit status field gets value 3 (deleted). Notice that only features which were originally in (and

which have been checked out from) the SDE database are marked as “deleted”. These features are deleted when they are checked back in to the database. The previous version of the feature goes to the corresponding history table. If a composite object (navaid) is to be deleted, only the mother object is deleted, the components are handled by the RDBMS. The same applies to link tables. *Supportdb.commfeat* is updated and the object id:s are collected to a list for releasing the objects.

4. *Adding new features.*

When shapefiles for object classes are created, a extra column, edit status, is created. This column has value 1 (“new”) if the feature is a new. When composite objects are added, first the mother component have to be added and then the child components. This is handled by sorting the Vtabs described earlier. *Supportdb.commfeat* is updated and the object id:s are collected to a list for releasing the objects.

5. *Replacing modified features*

Modified features get edit status value 2 (“modified”) if they have been checked out from the database. These features are replaced in the database, when checked back in. The previous version of the feature goes to the corresponding history table. *Supportdb.commfeat* is updated and the object id:s are collected to a list for releasing the objects.

6. *Collecting the object id:s of not-touched object.*

During the checkout, some extra objects may have been locked. These are marked with edit status values 4 (not touched) and 9 (can’t edit). The object id:s of these objects are appended to list of objectids to be used when releasing the objects.

7. *End the short transaction.*

If the commit went ok, transaction is committed. Otherwise the transaction is rollbacked.

8. *Releasing the locks.*

When the data was checked out for editing, a long transaction was started, and the features were locked. If transaction was successful, these locks are released and the long transaction is finished. During commit processing the list of objectid:s for deleted, modified, new, or not touched objects is created.

This information is used when the locks are released. Notice that unlocking is outside of the short transaction of database modification. This ensures that the failure of unlocking doesn't cause the failure of modification. Unlocking can be done at later time by the database administrator.

Geodetic database

Geodetic database, GDATCOMP, is set of tables geodetic information, like co-ordinate system, ellipsoid, projection and datum conversions. The three logical main components that GDATCOMP tables store are 1) Geographic Co-ordinate systems, 2) Projected Co-ordinate Systems and 3) geodetic transformations between Geodetic Co-ordinate Systems.

Editing HIS Data

The edit tools will be responsible for most of the processing of new Hydrographic data and the updating of existing Hydrographic data. HIS feature editing is object based. The edit tool initiation is co-ordinated by the Object Catalogue Data Dictionary to present to the edit operator the dialogs and tools necessary to process particular types of objects.

The appropriate line, point or polygon tools to edit geometry are made available depending on the data type of the object class. For some complex object classes, additional special purpose geometry tools have implemented. Attributes are edited through a Data Dictionary based Object Management Form (OMF). The OMF provides an object-based View of feature attributes, and relations. In addition, it provides links to object meta data.

HIS edit tools work on shape files. In order to edit HIS features permanently stored in SDE, these features first have to be checked out to shape files. This is handled in the checkout-checkin module. When external data is imported into HIS, it is converted from external file formats into shape files before editing takes place. New data entered through screen digitising, keyboard, or digitising tablet is stored to shape files.

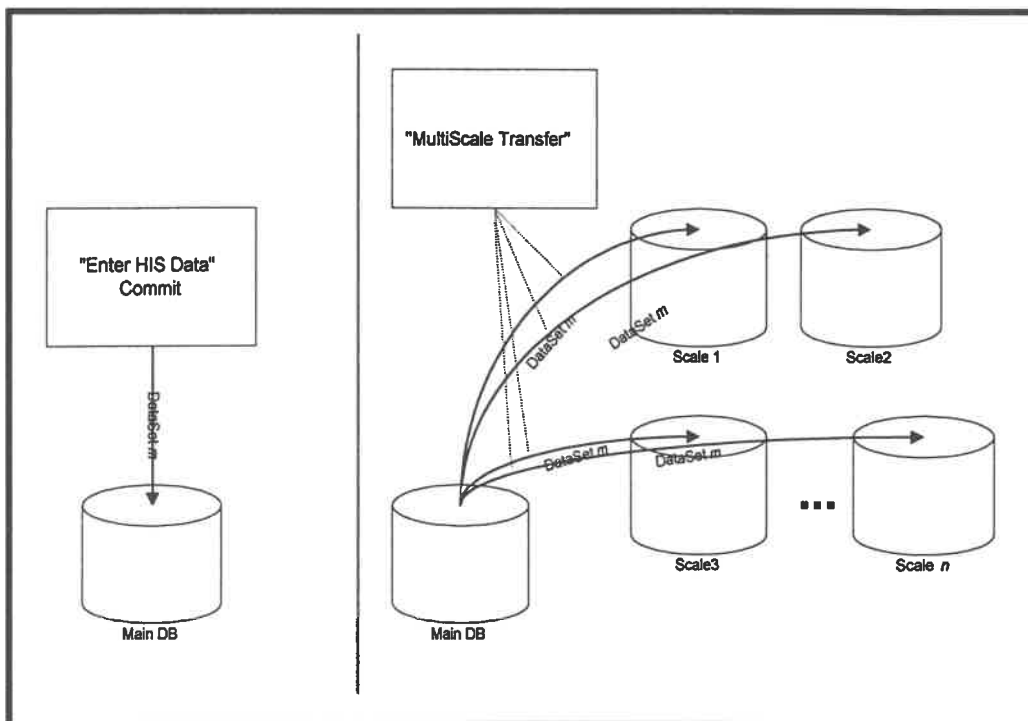
HIS editing is normally controlled for job management. A job describes the pre-defined steps (processes) necessary to perform a certain task. The edit tools are made available in the edit process of job types "Enter HIS data", "MultiScale Management", and to a limited extent "ENC production". Limited edit functionality is also made available in data input processes, currently the input process of "Enter HIS data". During input and edit processes the Edit subsystem is integrated with the Meta Data Management sub-system to ensure that the link between feature data and meta data is established and maintained.

Principle of database editing/updating

As a rule, the databases are populated according to the following principle:

- The meta data (source and data document information) is entered, and committed to the meta database. This is achieved through the Registration Utility.
- The features are entered, and committed to the main database. Meta data may be edited. This is achieved through the ENTER HIS DATA jobtype.
- The features are transferred (copied and generalised) to the scale databases. This achieved through the MULTISCALE TRANSFER jobtype. The meta data is not updated at this point.

It is possible to override this general rule, and commit feature data directly to one of the scale databases. This is of interest mainly when the data is of insufficient quality for the main database. Individual features, which have been committed to the main database and are transferred to the scale databases, will be represented by one feature object in each database. They do, however, share the same meta object. A new data set gets committed to the main database of the HIS, and transferred to all Scale Databases. One Multiscale job is required for each Scale database.



Meta Data Management

Metadata utilities

There are two metadata related user utilities:

Meta data user utilities

Utility	Functionality
Registration	Registration of new meta data (sources and data documents)

Metadata is involved in all input/edit activities, and it is required that an active data document is set whenever data is edited in an ENTER job.

Enter HIS Data

The entry of new data and the modification of existing data in the HIS database is controlled by a set of pre-defined, mandatory steps called the ENTER HIS DATA jobtype. New ENTER HIS DATA jobs can be initiated from the utility for Source management. By default the ENTER HIS DATA job has the main database as the target database, but this can be redefined by the user in job creation phase. The data can also be entered directly to one of the scale databases.

Processes of the ENTER HIS DATA job type

Process	Explanation
Input	Data input to job workspace. Conversion of data from external formats to one common format (shape files) or digitising.
Edit	Edit of workspace data files.
Validation	Visual checks, inspection and approval by an independent person
Commit	Commit of data to the target database (default: main database). Updating the transfer queue.

Input

The purpose of the Input process is to build the processing data set. During the Input process the features are stored to shapefiles in the job workspace and they are presented as themes in the view. Data input to OC themes is stored to the

\data directory of the workspace. Data input to draft themes is stored to the \draft directory of the workspace. All input functionality requires an active datadoc setting.

Edit

The purpose of the Edit process is to allow the Operator to edit the data, to integrate it with the existing data in the database, and to run quality checks on the data. The Edit process operates on shapefiles stored in the local workspace, with a backup copy on the server. During the Edit process data which is affected by the new data must be checked out from the target database. The affected data includes features of the same object class as the new features, but also features, which share geometry with the new data or are related to the new data through integrity rules. The checked out features are added to the dataset.

Validation

The purpose of the Validation process is ensure that an independent person examines the data before it is being committed to the HIS database. Editing of data is not possible. An entry condition for the process is that the person owning and starting the process is different from the person who did the previous processes. The implementation of this condition is based on workflow application login user.

Commit

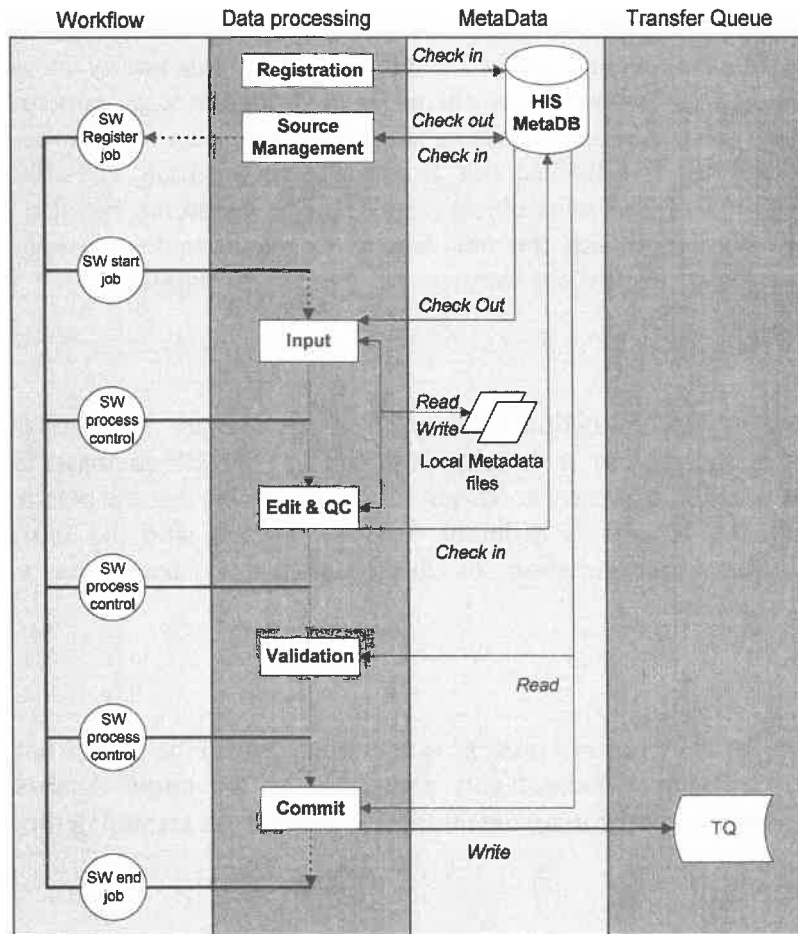
The purpose of the commit process is to commit (store) the feature data to HIS database. An accepted dataset gets committed to the target database. After successful commit to the main database, new records are created in the Transfer Queue.

Multiscale Transfer

The scope of the MultiScale Transfer jobtype is to provide functionality to maintain consistency of information between the main database and the scale databases of HIS. The transfer of data from the main database to the scale databases is controlled through a Transfer Queue. When data is first committed to the main database, references to the data are stored in the transfer queue. The references are based on the ID of the job, through which the data was originally entered to the main database. Additionally there is a database table which keeps track of each feature in a transfer queue record and its modification status in the enter job. The principle is that each feature in the main DB and its modification is copied to the scale databases if the operator deems that appropriate. The original feature ID is not maintained for the copied features.

The transfer of data from the main database to each of the scale databases is controlled by a set of pre-defined, mandatory steps, called the MultiScale jobtype. New MultiScale jobs can be initiated from a supervisor utility for MultiScale management, by selecting entries from the transfer queue.

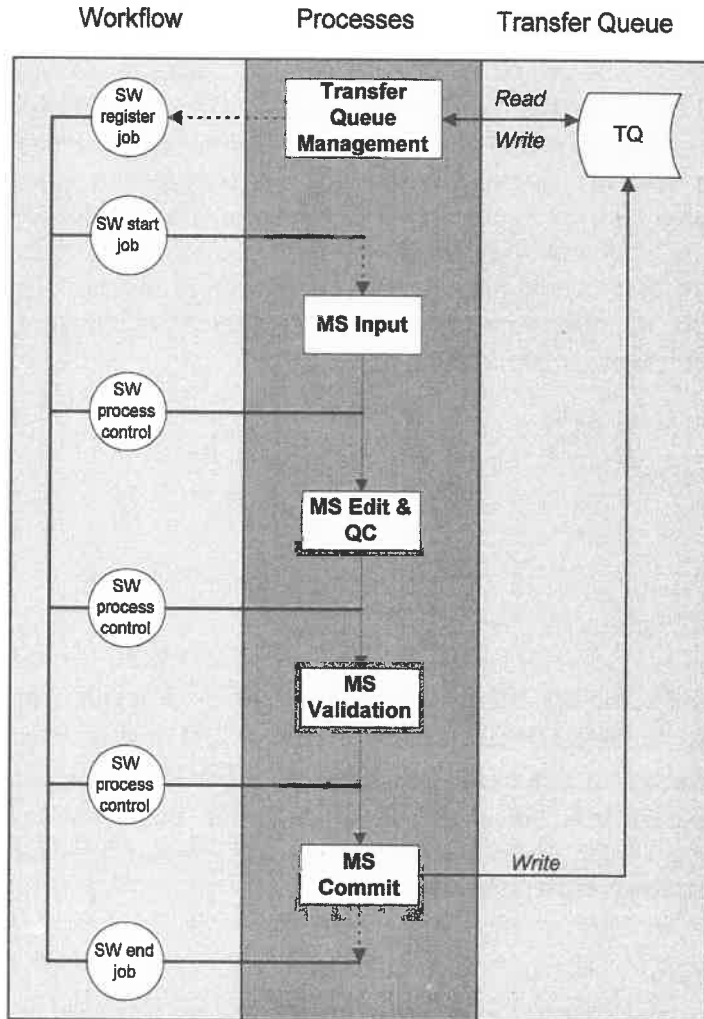
ENTER job flow diagram



Processes of the MultiScale jobtype

Process	Description
MS Input	Retrieval of data from the source database, based on reference in the transfer queue,
MS Edit	Edit and generalisation of the data
Validation	Visual inspection and approval by an independent person
MS Commit	Commit of data to the Scale Database. Updating the transfer queue.

