THE INFRASTRUCTURE REQUIREMENTS FOR A MARINE INFORMATION MANAGEMENT SYSTEM

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PREFACE

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THE INFRASTRUCTURE REQUIREMENTS FOR A MARINE INFORMATION MANAGEMENT SYSTEM

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PREFACE

This technical report is a reproduction of a thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Engineering in the Department of Surveying Engineering, August 1990. The research was supervised by Dr. John McLaughlin, and funding was provided partially by the Natural Sciences and Engineering Research Council of Canada and by Energy, Mines and Resources Canada.

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Abstract

This thesis investigates the necessary and sufficient infrastructure requirements to build a marine information management system capable of providing effective information services to the whole spectrum of users of marine information including governments, industries, and academic institutions.

To determine the current status of marine information management in Canada selected information systems from the federal and provincial governments and the private sector are examined. Based on this examination two case studies are presented to determine the user requirements. Aquaculture was selected as an application for a marine information system from which to determine the broader and more general user requirements. The Electronic Chart, since it is a tool to support an application (*the application being navigation*), was chosen to determine the more specific user requirements.

The results of the case studies indicated a need for networking the various data sets necessary to create and provide the information that users require. Design considerations for networking and sharing marine data sets are presented. These include basic data problems, financial and technical concerns, political issues, distributed data processing methods and trends, and network architecture and design.

The required infrastructure to support a marine information network consists of data collection systems, databases, and data transmission systems. Each of these elements requires a set of common standards and resolution of technological and institutional issues before the network can be implemented.

A proposed infrastructure design is presented along with recommendations for the development and implementation of a marine information network.

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ACKNOWLEDGEMENTS

This thesis could have been written only with the support, guidance and assistance of many people to whom I wish to express gratitude. For fear of omitting someone and due to space limitations (I am told a thesis cannot consist solely of acknowledgements) I will not attempt to personally name everyone. However, I must single out the following individuals and organizations whose support is gratefully acknowledged:

- Dr. John McLaughlin, my supervisor, for his understanding and support and for providing the direction and the insight into thinking, learning, and better judgment.
- Sue Nichols, Ph.D. candidate in Surveying Engineering at UNB, who was always available to provide advice and guidance.
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- The office staff of the Surveying Engineering Department for the many favours over the past couple of years.
- My children, Christopher, Jennifer, and Sandra for their confidence that one day this thesis would be finished and there would be time for other things.
- Jean, my best friend, for her unfailing support in countless ways. Someday, though it will be difficult to do, I hope I can return the favour.

Chapter 1

INTRODUCTION

We cannot manage what we don't understand. We generally do not focus attention on problems which are not identified. When the potential for problems is identified early, there are more alternatives and solutions. Unfortunately, we spend large amounts of money trying *to manage things we don't understand. We often allocate resources unwisely. We often fail to recognize early signals of developing problems and then try solutions no longer viable.*

[Richard A. Foster]

1.1 BACKGROUND

This thesis reviews the problems associated with managing information relating to Canada's coastal and ocean territory and proposes a framework for marine information management that will allow decision makers access to data on which to base management decisions for the sustainable development of Canada's ocean resources.

Canada has an extensive coastal and ocean territory. According to Sanger [1987] there are 1.29 million square nautical miles within the 200 mile Exclusive Economic Zone (EEZ). Of this territory, which is approximately 40% as large as the total Canadian landmass, only 50% of the area below and 20% of the area above latitude 60^0 north has been surveyed and mapped to modern standards [Douglas, 1988]. This territory provides the basic resource for three major sectors of the Canadian economy: the fishing industry, the offshore oil and gas industry, and the marine transportation industry. Growth and improved management of these sectors demand an improved information infrastructure

In 1985 Canada's ocean resources contributed more than $8 billion toward the Canadian economy and accounted for more than 140 000 jobs. The federal government undertakes some 75 ocean-related programs through 14 departments, involving more than 13 000 person-years and $1.3 billion annually [DFO, 1987]. Apart from these activities there are many highly specialized science and advanced technology-based industries such as coastal and ocean engineering, advanced technology manufacturing, marine systems and equipment design and fabrication, oceanographic, hydrographic, and marine environmental services [DFO,1987] associated with the ocean sector.

1.2 MANAGEMENT OF MARINE INFORMATION

People have been, in varying degrees, collecting and storing marine resource information for several centuries. As early as 1497 when John Cabot, an Italian Explorer, sailed his ship, **The Matthew**, across the North Atlantic and claimed Newfoundland in the name of King Henry VII of England there is documented evidence of the *"abundance of fish in the waters of the new found land"*[Turnbull, 1966]. In 1988 the Department of Fisheries and Oceans, Canada, sailed its research vessel, **Wilfred Templeman**, off Canada's east coast and concluded that there is a *"lack of fish in the waters off Newfoundland"* [Fitzpatrick, 1988]. In the nearly five centuries that have passed between these two voyages much data have been collected and many databases have been created. From the two contrasting statements above it is quite evident that merely collecting and storing data alone does not constitute good marine resource management. The data must be managed and be accessible to decision makers when it is required, and must be in a format that is usable. The data, in itself, are a resource. However, that data have not, until recent years, been viewed as a separate resource requiring specific management practices.

The value of the information as a resource was, and still is, not completely understood and is therefore inadequately managed.

Rapidly expanding populations and the desires of all nations to improve their standard of living is leading to a greater per capita consumption of world resources [Steel, 1987]. Under current consumption practices the earth's land resources alone cannot sustain the demands placed upon them, consequently the resources of the ocean are being more heavily taxed. Hence, there is a greater demand for information about the type of resources, the environment in which they exist, exploration and exploitation methods, their quantity and quality, ownership, etc. The information requirements will be different for different users. Even within the same organization the information requirements will differ. For instance, the information needed by a senior manager for policy formulation and regulation is different from that needed at the operations level for administration and planning.

Because Canada has sovereignty over, jurisdiction of, and the rights to such vast ocean territory, the responsibilities for managing its marine resources are very extensive and complex. In order to maintain these responsibilities an immense amount of information is required and therefore some kind of information management system must be constructed. Depending on the function of the organization, the system may be as simple as a set of filing cabinets or as sophisticated as the most advanced electronic data base management system.

In the context of this thesis **marine** means of or pertaining to the sea or matters connected with the sea. Therefore, the term **marine information** refers to all information related to coastal and ocean areas. Again, in this context the **coastal area** is arbitrarily defined as a narrow strip of territory extending not more than 1 km inland from a line defining the ordinary high water mark and approximately 1 km seaward of that line. **Ocean** refers to either and all of the three bodies of salt water surrounding Canada, namely; the Atlantic, the Pacific, and the Arctic Oceans.

1.3 NATURE OF MARINE INFORMATION

The nature or characteristics of marine information are such that there is an intricate interaction between the various information types. For example, information about water temperature may be, among other purposes, used to: (1) determine potential uses for a particular marine site, (2) study the influence of a water body on the local climate, or (3) determine the likelihood of the existence of certain marine species in a particular area. As a result methods used to collect, store, analyse, manipulate, and distribute marine data may have a significant impact on the use of the data.

The technology associated with providing marine information depends on the institutional and environmental aspects of the information and vice versa. To attempt to improve marine information management by changing one of these components will impact on the other components. For example, introducing new technology without considering the technical skills and capabilities of those who will be responsible for its use and maintenance may impact on productivity, morale, safety, staff changes, etc.

Marine information also interacts horizontally and vertically within and among organizations responsible for the use and protection of marine resources. There is horizontal interaction between various departments of government. The programs and policies of one department may very well change those of other departments. For example, approval of an aquaculture site in a given location may prevent recreational development or mineral extraction at that location. Unless the pertinent information is available to all agencies involved in marine resource management conflicting uses of resources may arise. In a similar way marine information interacts vertically within organizations. What is considered to be information at one level may be regarded as data at another level. For example, information used to implement policy at the operations level in an organization may be regarded as data to the top level executives who establish the policy.

1.4 MARINE INFORMATION INFRASTRUCTURE

The Chambers English Dictionary [1988] defines infrastructure as the i*nner structure, or the structure of the components parts* and Webster's [1976] defines infrastructure as "*the underlying foundation or basic framework of a system or organization*". It is clear from these definitions that the first step in providing access to marine information for the many potential users must be to develop the infrastructure on which to build a marine information system. An ocean information infrastructure should consist of the collection systems, databases and data transfer networks and access facilities necessary to provide an effective information service to the whole spectrum of users including governments, industries, educational institutions and other interests who make use of the ocean's resources.

An Ocean Information Infrastructure Development Program is one of the components identified in a document entitled "**Oceans Policy for Canada**" produced by the Department of Fisheries and Oceans, Canada (DFO).

> *... an ocean information infrastructure development programme to provide a more effective information service to offshore engineering and navigation, and to government to provide a more efficient, targeted accomplishment of*

government missions.

[DFO, 1987]

Since 1987 there has been increased concern over the environmental sensitivity of the oceans, consequently, information related to environmental contingency and resource management are now important applications for information management systems.

In order to build the infrastructure many factors must be considered. The key factors are policy, finance, technology, organizational structure, education, and research and development [RIM, 1988]. Before the infrastructure can be put in place the process of defining the user needs, identifying value-added, developing the policies, identifying and acquiring the funding, laying out the organizational structure, defining the enabling technology, and establishing the standards must be completed. MacDougall [1989] states that *"infrastructure must include the adoption of standards for both content and data interchange and it must also be extended to the conversion and operation of individual databases"*.

The infrastructure should be the foundation on which to build a marine information system to provide the marine community with the necessary information to effectively manage Canada's marine resources. A simple comparison to emphasize the role of infrastructure may be to compare an information infrastructure to a highway transportation infrastructure. It is generally accepted that a highway transportation infrastructure consists of the road networks, the roadbeds, the traffic control systems, bridges, service and maintenance vehicles, and personnel. In other words these are some of the necessary and sufficient components to make the transportation system functional.

1.5 TRENDS IN DATA COLLECTION

Marine databases, similar to land databases, have been largely built on a project by project basis and thus tend to be project specific. Information is needed to meet a specific requirement and consequently a data gathering mission is assembled to fulfil that specific demand. As a result most often only those directly involved in the project are aware of the existence of the data. In some instances this approach is necessary. For example, in the case of an emergency situation such as an oil spill the data requirements are immediate and specific.

In Canada, the majority of marine data bases are created by federal government departments. A few data bases are created by industry and by various educational institutions but these are usually created in support of government projects. The educational institutions require data for research in pursuit of new knowledge, for projects in the graduate studies programme, and also for use as demonstrations of marine phenomena in their teaching programs. According to Borstad et al. [1988] "*government and industry requirements are narrower, with government showing more interest in biological and chemical parameters such as plankton, fish, chemistry, water quality and seaweeds than industry*". Research in these areas is often specific and according to federal government representatives, "*requires the collection of most of the data by the researchers themselves*" [Scarratt, 1988]. Although the data are collected by the researchers, it is generally paid for by public funds.

1.6 THE NEED FOR MARINE INFORMATION MANAGEMENT

The Federal Government has identified the need to develop a program approach to **marine resource management** in order to coordinate the marine related activities of its various departments and has addressed this need in a Multi-Year Marine Science Plan for Canada [DFO, 1988]. The Plan promotes greater and easier access to marine information *"based on a geographically referenced electronic database network"*. The need to coordinate the marine information component was also addressed in the Plan.

> *It is recommended that detailed requirements for a national ocean data and information infrastructure be developed by DFO with optional participation by other government departments. The analysis should include the relationship to other biogeophysical information systems, and a strategy for involving industry in its implementation.*
>
> [DFO, 1988]

Through recent events such as the Inland Waters, Coastal, and Ocean Network (ICOIN) Forum several federal and provincial government departments have acknowledged the need for, and are cooperating with industry to implement, a marine information management plan. As well, fiscal constraints are forcing government departments to consider a program approach as opposed to a project approach to data gathering. More and more, in order to acquire funding for data collection, project managers must convince senior bureaucrats of the need and demonstrate how each project fits into an overall program [Doubleday, 1989].

There are many existing and emerging technologies such as remote sensing systems, spatial information systems, artificial intelligence, and expert systems which can be applied to the management of the oceans and their resources. The challenge of the future is to pull these systems together and create an information infrastructure to help increase productivity, improve safety, provide better environmental quality, and to establish Canadian sovereignty over the coastal and ocean territory.

1.7 THE APPROACH

The approach taken in this thesis is to first review the current status of marine information management in Canada. In Chapter 2 a number of marine databases and systems are identified and their purpose and contents are reviewed. In order to gain an understanding of the user requirements for marine information Chapter 3 presents two case studies. The first study is more specific and looks at the information requirements of a tool used in an application; The **Electronic Chart** is the tool and **Marine Navigation** is the application. The second study looks at the information requirements associated with a marine application, namely **Aquaculture**. Chapter 4 identifies and discusses the institutional issues associated with the networking of information systems and databases within the marine user community. Chapter 5 addresses the technological issues associated with networking and distributed data processing involving distributed heterogeneous databases. Chapter 6 presents the infrastructure components on which to build a marine information network. A proposed design for access to existing marine data is also presented. Chapter 7 consists of the conclusions drawn from the project and provides recommendations for follow-on work necessary to implement a marine information management system to meet the needs of the Canadian marine user community.