MultiScale job flow diagram



Reference System Transformations

All data input functionality handles transformations of geodetic reference systems on-the-fly, based on information in the active data document. In most cases the geodetic transformation is needed as reference. HIS supports more than one geodetic transformation between two geographic co-ordinate system. The idea behind this is that the transformations may be different in different parts of the country, or they may change during the time. Another major task for the geodetic database is to save all the information needed to do projection and datum conversions. Projection or un-projection is needed when the source or target co-ordinate system is projected co-ordinate system. Datum conversion is needed when the source or target system is based on different datum than the database co-ordinate system.

Shared Geometry

If two or more features are sharing geometry it means that they have a set of points with the same co-ordinates. The concept of shared geometry editing originates from the fact that there is *no stored topology* in SDE or Shapefile data structures. The features are stored individually and there is no information about the neighbours or features sharing co-ordinates. In HIS there are object classes which have *mandatory*-shared geometry between them. These object classes are referred to as skin of the earth object classes. The skin-of-the-earth object classes form a continuous, non-overlapping and non-intersecting surface. The skin-of-the-earth-concept is the fundamental basis for all topological integrity checks. The skin-of-the-earth object classes are:

- Depth Area.
- Generic (Land) Area.
- Depth Contour.
- Coastline.
- Closing Line².

All skin-of-the-earth object classes are either line or polygon type, so the geometry sharing is two-level (between 1-D and 2-D feature types³). The polygon object classes in skin of the earth are defined by the line object classes. The geometry of polygons themselves is not editable, but must be modified through the editing of the lines. These lines editing tools (in the edit feature dialog) support shared geometry editing:

- Add line.
- Delete line.
- Vertex editor.

Shared geometry is also supported in:

- Co-ordinate Form.
- Copy/Paste Special.

The lines defining the shared geometry polygons must always close. If an area does not otherwise close, the operator must explicitly close it using with a line feature of the Closing Line object class.

² Closing line is used for closing areas (like the country border line), or closing lines in some cases.

³ Shared geometry can be between feature types of any dimension. For example, shared geometry between 1-D and 0-D feature types is fairly common. This kind of shared geometry doesn't exist in HIS.

Integrity checking

The goal of the integrity checks is to make sure that the data (in the workspace as shapefiles) is correct before it is being committed to the database. The integrity check tool is implemented as a stand-alone tool in the client application. It is meant to be used in the editing process, perhaps in an iterative way, but also in batch mode, thus checking integrity within the whole database. The integrity check tool handles all kinds of integrity checks, as defined below. Additionally, internal integrity checks are implemented in the Object Management Form. Thus, the user is prevented from entering data out of range or of the wrong data type already when doing the attribute editing. The internal integrity checks are implemented also at the database level (during commit of the data), as ORACLE CHECKS and TRIGGERS and SDE feature type checking. This low level checking ensures that incorrect data cannot be stored to the database. The checks are divided into 5 groups :

- Internal integrity: Attribute values.
- Integrity between objects: Dependencies between objects (mostly Navaid and its components).
- Geometrical relationships: Relationships, which cannot be expressed using topological checks.
- Topological integrity (relationships): Several types of topological relationships.
- Shared geometry (Skin of the Earth).

Importers - Which importer does HIS support?

The external file types supported by HIS are listed in the table below. Importers supported by HIS

Name	Used in	Description
IRAP	SMA	Soundings, depth contours.
FINGIS	FMA	Map production system.
KATUS	FMA	Special polygon transfer format for FINGIS.
GINIS	SMA	Map production system.
S2	FMA	Soundings, binary format
S2 HAF	FMA	Soundings, depth contours, ASCII format
FAREG	SMA	RDBMS, Navaid and related info.
VATU	FMA	RDBMS, Navaid and related info.
VARE	FMA	RDBMS + .dgn files, survey data.

System architecture

Imports consist of the main Import extension and many specific importers. The main Import extension provides the user interface and drives the importers. It is designed so that it allows collecting the source systems and their parameters to the list, defining the parameters for them and then processing them in a loop.

When is the import functionality available?

Import is designed so that it can be used inside a job or outside of it. When it is used outside of a job, the user can import the data to the directory he or she wants to. When import is used inside a job, the data should be imported to the job workspace but it is still possible import the data to the directory she wants to.

ENC Production Line

The ENC production line is an application to produce Electronic Navigational Charts (ENC's) from the HIS database. S57 is a data standard developed by the International Hydrographic Organisation (IHO) to be used for the exchange of digital Hydrographic data. The ENC production line contains functionality to:

- Create, modify and delete ENC cell definitions.
- Produce ENC base cell files = EN.
- Produce ENC update cell files = ER.
- Define standard and non-standard product types.
- Manage ENC cell metadata.
- Manage ENC production jobs.

The ENC Production Line is HIS OC version 5.3.4 and S57 version 3 compliant. The ENC production line supports export of all HIS object classes, which can be translated into those S57 object classes, which are permitted for use in ENC. The translation is based on mapping documents HIS-S57.

Software requirements

The ENC production line requires:

- Basic HIS software. See section 1.
- ARC/INFO 7.2.1
- Four (4) additional ARC/INFO executables.

ENC definitions

ENC Product types

The Product Type defines which object classes to include in the output ENC cell. A Product Type is unique for each scale database. It is possible to define product types with the same name for different scale databases. The product types are defined in the ENC Product Definition Utility.

The system supports the Standard ENC product type, as well as user defined (non-standard) product types. The Standard product type contains all HIS object classes, which are allowed in ENC files. User defined product types can contain any sub-set of object classes from the Standard Product Type.

Navigational purpose and Scale Databases

The mapping between ENC Navigational Purpose and HIS Scale databases preloaded according to the following definitions:

Code	Navigational Purpose	ScaleDB
1	Overview	Generaldb
2	General	Generaldb
3	Coastal	Coastaldb
4	Approach	Coastaldb
5	Harbour	Specialdb
6	Berthing	Specialdb

ENC workflow

Utilities and Processes

The ENC production line has two utilities:

Utility Name	Functionality
ENC Product Definition	Define ENC Product Types and Cells
ENC Create Job	Create ENC Jobs

The ENC job type is composed of three processes:

Process Name	Functionality
ENC Input	Read HIS data and translate HIS-S57 object catalogue
ENC Edit	Optional editing of geometry and scamin attributes. Mandatory geodetic datum conversion.
ENC Convert	Convert to S57 compliant files

ER production

The decision to make an EN or an ER cell is taken when the ENC production job is created. ER files can only be produced for ENC cells, which already have EN files.

Exporting Data from HIS

Extracting data from the HIS database (SDE) to shape files can be done in two different ways:

- **By plain copy-out of selected DBTheme features in the view**
- Based on a product definition.
- Further the shape files can be exported to external file formats. The exporters work on shape files in the view.

Copy Out

Any data in the database can be copied out the shape files, using the copy-out menu choice. The copy-out menu choice applies to all features selected in from the DBThemes in the view. The features are stored to shape files.

Product Definition

Implementation principles

The product definition utility is a first step towards a chart production system for HIS. Product definitions, which include scale, spatial extent, and object classes, are managed primarily by a product definition database table. There is one product definition per output chart. The scale of a product definition defines which scale database in HIS the data should be retrieved from. Based on the product definition, data for a specific output product can be retrieved from the database. The data is loaded to themes in the view. From the view, the data can be exported in any format supported by the HIS exporters.

Functionality

The HIS supports the following product definition functionality:

- Create new product definition (= new record in metadb.productdef)
- Update (edit) product definition
- Delete product definition
- Extract data for a product definition

Data for a product can be extracted to shapefiles, based on the product definition. Object classes to extract are defined in the product definition product type and can be added or deleted. The user selects a directory for the storage of the shapefiles.

	Extract data for a product
Functionality	Extract data for a product definition
Meta Data	Metadb.Productdef, metadb.Producttype, metadb.Objclasses
Input Data	Product Definition(s)
Output Data	Shapefiles

Export

Which exporters does HIS support?

The following table lists the export formats of HIS.

Name	Used in	Description
IRAP	SMA	Soundings, depth contours.
FINGIS	FMA	Map production system.
GINIS	SMA	Map production system.
S2 HAF	FMA	Soundings, depth contours.

System Architecture

The HIS export extension contains one Export dialog and the scripts associated with it, as well as format specific exporters. Export is divided to main dialog and extension running it, and separate system specific “workhorses”, the exporters. Exporting to the system transfer format is done by the system specific exporter. This exporter uses the system specific mapping to map from HIS objects to system feature types.

Session V

**Protection of the marine
Environment Hydrography,
Contract Work**

BUILDING A NATIONAL INFRASTRUCTURE FOR MARINE INFORMATION ACQUISITION & MANAGEMENT - A CASE STUDY

Terje Lund Henriksen

Abstract

Indonesia, as an Archipelagic State, under the terms of UNCLOS '82, has the right to designate Sea Lanes for "continuous and expeditious" passage of foreign shipping through its waters and the adjacent Territorial Sea. At the same time the State has an obligation to accurately chart such Sea Lanes and to facilitate safe navigation by the publishing of appropriate and correct charts.

The UN Convention on the Law of the Sea 1982 is ratified by Indonesia by Law No. 17/1985 and has been effective since 16 November 1994. As result of Indonesia's ratification of UNCLOS '82, Badan Koordinasi Survey Dan Pemetaan Nasional (BAKOSURTANAL) was appointed as the executive Indonesian agency to carry out the Digital Marine Resource Mapping Project within Indonesian Waters in order to produce completely or partially updated charts in the following scales.

- 1:1.000.000 for the EEZ and the Continental Shelf.
- 1:200.000 for the Baselines and the Territorial Sea.
- 1:300.000 covering the Sea Lanes.
- 1:100.000 covering the Sea Lanes for designated areas.

In addition, to carry out Verification Surveys of a total of 233 Archipelagic Basepoints, including complete re-survey of 70 Basepoints, in accordance with Internationally accepted guidelines as defined by IMO and IHO, and as laid down in UNCLOS '82. In order to reach these goals BAKOSURTANAL signed a contract with Blom ASA Norway, to carry out the following activities:

- Build up expertise in BAKOSURTANAL to fully supervise the implementation of the project.
- Establish a Network of Satellite Reference stations in order to produce Pseudo Range Corrections (PRC), to be used for Differential correction of positioning for the survey vessels.
- Define the Indonesian Coastline, of approximately 81 000 Km, by a combination of Airborne laser bathymetry, Satellite remote sensing,

Digitising of acceptable existing analogue data (maps or charts), Aerial photography or Existing digital data where available.

- Establish a total of 25 Standard Port Tidal reference Stations Equip three Survey Vessels with Multibeam echo sounders, DGPS (Differential Global Positioning System) as well as with satellite communication equipment.
- Operate one vessel supported by a Bell 212 helicopter to carry the airborne Laser survey for the Shore-Line and Basepoint measurements.
- Procure, install and tailor hardware and software, for a National Marine Resource Database.
- Establish a primary Satellite based Communication system between the vessels and the Project Production Centre.

This *outlines* the considerable contribution of the Digital Marine Resource Mapping Project to fulfil Indonesians obligations to UNCLOS '82.

DMRM Overview

The DMRM Project (Digital Marine Resource Mapping of Indonesian Waters) was born from the Indonesian government's desire to adhere to internationally accepted standards while complying with UNCLOS '82 (the 1982 United Nations Convention on the Law of the Sea), which came into effect 16th November 1994. This allows a state to declare itself as an Archipelagic Nation providing certain criteria are met. It also recognises a limit of the Territorial Sea of up to 12 nautical miles, and ratifies the concept of the EEZ (Exclusive Economic Zone). Under this concept, Archipelagic Nations possess sovereign rights to explore and exploit all the resources of the sea-bed, the subsoil and the water column out to a distance of 200 nautical miles from the Baselines, which determine the Territorial Sea, the EEZ, the Contiguous Zone and the Continental Shelf.

Moreover all such nations are obliged to facilitate safe and expeditious passage in designated Sea Lanes through its waters and to maintain environmental monitoring and control mechanisms. For Indonesia, which has a total marine area of some 5.8 million km², this is clearly a major undertaking. Blom Dantarsa Co, with its wealth of experience and technical resources, has accepted the challenge and is helping to fulfil the obligation.

The Project Production Centre (PPC) was established at Kemang Raya in Jakarta and staffed by 16 expatriates (each one an expert in his own field) and 61 Indonesian Counterparts and ancillary personnel. All data processing and production of both paper and electronic charts was completed here, in addition to the development of the National Marine Resource Database (NMRD). PPC was

also the Hub of the computer and satellite communications network and monitored and processed data received from the Project's tidal stations, satellite reference stations and survey vessels. Additionally it was the administrative centre for the vessel operations, logistics and management of the PPC based personnel and the further 74 expatriates and 15 Indonesians employed on the Project's survey vessels.

Swath Bathymetry surveys were performed by three vessels Baruna Jaya 1, 2 and 3, through the designated Sea Lanes and around the EEZ using state-of-the-art techniques. Multibeam Echosounders.

Airborne Laser Bathymetry, was performed using the SAAB Hawkeye system, mounted on the Project's Bell 212 helicopter operating from helicopter support vessel Kri "Multatuli".

The Indonesian Coastline has a length of approximately 81,000 km. The coast of Java, Bali, Nusa Tenggara and South Moluku was derived from existing digital information. More than 300 accurate analogue maps covering Sumatra, Eastern Kalimantan and Sulawesi, were digitised or retrieved in digital form where available. The remaining 46,000 km was covered by airborne Laser Bathymetry, which maps the shoreline as well as depths to a high degree of accuracy and Radarsat (shore line only). This information was essential for the Verification of Basepoints, through which the Baselines were drawn. This operation was supported by a fifth vessel Kri "Dewa Kembar", equipped with a helicopter for access to remote locations.

LAT (Lowest Astronomical Tide) is the established vertical datum for tidal reductions as recommended by the IHO. Tide Gauges, installed at 25 Standard Ports, provides information for tidal analysis and data reduction.

WGS84, which is internationally accepted and also recommended by the IHO was the horizontal datum for all charts. Hence, six DGP's Reference Stations were installed to establish a permanent DGPS (Differential Global Positioning System) network. These stations were referenced to the National Zero Order Network and transmitted DGPS corrections via satellite link.

The NMRD (National Marine Resource Database) was constructed to serve as Indonesia's national data hub for marine resource information. Expert and financial resources were allocated to configure the infrastructure at all marine associated institutions. The mandatory part of the S-57 object catalogue deemed by the IHO was the basis for data modelling of all the relevant databases. This allows the automatic production and update of ENC's (Electronic Navigational

Charts) and facilitate the publication of Paper Charts requiring very little manual editing.

Vessel Traffic Surveillance will be installed during Phase II of the project in the most critical areas of the sealanes, particularly the Malacca Strait, the Singapore Strait, the Sunda Strait, the Lombok Strait and the Ombai Strait. These will monitor the movement of vessels in any given area to ensure compliance with local traffic regulations and provide safer navigation. They will also aid in the protection of the local environment and provide a data network to authorities of any particular port or coastal region for administration, research and planning purposes.

Sealanes

As an Archipelagic State, Indonesia has the right to designate Sea Lanes for “continuous and expeditious” passage of foreign shipping through its waters and the adjacent Territorial Sea. Consequently the State has an obligation to accurately survey such Sea lanes and to facilitate safe navigation by publishing appropriate and correct navigational charts.

Sea Lane ALKI I starts in the South China Sea west of Kalimantan and goes southwards through the Java Sea and the Sunda Strait, into the Indian Ocean.

Sea Lane ALKI II starts six nautical miles north of equator between Kalimantan and Sulawesi. It heads southwards through the Java Sea and passes through the Lombok Strait before entering the Indian Ocean.

Sea Lane ALKI III divides into three sections after the first common section, which starts in the Maluccu Sea and heads southwards into the Banda Sea east of the Maluccu Islands. From here it proceeds as follows:

- Southwards through the Banda Sea towards Timor Island heading south-westwards into the Indian Ocean.
- Southwards through the Banda Sea, east of Timor Island into the Timor Sea.
- South-eastwards to the south of the Maluccu Islands into the Arafura Sea north of Australia.

Exclusive Economic Zone and Continental Shelf

In accordance with UNCLOS '82 an Archipelagic State can extend the Exclusive Economic Zone (EEZ) up to 200 nautical miles and the Continental Shelf (CS) up to 350 nautical miles from the Baselines drawn between Basepoints on its coastline. The State has jurisdiction over all installations and artificial islands

and sovereign rights to exploit the natural resources contained therein. It can also regulate marine scientific research and has responsibility for protecting and conserving the marine environment.

Basepoint Verification

A Basepoint is the outermost extent of land with an altitude of zero based on LAT. Its position was determined by range and bearing from a concrete Basepoint Monument using a Wild TC1700 Total station. The Basepoint Monument's position was verified by GPS carrier phase measurement simultaneously with two predetermined zero order Geodetic Reference Monuments using Trimble 4000SSI GPS receivers to form a triangle of observable vectors.

There are 233 Basepoint Monuments around the exterior coastline of the Indonesian Archipelago. Many were in remote and inaccessible locations and the shore teams carrying out this operation spend many days campaigning in the bush. They were transported to most locations by either helicopter or small launches and supported by the helicopter vessel Kri "Multatuli", which also was involved in the Laser Bathymetry operation. This operation was supported by a fifth vessel Kri "Dewa Kembar", equipped with a helicopter for access to remote locations.

Tidal Analysis

Tides are caused by the gravitational influences of the moon and the sun, which create tidal waves. These waves have periods of about 12 and 24 hours. The water movements are affected by the Earth's rotation and the land masses and are therefore different for each location.

One reason for monitoring tidal behaviour was to establish vertical datums from which heights and depths for both hydrographic and land surveys could be measured. It was also to facilitate accurate tidal predictions to allow safe navigation in harbours and shallow areas, and assisting in planning of coastal zone management.

Standard Port Tide Stations were established for the DMRM Project at 25 locations throughout the Indonesian Archipelago. These stations were equipped with SM5075 logging hardware with a storage capacity of 10 days. Tidal records were stored at 10 minute intervals based on observations taken every 15 seconds. Barometric pressure observations were recorded hourly and a level switch was provided for quality control purposes. This data was automatically collected daily by the PPC via telephone modem.

WLR7 Tidegauges with a 3 months storage capacity for tidal observations records at 10 minute intervals were used by the DMRM Project. These both deployed from the survey vessels onto the seabed in the survey areas and retrieved using a system of acoustic releases and oceanographic buoys. This data was complemented by barometric pressure observations made hourly onboard the vessels. The information was then transferred via the satellite link to the PPC for processing.

Tidal Analysis was carried out using the data from the Standard Ports along with data from BAKOSURTANAL's existing network. The aim was to reproduce significant parameters to describe the tidal regime at the place of observation. These 'Tidal Constituents' were based on the assumption that the responses of the oceans and seas to tidal forces do not change with time.

In Indonesia the 'Harmonic Analysis' method was used. Here the sum of a finite number of Harmonic Constituents, whose angular speeds and phases was determined from the astronomical arguments, and used to predict the tides. These were published in official tables containing high and low water times for Standard Ports and constants for adjustment to Secondary Ports.

The Survey Vessels

Indonesia has owned three French built Kal 'Baruna Jaya' research vessels since 1990. Their two diesel engines each deliver 825 horse power, giving a maximum speed of 14 knots and a range 7500 nautical miles at 12 knots. With an overall length of 60.4m and a beam of 11.6m they can accommodate up to 50 persons including the 34 officers and crew.

The DMRM Project utilised these vessels for bathymetric surveys throughout the Indonesian Archipelago. Differential correction signals were received via dedicated satellite link and applied to GPS signals by "Seadiff" to give DGPS positional accuracy of better than 3 meter. Simultaneously the Seapath used the DGPS signals and data from other motion sensors to calculate the exact attitude of the vessel. All this information was fed into the Navipac navigation system and applied to the bathymetric data. Bathymetry acquisition was acquired using Simrad Multibeam Echosounders, logging and quality control was carried out using dedicated Merlin and Mermaid software systems.

Kal Baruna Jaya III was equipped with a Simrad EM12D Multibeam Echosounder for deep sea and reconnaissance surveys of the continental shelf to determine the limits of the EEZ. Kal Baruna Jaya I & II were both equipped with a Simrad EM1000 Multibeam Echosounder for surveying the Indonesian

Sea Lanes. Each Blom Dantarsa survey team was led by an Activity Co-ordinator and comprised of:

- Two Senior Hydrographic Surveyors.
- Two Data Quality Controllers.
- One Navigation System Engineer.
- One Acoustic System Engineer.

Each member of the survey team had an Indonesian 'Counterpart' to enable the transfer of technology, which was an integral part of the Project.

Laser Bathymetry

The Kri "Multatuli" was also employed on the DMRM Project. She is single 5500 horsepower diesel engine gives a maximum speed of 18.5 knots and a range of 6000 nautical miles at 16 knots. She have an overall length of 111 m, a beam of 16m and can accommodate up to 150 persons. Designed with a helideck, she was an ideal platform for the Project's Bell 212 helicopter, to which DGPS signals were transmitted via UHF radio. The vessel was also used to support the basepoint survey teams working in remote coastal locations. Each Blom Dantarsa survey team was led by a Vessel Operation Co-ordinator and comprised of:

- One Senior Hydrographic Surveyor.
- One Senior Geodetic Surveyor.
- One Laser Bathymetry Operator.
- One Laser Bathymetry Engineer.
- One System Engineer.

The Hawkeye Laser System played a key role for the bathymetric survey in shallow water areas (between 5 meter and the Zero line). These areas are normally very time consuming since braking waves make it difficult for traditional survey methods. One of the main tasks for the DMRM project was to survey the Zero line around each Basepoint Monument to identify the Basepoint, which was the basic input to determine Indonesia's Maritime Zones.

SAAB Hawkeye is an airborne laser bathymetry system used for surveying shallow water and coastline. Housed in a pod mounted on the Bell 212 helicopter, it has the capacity to cover approximately 15 km² per hour at high resolution.

A rapid scanner fires laser generated optical pulses of two wavelengths, covering a swath at right angles to the line of flight. The infra red laser is reflected from the water surface while the green laser penetrates the water column. Depth is then derived from the elapsed time difference between the two reflections and the two pulses are polarised to discriminate sea from land. The normal Search Mode scans in front of the helicopter through an arc of 20° from the nadir point. For more detailed inspection High Resolution Mode is used. The helicopter's attitude is established using a laser gyro and the laser pulses are adjusted accordingly to maintain the planned coverage. The scan pattern is displayed real-time and approximately 1 Gb of data per hour is logged onto tape via a UNIX Workstation. Each mission is also recorded on video tape for quality control. All post processing is done onboard the helicopter carrier using dedicated software packages. Only accepted ASCII xyz-data is transmitted to PPC via the satellite link.

RadarSat

What is RadarSat?

Radar is an acronym for RAdio Detection and Ranging. Radar systems were originally developed in order to detect the presence and position of objects using transmitted and received radio waves. Due to the electromagnetic properties of radio waves radar systems are capable of collecting data in nearly all atmospheric conditions, by day and/or night. For this reason they have proven to be useful in a number of applications.

Radar systems were first implemented in the 1930s to detect ships on water and to measure their proximity. Imaging radar systems have been in use since the 1950s. They were originally developed by the military. Radar as a remote sensing tool became more commonly used as military systems were declassified and scientists developed new applications in mapping and resource monitoring.

Traditional mapping techniques for land use and land cover applications using aerial photography and optical satellite imagery are hindered by persistent cloud cover in tropical areas. However, radar data can be acquired at any time since imagery acquisition is not hindered by atmospheric conditions or darkness.

Use of Satellite Remote Sensing in the DMRM Project

For the Digital Marine Resource Mapping of Indonesian Waters (DMRM) the use of Radar Sat has played a key role for the coastline survey. These areas are normally very time consuming and costly using traditional survey methods. A

total of 136 images have been processed and vectorised and included into the Marine Recourse Database. One of the main tasks for the DMRM project was to include new coastline on “Baseline Charts”. Bathymetric survey around each Basepoint Monument to identify the Basepoint and new coastline, is the basic input to determine Indonesia's Maritime Zones.

Area covered by RadarSat

Coastlines	Area (km ²)	Mode	Note
Basepoint- and Sealane chars	496,625	WIDE	Scales 1:200.000=> <i>No. of scenes: 92</i>
High resolution areas in Sealanes	51,651	FINE	For use in chartscale 1:100.000 <i>No. of scenes: 44</i>
Satellite programming			136 images
Courier delivery			Included
TOTAL	548,276		

Navigation

Seatex Seadiff DGPS Positioning System was installed on the three Kal Baruna Jaya survey vessels and Kri “Multatuli”. The positioning system was extracting raw GPS pseudo-range signals from its built in Trimble GPS receiver from a maximum of 8 available satellites. Seadiff was able to decode DGPS data from up to 24 reference stations, and position fixes from up to 12 of these could be calculated simultaneously to provide the primary solution. An integrated solution could be derived by combining data from a set of reference stations. This provides increased accuracy and minimises the effects of temporary errors from a single reference station.

The Seadiff software was also providing an estimate of the quality for the final position solution by using redundant observations. All available satellite data together with external height information was utilised to generate a set of statistical parameters. Prior to position computation pseudo-ranges was all statistically tested for gross errors. Each observation was weighted with regard to the satellite's elevation, the age of the differential corrections, the distance from the reference stations and the rate of change of correction. Ionospheric & tropospheric models could be selected for enhanced performance over extended distances.

Seatex Seapath derives attitude, position, velocity and time information using data from its four GPS antennas mounted on a fixed cruciform bracket on the forward mast. It performs carrier phase measurements and calculates the vessel's movements about its' X, Y & Z axis (pitch roll and heave). Differential signals were used to give a greater degree of accuracy. An MRU (Motion Reference Unit) was also registering the vessel's pitch, roll and heave.

At the same time a Digital Gyro was using the latitude from the Seadiff position to gain an accurate heading. Data from both Gyro and MRU was imported into the Seapath system for calibration and backup. The vessel's motion was then provided both to Navipac for positional calculations and to the Echosounder for beam array adjustment.

Eiva Navipac takes the final antenna position from Seadiff and transforms it to the centre of the Echosounder transducer as a layback position using attitude information from the Seapath. This 'Reference Position' was then transferred to the Echosounder itself. Other inputs were constantly monitored on various Navipac pages to gain necessary information throughout the survey operation. The Navipac was also used to create runlines as well as way points.

Swath Bathymetry

The Simrad EM1000 (Baruna Jaya I & II) was used for water depths down to 1000m.

The EM1000 has wide range of coverage with a normal operating angle of 150° covering up to 7.4 times the water depth.

The Simrad EM12D (Baruna Jaya III) is used for water depths down to 11,500m. This system has two transducers (one transmitting and one receiving) fix mounted on either side of the keel, producing a total of 162 beams. In addition to the operating console, a console also monitors both port and starboard systems

The EM12D is an ocean depth precision seabed mapping system. It has wide range coverage and a maximum operating angle of 150° covering 7.4 times the water depth.

The Simrad Mermaid was used for logging of data, which was converted to the Simrad Survey Format files used by Merlin.

The Simrad Merlin was used to providing real time inspection and quality control of data. The default main window showed survey lines recorded and

IRAP (Interactive Reservoir Analysis Package) was the next stage in the processing. This imports and grids the randomly distributed xyz-data from Neptune and EBI as Freepoints. It then constructs a DTM (Digital Terrain Model) by interpolating values for each grid node from the surrounding Freepoints. When this was complete a contours was generated at chosen intervals by interpolating between these grid nodes.

The NMRD

There has been a major shift in relations between Hydrographic offices and their consumers. The presentation of geographic data by traditional means, such as paper charts, is entirely in the hands of the publishing authority, down to the smallest detail. Geographic information may now be distributed by any electronic media such as CD-ROM, Internet, dedicated satellite links, etc. This information may then be displayed and utilised by consumers in the format of their choice. For example an ECDIS user will visualise his ENC (Electronic Navigational Chart) according to the internationally accepted IHO S-52 Symbolisation Standard.

It is difficult to manage and maintain a database if it includes all the information specific to presentational matters but by extending its structure, Geographical information can be stored with some attention to traditional cartographic presentation required for paper charts, which are just one of the possible products; ENC's, List's of Lights, Tide Tables, etc. being among other possibilities. The NMRD is designed, to meet these new demands and to connect the different maritime organisations in Indonesia. It will be administered and updated centrally by BAKOSURTANAL, which is the authority for mapping and surveying.

The database has been developed using Sysdeco-DIKAS software based upon The Spatial Server. This is a data hub, for managing large volumes of complex geographic and other related information in a seamless form. It is designed to interface the best-specialised tools for geographic editing, quality control, data capture, processing and production. Processed survey data output from IRAP was directly imported into the NMRD via The S-57 Gateway using the DIXI file format. This is an ASCII file type, which is able to contain data linked to any object catalogue.