The major contribution of this thesis is twofold:

1. It provides a synthesis of the ideas and concepts of marine information management discussed at various workshops, seminars, and forums over the past several years and presents it in one document.
2. It provides a framework for:
    a) defining and analysing the issues and the problems,
    b) defining the user requirements, and
    c) designing an infrastructure on which to build a marine information system for Canada.

Chapter 2

CURRENT STATUS OF MARINE INFORMATION IN CANADA

Before we look into the heart of the information society - at the industries that produce information, the networks that move it, the corporations and institutions that use it and the scientists who study its technical and human facets - we need to step back and examine the long-range social, economic and technical trends responsible for the ascendancy of the information society. Only by understanding the long-term nature and direction of change can we chart a course for the future.

[Communications Canada, 1987]

2.1 INTRODUCTION

There are several information systems in place in Canada which support marine-related activities. Table 2.1 shows a selection of government and private sector systems along with their sources and functions. With the exception of a few such as the Marine Environmental Data Service and the Canadian Hydrographic Service, organizations have generally implemented systems to meet their own internal information needs on an as-required and often on an adhoc basis. Generally accepted procedures for defining user requirements may have been followed, but only with respect to internal requirements.

To date geographic data bases have not generally been created with the idea that they would be used in any way beyond their original purpose, which in most cases was a single purpose, that being to create a paper map or chart. These data bases, whether electronic or manual, were not amenable to any other usage and especially by outside agencies. In order to use these data bases, a good understanding of the data contained within them was required. There was no attempt to generalize the data so that it would be more amenable to a myriad of other uses. There was no attempt to standardize on basic data elements to assure users of the precise meaning of such data. All this happened because most of these data bases were created *in-house, and were used solely in-house.*

[R.Baser, 1989]

Table 2.1 Selected marine-related information systems and databases.

System	Developed by	Function
Marine Environmental Data Service (MEDS) System	MEDS, a Branch of Ocean Science Section Dept. of Fisheries and Oceans Canada	National Ocean Data Centre for Canada and the data management focus for Ocean Sciences Branch.
Canadian Marine Data Inventory	MEDS	Inventory of data holdings in government, industry, and universities.
Canadian Sea Ice Information System	Centre for Cold Ocean Resources Engineering (C-CORE), MUN	Provision of sea ice information for marine users.
Canadian Hydrographic Service (CHS) System	CHS, a branch of Ocean Science Section Dept. of Fisheries and Oceans Canada	Provision of navigational information to marine users.
Climatological Ice Data Archival System (CIDAS)	Dept. of Environment Canada, Atmospheric Environmental Service	Archival data storage for Arctic and East Coast ice data.
Canadian Oil and Gas Lands Administration (COGLA) System	Depts. of Energy, Mines, Resources/ Indian and Northern Affairs Canada	Information on administration of oil and gas activities on Federal Lands.
Climate Research in Ice Software Package (CRISP)	Dept. of Environment Canada, Atmospheric Environmental Service	Manipulation of ice information taken from archived AES weekly ice charts.
Environmental Data Base System (EDBS)	Petro-Canada Exploration Limited	Provision of on-line environmental data for the Labrador Shelf, the Grand Banks, and the Scotian Shelf.
Shipboard Ice Navigation Support System (SINSS)	Transport Canada and NorthWater Navigation	Integration of shipboard, satellite, and airborne remotely sensed data in support of historical ice/climatology studies.
Arctec Canada Macintosh System	Arctec Canada	Modelling and statistical analysis of oceanographic data.
Institute of Ocean Sciences (ODIS) System	Institute of Ocean Sciences, DFO Canada Sydney, B.C.	Physical, Chemical, and Biological oceanography in support of ocean research.
Fisheries Information Network System (FINS)	DFO Canada, Gulf Region, Moncton, N.B.	To facilitate the coordination, access, and flow of oceans and fisheries-related data among user groups.
Geophysical database of the Atlantic Geoscience Centre	Atlantic Geoscience Centre, Bedford Inst. of Oceanography, Dartmouth, N.S.	Provision of geophysical data for marine areas.

2.2 THE NEED FOR MARINE INFORMATION SYSTEMS

The definition of a Marine Information Management System (MIMS) is immaterial to the user for which it was created as long as it adequately performs the functions for which it was intended. However, problems may arise when other users want to access the system and share or exchange information. This is particularly true in the case of information contained in electronic databases more so than that contained in filing cabinets. At least one can search through a filing cabinet and physically extract the information and pass it on to other users.

One method avoiding the problems associated with information exchange, would be to have the entire marine information user community agree on a universally accepted system and proceed toward implementing it. In practice such an arrangement is likely not achievable. Consequently, the approach most likely to be accepted for information sharing of electronic databases is to develop standard data transfer formats which can be used to transfer data between a number of different systems.

A MIMS would be a system which would collect, analyse, store, and distribute information for marine applications. The system would be accessible to all users and allow full integration of data sets contained in the various databases. This would be similar to the idea of networking geographic information systems (GIS) with standard interchange formats for land based applications. Several authors suggest that GIS technology could be the *"principal enabling technology"* on which to build a marine information network [Anderson, 1989; LeBlanc, 1989; Baker, 1989]. The marine information network suggested by the proponents of ICOIN would include databases covering all marine related programs and activities having information requirements such as those shown in Table 6.1.

2.3 MARINE INFORMATION SYSTEMS IN GOVERNMENT

The majority of the marine-related systems in Canada are situated within federal government departments or agencies. This is because:

> *The federal government has the broad responsibility for the stewardship of Canada's oceans jurisdiction. That responsibility encompasses activities on, in, and below the water, and extends to resources and resource users. The role of the government in oceans can be summarized as follows:*
>
> - *understanding the offshore environment and its resources;*
> - *encouraging economic development;*
> - *mediating conflicts between user groups;*
> - *protecting the common resource base and the marine environment;*
> - *providing infrastructure for safe navigation; and*
> - *preserving and enhancing Canadian sovereignty.*
>
> [DFO 1987]

In order to help fulfil its role and undertake the responsibility assigned to it the federal government has created several marine information systems between the fourteen departments which administer the approximately 75 programs having a direct bearing on the marine community. DFO alone, has 48 offices across Canada which hold marine information of various types and in varying formats. In addition to the federal government information systems there are provincial government and private sector systems as well. Three public sector marine information systems, two federal and one provincial, as well as an example of a private sector data holdings, will be reviewed in the following subsections.

2.3.1 Canadian Hydrographic Service Information System

Figure 2.1 shows the major databases contained within the Canadian Hydrographic Service (CHS) and how they interact in the proposed model for the creation of a CHS Information System. The CHS is a Branch of the Ocean Science and Surveys Section of

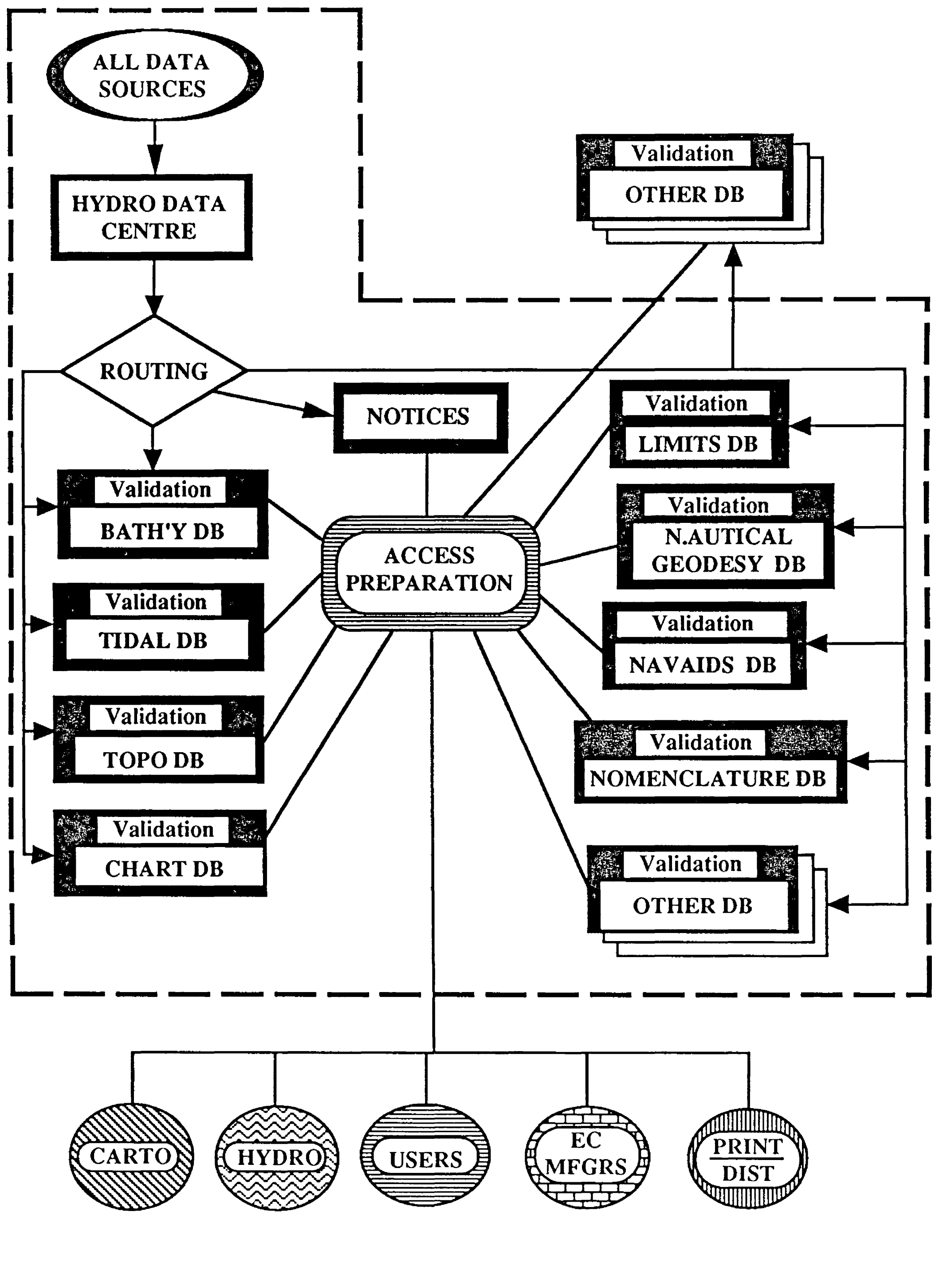

Figure 2.1
Canadian Hydrographic Service information system.
(After [MacDougall, 1989])

DFO Canada. The CHS system is being developed to more efficiently carry out its mandate of providing navigational charts, sailing directions, tides and current tables, and other related information to mariners. The raw data will be collected and channelled into the system through the Hydrographic Data Centre and routed to the relevant databases to be stored as individual themes. When navigation charts are in production the cartographic section will be able to access each theme database as the data is required for each step in the production of the chart. It is anticipated that in the future the data will be accessed directly by mariners, through satellite links, to update electronic navigational charts in real time at sea.

Although the major use of the hydrographic data collected by the CHS is for the in-house creation of nautical charts, other Federal Government departments such as National Defence (DND), External Affairs, Transportation, Public Works, Indian and Northern Affairs, Environment, Industrial and Regional Development, Supply and Services, and Energy, Mines and Resources use the data for various programs and activities.

Many private sector companies such as offshore oil and gas exploration companies, shipping companies, and marine engineering companies also use the data in formats from its raw state to its processed state, aside from its nautical chart form [MacDougall, 1990].

2.3.2 Marine Environmental Data Service Information System

Figure 2.2 shows the databases and the flow of information within the Marine Environmental Data Service (MEDS). MEDS is a branch of the Ocean Sciences and Surveys Section of DFO Canada. MEDS was established to be Canada's national centre for the management and care of physical and chemical oceanographic data [DFO, 1981].