Other Source Material will be needed to supplement the data being gathered in the survey areas. Items such as existing navigational charts and lists of navigational aids are collected from the various authorities and scrutinised for their reliability.

Existing charts are scanned to raster format and datum transformed before being digitised using Chart Toolbox. This is a system for vectoring and updating digital charts according to the IHO S-57 Standard. With this system the monitor screen is used as a digitising tablet with the raster as a background. Data can then be digitised quickly and accurately using an integrated automatic line following routine. Full topology can also be created during this process.

Alternatively digitising can be done manually on digitising tables using Micro Station Software. Other textual information is collated and entered into spreadsheet format before being imported via the Gateway. Because the complexities of the real world it can not be fully represented and stored in digital form, a simplified data model is used. Object geometry is represented on one level over which is the user configurable data model. This performs an interface with terms and rules in the real world by describing the structure, identity, attributes and operation of objects, and their relationship to others.

The Object Editor is designed to adapt the model for any object catalogue which in this case is configured strictly according to the latest IHO S-57 Standard for Transfer of Digital Hydrographic Data. This standard states, for example, how a coastline must be encoded according to its characteristics. Using this tool each object class defined in the user data model can be viewed and may have its attributes configured and revised individually so that scaling and symbolisation can be controlled for each instance of that object.

The Object Editor can also, edit geometry and topology, connect to and share geometry of other objects, transform co-ordinates and make verification queries on the data. Moreover it records the update history of each object. In this way the IHO symbolisation is set up according to the references in the S-57 object catalogue.

Vector symbols can be created and configured for presentation using a Symbol Editor and these are stored in a library for later use. A Presentation Configuration Tool sets the required parameters and provides a very flexible way of controlling the presentation of a selected area from the database as an ENC with the Preview and Plotting Tool.

Production of ENC's

Because data within the NMRD was collected and maintained according to S-57, ENC's can be exported via the S-57 Gateway without the need for further editing or filtering. This so called EN Cell can then be read directly into an ECDIS system.

A unique identifier defines all geographic objects in an ENC, updates may be performed automatically. Moreover, as the Object Editor records the update history within the data set, it is possible to export only the latest updates of a chart as a so-called ER Cell. This kind of updating is also a crucial part of the S-57 Standard.

Paper Chart Production

The DMRM Project was required to produce 113 paper Navigational Charts complying to IHO standards.

MapInfo Professional was used for the production of Paper Charts. Data from the NMRD was exported as S-57 object files. MapInfo has been developed, in-house, to import these files as MapInfo tables which, by the addition of tailor made symbol sets automatically created an INT I chart, complete with borders and all the chart data. At this point the cartographer will need to perform some minor cartographic editing to make the chart less cluttered this editing is completed in MapInfo so that it is possible to export the edited data back into the NMRD, retaining the cartographic editing information applied manually. This should amount to about 5% of the total work being done manually. After final cosmetic editing in Adobe Illustrator the chart is ready for output in Postscript format already separated into the four chart colours required for printing.

The Postscript files were converted into raster format by advanced “RIP” technology. These were then processed by an Image Setter to produce full size, fine resolution films for each of the four chart colours. The four films were then used to manufacture the required lithographic printing plates. This means that the next time the chart is exported, much of the manual work performed on the previous edition will already be applied and only matters related to the cosmetic appearance of different scale charts will need to be considered.

Training and Technology Transfer

Introduction

As part of the contractual obligations and the general policy of Blom Dantarsa’s parent company, Blom ASA, there is a strong emphasis on training of local personnel, and technology transfer.

The methods, teaching aids, materials, training libraries, etc, were constantly being improved and refined in an effort to ensure maximum efficiency in this field, and in the end the project it is felt that the Training and Technology

transfer was a successful and continually evolving enterprise which was producing well trained local personnel.

Obligations

The training was an integral part of the project both as “on the job” training and through seminars and courses. The Project Implementation team designed and executed relevant training programs, suited to actual requirements.

All Offshore counterparts engaged in the project were subjected to necessary onshore training in basic Geodesy and training in operation of the specific system/equipment related to their individual tasks.

The On-shore counterparts were trained in Database management, manipulation, and digital map production, which was an integral part of the establishment of the National Marine Resource Database.

Implementation

The initial familiarisation programs run at PPC have been successful and achieved good results. Personnel who have attended these introductions are properly prepared to advance through the system and fully benefit from further training.

Training Aids

As a result of a policy of continuously upgrading the reference libraries available to the counterparts, a good selection of material was available. These libraries were built up with materials sourced through PPC, items acquired by individual members of the project, and the counterparts themselves also sourced material written in Indonesian.

A set of basic study notes was written for use by offshore counterparts, to give a general outline, and aid in the understanding of the systems on board the vessels. These include such topics as the general principals of GPS and DGPS positioning; Underwater Acoustics; and Tides, as well as other related topics.

Phase II (2001-2005)

During Phase II, survey and charting of non-critical parts of the Sea Lanes and other high priority areas will continue. Investments for surveying and chart production equipment has already been made in Phase I, however upgrading of communication and GPS are proposed.

TECHNICAL ASSISTANCE FOR HYDROGRAPHIC OFFICES

Erwan L'Arvor

Abstract

The French Naval Company for Training and Advice (NAVFCO*) is involved in Hydrography to propose the transfer of the French Hydrographic Office (SHOM**) know-how for the benefit of requesting foreign countries. This assistance can cover simple consulting up to modernisation of hydrographic offices with equipment and specific training provided by SHOM hydrographic experts on behalf NAVFCO.

NAVFCO is a private company under French State tutelage which benefits of the French Naval Staff co-operation and, especially in hydrography, of the French Hydrographic Office namely SHOM which is officially responsible of hydrography and marine cartography in France and French overseas territories.

Thus, NAVFCO and SHOM are associated in order to export French know-how in the field of hydrography within the scope of co-operation projects with foreign governments and organisations. To manage this scope, an engineer in hydrography from SHOM is permanently appointed to NAVFCO. NAVFCO prime objective consists of adapting French Hydrographic know-how to the needs of foreign hydrographic offices and exports advanced knowledge on matters of consulting, instruction, technical assistance and training. It meets specific requirements with precision and guarantees the quality of its services.

Hydrographic Services offered

NAVFCO provides all the necessary skills for the execution of a good co-operation and know-how transfer project from beginning to end, as :

- Technical assessment and consulting.
- Training and technical assistance.
- Prime contracting.
- Surveys.

In this scope, NAVFCO offers projects to enhance the capacity of foreign services in hydrography and nautical charting but also hydrographic surveys conducted by SHOM.

*société NAVale française de Formation et de Conseil (NAVFCO)

**Service Hydrographique et Océanographique de la Marine (SHOM)

Technical Evaluation and Consulting

First, upon request of the concerned country, NAVFCO carries out a concrete assessment including an inventory of the situation and requirements in :

- Conception and organisation of Hydrographic Offices.
- Studies and analysis of needs in hydrography and oceanography fields.
- Assistance for selection of specific hydrographic equipment or processing like Data base management and installation of multibeam echosounders or DGPS inshore stations.

This preliminary phase is normally achieved by a consulting report or a project establishment between NAVFCO and the concerned country, which defines the objectives to be reached. To guarantee the validity of proposed solutions, NAVFCO is supported by the competence of SHOM experts in all the fields of hydrography (Survey, Cartography, GIS, ...).

Training and Technical Assistance

After fifteen years of experience gained in navy training, NAVFCO is convinced that training is an compulsory element for the success of a project which involves transfer of technology and know-how, regardless of the field concerned. NAVFCO, in co-operation with SHOM, offers several training courses as:

On-the-job-training

This training is generally ensured by a technical assistance team sent to the Client country by NAVFCO for the technical follow-up of the project with the scope to give suitable methodology for data acquisition and data processing with all the steps for data quality control.

Training by SHOM

Two training courses are proposed by the hydrographic school in Brest:

- Level A FIG/IHO, hydrographic engineers.
- Level B FIG/IHO, technicians.
- Request for enrollment in these courses is made through diplomatic channel to SHOM. In some cases, NAVFCO can intervene to obtain bursaries from financial backing organisations.

Specialised Training

For special requirements, NAVFCO can organise specific adapted training cycles

in hi-tech fields in collaboration with SHOM and/or manufacturers like:

- Satellite image processing (bathymetry, coastline).
- Computer-aided cartography.
- Data acquisition and processing system for hydrographic surveys.

Project Prime Contacting

In general, when NAVFCO is in charge of a project, we ensure a complete prime contracting for it. This has several advantages:

- The Client country has a single interlocutor which main concern is to provide the most adapted services to its requirements.
- Financial backing organisations demand to deal with one organisation or company, which takes total responsibility for the project.

In particular, when the project includes equipment delivery, NAVFCO ensures:

- A coherent package for equipment with all the interfaces, accessories and spares.
- Factory and Site acceptance on the suppliers' premises, in compliance with the standards usually applied by SHOM for its own equipment.
- Transport.
- Initial start-up of equipment and operator training in the Client country.
- Follow-up of guarantees during the contractual period.

Projects Recently Developed by NAVFCO

NAVFCO has intervened in more than twenty countries to train people in different specialties related to the maritime field.

In the field of hydrography, NAVFCO has recently provided assistance in association with SHOM in the following countries:

- Indonesia: technical assistance and training on hydrographic equipment within the scope of the delivery of a hydrographic-oceanographic vessel.
- Tunisia: assistance in the creation of a hydrographic service.
- Vietnam: assistance in the upgrading of hydrographic means belonging to the Vietnamese government.
- Bangladesh: assistance in the modernisation of the Bangladesh Navy Hydrographic Department.

An example of NAVFCO Technical Assistance: Development of the Bangladesh Hydrographic Office

The HYDROBANGLADESH project has been financed by the Franco-Bangladesh Protocol under the control of the French and Bangladesh ministries of finance. The aim of this project is to enhance the development of Hydrography in Bangladesh and provide modern equipment for carrying out Survey Works in a view to produce Nautical Chart respecting IHO (International Hydrographic Organisation) standard.

The first phase of this project was completed in 1997, it consisted of:

- Training in France (one month).
- Delivery of modern hydrographic equipment and installation in Chittagong (data acquisition and post-processing system, echo-sounders, tide-gauges, current meters, DGPS receivers and stations,...).
- Technical assistance (one engineer in hydrography and one technician stationed in Bangladesh for one year).

The missions of this technical assistance team were to :

- Advise BN Hydrographic Department for installation of equipment on board Survey Ships like the hull mounted echosounder transducer.
- Carry out sea trials to confirm the performances of all hydrographic equipment installed (echosounders performances, max. range of DGPS/HF station, ...).
- Organise specific training course with most of the time on the job training for Surveyors and people in charge of the equipment maintenance. In this way, a practical model survey was done in real condition with equipment by both BN officers and Surveyor during 3 months in order to give full confidence in running all the hydrographic equipment. All Chittagong Outer Anchorage Area has been surveyed during this period and Hydrographic data have been processed. By the end, a final fair sheet as per limit and scale given on the Admiralty Nautical Chart **84** has been printed out.

NAVFCO, in co-operation with the Bangladesh Navy Hydrographic Department, is currently dealing with a second phase of this project with:

- Delivery of GIS, cartographic softwares and training in cartography.
- Giving capacities for carrying out recommended navigation routes with the use of sidescan sonars.
- Modernisation of the BN Hydrographic School.

To set up and give suitable training, a NAVFCO team (one hydrographic engineer and one technician) will assist and advise BN hydrographic Department for six months.

Reference

International Hydrographic Review (1998). LXXV (2), Monaco.

STRATEGIC ISSUES FACING NATIONS IN THE ROPME REGION

John Leech

Introduction

This presentation aims to focus on some of the strategic issues, which face the hydrographic departments of the nations of this region, and to comment on some ways of dealing with those issues.

Responsibilities of National Hydrographic Offices

As a starting point it may be useful to summarise the responsibilities of the national hydrographic offices. In a few countries these responsibilities are enshrined in national legislation. The basic responsibilities are:

- To undertake surveys.
- To compile and distribute charts.
- To publish maritime safety information.
- To maintain national hydrographic data bases.
- To provide data and services for GIS applications.

In 2002 the first four of these responsibilities will be formally recognised in an international treaty, when Regulation 9 of Chapter 5 of the SOLAS Convention will come into force. This is a most important development for national hydrographic programmes.

The last item, data for GIS applications, recognises the increasingly important requirement to be able to service other user communities who need marine spatial data for national development purposes. We in the IHB feel that, at some time in the future, this will be a more important role for the hydrographic offices than the navigation role.

Strategic Issues facing IHO Member States

During the development of the IHO Strategic Plan the IHO Member States identified 6 strategic issues which currently affect their activities. These are, in order of priority:

Transition to the digital era, ensuring the successful transition to provision of digital services, including production, distribution and updating.

Achievement of an adequate global hydrographic data coverage, ensuring that good quality hydrographic data is available throughout the world where needed.

Responding to the external environment, providing an appropriate and timely response to developments in government policy, technology, distribution, service delivery, etc.

Achievement of adequate funding, ensuring that sufficient funding is available for the provision of the necessary services.

Capacity building, building effective national organisations, with appropriate numbers of skilled staff and equipment.

Providing services other than for navigation, ensuring that the national hydrographic data satisfy also the needs of, and are fully and conveniently available to, scientists, administrators and institutions with interests in marine issues.

Strategic Issues Facing Nations in the ROPME Region

Seen from an IHO perspective, the issues facing the nations in the ROPME Region are the same, but perhaps the emphasis is different.

Capacity Building should probably be the first priority in this region. This is because the hydrographic services in the region are not very well developed.

Iran has a well developed hydrographic capacity. Oman and Bahrain both have small but effective services, which are undertaking surveys and producing charts. Kuwait has an effective system in which major work is out-sourced, using government project funds. There is a small hydrographic department in Basra.

In Saudi Arabia a hydrographic department has been established, but the government has not yet provided any money for equipment or personnel. The International Ports Authority carries out some hydrographic work. In Qatar a small hydrographic section exists within the Land Information Centre. In the Emirates there is no hydrographic department, but the military carry out some hydrographic work.

The governments in the region do not seem to regard hydrography as a high priority activity, despite the important place of maritime trade in the national economies. Capacity building requires educated people, hydrographic training, equipment, and vessels.

Adequate funding is the foundation of capacity building. One of the great difficulties facing the nations in this region is to obtain adequate funds to build up hydrographic capacity and to conduct hydrographic operations. These are classified as investment costs and operating costs. As mentioned above, considering the important place of maritime trade in the national economies, a higher priority should be given to this task.