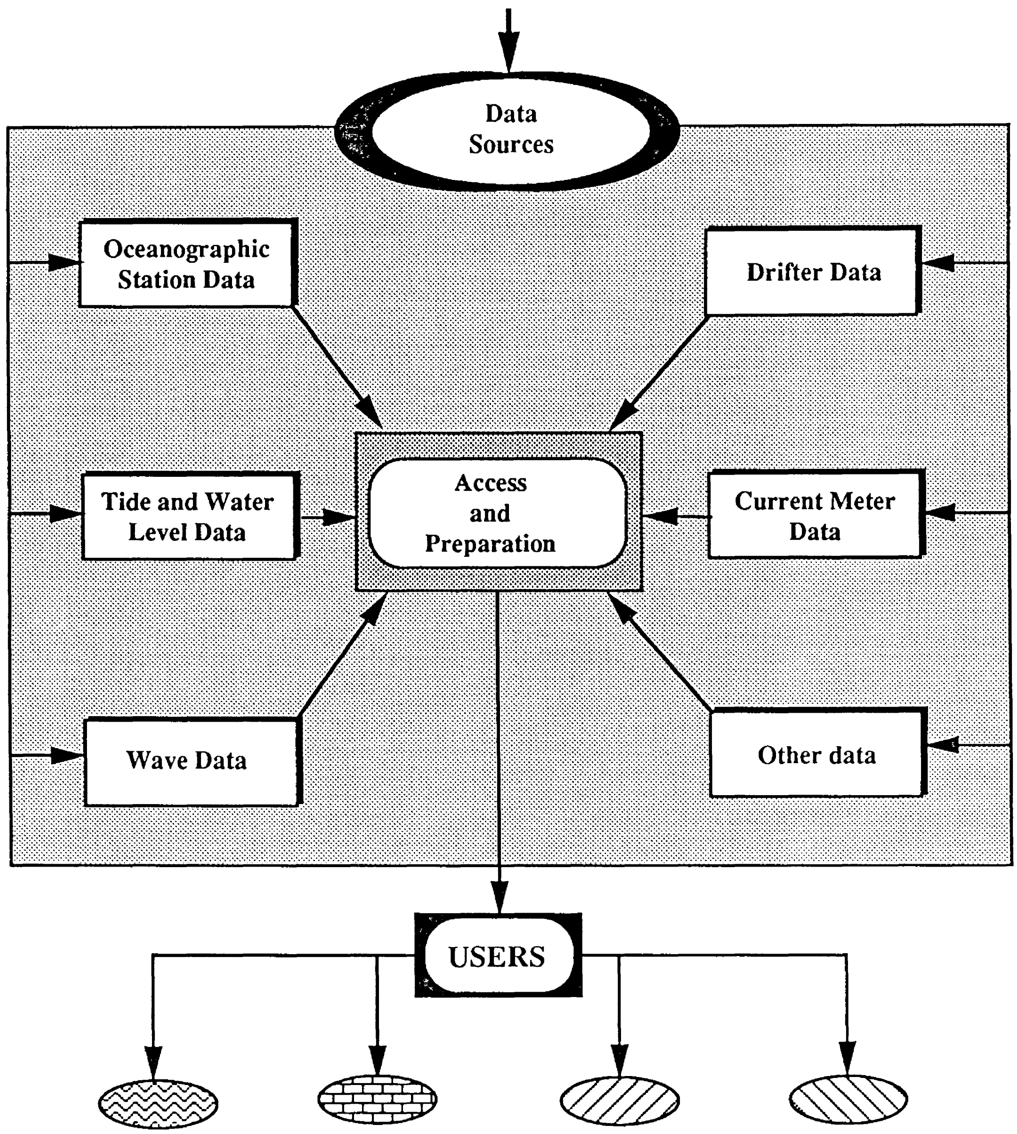

Figure 2.2
Marine Environmental Data Service data flow.

Certain oceanographic and tide and water level data sets extend back before the turn of the century and contain, in total, from 0.5 GB to 1 GB of data in its processed form. Wave data is collected from more than 130 locations around Canada, including the oceans and inland waters. These data sets extend back to the 1960s. MEDS records Drifting Buoy data from hundreds of buoys deployed by many different countries. These data are recorded in real time (every 3 hours) via satellite down link to the MEDS headquarters at Ottawa. Over the last 10 years MEDS has collected more than 1 GB of Drifting Buoy data. Other sources of data include private fishing companies [Jones, 1990].

An inventory of MEDS data holdings can be found in the Canadian Marine Data Inventory (CAMDI). CAMDI is a computerized database that has been developed at MEDS and contains information about the marine data holdings of many of the different levels of government (including MEDS), industry, and educational institutions across Canada. CAMDI can be accessed online by outside users and can be searched by geographic location, time, and observation type. The system will provide the searcher with a descriptor that can be given to MEDS for retrieval of the data. MEDS provides the service of retrieving the data regardless of where it is housed [Jones, 1990].

MEDS data is currently stored in an Index Sequential Access Method (ISAM) format, not in a database management system. ISAM is a file based data structure rather than a database management structure. Hardware consists of DEC VAX11-750 and 6320 CPUs with 8 gigabytes of online storage and all internal databases are linked via a DECnet-VAX local area network. MEDS is also one of the nodes of the DFOnet, a network being built within DFO to link all of the Regional Offices of the department. DFOnet will operate on Bell Canada's DATAPAC, the X.25 packet switching system.

2.3.3 New Brunswick Department of Fisheries and Aquaculture Information System

As an example of a provincial government information system the data managed by the New Brunswick Department of Fisheries and Aquaculture (DFA) will be presented. DFA has established a Working Group on Information Management and Reporting Systems to *"...provide reports and make recommendations on matters related to the information management and reporting systems of the Department" [DFA, 1989]*. The data types shown in Figure 2.3 are those presented by the GIS Working Committee of the Working Group on Information Management and Reporting Systems. These data items were identified as the *"GIS Priorities for a Demonstration Project"* [Sisk, 1989]. The data are currently stored in several different formats within the Department. Most of the data are in hard copy format in the form of paper files and conventional maps. However, the Department is proceeding with plans to undertake a GIS Demonstration Project [Sweeney, 1990]. A Systems Requirement Definition study is currently being completed for DFA by the New Brunswick Department of Supply and Services, Information Systems Group. The results of the study are not available at the time of writing [Kolls, 1990].

2.4 ACCESS TO GOVERNMENT DATABASES

Access to the majority of existing databases is via the mail or the telephone system. Users that are aware of the data will determine the location of the data they require and arrange to have a copy delivered. The data will be delivered to the user in the form of a magnetic tape or disc or in hardcopy format such as tables or log sheets. In certain instances the data are available on-line via computer networks using DATAPAC. Within some organizations the data is transferred between divisions via a local area network. For example, as mentioned earlier MEDS uses DECnet.

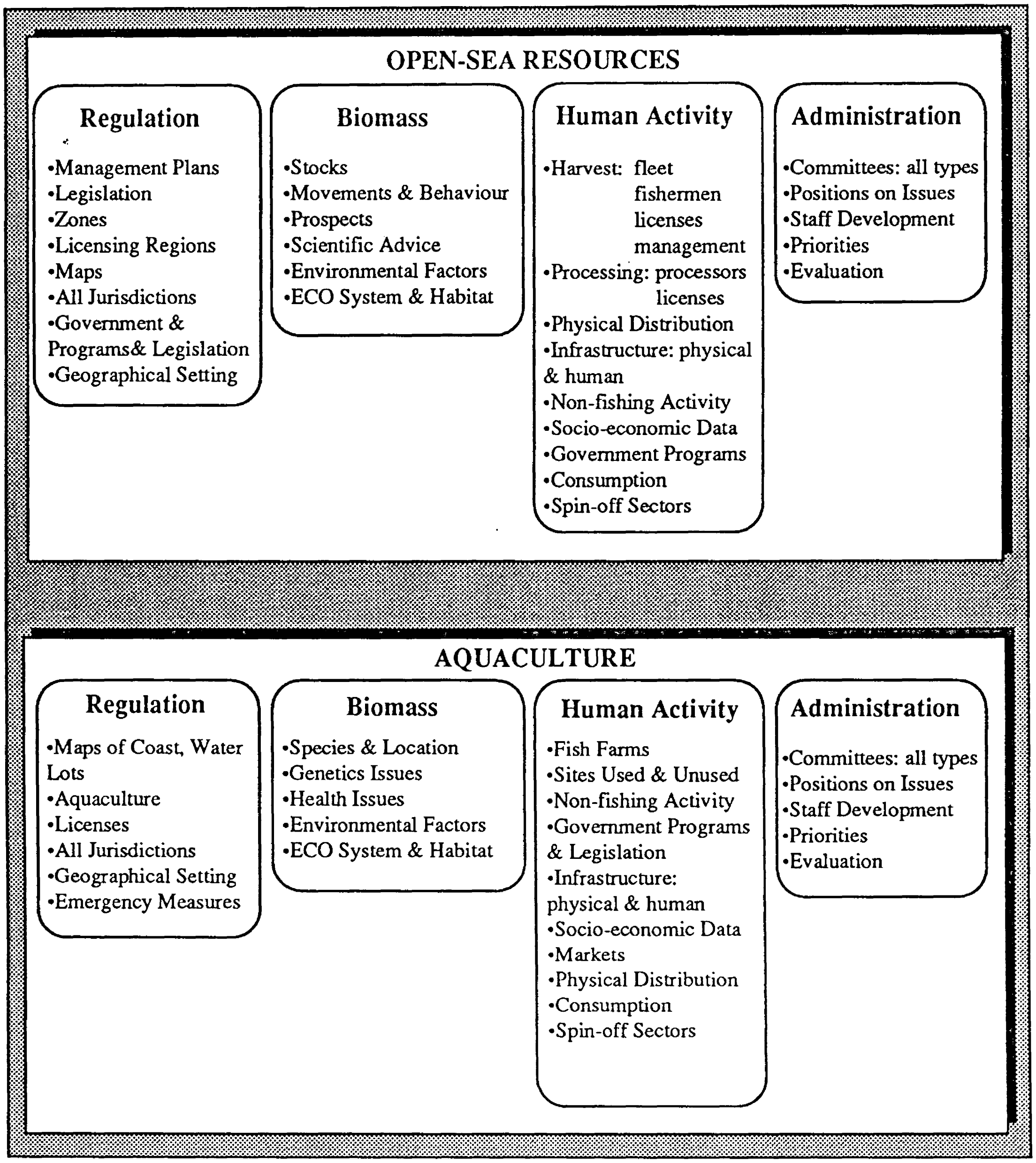

Figure 2.3
New Brunswick Department of Fisheries and Aquaculture information requirements.

Accessing the various marine databases has been generally difficult for the users outside the respective organizations responsible for collecting and storing the data. In other words, access is difficult to everyone except the owners or custodians of the data. There are several reasons for the lack of access. First, there is the fact that outside users are unaware that the data exist since there is no official library or inventory system, with the exception of MEDS, in place to catalogue or record the existence of the data. Second, the data are in many different forms and formats and is often difficult or impossible to interpret by users other than the collecting organization. For example, objects of the same type may be given different names in different databases. There has been no attempt made to generalize the data, either in electronic or manual format, such that other users can interpret it. Third, certain data have certain restrictions placed on it such that it cannot be released to the public in spite of the fact that there is legislation to ensure access to information in Canada. The Federal "Access to Information Act" [1983] states that:

> *The purpose of this act is to extend the present law of Canada to provide a right of access to information in records under the control of a government institution in accordance with the principles that government information should be available to the public, but necessary exceptions to the right of access should be limited and specific and that decisions on the disclosure of government information should be reviewed independently of government.*

Although the "*necessary exceptions ... should be limited and specific*" they give government officials enough powers to refuse to disclose certain information to the public. Although no examples of refusal of access to ocean data can be cited the point is that mechanisms are in place to allow refusal if so desired. The reader is referred to Sections 13 through 25 of the Act for further details on exceptions.

2.5 MARINE INFORMATION SYSTEMS IN THE PRIVATE SECTOR

Some of the marine information used by the private sector is provided by the government. However, the private sector must supplement the information for much of its operational needs. Since the marine environment is such a dynamic regime it is necessary to make virtually continuous observations during operations for certain applications. For example, ships transiting ice infested waters must be constantly aware of the ice conditions in their immediate vicinity and as well be aware of what conditions lie ahead in order to avoid damages and minimize delays. Offshore drilling operations must constantly monitor sea state and weather conditions to ensure safe operations. Similarly, the fishing industry, the aquaculture industry, and the marine science and engineering industry collect large quantities of marine data in their day to day operations. The data that is retained could be valuable to many other users if it were available. Unfortunately, for some applications (see Figure 2.4), much of this data is not retained for subsequent use and as a result a potential source of information is missed.

The private sector is a valuable source of data for several government programs. In certain instances the private sector is bound by regulation to make its data available to the regulating agency of government. For example, the fishing draggers are bound by regulation to have observers on board to monitor fish catches and report to DFO. Ocean going vessels operating in northern waters are obligated to report iceberg sightings to the nearest Canadian Coast Guard station. Fishing companies operating off the East Coast such as Fishery Products International Limited (FPI) and National Sea Products (NatSea) send marine-related information to MEDS daily.

Governments sometimes contract to the private sector as a source of data collection and analysis for projects which, for various reasons, cannot be undertaken in-house. In this case the work is done under contract and all results passed over to a particular government department at the end of the contract. The government then has the same control over the data in terms of quality, quantity, resolution, and ownership rights as if it were collected in-house. The company conducting the contract may sometimes, under special agreement, be allowed to keep a copy of the data and use it as per the agreement. The company may add value and market certain information derived from the data or use the data to support other business enterprises.

2.5.1 Deep Sea Fishing Companies' Databases

Although they are not all publicly accessible there are many private sector marine information systems throughout the marine user community. Large fishing companies such as FPI and NatSea hold massive amounts of data in their organizations. Figure 2.4 shows the data being collected by the Captain and officers of a fishing vessel operated by FPI. FPI operates a fishing fleet consisting of 52 deep-sea wet fish trawlers, two northern shrimp trawlers, and 8 scallopers [Hogan and Clarke, 1989]. NatSea collects and uses similar data and information and has an even larger fishing fleet in operation.

The amount of data collected by these two organizations in a year can make a significant contribution to marine science provided scientists could access the data and that it were in an acceptable state. That is, that it meets accuracy and resolution (temporal and spatial) requirements and can be accessed in a reasonable amount of time. The access time would vary with the particular application. If the data were being used for emergency response the data would be required in near real time whereas for statistical purposes access time of days would be acceptable.

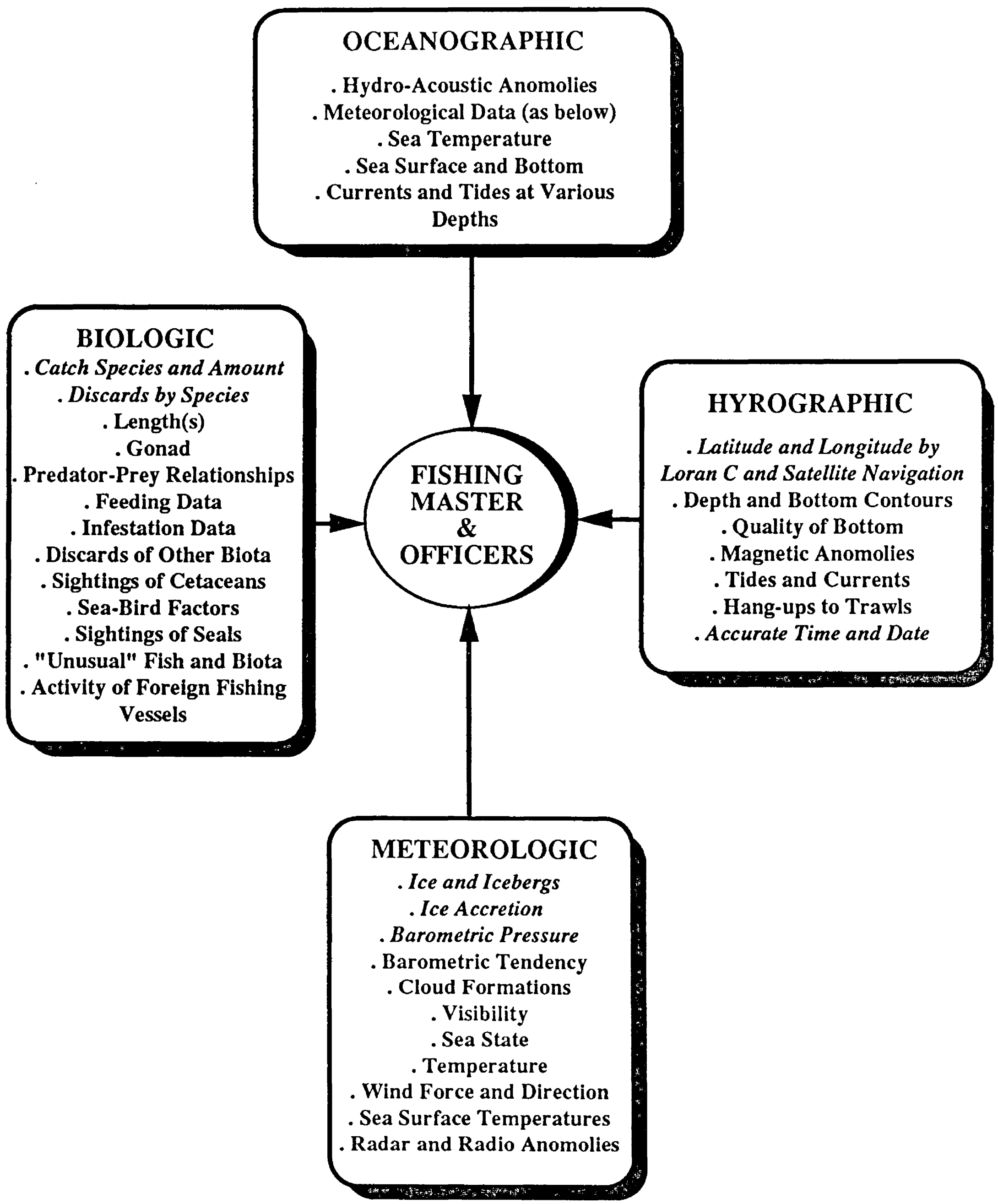

Figure 2.4
Data collected by the Captain and Officers of a fishing vessel.
Retained data in *italics*.
(After [Hogan and Clarke, 1989])

It is interesting to note from Figure 2.4 that of all the data collected by the Captain and Officers of a fishing vessel only a very small percentage is retained. The bulk of the data is used for immediate operational activities and never recorded. There appears to be an opportunity to acquire some valuable ocean-related information from these data sets if they were recorded and passed on to the relevant authorities. However, it must be determined whether the data are of significant value to justify the extra resources such as equipment and personnel required to record and handle them. The fishing companies could not be expected to absorb the cost of providing these resources unless they could be guaranteed a return on their investment.

2.6 ACCESS TO PRIVATE SECTOR INFORMATION

Much of the data holdings of the fishing companies is in paper format rather than electronic format. Therefore the data cannot be accessed electronically, online via communications networks. The data could be transmitted via facsimile provided the company was willing to share it and have a person feed the data into the Fax machine. Of course the data could be transferred in hard copy format as well. Wedler [1989] states that *"users want computerized products and access to data in future, but hardcopy should not be excluded"*.

Access to certain private sector data is often limited for reasons of competition. For example, a private sector company collecting data for exploration and inventory purposes would not permit a competitor access to that data. One company could gain a competitive edge and consequently profit from access to certain proprietary data of another company. Releasing the data to government might still allow it to get into the wrong hands. Therefore the private sector tends to be reluctant to allow anyone to access their databases unless there are high security measures taken to ensure unauthorized access to the data does not occur. As Dobbin [1989] points out *"information gathered from one source often appears somewhere totally unexpected"*. The easier it becomes to access multiple databases the more likely data will appear in unauthorized places.

The general trend is for industry to create its own databases and information systems to meet its own needs with little concern for access to the data by other users. For example, the Shipboard Ice Navigation Support System (SINSS) was designed specifically for the icebreaking cargo vessel the "M.V. Arctic". There was no consideration given to access to the system by other vessels. As a result there was no need to consider such issues as standards for data transfer. However, other ships operating in the same general area may wish to access the information and be willing to purchase it if benefits such as time and fuel savings can be realized.

2.7 CONCLUSION

It is not the intent here to analyze the constituent parts of marine information systems nor to determine whether they perform the functions for which they were created. Rather they are introduced to show the range in magnitude of existing systems and to illustrate the problems and issues associated with incorporating such a variety of systems into a marine information network. These systems range from a system such as Shipboard Ice Navigation Support System (SINSS) designed to determine ice conditions and help select the path of least resistance for a ship navigating through sea ice to a system such as Marine Environmental Data Service (MEDS) designed to provide marine environmental data to national and international users. These two systems operate on vastly different hardware and software environments and as well operate in vastly different physical environments. These are the extremes at the high and low ends while all the other systems fit somewhere between. SINSS was designed to serve one specific user with a specific application while MEDS, on the other hand, was created to serve multiple users with multiple uses.

Several other private sector organizations and provincial government agencies hold marine databases and operate marine information systems such as the Mobil Oil Marine Environmental Data [Abel, 1990]. However, the objective of this exercise is not to provide an inventory of marine-related databases and information systems but rather to provide few samples to give the reader an appreciation of the variety and volume of data contained in only a small percentage of the currently existing databases.

Chapter 3

USER REQUIREMENTS

Man, in fact has emerged from the "pioneering" age where the ocean was an unexplored, little-understood environment into the homesteading age where the ocean must be described, harnessed and conserved for the benefit of present and future generations.

[DFO, 1980]

3.1 INTRODUCTION

The information requirements of those who work in the marine environment and are associated with marine-related activities are very broad. Richards [1990] identifies some 400 parameters, with some obvious omissions such as coastal land tenure information, that are collected and directly related to seven categories of marine applications.

Marine information is required to assist in decision making for the exploration, exploitation, and management of marine resources, to ensure safe navigation at sea, to monitor marine environmental pollution, and to establish and maintain national sovereignty. To undertake these tasks requires the collection, analysis, storage, and dissemination of massive amounts of diverse and complex data. A wide variety of users, including governments, industry, and educational and research institutions need access to the databases in order to fulfil their respective mandates. The ease with which access to the databases can be gained becomes a critical factor for certain applications, particularly those which involve quickly changing parameters. For example, ships operating in ice-infested waters need information on ice conditions and the factors that influence changes in the conditions, such as wind, waves, and currents, in near real time.

Defining the user requirements for the broad range of users of marine information goes beyond the scope of this work. The reader is referred to a study by Borstad et al., [1988] for a more in-depth treatment of user requirements. Since the applications of ocean information are so broad and diverse it is proposed that two case studies be used to demonstrate the user needs, technology and institutional issues, and system design and implementation of an infrastructure. Electronic Navigation Charts will be studied as the tool used to aid in marine navigation and will be considered in the narrow scope of the information requirements of a navigation officer on the bridge of a ship. Aquaculture will be presented as a marine application and will be considered in the broader context of the information requirements of the multiple players involved in the site selection, approval, development, and operation process.

The reason for selecting these two subjects is because they represent distinctly different information management issues and data characteristics. Electronic chart data for Canadian waters are presently provided by two main sources and are fairly well standardized. It comes from the CHS in a standard format and from the vessel navigation systems in a format controlled by the vessel operator. The exception is that Electronic Navigation Systems vendors provide chart data but these data are derived from CHS sources. The data required to select, approve, develop, and operate an aquaculture site comes from a variety of sources and in a variety of formats. As a result the user requirements and consequently, the information management issues will contrast significantly.

3.2 ELECTRONIC CHARTS

The concept of Electronic Charts has been around for more than a decade [Eaton et al., 1983]. However, it is only in the last few years that the idea has been developed and electronic chart systems have been developed and marketed around the world. According to Underwood [1985] there were some 10 to 20 electronic chart systems in the world at that time. The rapid technological advances in the fields of computer science and electronics have allowed scientists and engineers to design and build electronic systems which are capable of integrating data from the vessel's navigation systems and marine radar with digital navigation charts. The object created by the integration of these components into a single system is what is generally referred to as an electronic chart.

Developments such as the electronic chart will allow for the availability of a proliferation of navigational information to the navigator on the bridge of a ship. Unfortunately, merely having access to voluminous amounts of data will not solve all of the navigation problems for the navigator. In fact, it may create problems unless the navigator is fully aware of some of the limitations of the data. Unlike the present paper products which attempt to satisfy the information needs of all users at once, electronic charts will select and display specific information without the distraction of other information not presently needed. In other words much of the clutter will be removed from the screen and the navigator will see only the information that is currently relevant.

3.2.1 Background

The first ever electronic chart workshop was held in 1982 at the University of New Brunswick, Fredericton, New Brunswick. At that workshop the concept of the electronic chart was presented as: "*... all of the data needed by a mariner on the bridge of a ship would be stored in a computer memory and would be instantly available for display*" [Hamilton and Nickerson, 1982]. Since then technological developments in electronics, digital cartography, and communications have allowed for the development of electronic chart systems, with varying degrees of sophistication, in several countries. In Japan *"4000 fishing vessels and 150 merchant ships were using electronic charts in 1985"* [Oshima, 1986]. However, according to Crowther [1988] Canada is leading the world in electronic chart research. Grant [1988] stated that: *"Although a few dozen rudimentary systems are presently in operation worldwide, it could be ten years before an electronic chart display and information system, ... is available and used as the legal equivalent of the nautical chart"*.

From a technological point of view, one of the major impediments to the marketing of electronic chart systems was the poor resolution of the image display systems. Mariners expected navigation information presented via the electronic medium to be of the equivalent quality and integrity of the conventional paper navigational chart. Over the last few years technology has overcome the display resolution problems and subsequently several electronic chart systems such as the PINS 9000, DXL 6600 LORAN-SEE:, and MARIS have appeared on the market. However, that is not to say that all the electronic chart production, distribution, and usage problems are solved. There are some technical problems, and even more institutional problems still outstanding. Some of the outstanding problems include:

- The lack of chart data in electronic format.
- Transferring graphical data over the communications networks.
- The lack of agreements on standard formats for data collection and presentation.
- Disagreements between the various users on what should be contained on an electronic chart.
- Who is responsible for up-dating and maintenance of the databases?
- Who holds the liability for errors in or misuse of the data.

These problems must be solved before electronic charts will be widely accepted and used as the conventional paper chart. The systems currently in operation have been developed by manufacturers responding to a market demand for specific applications. If the manufacturers wait for the agencies responsible for supplying chart information to resolve the issues a window of opportunity will have passed [Ridgewell, 1985]. As a result the vendors of electronic chart systems have gone ahead and built their own version of what they think the market will sustain. Each vendor wishes to "build a better mouse trap" in order to gain a competitive edge over the competition. At the same time the attitude of the individual research and development division associated with each vendor is that its system will become the "de facto" standard.

The responsibility for the collection of data and the publishing of nautical charts for Canadian waters lies with the Canadian Hydrographic Service. To date the CHS is committed to the production of paper charts, and until recently has been able to direct only a small portion of its resources to the production of electronic charts. The increased demand from industry for nautical charts in digital format has pushed the government into reviewing its policy on the provision of chart information [Evangelatos, 1989].

3.2.2 Users and Applications

The electronic chart is more than a video display of the traditional nautical chart. The concept has evolved into a micro-processor based integrated navigation system which is now referred to as Electronic Chart Display and Information Systems (ECDIS) [van Opstal, 1987]. Figure 3.1 shows the components of an electronic chart and how these components interact to provide the information needed by the navigator on the bridge of a ship. A high speed, high resolution, colour monitor on the bridge will now display the traditional nautical chart information, positioning information from the navigation system, and information provided by the radar. Other information sources such as depth sounders, speedlogs, anemometers, and gyros can also be incorporated. The information can be provided and displayed at a variety of scales. For example, large scale, detailed information is provided for entrance to ports and harbours while small scale, less detailed information is adequate for general navigation offshore.