Adequate funding will only flow if we are able to explain to our governments the importance of hydrographic services to the national economy and to national development. Therefore influencing the external environment is a particularly important strategic issue for all of us.

Transition to the digital era and provision of services for GIS applications are closely linked. They are important for two reasons. The first is that modern ships visiting the regional ports with bulk cargoes and with containers will all be equipped with integrated navigation systems within the next five years, and they will need digital charts. The second is that provision of services for GIS applications imply the provision of vector data, with associated costs.

GIS applications will become a key component in the rationale for obtaining funds in the future, since they provide support to important sectors of the national life. These include marine scientists, engineers, coastal zone administrators, environmental modellers, resource companies, maritime boundary lawyers etc. The list is almost infinite. When competition exists for funding, it seems that GIS applications may in the future carry more weight than navigation. This explains why IHB are holding this workshop jointly with ROPME.

Responses to the situation

The main difficulty is to convince senior decision makers that hydrography is an important activity. The problem is to ensure that the needs of the hydrographic department are properly presented and understood.

This is a difficulty faced by IHO Member States all over the world, and has led to the creation of an additional programme within the IHO relating to public information. The IHB is in the process of producing a book (M-2), explaining the importance of hydrography within the national maritime framework. The IHB also tries, when visiting Member States, to speak with Ministers and Under-Secretaries about the importance of the work. IHB Directors welcome invitations to visit nations to assist in raising the profile of hydrography within

the region. The IHB is able to write independent reports concerning the development of national capabilities.

Another important aspect is to ensure that good co-ordination exists between national agencies that have need of hydrographic information. These agencies include the Ministries of Transport (navigation), environment (environment protection, sustainable development), Foreign Affairs (national boundaries), Defence (national security) and Natural Resources (development of seabed resources and fisheries). If good links and good relations can be developed with other responsible ministries, the appreciation of the importance of hydrography in national maritime affairs will improve, and more attention may be given to provision of funds. The IHB recommends the establishment of a National Hydrographic Committee at the technical level, in order to ensure that there are good links between agencies, and that all subscribe to a national strategy regarding hydrography.

A number of governments, which have recognised the importance of hydrography, have passed national laws, which define the responsibility of the hydrographic department. This assists in justifying the allocation of government resources.

It is important to ensure that the national arrangements are cost effective. It is difficult to generalise about this, since there are many different models in use in the region. However there is a choice. One choice is to establish an in-government capacity to undertake surveys and to produce charts. This model is more common in the region. The government capacity that is built is a useful national asset, but the overhead costs are significant. Another choice is to contract out most of the work on a project basis, maintaining only a small government unit to control the work. In North America and Europe the latter model is claimed to be more cost effective, and governments are directing that an increasing amount of work be done in this way. This model probably reduces overheads, but national capacity is not developed.

A further possible solution is to pay for hydrographic services by levies on shipping. Traditionally this is the means used for funding other types of navigation infrastructure, such as lighthouses and traffic control services. This type of approach can make a significant contribution to the cost of surveying. Similarly, good marketing arrangements can make a significant contribution towards the cost of chart production.

In an era in which spatial data are seen to be a valuable economic commodity, it is important to try to ensure that these data are easily accessible to users in the various sectors of the national economy. An ability to demonstrate that these data are widely valued should assist in the efforts to obtain funds. Wherever possible it is advisable to ensure that these data do not carry any military classification, since such classification will prevent the hydrographic office from making a useful contribution to the national economy.

It is difficult, when funding is short, to give much attention to the provision of GIS services. Nevertheless this has been identified as an emerging issue of high priority, and it is recommended to include the strategic planning, and to build the necessary networks within the national administrations, in order to ensure that the contribution to the national spatial data infrastructure is not overlooked.

Regional Co-operation is also important in the development of hydrographic services, since navigation and spatial data infrastructures are regional in nature. It would be useful to consider the establishment of a Regional Hydrographic Commission. By working together in a regional commission it may be possible demonstrating benefits on a regional as well as a national basis.

Other Issues

There are some other issues, which are faced by the nations of the region. The problem of distribution of charts and the international distribution are major issues for small hydrographic services.

Conclusion

The greatest difficulty faced by the hydrographic services in the region is to obtain an appropriate level of financial support. This is a major issue for many Member States of the IHO. The IHO will do everything that it can to assist in dealing with this matter, if assistance is required.

The transition to provision of digital services for navigation and GIS applications is also an issue, but is closely related to the question of funding.

REMOTE SENSING APPLICATIONS IN THE ROPME REGION

Peter Petrov and Mahmud Abdulraheem

Introduction:

Over the past decades, remote sensing (RS) has demonstrated the effectiveness of orbital platforms in monitoring marine environment. The cost-effectiveness of satellite technology applications has increased rapidly during the past few years, including that of monitoring coastal areas. The main advantages of this process are coverage and detection capability overcoming time and weather limitations and image cost. This paper examines available RS technologies to provide remote sensing inputs concerning environmental monitoring and oil spill pollution estimations in the ROPME Sea Area, (RSA). The objective of this paper is to summarise the possibilities of a regional RS monitoring program in the RSA, with special focus on the main RS procedures related to the assessment of the state of the environment in the Region. The system concept and the algorithms developed for remote sensing applications related to region-specific characteristics are described in the paper.

Oil pollution in the RSA is a common phenomenon along tanker routes, offshore platforms and oil terminals. The Integrated Project Plan for marine environment (IOC/UNESCO, ROPME, 1996) identified RS activity as one of the most important tools to track exploration activities, distribution of pollutants in the area, especially oil and surface phenomena and physical alteration of marine and coastal ecosystems.

The ROPME Sea Area is characterised by unique environmental conditions. Relatively cloudless weather conditions support modern hyperspectral approaches in remote sensing, and synergetic processing of optical and microwave data processing. The inner ROPME Sea Area is also characterised by the large input of aeolian dust and erratic flow of fresh water from an input of fresh water from Shatt Al-Arab and the Qaroon and other river systems from I. R. Iran (the Hendijan, the Hilleh and the Mond rivers).

The laboratory-based system and the processing procedures were recently established at ROPME for regional operations and to create an RS regional archive. Using examples from the RSA, the efficiency of RS observations of the state of marine environment is demonstrated through image analysis of the southern marshes of Iraq, NDVI and actual oil releases from various platforms. The examples cover the time period for the past 15 years and include areas from North RSA to the Oman coast. It shows the ability of available sensors in optical (VIR) and microwave (SAR systems) region to fulfil specific tasks.

System concept, procedures, processing, and archive:

Over the past two years, ROPME has explored the potential for utilising image processing technology. A custom-designed, laboratory-based system for image processing along with an RS regional archive has been established at ROPME. The System utilises various formats, and processing procedures allowing analysis of data from the most popular orbital platforms.

The dynamic nature of ROPME coastal areas requires regular observation in order to evaluate the environmental changes and their impact on natural processes, ecosystems and populations. The other major area of RS applications is habitat characterisation and monitoring changes in wetlands, vegetation cover, river course monitoring and monitoring of sedimentation patterns and physical changes of beach profiles, etc.

Characteristics of ROPME Sea Area:

RSA is an arid region located between the Equator and the Tropic of Cancer. The Area is characterised by high temperatures, high evaporation rates and low rainfall. The inner part of the RSA varies in width from 56 to 338 km. The NW-SE axis, from the Shatt Al-Arab to the Strait of Hormuz is approximately 900 km long, with a mean depth of 36 m. In spite of its harsh environment conditions, the Area is considered to be one of the most productive water bodies in the world in terms of benthic production.

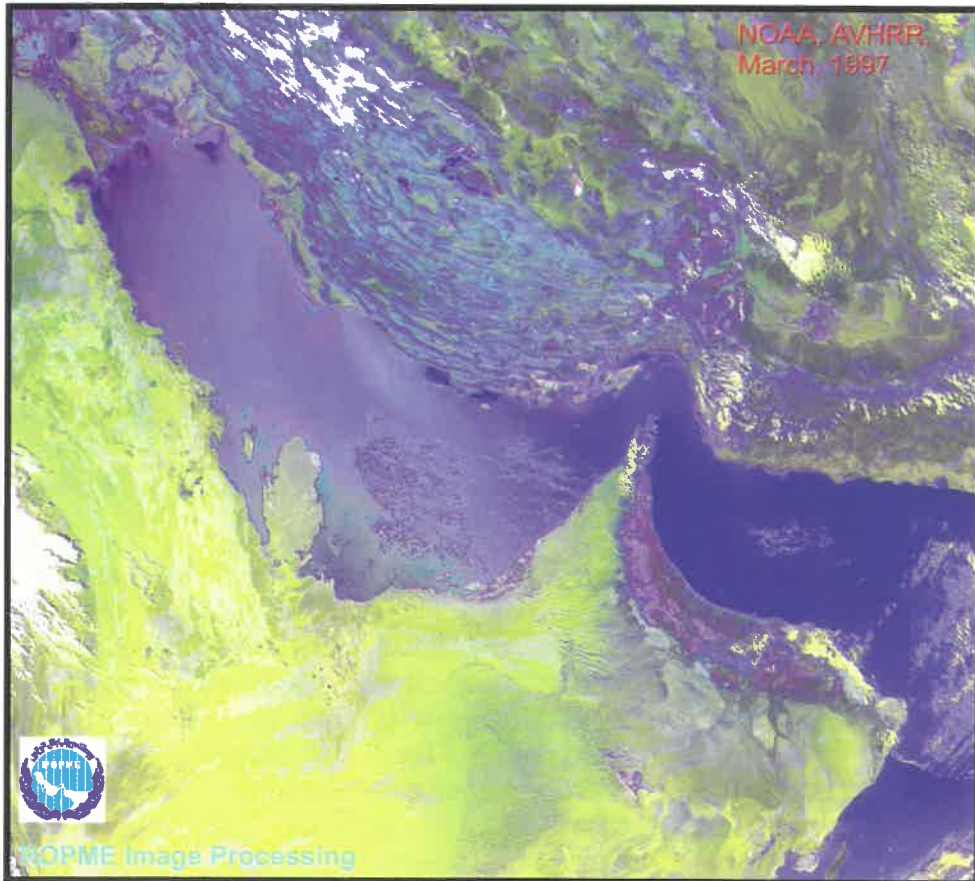
Although RSA is one of the most economically important regional seas, it remains one of the least investigated. Approximately 2/3 of the world's marine oil transport passes through the Region. Even though oil-related activities presently dominate the RSA's commerce, the long term importance of renewable resources, especially fisheries, is fully recognised by the Member States. Figure (1) shows a part of ROPME Region from Space (Masira island to Shatt Al-Arab). This is NOAA 14 AVHRR Image from March 1997. RGB Colour composition of visible and IR bands, ch1, ch2, ch3 with spatial resolution 1 km/pixel. The image is obtained in significantly clear atmospheric conditions. The main features of the above figure are as follows:

- Atmosphere.
- The atmospheric conditions in the region are significantly clear. Small cloud development is observed on the East, South and West, shown on the images as white and yellow contours.
- Seawater.
- Seawater is presented in dark blue to light blue-greenish. The large dark blue area corresponds to the deep waters of Gulf of Oman. Different colours show the sea-atmosphere interactions (North RSA), river plumes (Shatt Al-Arab, the

Mond, etc.) and shallow waters (North RSA, Central part: Bahrain, Qatar, UAE).

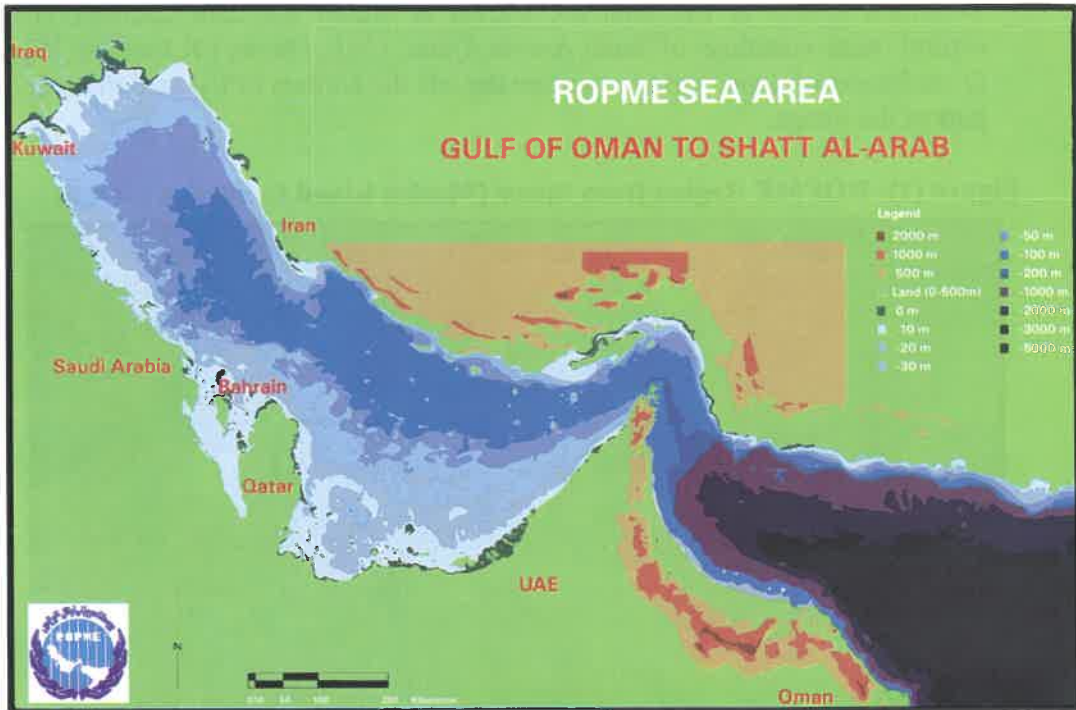
- Coastal areas and Land Cover.
- The high white contrast (sharp) contours on the peaks of the Zagros Mountains denote the snow cover in the North. Flat desert sands are presented in yellow-greenish on the West Coast of the RSA. The South Mesopotamia marshes are shown on the North upper left corner of the image in dark green-blue. Oman's Al-Hajar Al-Gharbi, Akhdar Mountains and Beshagrad Mountain chains in I.R. Iran are shown in brown and dark patches on the central west coastline of Saudi Arabia, Qatar, UAE, Oman, I.R.Iran and Iraq. Disturbance of land surface texture depicts the borders of Kuwait on the left part of the image.