Many large shipping companies are now using electronic chart systems as a major source of information for navigation. For example, the American President Lines, one of the worlds largest cargo carriers, uses an integrated navigation system (INS) on several of its ships. The INS

> *"processes data from several positioning networks, merges it with a digitized chart program, and displays the ship's location as a moving point of light on a color monitor. The electronic bridge allows the vessel to be operated at sea with as few as two people - a licensed watch officer and an able-bodied seaman - during calm daylight weather with light traffic. Of course, night time, near-coast, or foul weather require additional personnel"*
> [Gibbons, 1990].

The main use of electronic charts to date is to aid in safe navigation, including collision avoidance. However, there are a variety of other applications as well. Automobile

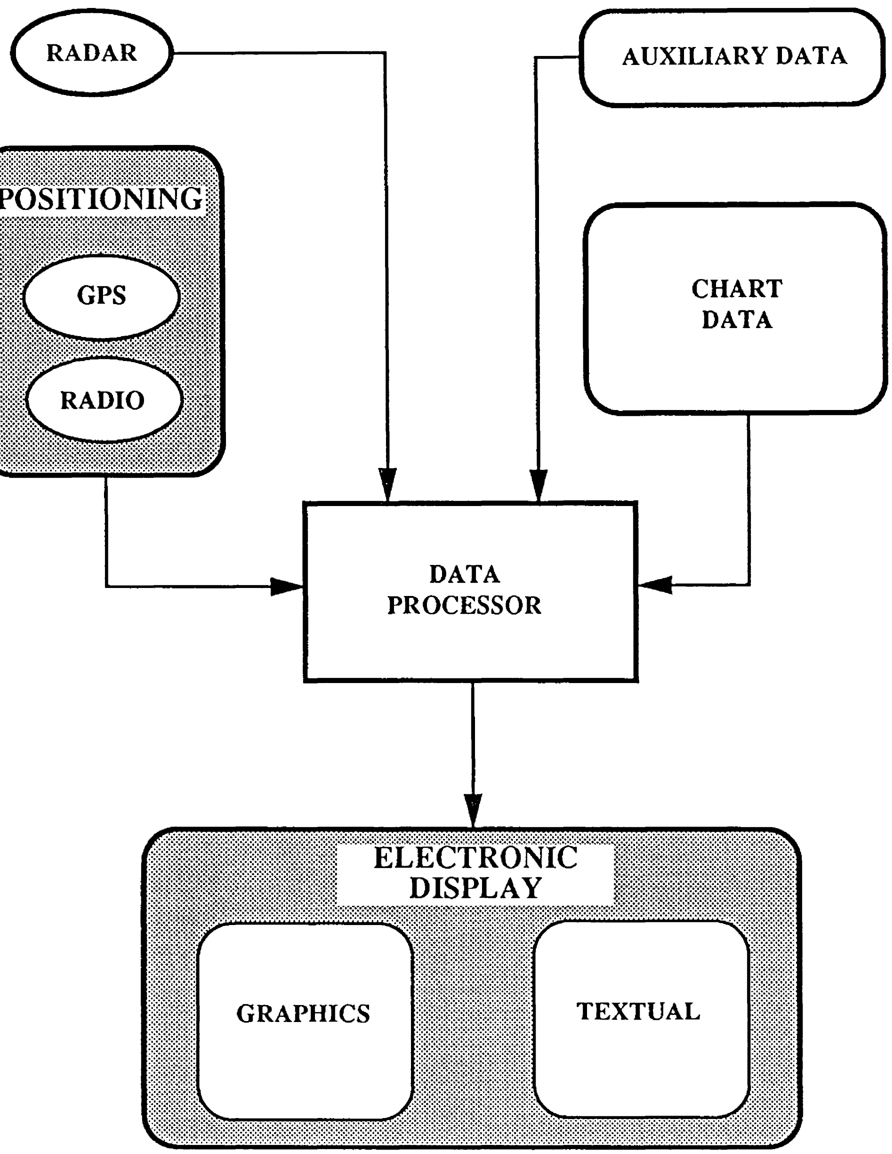

Figure 3.1
Integrated Navigation System.

manufacturers and the aviation industry are also using a form of the electronic chart to build vehicle and aircraft navigation systems. Oil exploration and production companies use electronic charts for vessel management around offshore oil platforms. Port and harbour authorities also use electronic charts for vessel management systems to monitor traffic in several harbours around the world. For example, the port of Rotterdam has

> *... 26 unmanned radars scattered throughout the port. Each is accompanied by three minicomputers that turn radar images into numbers. Then, by comparing images received from one moment to the next, they cancel out false echoes caused by ephemeral objects such as the wake of a ship. When the images have thus been cleansed, the computers measure the dimensions of the vessels, calculate their speeds, and determine their directions. When all this information is knitted together, the computers send the images to one of three regional control stations, where operators watch ship symbols on a map of the waterway and call up the information by touching the symbols with a light pen.*
>
> [The Economist, 1988]

The next step in the automation of traffic management for port and harbour operations is to link the radar system with databases containing information on each vessel entering a port. The databases could contain information such as: registration, contents of the cargo, port of origin, port of destination, destination within the port, information on the shipping agents, etc. Such information displayed in conjunction with the map of the waterway can help traffic controllers prioritize vessel movements through the port. Vessels carrying dangerous goods could be given wider berths while vessels carrying perishable goods could be assigned a higher priority to docking facilities.

There is no distinction made here between the electronic chart systems used to provide information for moving vessels and those used as vessel traffic management systems at central tracking sites. Although the applications are different the technological and institutional issues associated with providing the data and the information management issues are the same.

3.2.3 Assessment of Existing Situation

There are several electronic chart systems, with varying degrees of sophistication and price ranges, currently available to the mariner. The majority of the existing marine electronic chart systems in Canada are used to aid vessels in channel navigation and docking. As pointed out earlier the three main uses of electronic charts currently are safe navigation, harbour monitoring, and vessel traffic surveillance. The type of information shown on an electronic chart depends on the application. The navigation systems concentrate on showing the vessel position relative to other vessels, navigation aids and hazards, and the shoreline. The harbour monitoring systems emphasize anchorage grids and the traffic anchored within them. The surveillance systems are mainly concerned with showing and controlling traffic around sensitive areas such as oil drilling platforms

Because there is a lack of digital hydrographic data available from the agencies responsible for providing nautical charts the electronic chart manufacturers must create their databases from existing hard copy sources. Generally the features such as land, shoals, and other physical features are digitized from the paper hydrographic charts using the largest scale chart available from the CHS (in Canada). Sometimes for more detailed information the hydrographic field sheets are digitized to get more accurate data. Port and harbour facilities are sometimes digitized from existing engineering drawings. In some cases the manufacturers may actually collect field data by standard site survey techniques for specific ports [Lanziner et al., 1986]. After digitizing, the navigational aids are added according to their published latitude and longitude [Johnson-Orrick, 1985]. All other data shown on an electronic chart such as radar data, positioning data, and other auxiliary data are subsequently provided by sensing equipment on the ship and are added in real time as shown in Figure 3.1.

One of the major drawbacks associated with the use of electronic chart systems is the large expense associated with building the databases. Many of the existing data sets have been built for a single user for a specific harbour. For example, Marine Atlantic uses a Precise Integrated Navigation System (PINS 9000) on its ferry the M.V. "Caribou" operating between North Sydney, Nova Scotia and Port Aux Basque, Newfoundland. The manufacturer of PINS 9000, Offshore Systems Limited, had to build the digital chart databases for both these harbours. Since there were no other users wishing to purchase these data sets the whole development cost had to be underwritten by one user. *"Creating a digital data set for a single user is an expensive proposition and only when it finds multiple users does it become truly cost effective"* [Hayes, 1987].

The electronic chart systems that are currently in operation are producing acceptable results and for the most part the users are satisfied with the systems especially for entering port and docking where precise positioning relative to physical features is necessary during periods of poor visibility [Pike, 1987]. However, most mariners say that electronic charts will never replace the paper chart. They say that the paper chart will always need to be on board the vessel as a backup to the electronic chart.

> *Once a mariner has proved an EC navigation display to his satisfaction, it seems unlikely that he will refer continuously to a paper chart as well, (though I believe the paper chart will be needed in the background to fill in details). This means the EC has to have the same reliability as the paper chart for which it is acting as a selective mirror.*
>
> [Eaton et al., 1988]

Does this mean that the CHS will be responsible for providing nautical charts in both digital and paper formats in the future? Considering the fact that in the very near future all new raw data will be in digital format, creating charts in electronic format may not be a difficult task. However, decisions will have to be made whether or not the paper chart will continue to be mass produced as is currently done.

Updates and revisions to the existing paper charts are done directly by the user. The information on changes affecting navigation such as navigational aids out of position or the existence of new hazards is distributed via Notices to Shipping and Notices to Mariners. The Notices to Shipping are broadcast through Coast Guard Radio and supplemented by the CBC fishermen's broadcast. Many of these notices are of temporary nature such as temporary light failures or oil rigs temporarily anchored off a harbour and are never published in the Notices to Mariners. The Notices to Mariners are prepared by the CHS and the Canadian Coast Guard and mailed out weekly to anyone wishing to be on the mailing list. *"More than 14,000 copies are sent to a worldwide mailing list; the purpose of the Notices to Mariners is to enable everyone everywhere who has a Canadian nautical chart to be able to update it"* [Hamilton et al., 1983].

Existing electronic charts are updated by the manufacturer on an informal basis as the manufacturer or the client agrees an update is necessary. As far as can be determined from this research two approaches to updating are used. With some systems the entire database is replaced when a permanent change or a revision affecting navigation occurs in the particular area of coverage for which the database was created. With other systems, when the area covered is large enough, the chart can be updated by replacing a cell. For most systems a cell consists of all the data contained within a 15 minutes of latitude by 15 minutes of longitude area. Otherwise, temporary changes are still recorded and shown on a paper chart of the area [Evangelatos, 1989].

3.2.4 Requirements of the Network

The fundamental requirement of the Electronic Chart is to mirror the paper chart and to incorporate with it, the information necessary to safely navigate a vessel from its port of origin to its port of destination. The information is to be displayed on monitors, in a format that is as close as possible to what the navigator is familiar with in paper format. The information must be up-to-date, accurate, and reliable. To satisfy these conditions the mariner must have access to the most current data available. A marine information network is necessary to provide that service.

To put such a network in place will require policy decisions by DFO since that department has the responsibility for the provision of charts. Decisions to be made will be with respect to:

- Whether to use land or satellite communications systems.
- If satellites; the type of ground stations to transmit and receive the data.
- If land systems; the location, functions, and role of the data distribution centres.
- The type of hardware and software systems to prepare the data and get it into and out off the network in a format that is functional to the user.
- The network configuration chosen. It must be capable of delivering the data updates to the mariner in near real time (equivalent to time frame associated with the Notices to Shipping broadcast).

Once these decisions have been made the network can be implemented from the technological point of view. But in order for the network to function properly several institutional issues must be resolved. Some of these issues include:

- Who will provide the data interchange formats, DFO or the user.
- Whether updates will be made on a cell by cell basis or in the form of an electronic patch similar to the practice of updating paper charts.
- The arrangements for transmission of the data.
- The cost of providing the service and how it will be funded.
- How much and how will billing be done if there is a charge to the user.
- Who is to be liable in the case of inaccurate data entering the user's database.
- The format in which they will provide data.

- The frequency at which the updates will be made available.

Two scenarios for the provision of a marine information network are presented in the following section.

3.2.5 Proposed Network Configuration

The first scenario provides for direct data transfer from the source (the hydrographic office) to the target (the user's electronic chart). In this case the data transfer is carried out via satellite links. The data are distributed from the CHS headquarters in Ottawa, as shown in Figure 3.2, regardless of where it is prepared. Any data prepared at the regional offices are transmitted to a central distribution centre, the CHS headquarters, to ensure a standard format is adhered to for the distribution of data to all users. This also ensures that when updates are made or errors corrected the same information is available to all users at the same time. All Notices to Shipping and Notices to Mariners are stored in the databases as soon as they are issued. The user can access the database at anytime and check for changes. Any changes can then be made to the vessel's database.

Satellite systems are already in place which provide data communication linkages. INMARSAT's series C communication service is operational and has already been tested for hydrographic data transfer capabilities in both Canada and in the Netherlands. These satellites will continue to improve over the next few years. Other satellites such as GEOSTAR Corp. will also provide data communication links.