Figure (1): ROPME Region from Space (Masira island to Shatt Al-Arab)



The bathymetric characteristics of ROPME Sea Area, from the Gulf of Oman up to Shatt Al-Arab are shown in Figure (2). Figure (3) shows an Integral multispectral view of Sabkha Matti (UAE). NOAA/AVHRR RGB colour composition ch1, ch2, ch3 with a resolution 1 km. Gradation of humidity in the sabkha areas, depending on the distance from the coastline is shown, with various dissolved salts affecting the colour of the background sand.

Figure (2): Bathymetric characteristics of ROPME Sea Area

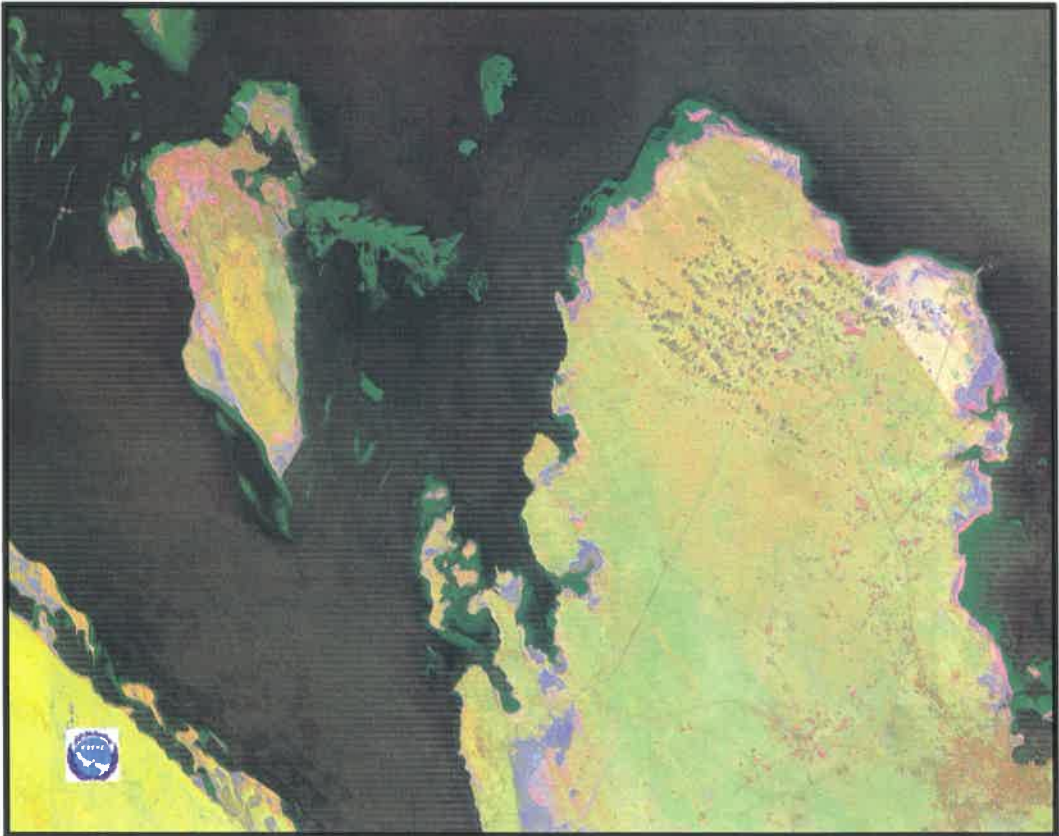


In Figure (4) the Coastal features on the West Coast of the Central part of RSA are shown covering Bahrain, North Qatar and Saudi Arabia Coast. The sabkha areas appear in gray-blue. Coral reefs, sand banks and intertidal zone appear in green. Dark spots in the seawater represent sea grass areas. Tanker channels appear as dark strips in the water. Urban fabrics (Doha and Manama) appear in light brown-reddish colour. The image is a Landsat 5 TM, from February 1995, applying image processing of ch1, ch2, ch3, ch4, ch5, ch7, including digital filtering and equalisation. Resolution is 30m per pixel. It should be noted that gradations of humidity in sabkha areas, depending on the distance from the coastline, affect the colours of the background.

Figure (3): Integral multispectral view of Sabkha Matti (UAE)



Figure (4): Coastal features on the West Coast of the Central part of RSA



Sea State and topography:

Accurate sea surface heights are needed for sea dynamic topography, Regional Sea Circulation models (RSCM), etc. Since 1975, satellite altimeters are applied for studying the geoid and gravity field of the Earth. The NRA/TOPEX satellite altimeter ground track at the equator has a spacing of 314km and an along track sampling rate of 7 km and the sea level measurements are with precision of ± 2.4 cm. The synthetic aperture radar (SAR) is used to study the generation and propagation of long ocean waves. The distribution of short gravity waves, recorded by SAR/SEASAT shows correlation with a number of significantly large-scale phenomena, such as local wind structure, long gravity waves, currents and the local bathymetry. Internal and surface waves have also been studied by LANDSAT/MSS channels. The gravity anomaly contour maps have been used for locating hydrocarbon-bearing structures.

Salinity:

Salinity and sea surface temperature are the two major climatic factors controlling the circulation of the ocean. LANDSAT/MSS and TM data are used for retrieval distribution of salinity, applying regression models. Due to the major impact of clouds on optical remote sensing, the microwave spectral range is used for temperature and salinity retrievals. Passive microwave radiometer at L band (1.43GHz) and dual frequency microwave radiometer L band and S band (2.65GHz) have been used for remote sensing of water salinity and temperature with high accuracy.

Sea surface temperature:

Sea surface temperature controls the air temperature and moisture and depends on the circulation patterns. Satellite observations in atmospheric windows of microwave and infrared spectral range are used for SST retrieval. Infrared spectral measurements are with higher resolution (<1km), but are affected by atmospheric constituents and clouds. Microwave measurements in spectral range (>4cm) are transparent for clouds, but their resolution is very low. The sea surface temperature defines the heat transport and evaporation, which affects precipitation and cloud formation. Under clear sky conditions, the observed values of the atmospheric greenhouse effect rise with spatially increasing sea surface temperature at SST above 298K. Coupling the predicted sea surface temperature anomalies with Circulation Models allows us to evaluate the impact of the sea surface temperature on the weather and climate system. Future AATSR / ENVISAT will allow long term monitoring of the sea surface temperature with accuracy of less than 0.5 grad K.

Ocean bio-optical data:

The main RS parameters for the analysis of fish distribution are: the comfort temperature for each species, and food abundance for that particular type of species. These two main parameters allow us to create estimation maps and areas of where to expect sufficient fish congregations. The colour of the ocean is directly related to chlorophyll concentration. Satellite systems provide a scale that can be used for mapping shallow sea floor environments, determining reef from non reef structures, detecting general zonation distribution patterns (atolls, etc.) and providing important information on oceanic processes and current patterns around the reefs. Available satellite imagery can be used to delimit multispectral features with spatial resolution on the order 10 - 30 meters, which is adequate for locating reefs, general zonation distribution patterns, dominant benthic communities (coral, sea grass beds, sand, etc.). On the other hand, SeaWiFS is more useful in the main wavelengths channels for sea bio-optical remote sensing, despite its low spatial resolution. Remote sensing digital image

processing techniques used in satellite imagery can be applied easily to aerial and underwater imagery. The compatibility of spectral channels is very important in the above processing. Airborne imaging spectrometry and high-resolution spectrometry (hyperspectral system) would be extremely useful for validation of specific processing techniques concerning reefs monitoring. Utilisation of systems like MODIS, AVIRIS, Lewis and MERIS / ENVISAT would provide important data for this activity.

In general, RS observation of seawater is not the only instrument for the analysis of existing processes, but it has a unique ability to reveal and generalise new phenomena (according to their content of dissolved and suspended matter).

Figure (5) shows the Fasht Al-Adham reef system – one of the largest and most productive marine ecosystems in the Northern RSA. It is possible to see trenches from surveillance. Clouds are observed over the Northern part of Qatar, Landsat 5 Thematic Mapper, image from February 1994 with spatial resolution 30 m/pxl. Digital Processing and colour composition was performed on the image.

Figure (5): Fasht Al-Adham reef system

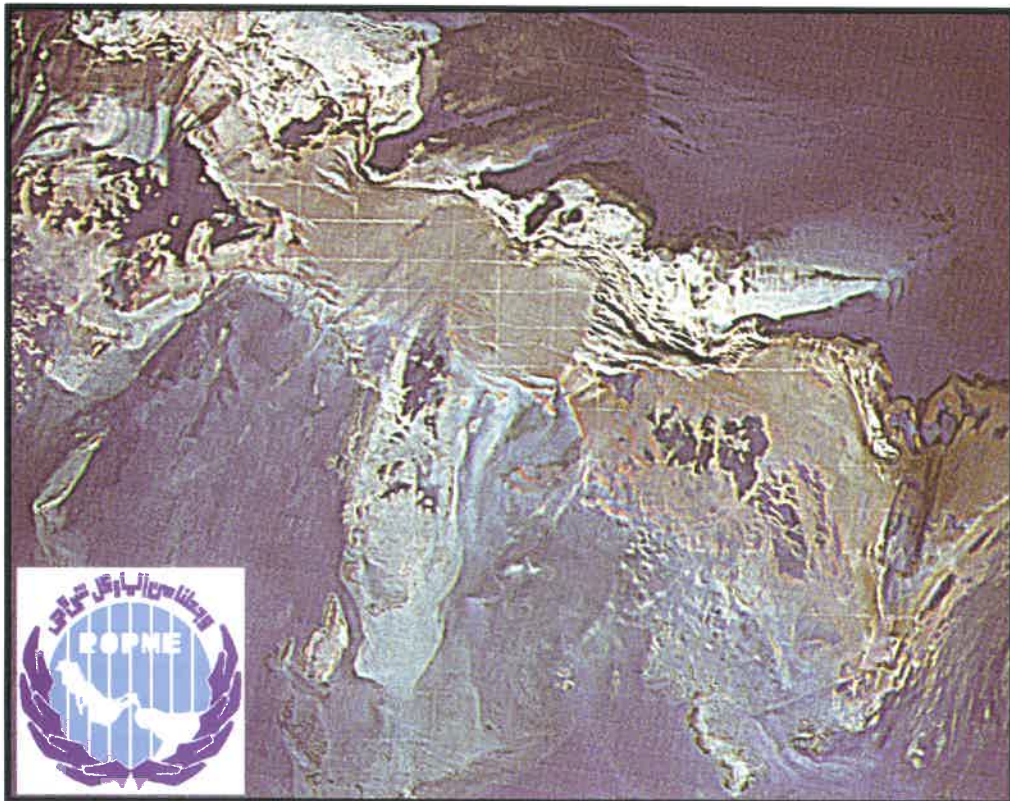
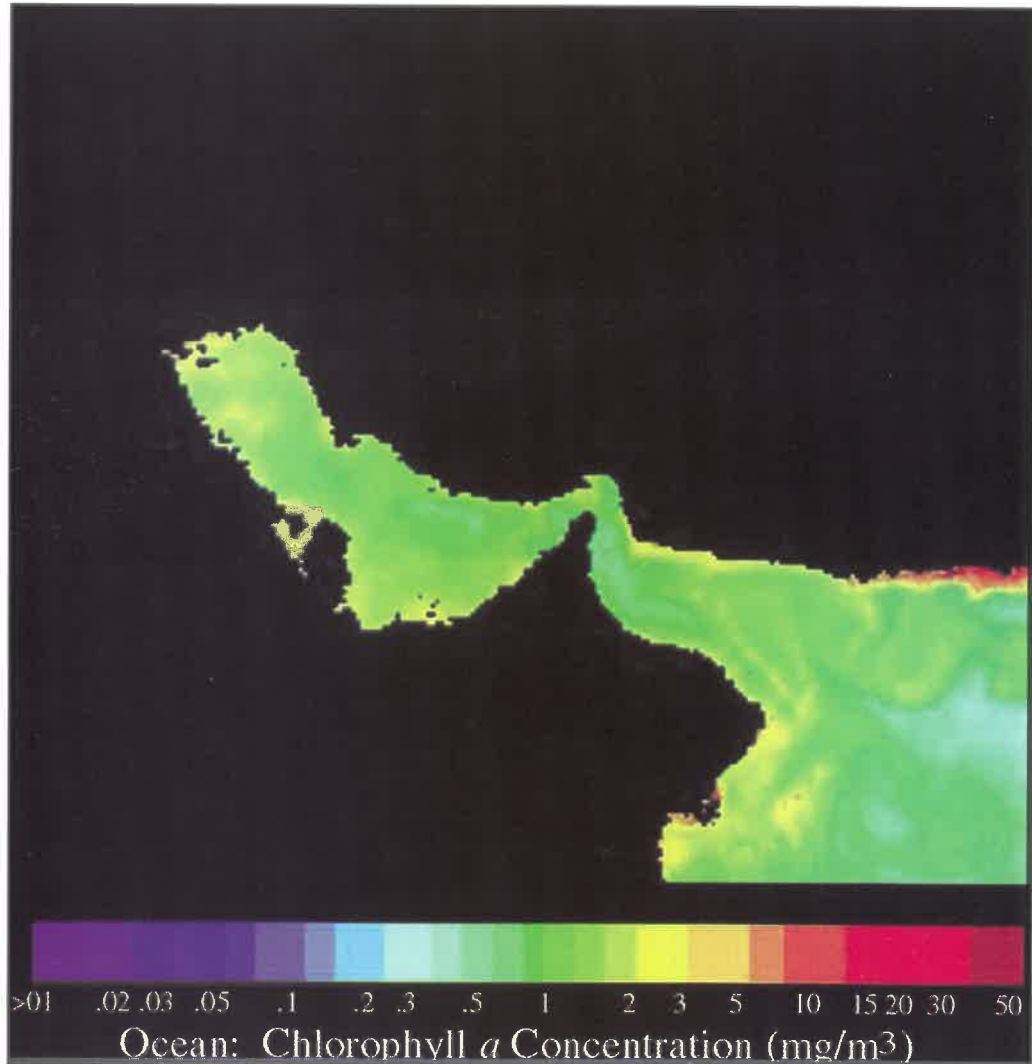


Figure (6) shows the Chlorophyll distribution, SeaWiFS data from September-October 1999. Figure (7) shows a thin dust layer superimposed over eddies

glittering under the sun's reflection, (6, NASA). A Heavy dust storm on the Iranian coast is show in Figure (8), (6, NASA).

Figure (6): Chlorophyll distribution.