The second scenario proposes a marine information network based on the existing telecommunications networks. Again all the data would be distributed via a central

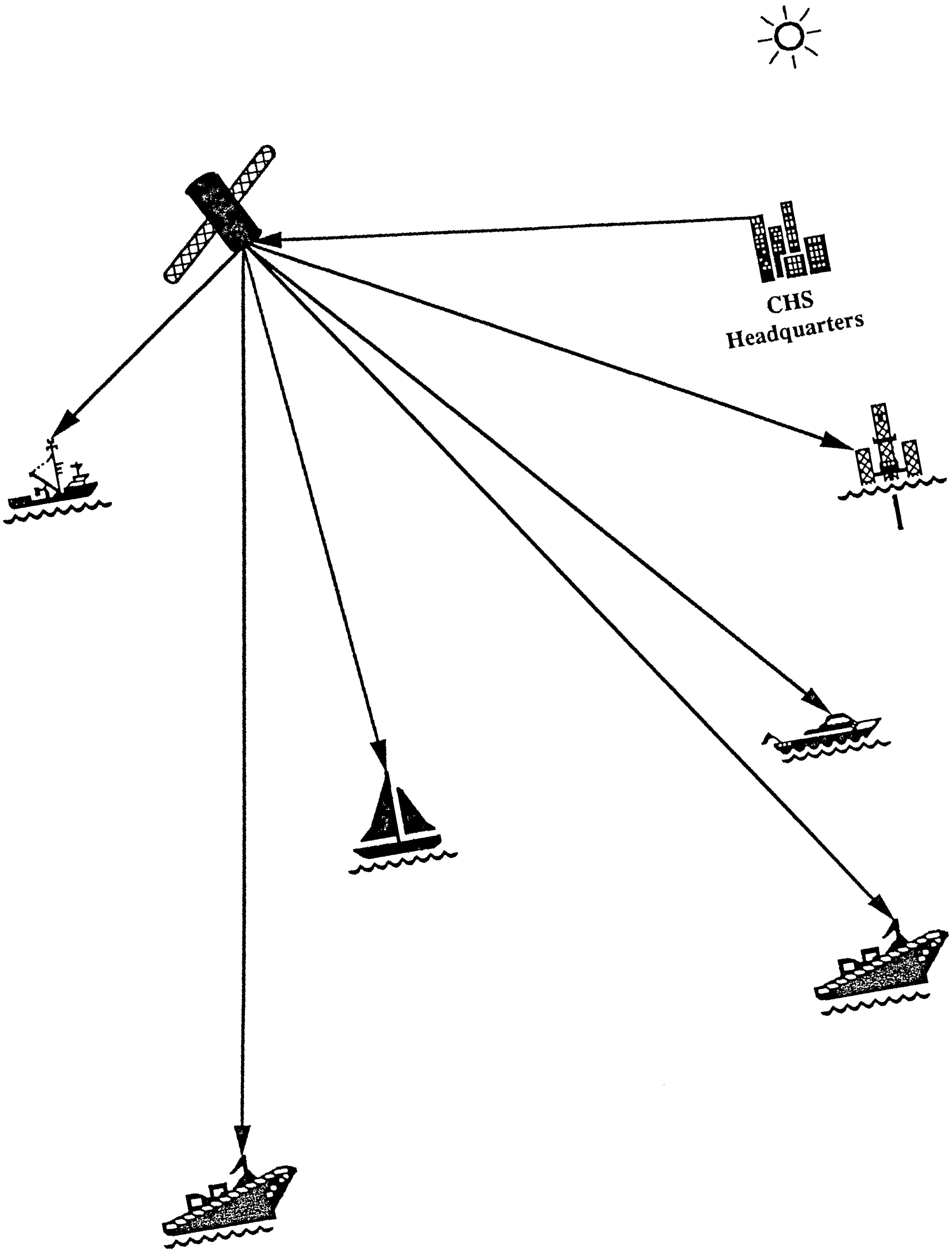

Figure 3.2
Electronic chart data transmission based on satellite communications.

distribution centre similar to the previous scenario. In this case the data would be distributed to a selection of major shipping ports. The data would be stored on magnetic tapes or discs and provided to the vessels upon entry to the port. This process is similar to what currently takes place in updating paper charts. The only difference is the medium and the technology involved in carrying out the data distribution. One difficulty with this approach is that since there are so many different electronic chart systems on the market with different data formats, the system at the port would need to be able to produce the data in several different formats.

3.2.6 Conclusion

The information presented on the user's monitor must be accurate in both location and timeliness. The information must be up-to-date and as a result the delivery time of updates is critical. For example, paper charts can be updated on board a vessel as soon as the Notices to Shipping broadcast is heard or the Notices to Mariners are received. Ease of frequent update is germane to the successful implementation of electronic chart systems into the shipping world. *"The objective of easy access is to design a system which not only allows ready access, but which allows the user to obtain the information required in a directly usable format with the minimum interaction and delay"* [Hayes, 1987].

The example of the electronic chart was presented here to demonstrate the issues related to providing information through a network for one tool used in a marine application. Other information needed for marine navigation such as weather, sea state, ice conditions outside the range of the ship's radar, etc. must be provided through other means and present their own set of network requirement problems.

3.3 AQUACULTURE

Aquaculture is defined as *"the cultivation of aquatic organisms using artificial reproduction methods and husbandry techniques"* [Comeau, 1988]. There are several other terms which are often used when referring to specialized aspects of aquaculture. For example, "Fish farming" is used to refer to the practice of cultivating fin fish in pens or cages or man-made ponds. "Sea ranching" generally refers to the raising of fish in a large natural area such as a bay which is closed off to prevent escape. The fish feed on the natural food sources of the area. "Mariculture" is a term sometimes used to refer to an aquaculture operation in sea water (marine) as opposed to a fresh water operation [Wildsmith, 1982].

3.3.1 Background

The practice of aquaculture in Canada *"... dates back to 1857, when the first Superintendent of Fisheries for Lower Canada, Richard Nettle, incubated and hatched eggs from brook trout and later from Atlantic salmon"* [Wildsmith, 1982]. Although, since that time both government and industry have become involved in aquaculture development, the growth in Canada has been slow and irregular. In 1975 the total aquaculture production was 5,000 tonnes while in 1980 the reported total production was 4,000 tonnes. No attempt was made here to determine the cause of the drop in production over that five year period. According to DFO there were 3,100 licensed aquaculture sites in Canada in 1986 with a total production of 11,000 tonnes and a market value of just over $32 million. In 1987 the Bay of Fundy Atlantic salmon production, from 34 salmon farms, was 1,300 tonnes with a market value $18 million [Government of Canada, 1988]. The same area produced 3,000 tonnes of salmon in 1988 [DFO, 1989].

The aquaculture industry in Canada consists mainly of the cultivation of four major species: salmon, oysters, mussels, and trout. Price Waterhouse [1989] provides production and employment forecasts for the total Canadian aquaculture industry to the year 2000. Under a low growth scenario they forecast 50,000 tonnes by the year 2000. This is up from a base of 18,000 tonnes in 1988. The high growth rate scenario predicts 107,000 tonnes by the year 2000.

If these predicted growth rates materialize there will be a significant increase in employment opportunities in the aquaculture industry in the coastal regions of Canada. By 1995 the aquaculture industry could potentially employ between 1,800 and 3,200 full-time employees. By the year 2000 the numbers could be between 2,100 and 5,000 employees [Price Waterhouse, 1989].

As the industry continues to grow, the amount of data created will increase and there will be an increasing need for information management. Information related to the health, physical site, products including quantity and quality, personnel, planning, administration, policy, etc will be required. Each of these categories will contain several sub-categories of information. For example, sub-categories related to the site would be: location, property rights, oceanography, water quality, bottom type, other uses, climate, and so on. The majority of the information will be required by most of the parties involved in the approval, development, and operation of the aquaculture site. The information requirements for the site approval process will be presented as an illustration of the development of a user requirements framework.

3.3.2 Organizations Impacted by Aquaculture Development

The aquaculturist considering the development of a marine aquaculture site may, directly or indirectly, have contact with international, national, provincial, regional, and local governments, crown corporations, and the general public. Several factors will determine the extent to which the various players will be involved. The site location, resources, and products will be the major influencing factors.

From the international perspective the site location may well extend outside the limits of Canada's territorial sea. In the case of "sea ranching" operations the kinds of migratory species raised, such as the Atlantic salmon, have no regard for boundaries recognized by international law such as those defined by the U.N. Convention on the Law of the Sea. The produce from the site may be destined for international markets. In that case one must be concerned with various international treaties covering aquaculture to which Canada is a party. An example of such a treaty would be the General Agreement on Trade and Tariffs (GATT). Canada's agreement on its role in the promotion of aquaculture on an international scale under the United Nations Food and Agriculture Organization should be considered as well [Wildsmith, 1982].

On the national scene aquaculture may cross inter-jurisdictional legislative powers. Legislative authority in Canada is divided between the federal and provincial governments under the British North America (BNA) Act of 1867, now the Constitution Act, 1867. However, Sections 91 and 92, which outline the federal and provincial powers respectively, of the BNA Act do not mention aquaculture. Therefore, *"it may be concluded that the BNA Act is ambiguous upon the question of which level may legislate in relation to aquaculture"* [Wildsmith, 1982]. Any disputes arising from such ambiguities may be resolved by the court system. Currently all applications for aquaculture development in coastal waters are referred to both levels of government either by the provincial government department responsible for aquaculture or by the applicant directly.

At the provincial level various government departments may have jurisdiction over certain aspects of a particular site. For example, the provincial department responsible for transportation may regulate certain vessel traffic in the area while the department responsible for preservation of recreation may have jurisdiction over recreational activities in the area. Various public and private agencies as well as private citizens may also hold certain rights over a proposed site. As an illustration of the interaction of the various parties' involvement in the aquaculture site approval process the current procedure in New Brunswick will be presented.

Figure 3.3 shows the current process involved in gaining permission to develop an aquaculture site in the Province of New Brunswick under the *Aquaculture Act* [1988]. The applicant submits an application to the Department of Fisheries and Aquaculture (DFA). DFA then sends a copy of the application including a map showing the site location and size to the various other organizations having a potential interest in the site. The site is plotted on a CHS field sheet at a scale sufficient to determine horizontal plane coordinates that can be given to the surveyor to establish the site boundaries in the field. Other organizations to which the application is forwarded include those shown in Table 3.1.

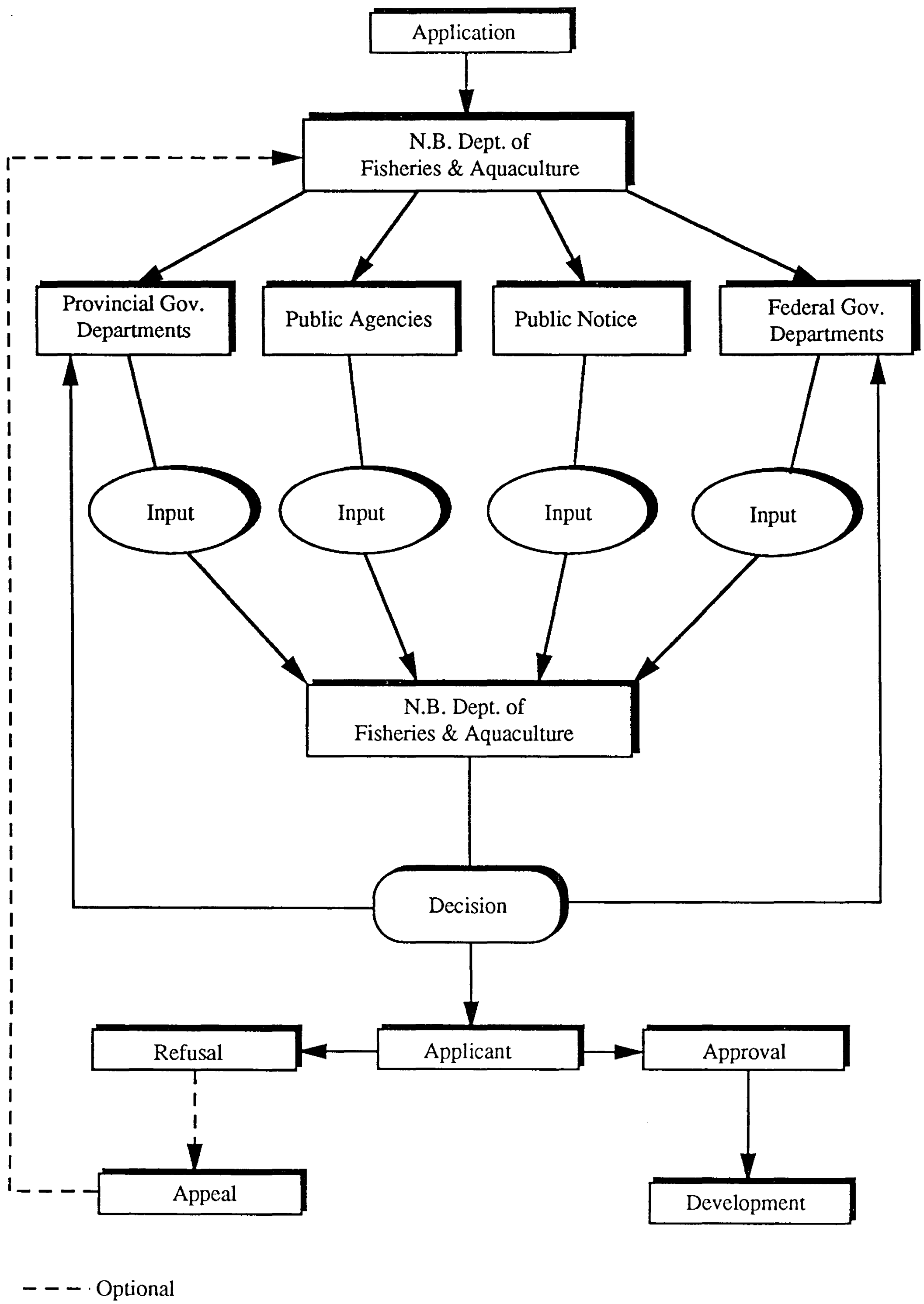

Figure 3.3
New Brunswick aquaculture site approval process.