Marshes in Southern Iraq:

Satellite observations has allowed for study in detail the hydrology and river geometry, erosion of riverbanks, changes in irrigation channels and river valleys, as well as sedimentation and morphology of river beds, evolution of river deltas, and river outfalls into the sea. Shatt Al-Arab and South Mesopotamia Marshes act as a source and filter of fresh water and nutrients responsible for the Northern part of ROPME Sea Area's productivity. Assessment of the effects of Shatt Al-Arab's altered discharge regimes on the ecology of the Northern RSA shows

significant drainage of the world-famous marshes of upper Shatt Al-Arab. Approximately 60% of the marsh areas, more than 15 000 km², has disappeared in the last 15 years. Systematic draining of vast stretches of marshlands in southern Iraq, where the Tigris and Euphrates rivers merge into the Shatt Al-Arab River; reduction and control of the Shatt Al-Arab's freshwater flow into the delta and the construction a new canal (the Third River) represent major alterations the estuarine ecosystem that may have drastic effects on the fisheries and ecological balance in the region. Although the exact effects of these changes are unpredictable, the results will undoubtedly be negative.

Figure (7): A thin dust layer superimposed over eddies glittering under the sun's reflection

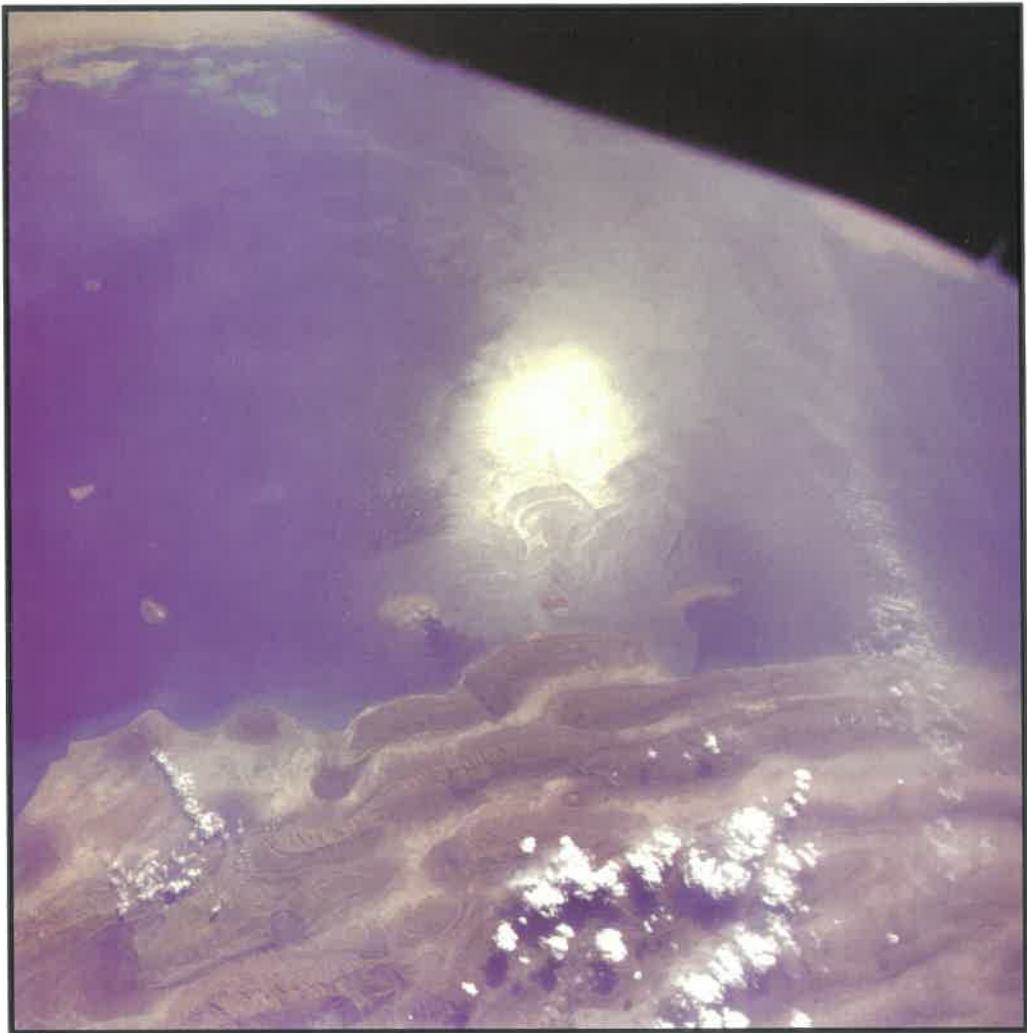


Figure (8): Heavy dust storm on the Iranian coast

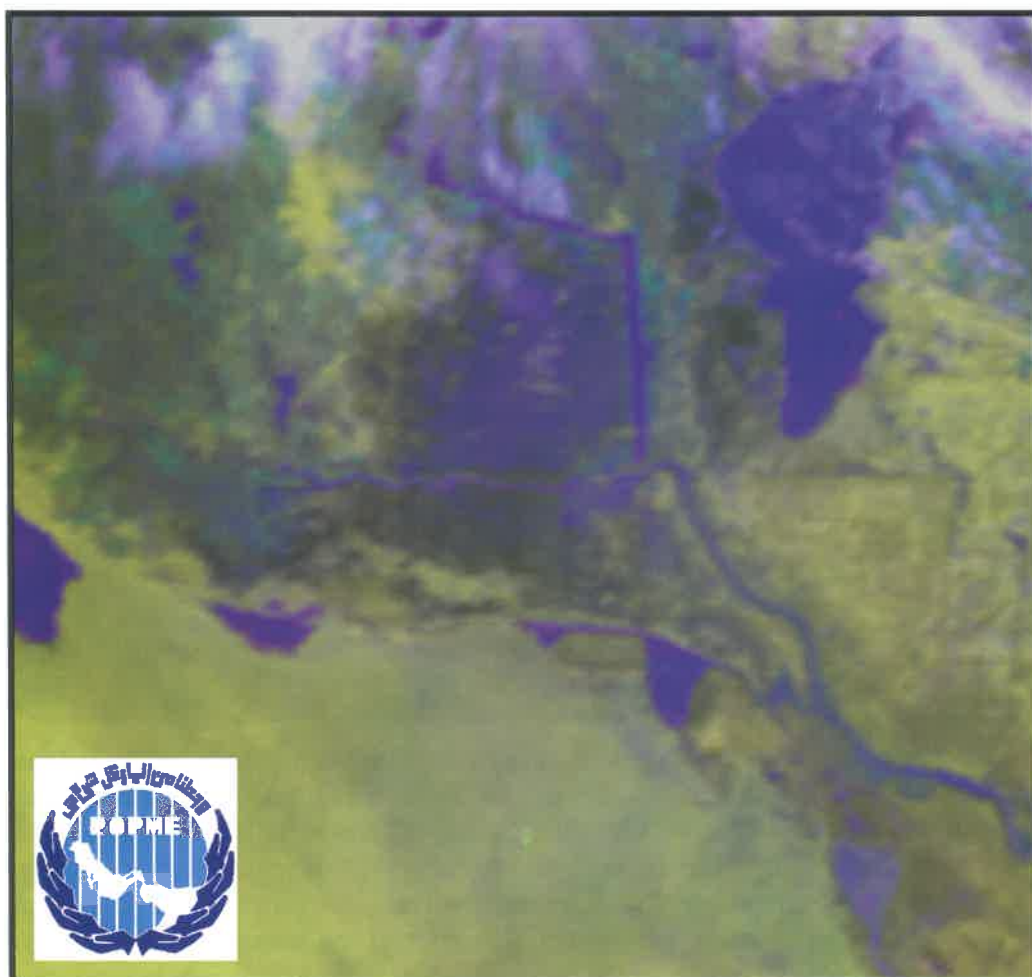


Remote sensing studies of the area have revealed the complex hydrology of the fertile Tigris and Euphrates valleys. To show a regional perspective, low-resolution images from NOAA AVHRR have been selected from spring to minimise the seasonal variation effects. Although in this regional scale only the major waterways, marshes and lakes are resolvable, significant changes can be seen such as construction of channels, bared land and scarce vegetation areas. Figure (9) shows an Integral multispectral view of the Mesopotamian marshes using NOAA / AVHRR fragment with resolution 1 km/pixel, March 1997 (RGB colour composition image of ch1, ch2, ch4). The melioration works include drainage of South Mesopotamian marshes.

The extent of the marshlands (yellow greenish) and lakes and water bodies (blue) has been reduced, with a corresponding increase in bared soil (yellow brown).

Lakes are visible as blue spots. Barren soil areas uncovered by vegetation are presented in yellow, grey or brown. Clouds, in the north appear in white light blue. Scarce (rear) areas covered by vegetation appear as green. The areas within high biomass concentration (higher density vegetation cover) appear in darker green. More than half of observed area is covered by bared land. It should be noted that while some of this change could be attributable to annual variation in rainfall, the deliberate draining of this area is irrefutable, confirmed by the artificial straight edges to the remaining marshes.

Figure (9): An Integral multispectral view of the Mesopotamian marshes



Normalised Difference Vegetation Index:

Normalised Difference Vegetation Index (NDVI) in remote sensing could be used to better understand seasonal and inter-annual variations in vegetation. It is one of major ecosystem characteristics and shows how these system properties

interact with the climate system in order to predict long-term environmental consequences of climate and land use changes on ecosystem function and sustainability for estimating remotely sensed vegetation properties. The way for this investigation is to examine space or time dependent patterns in the NDVI with the assumption that fluxes are proportional to the amount of green leaf area or biomass. NDVI generally responds linearly over a range of leaf area. Many studies have supported the near-linear correlation between NDVI and the fraction of photosynthetically active radiation absorbed by vegetation patterns at very large regional to global scales. In the case of arid lands NDVI needs additional assessment. RSA is a typical region for future assessment and application of the above approach.

Oil spills:

As stated earlier, oil pollution is a common phenomenon along tanker routes and offshore platforms and oil terminals in the RSA. The inner part of RSA has experienced two of the worst three oil spills in history. The largest oil spill in history occurred during the 1991 "Gulf War". The third largest oil spill (of 3 million barrels) also occurred in the Region during the Iran-Iraq War. In the case of oil spills, near and real time information is required for effective combating and law enforcement operations.

Using examples from ROPME Sea Area, the efficiency of RS observations of oil spills from various orbital platforms is demonstrated i.e. manned space flights-Space Shuttle, automation platforms as NOAA/AVHRR, Radarsat and aerial surveys. The examples cover the time from Nowruz oil spill to the Kuwait oil spills in 1991 and covering the inner RSA to the Gulf of Oman. It shows the ability of available sensors in optical (VIR) and microwave region (SAR systems), for oil spill detection. New sensor systems on board of future NASA's and ESA's satellites missions are also appropriate for oil slicks observation in the Area. Figure (10), based on Space Shuttle observations, shows large petroleum slicks in the anchorage areas of super tankers off the Northern coast of Oman, RSA, 1983. The lighter spots represent small oil slicks. In Figure (11), oil pollution near the island of Sir Abu Nu'ayr, RSA (1984). Figure (12) shows a massive oil spill in 1991. The oil storage facilities, terminals were destroyed, and several loaded tankers were emptied into the Northern RSA. The spilled oil drifted about 100 km to the south from Kuwait's terminals. Oil appears as purple streaks, a NOAA / AVHRR image with resolution 1 km / pxl, January, RSA, 1991. A more recent oil spill is shown in Figure (13), the Northern part of RSA, near the Kuwaiti coast (1998), oil appearing as black strips (Radarsat SAR, C band). Small oil slicks in the area are shown in Figure (14), near Mina Al Zour, Kuwait, May (1991). Oil appears in strips of light greenish – yellow, based on pictures taken during an aerial survey, UNEP Gulf Imagery DataBase, texture analysis.

Figure (10): Large petroleum slicks in the anchorage areas of super tankers off the Northern coast of Oman, RSA, 1983

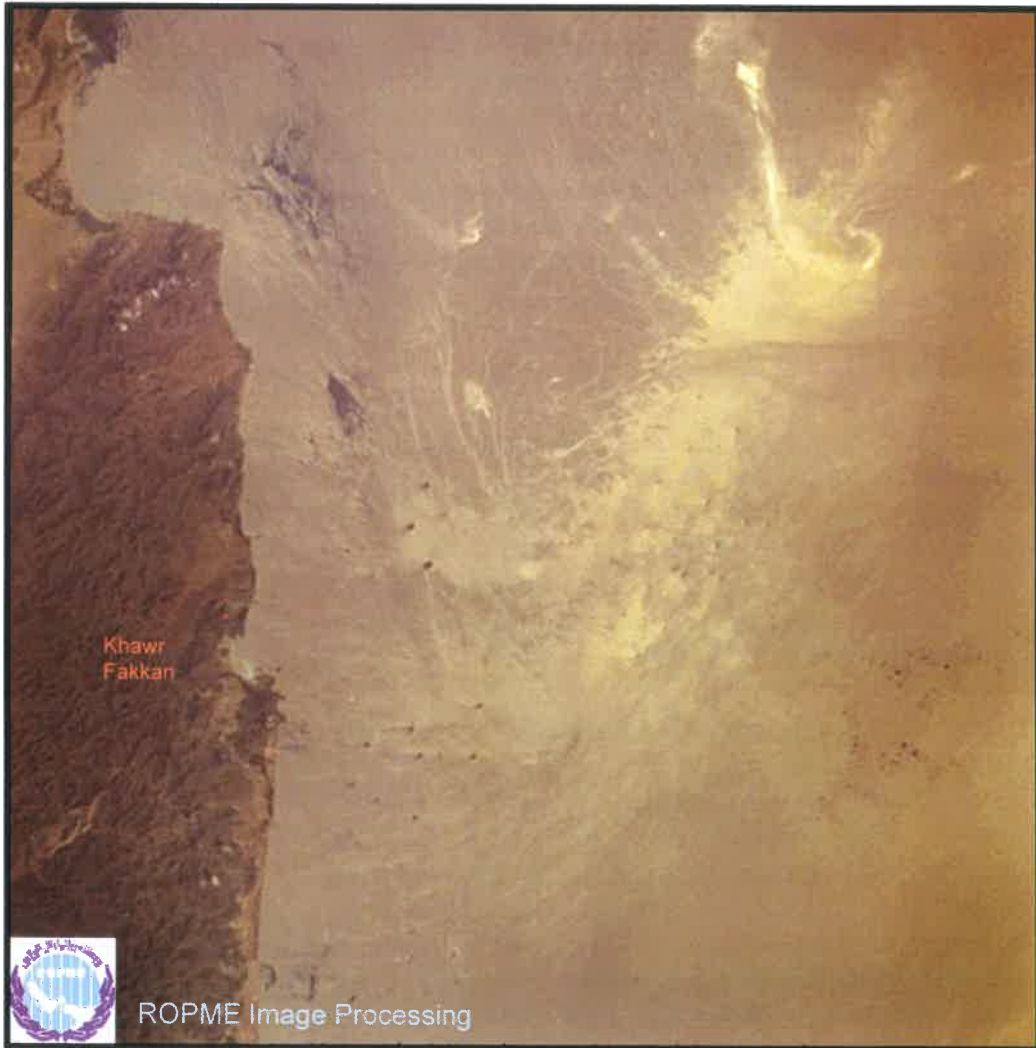


Figure (11): Oil pollution near the island of Sir Abu Nu'ayr, RSA (1984)