Table 3.1 Distribution of applications for aquaculture sites in New Brunswick.

1. The Department of Fisheries and Oceans Canada.
   a) Small Craft Harbours Branch
   b) Ocean Science and Surveys Branch
2. Transport Canada (Canadian Coast Guard)
3. Environment Canada.
4. Public Works Canada
5. New Brunswick Department of Natural Resources and Energy.
6. New Brunswick Department of Tourism, Recreation, and Heritage.
7. New Brunswick Department of Transportation.
8. New Brunswick Department of Environment.
9. New Brunswick Telephone Company.
10. St. Croix Waterway Commission (Bay of Fundy sites only).
11. New Brunswick Electric Power Commission.
12. Local Newspaper. (Beside the notification to the above mentioned organizations a notice to the general public in the form of publication in a local newspaper for a two week period is required) [Collette, 1989].

Each organization responds directly to the DFA with its input. This process takes anywhere from a month to three months [Sweeney, 1990]. The general public may call a public meeting of local residents to air concerns or objections to the development. Based on the response of the various organizations and individuals the DFA will make a decision to approve or refuse the application for development. If approval is granted the applicant may proceed with the site development according to the terms and conditions of the DFA. If the application is refused the applicant has the right to appeal the decision.

A notice of the decision is also sent to some of the organizations that had provided DFA with input into the decision. Not all of the organizations are notified. According to DFA sources the New Brunswick Department of Natural Resources and Energy and DFO are the only two notified currently [Sweeney, 1990]. However, there is a Memorandum of Understanding (MOU) between the Government of New Brunswick and the Government of Canada to share aquaculture information. The MOU is open ended with respect to exactly what type of aquaculture information is covered and when and how often updates should be made [Kolls, 1990].

3.3.3 Assessment of the New Brunswick Aquaculture Information System

The information system, as described above, for aquaculture currently operating in New Brunswick is in place to respond to applications for aquaculture site development. Its main function is to provide information to regulate the development of the industry by ensuring conflicting use does not exist rather than deciding whether the site is best used for a particular application. The system is not in place to do planning for aquaculture development in the province. For example, the system cannot be used to determine the most appropriate location(s) for the development of aquaculture sites in the province, to trace contaminants, to monitor productivity or to provide other information identified in Section 3.3.1.

As far as can be determined from this research most of the organizations asked for input into the decision by the DFA to approve or refuse an application are never notified of the final decision. For example, The Department of Public Works (DPW) Canada may have been sent a copy of the application for comment on their plans for the proposed site. On responding positively DPW may have recorded the site in their database (paper format or electronic). However, DFA may have refused the application on the basis of input from another organization. Unless otherwise notified DPW continues to maintain incorrect information about that particular location. They have an aquaculture site recorded in their database where, in fact, only an application to develop a site was submitted and was subsequently refused by the DFA.

There is a shortage of marine information for the New Brunswick coastal regions. The Bay of Fundy region is most extensively covered for oceanography, hydrography, and marine biology. There exists a good coastline inventory (land and water based) from several different sources for the Bay of Fundy region of the province [Kolls, 1990]. DFO, Moncton maintains site specific shellfish habitat data for certain regions of northeastern New Brunswick. LRIS, Amherst has some small scale (1: 2 million) Atlas style information for some areas of the province as well. DFO, Moncton also has a digital inventory of Small Craft Harbours facilities for the Gulf Region on a CARIS geographic information system [Legault, 1989]. However, these data are scattered throughout the various organizations, at varying scales, accuracy, resolution, format, and accessibility.

3.3.4 Marine Information and Infrastructure Requirements

Based on the analysis of the aquaculture site development application approval process in New Brunswick, albeit a small sample on which to base user requirements, some basic marine information system and infrastructure requirements have been determined. The two main users of aquaculture information and marine information related to the sites are the regulatory agencies of the various levels of government and the aquaculturists who operate the sites. The responsible regulatory agencies require information to maintain control over the site and the natural resources, while the aquaculturists need information to control the life cycles of the cultivars to maximize production. The aquaculturist needs information in real time to continuously monitor conditions such as water and air temperature, oxygen content of the water, salinity, etc. on the site [Bardach, 1988]. Other organizations and individuals such as developers, recreational organizations, utility companies, etc. also need access to some of the information from time to time. Therefore it is important to have the information readily accessible and in a format that is usable by a broad range of users. Unfortunately, much of the data collected at the site is done on an operational basis and the data are not retained for future reference. The information could potentially be of benefit to other operators in determining causes of diseases, tracking contaminants, or other phenomena.

3.4 CONCLUSION

To meet the needs of the marine information users and providers discussed in this chapter a method must be developed to place the data where it is needed, when it is needed, and in a format that is usable for the given application. The trends in the use of electronic data collection systems, computerized databases, and computerized data analysis systems, along with the rapid advances in the telecommunications technology, indicate that the creation of a marine information network would be the most practical solution to the problem. In order to build the required network many institutional and technological issues must be resolved. These issues are identified and discussed in the next two chapters.

Chapter 4

DESIGN CONSIDERATIONS FOR MARINE INFORMATION NETWORKS

Information, in essence, is what we as individuals and as a nation will increasingly produce, process, transmit, receive, and export.
[Geeslin, 1989]

4.1 INTRODUCTION

The results of the two case studies carried out in Chapter 3 indicate the need for networking the databases in order to more efficiently manage marine resources. There is also an increasing awareness among the marine resource managers of the need for information sharing. This is evident by the opinions expressed by the various participants attending conferences and forums such as the Inland Waters, Coastal, and Ocean Information Network (ICOIN) Forum held in Fredericton, New Brunswick in June, 1989. At that forum marine-related scientists and marine resource managers unanimously endorsed the idea of networking marine data bases to improve the accessibility of marine information for better decision making abilities within their respective jurisdictions. As will be pointed out in Chapter 5 there are many technological problems associated with networking databases. However, when one pursues the idea of data sharing between different organizations with different mandates, political agendas, and organizational structures the technological problems pale in relation to the institutional issues that arise.

The bulk of the marine data collection, storage, and dissemination in Canada is carried out by the public sector, predominantly by the federal government departments. Consequently, it should be less difficult to solve the institutional problems associated with sharing data than if multiple levels of government and industry were involved. In this chapter some of the issues to be considered when designing data networks are identified and discussed.

4.2 THE BASIC DATA PROBLEMS

Research into marine information database contents and location has shown that large quantities of marine-related data exist in various formats throughout Canada [Borstad et al., 1988]. However, the potential users are either unaware that the data exist, the data are inaccessible, or the data are not in a format that is usable. Many users would be willing to pay for the privilege to access broader sources of data; hence, creating value-added to the data.

The problem is not so much one of a lack of marine-related data but rather the lack of access to the data. The marine resource manager is generally unable to acquire the information when it is needed unless the data is collected and managed within the manager's specific organization, which has been the general practice. This practice leads to a duplication of data which is again project/application specific and most likely not accessible or useful to other users.

4.2.1 Data Access

For several reasons access to the data has been difficult for many users. Until the last few years it has been necessary for several individual users to duplicate the storage of data because of the lack of convenient systems to transfer the data. That is no longer the case. There are transportation and communication systems now available to move data around in a timely and efficient manner in either hard copy or electronic format. Because of recent developments in the telecommunications industry, from a technological perspective, it is possible to develop communication networks to transfer and share data among the various users. Unfortunately, responses to the institutional problems of data sharing have not evolved as fast as the responses to the technological problems.

Databases are still being structured such that access is not readily available. Data are collected and stored with concern only for the current application and without consideration for future applications or other user's needs. Though the majority of the marine databases are in the public domain, various government agencies treat the data with the attitude of ownership as opposed to custodial rights. Until attitudes such as these change and policy on data sharing is developed and implemented data will remain inaccessible regardless of technological developments and progress.

4.2.2 Data Quality

The quality of the data is a concern of many users. Users tend to place less confidence in the data unless they have collected it themselves or have some assurance provided that the data is reliable. For example, the data collection methods, the instrumentation used, and the data resolution are often so different across different organizations that the data is invalid for multipurpose applications. There is, therefore, a need for information about the data such as the type of instrumentation used to collect the data, the collection methods and procedures, the quality control measures taken, etc. Most often this information is not available. As a result users will often disregard the data and collect their own.

The accuracy of the data collected and stored by one user may be a concern to another user particularly if it is to be used for a different application. Data is often subjective in nature. An example of such subjectivity is the Ice Observer Program on board Canadian Coast Guard icebreakers. The ice observer on duty during one "watch" may judge the ice conditions to be slightly different from an observer on the previous or the subsequent "watch". Since there was no actual change in the ice conditions there would have been no notable change in the vessel performance. However, the results of subsequent analysis of the records for other purposes may be in error due to wrong input data. For example, a variation in fuel consumption may be determined to have been due to changing ice conditions when in fact it was due to a change in the power system.

Data collected by instrumentation is most often more objective. However, one should not forget the fact that most of the instruments are operated by people and are sometimes adjusted improperly and consequently provide inaccurate observations. Experienced operators who understand how the instruments function and have an intuitive sense of how the observations made by the automated data collection systems should look can virtually eliminate this problem. Nevertheless, the fact remains that there is still subjectivity in instrumented observations.

Another concern with respect to data quality is the reliability of the data. Users are concerned as to whether or not the data have been tampered with or changed since its initial use. Depending on the number of people having access to the data any number of changes could be made to it. Generally built-in security checks will not allow unauthorized users to change the data. However, in certain cases authorized users will make changes and not necessarily record the change. As a result of these changes, the data may no longer accurately reflect the original conditions being observed and provide the user with totally inaccurate information. For example, if the data have been updated then it would be critical to be aware of which version is being acquired.

4.2.3 Data Coverage

In many cases marine resource information is not available to the user simply because the data have not been collected. The lack of a formal policy on marine information management has led to disparate data collection both in terms of the spatial and the temporal domain. In some regions of the marine environment data collection coverage is dense while in other regions it is sparse. Several arguments can be made for such disparity. For example, unless there has been mineral or energy resource exploration or development activity in a particular area, geophysical or geological data are unlikely to be collected in that area. Similarly, oceanographic data in areas of relatively low marine activities are sparse.

Even in areas of relatively intense marine activity there is often little or no up-to-date information available. For example, there are areas of coastal Newfoundland, where intense inshore fishing activity has taken place for centuries, for which the latest hydrographic information available is from the British Admiralty Charts produced in the late eighteen hundreds. There are other areas where absolutely no information is available. Examples of both cases exist in the area of Bonavista North, Newfoundland.

However, in a dynamic regime such as the oceans, occurrences in one region may be influenced by activities conducted in several other regions. For example, an oil spill at sea could have an impact on the marine environment hundreds of kilometres away. Consequently, the utility of the existing data becomes questionable or is at best, limited. To help overcome the issue of sparse data coverage and access to data Canada has developed an **Oceans Policy** in which one component is "an information infrastructure development program" [DFO, 1987].

4.2.4 Ownership and Responsibility

Marine information is sometimes unavailable to users because it is considered to be confidential or private to a particular group or organization. In certain instances this notion is valid both in the private and the public sector. In the public sector, however, most data can be made available to anyone requesting it. Although the information is focused on the marine environment and not on people, individuals are sometimes involved either in a cause or effect situation. Therefore, confidentiality to protect the individual is sometimes necessary, at least for a certain period of time. The time period in which the information is unavailable may be critical to its usefulness for a particular application.

As stated earlier the bulk of the marine-related information in Canada is held within the various federal government departments. As a result most users are of the opinion that the data are owned by the government. The same situation often occurs within government departments. Public employees take the attitude that since the funding to collect, analyse, and store the data comes out of their particular departmental budgets, other departments should not have access to the data. Even charging the other departments for the data is not an option because the funds go to general revenue accounts instead of to the department responsible for or having custody of the data. According to government representatives this situation appears at both the federal and provincial government levels.

Private sector information, collected at the expense of individual companies, is often not made available to other companies or the general public for reasons of competition. Sometimes information of this type is supplied to governments in confidence with restrictions on its use. Consequently, the public sector must be careful how this information is used thus limiting its use for public policy. For example, certain information supplied to government by offshore drilling companies cannot be released to the public for five years [Abel, 1990].

The private sector databases are created to support the operations of a particular organization. Generally the cost associated with creating these is absorbed totally by the organization. As a result the organization has full ownership rights to the data. This includes the right to decide the collection and storage formats, resolution, quality, frequency of updates, and data sharing policies.

In some cases private industry collects data under contract to a government agency. In this case the client (government agency) is the owner and acquires the data as part of the deliverables of the contract. The client, therefore, defines the format, resolution, quality, etc.of the data.

In Canada, amendments to the Copyright Act have given copyrights to databases. This is to give database owners the right to prevent others from extracting from or injecting data into the databases. Mukherjee [1985] states that *"Copyright is a commercial concept on the one hand and a moral concept on the other"*. The moral concept concerns the rights of a person who creates a work of art or a literary work to prevent someone else from copying it. The commercial concept applies to a person or entity who wishes to market a created product but does not wish to suffer commercial losses due to the product being copied and marketed by someone else. It is the commercial concept of copyright that most often applies to the case of gaining access to marine information or marine databases.