Figure (12): Massive oil spill in 1991

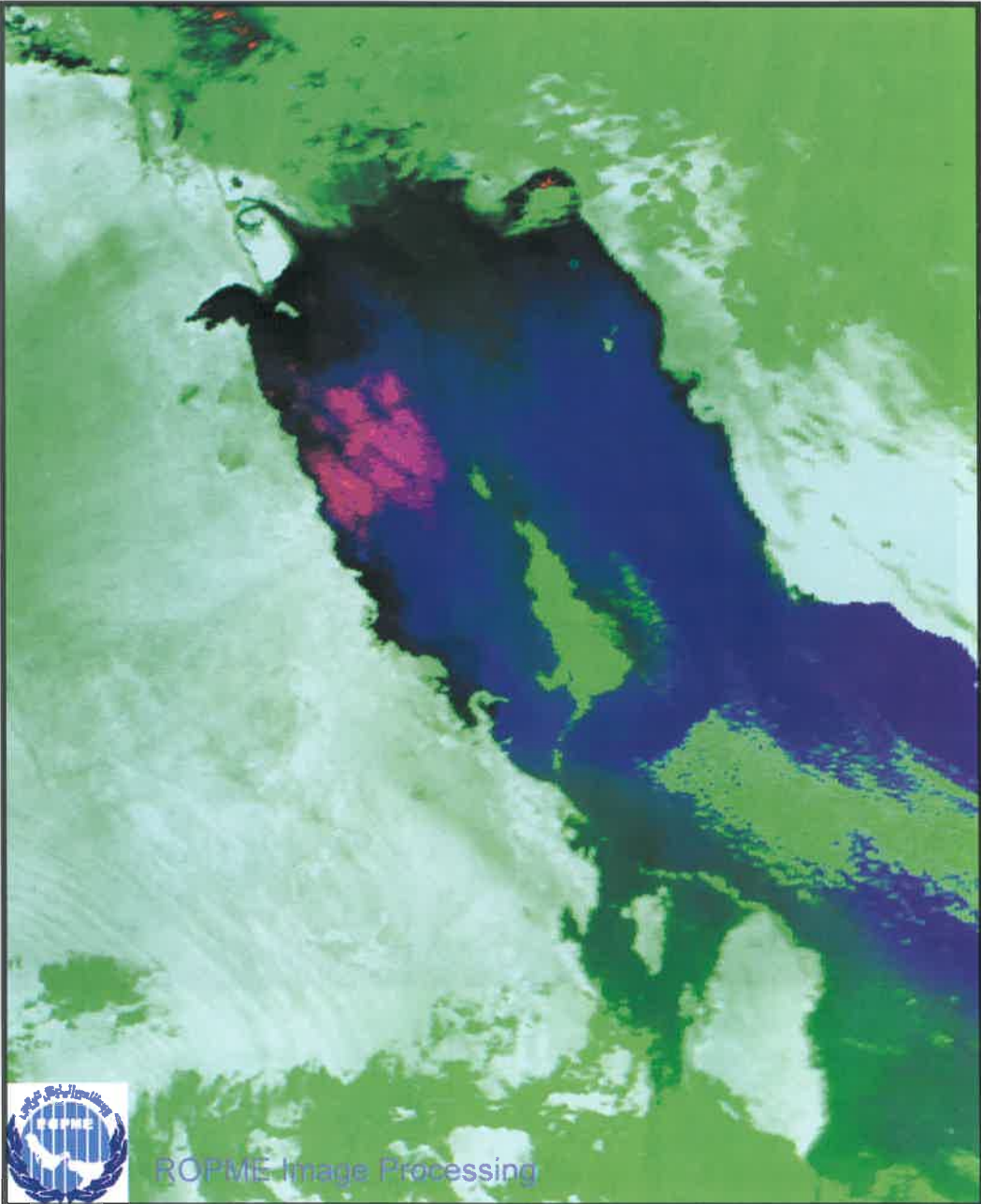
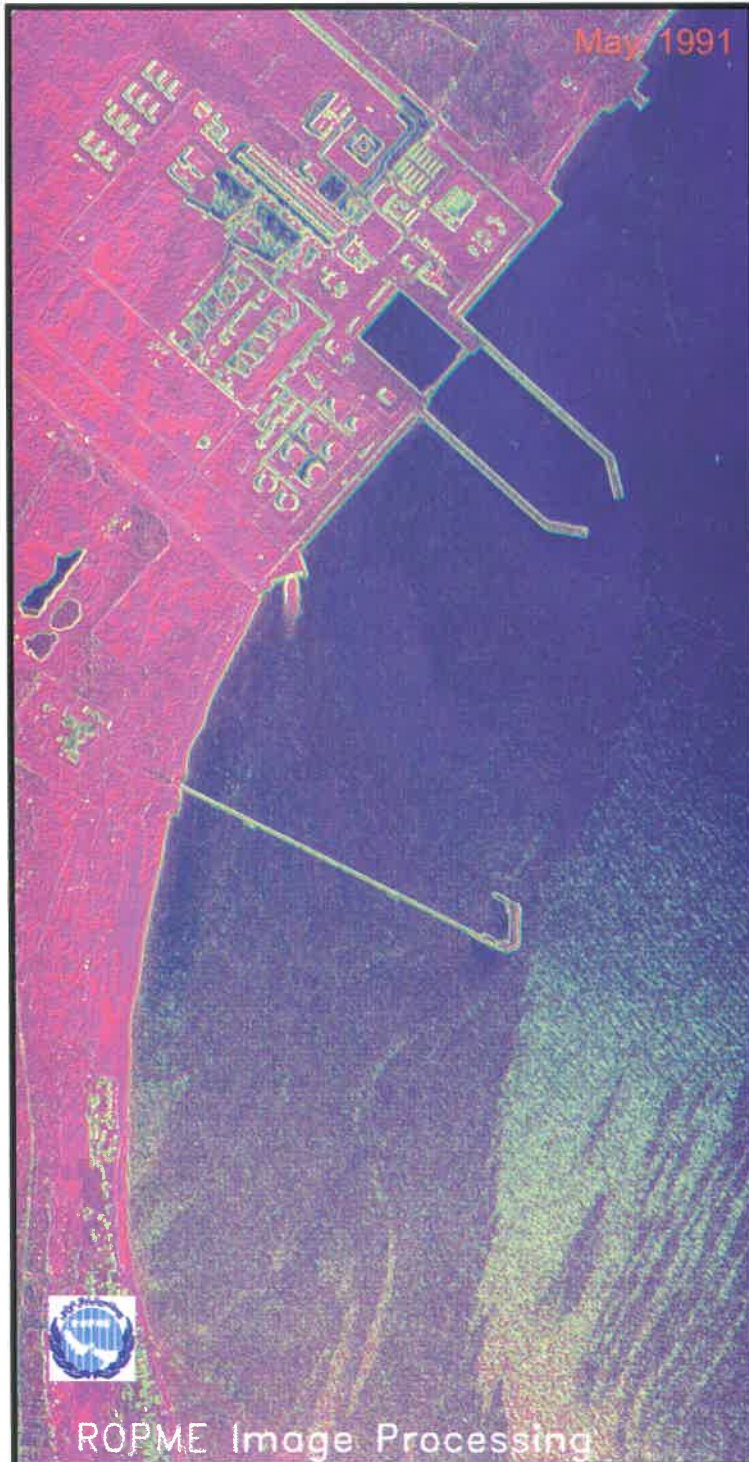


Figure (13): Oil spill in the Northern part of RSA, near Kuwaiti coast (1998)




Figure (14): Small oil slicks near Mina Al Zour, Kuwait, May (1991)



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**Closing Session
and
Recommendations**



**DECLARATION ON SAFETY OF NAVIGATION AND PROTECTION
OF
THE MARINE ENVIRONMENT**

Participants at the ROPME/PERSGA/IHB Workshop on Hydrographic Activities in the ROPME Sea Area and the Red Sea assembled in Kuwait during 24 – 27 October 1999,

RECOGNISING the importance of hydrography and marine charting for safety of navigation, protection and sustainable development of the marine environment, development of the maritime economy and marine research;

RECOGNISING that the needs and requirements of marine environmental protection and hydrography can be ensured through bilateral and multilateral co-operation, including co-operation with relevant regional and international organisations

DESIRING to further develop the national capacities of Member States of ROPME, PERSGA, and IHO for the provision of adequate hydrographic and environmental services

Decide to adopt the following:

- Organise joint technical workshops on hydrography with industry participation in the Region at intervals of 2 – 3 years.
- Strive to adhere as closely as possible to regional and internationally adopted standards and specifications on hydrography, protection of the marine environment and the promulgation of maritime safety information.
- Endeavour to establish close links between the respective national authorities responsible for hydrography and protection of the marine environment at the national and regional levels.
- Support regional plans in the ROPME Sea Area and the Red Sea for hydrographic surveys, the development of marine charts, the distribution of maritime safety information, and the formation of a Regional Hydrographic Committee.

IHO CLOSING REMARKS

The IHO would like to thank ROPME for the administrative arrangements, which have made this workshop such a success. The organisation of the event has been impeccable.

We would also like to thank the speakers and exhibitors on the high quality and great interest of their papers and displays. We have had an opportunity to be briefed on the very latest technologies, techniques and applications in hydrography. The lectures and displays have made the technical aspects of the workshop a great success.

And we would like to thank the representatives of the ROPME and IHO Member States for your very active participation in the discussions, both formal and informal. We hope that you have found the workshop to be useful.

It is pleasing to report that the workshop has confirmed and re-emphasised two things.

The first is that hydrographic services are focussed on prevention of accidents and pollution. The word response has not been mentioned.

The second is that the responsibilities and contributions of the hydrographic services within the national economic infrastructure go well beyond navigation, and are fundamental to the sustainable development of the maritime zones and maritime resources.

Another important outcome of the workshop has been the decision, in principle, of ROPME and IHO Member States to form a Regional Hydrographic Commission for the ROPME Sea Area, which will greatly assist international co-operation in hydrographic development in the region.

The IHO is well satisfied with the result of the workshop, and looks forward to further co-operation with ROPME in the future.

Thank you all very much indeed.

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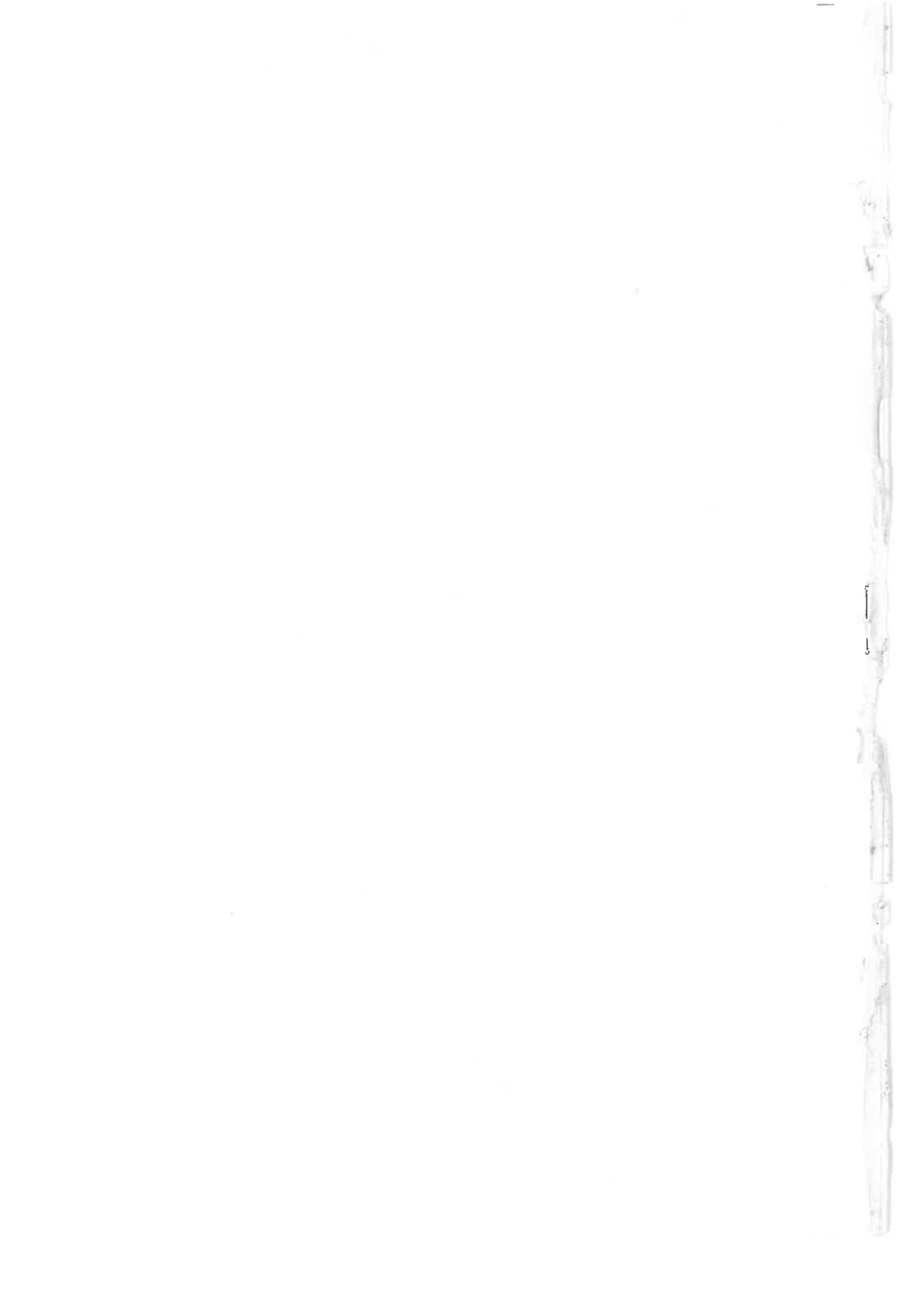
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