The basic legal principles are the same whether the data are in electronic format or in paper format. A person claiming damages due to the negligence of another must prove:

Table 4.1 Factors to prove when claiming damages due to negligence.

1) That there was duty of care.
2) That there was a breach of that duty.
3) That the breach of that duty was the cause of the particular damages.
4) That the cause of the damages could have been forseen.
5) That the claim for damages was made within a reasonable time frame.

However, determining where the liability falls with respect to electronic data may be a little more difficult than when the data are in paper format. First of all there will likely be more players involved in getting the data to the user. As a result it may be more difficult to trace where any error occurred consequently leading to time delays in arriving at decisions and also incurring higher legal fees.

The responsibility for maintenance of the government databases currently lie with the departments responsible for the marine application for which the data are collected. The data are collected internally by departmental personnel or by contracting out to the private sector. Even when the data are collected under contract the government department is generally considered to be the owner. Therefore, all data are turned over to the owner at the completion of the contract. All changes and updates to the databases are made by the database holders regardless of the source of the data.

Maintenance of the private sector databases is solely the responsibility of the private sector. However, there are regulations laid down and enforced by governments that dictate certain responsibilities of the private sector with respect to data gathering, recording, and maintenance. For example, deep sea fishing vessels must maintain records of catches by species and amount and discards by amount only [Hogan and Clarke, 1989].

4.2.5 Data Costs

The major costs associated with marine data today are in the collection and processing of the data. The cost of data storage and transmission has been constantly decreasing and is now insignificant relative to other costs. For example, the costs associated with purchasing or leasing and operating ships, providing sensors (for whatever the platform: aircraft, satellite, or ship), and processing the large volumes of data currently collected are very high relative to data storage and transmission. Governments are becoming more conscious of these costs and are considering ways of reducing duplication of effort. There appears to be a shift toward a program approach to data collection as opposed to the project approach of the past.

Nevertheless, duplication of data collection will never be totally eliminated. Duplication becomes necessary when different users collect data at varying temporal and spatial resolutions which are incompatible with each other. There may be several reasons for collecting data at varying resolutions for the same geographic area. For example, bathymetric observations made in support of the development of an aquaculture site would not require the same spatial resolution as would observations in support of a harbour dredging project in the same location.

The collecting agency will usually only cover expenditures necessary to meet its own minimum resolution requirements and may not be willing to bear the added cost of increasing the resolution. On the other hand, if the data exist in a finer resolution than is required it may not be necessary to collect it again. Instead some method of generalizing the data could be applied to make it more relevant to the particular need.

Duplication is caused by the fact that data sets are unavailable to users due to the factors previously discussed. However, this is only a problem when the data is duplicated unnecessarily. Unnecessary duplication occurs when two or more organizations having the same data requirements collect and store similar data sets thus incurring extra costs associated with collection equipment, extra personnel or reallocation of personnel, time delays in collecting the data, and extra storage space requirements. On the other hand duplication is sometimes necessary. For example, it is sometimes more efficient to maintain duplicated data sets at several locations than to transfer the data around. In this case duplication of data storage is necessary but duplication of data collection may not be necessary.

4.3 FINANCIAL CONCERNS

There are three possible scenarios for funding the networking of marine databases. There is public sector financing, private sector financing, and possibly a combination of the two. In order to acquire public sector funding governments must be convinced that the social benefits resulting from building the networks are sufficient to justify diverting the funds away from other programs such as for example social programs, transportation programs, or industrial development. It can be argued that the public sector should not fund the network unless access to the data is of such value to the users that they are willing to pay for the service. Outside the public sector demonstrating the value of the network for acquiring the data to fulfil their social obligations, the best measure of value-added is private sector profits.

In order to acquire private sector funding to build the networks investors would require a reasonable rate of return on their investment. In this case the demand for the service provided by networking marine databases would need to be defined and the markets clearly identified. It is most often the case that the ideal situation will not occur in either of these scenarios. However, if both parties recognize the basic need to provide the service they may be willing to risk smaller individual commitments. Consequently, the public sector and the private sector may reach a funding agreement to develop the networks whereby each party may attain its objectives over a certain period of time. It has been suggested that "*public funding should be a fall-back position that could always be employed in less attractive markets*" [Geeslin, 1989].

Since DFO is responsible for the "*coordination of programs and policies of the Government of Canada respecting the oceans*" [Doubleday, 1989] that department has traditionally been a primary funding agency for marine data collection and dissemination. However, according to Doubleday [1989] DFO *"cannot, at this time expect new resources for initiatives such as ocean mapping or ICOIN"*. The government and other interested parties must find new ways to finance new initiatives within the existing fiscal framework. Fiscal restraint by government places constraints on both the quantity and the quality of data collected. That is a good thing. It may force users to realize that there is data existing elsewhere that is usable. As a result governments may think about using a program approach as opposed to a project approach to data collection.

Funding is required to convert the existing hard copy data to electronic format in order to transmit it through a network. Until recent years (the mid 1980s) most data were collected and stored in paper format in the form of maps or log sheets. A major funding effort would be required to transfer that data to computer databases. To ensure the maximum value-added to the converted data it would be necessary to assess the need for the data on a case-by-case basis. It would not make economic sense to attempt to convert all of the marine data held by the various organizations since some data sets are seldom, if ever, used after their initial use.

Funding is also required to build the infrastructure necessary to establish the marine information network. The infrastructure will provide support for all users. The question then becomes one of who should pay? The logical solution would be to have each user pay on an equitable basis, based on the benefits derived from having access to multiple data bases (then, it is not always easy to determine the benefits of new developments). However, in practice it doesn't work that way. Usually the first users pay heavily while subsequent users pay considerably less for the same benefits (e.g. televisions, microwave ovens, computers).

One could compare the information infrastructure to the transportation infrastructure. In this case highways and transportation systems were developed and constructed for the benefit of all citizens. Not every citizen uses the system directly but benefits from it in certain ways; Therefore, everyone pays through the taxation system. For example, the medical supplies to support our health care facilities are transported over the highway network. The Canadian Broadcasting Corporation is supported by public funds because the Federal Government has been convinced that the information and entertainment provided over the radio and television networks are of sufficient value to Canadian citizens to justify the expenditures.

The same arguments could be made for the need for marine information infrastructure. Management of resources to ensure sustainable development is in the interest of all Canadians. Therefore, it should be the responsibility of all Canadians to ensure the information necessary to make the correct management decisions is in the hands of the managers and policy makers. Consequently, funding for infrastructure development and implementation should be available from general funds within government rather than from the budgets of the line departments. Those departments need their information-related budgets to sustain their current commitments to data collection and maintenance and for provision of services under their mandate.

In the past governments were seldom concerned with full cost recovery for services provided. In certain instances governments have a social responsibility to provide the service for the citizens. For example, providing information to mariners to ensure the maximum safety at sea has been traditionally accepted by governments as a social responsibility. As a result the cost to the user to purchase public sector information has been much less than the actual cost of the data collection, processing, and distribution.

There has been generally a nominal fee charged to offset the cost of reproduction and handling. For example, a nautical chart prepared by the CHS can be purchased for approximately $10.00 but the cost to produce it is orders of magnitude higher. Even when one considers that multiple copies of the same chart can be sold, with the exception of a few charts covering areas used quite frequently by recreational crafts, the cost of collecting the data, processing it, and creating the final product could never be recovered.

There is generally resistance by users to pay for public sector data. Since the data has been collected by the public domain and paid for by the public purse, users feel that it should be made available free of charge. However, in recent years the increasingly large public deficits are forcing governments to become more cost conscious. As a result governments are gradually increasing user fees for certain services and even transferring some of these services over to the private sector. The funding arrangements between the governments and the private company that provides the services vary. In most cases the private sector can not recover the full cost of providing the service until stable markets are established and the clients are conditioned to paying full market price.

4.4 BUREAUCRATIC CONSIDERATIONS

When it is perceived by one government department that other departments or even outside organizations may be controlling its data there is a tendency for the department to be somewhat protective over the data which often leads to non-cooperation. This is especially true of different levels of government such as between federal and provincial governments. The old "protection of turf" is still a real issue within the government realm. For example, one Division of DFO would not allow the word "informatics" to be used in a contract report but insisted on using "geomatics" instead for fear of being challenged by another Division of the Department responsible for informatics as invasion of territory.

The issue of budgets for data collection also arises when the idea of data sharing among government departments is raised. One department will question why its budgets should be used to collect data for another department's benefit while that other department's budget is used to expand its mandate, for example. The larger budgets and maximum support still goes to the region with the strongest political representation in the government of the day.

In some other instances job protection or job "justification" becomes an issue when data sharing is considered. Some organizations will resist using another's data and collect and maintain its own data to justify holding staff positions. It is these inefficiencies in the system that networking of data and sharing of information and resources are aimed at improving. A program approach to marine resource management would also help solve some of these bureaucratic issues.

4.5 TECHNICAL CONCERNS

MacDougall [1988] states that *"databases will form the infrastructure of the information age"*. If that is the case database management systems (DBMS) will be the principle enabling technology to support the development of the infrastructure. According to Burrough [1986] a database is *"a collection of interrelated information, usually stored on some form of mass-storage system such as magnetic tape or disk"*. A DBMS is a set of computer programs designed to manage the information in a database.

Because of the variety of databases containing marine information and the multi-disciplinary nature of these databases it is inevitable that there will be a variety of DBMS with many technical differences. Although it is now technically possible to network multiple databases, designing an infrastructure to access non-standardized, multi-disciplinary databases to serve all applications within the marine environment will require more than solving the technical puzzle. Policy changes affecting both organizational and procedural structures will be necessary. Therefore there must be a political will to build the infrastructure before policy changes will be considered and implemented.

4.6 CONCLUSION

The reason that problems such as those mentioned above exist is because of the lack of policy with respect to marine data and information management. For example, the lack of coordination in data collection is a direct function of the lack of a marine information policy. The public sector has not yet realized the value of information as a resource. There are other issues such as the lack of incentives for line departments to implement user pay policies. For example, revenues derived from the sale of nautical charts by the CHS goes directly into general revenue as opposed to going to DFO to offset costs associated with providing the charts. Although the revenues were created by DFO the department subsequently has to compete with other departments for funding at budget allocation time.

However, considering the number of organizations involved, Canada's immense marine territory, and the different jurisdictions involved it is understandable that such a policy does not exist. As pointed out in Chapter 1 there are 75 marine-related programs spread throughout 14 departments in the federal government alone. Developing a policy to cover these many programs at just one level of government would require significant effort. Earlier on when the programs were being developed the need for a policy on information management was not identified. However, over the past several years the need has been identified by governments and now the resources are not available to tackle the issue [Doubleday, 1989]. Cutbacks in person years due to fiscal restraints by the federal government has been identified as the major reason for the shortage of resources.

Dale and McLaughlin [1988] claim that *"every organization requires an information-handling policy that covers its creation, availability, and value"*. Recognizing that information is a corporate resource is the first step toward identifying the need for an information management policy. According to Diebold [1985]:

> *Effective information resource management means treating information like any other corporate resources - such as labor, capital, plant and equipment, - and integrating technological capabilities with human resources. As advances in information technology bring the business into a new era, the strategic management of information will be pivotal, and the organization will be effected at every level.*

Dale and Mclaughlin [1988] also gives a list of factors that determine the form and content of a policy on land information management. These factors are directly applicable and thus have been adapted to the marine environment and presented in Table 4.2

Table 4.2 Factors that determine form and content of a marine information management policy.

1. The resources available to develop marine information products and services.
2 The relative responsibilities and institutional arrangements within the public sector.
3. The role of the private sector.
4. The role of the education and training institutions.
5. The problems associated with technology.
6. The perception and legal status of social issues such as accessibility to the data, security of the data, and privacy of the data.
7. The identifiable needs and priorities for marine information.
8. The impact that such information may have on society.

The issues dealt with in this chapter must be addressed by the organizations associated with marine information management. The traditional, established customs and methods of governments and the other institutions involved in marine data collection, use, and distribution have created the existing system. The system is not amenable to the concept of a marine information network that will allow data sharing. A process to bring about changes to the system must be developed before a network can be implemented. One of the first steps in the process is the development of a marine information management policy to address the factors listed in Table 4.2.

Chapter 5

NETWORKING AND DISTRIBUTED DATA PROCESSING

It is easy to perceive the idea of networks, but very difficult to understand the technical subtleties. The subtleties can and must be hidden from the end user. The user perceives merely the dialogue or simple procedure that is provided for him.

[James Martin, 1981]

5.1 INTRODUCTION

Modern computer communication networks allow data to be transferred between multiple users with high reliability, transparent operation, and multi-vendor connectivity [Allan, 1989]. As a result, most major organizations are now using a form of networking to link their various departments or divisions as well as to interconnect with other organizations. Depending on the geographic distribution of the organization, local area networks (LANs) or wide area networks (WANs) are used to fulfil their data sharing and data transfer requirements. A LAN is defined by Cohen [1989] as a smaller network involving communications among computers located within a room, a building, or a small group of buildings. He defines a WAN as a bigger network involving communications of computers across towns, states, and continents. Generally a WAN is composed of two or more LANs connected by bridges or gateways. *"A bridge is a device that connects two local area networks of the same type; a gateway is a similar device that performs protocol conversion between a local area network and a network of a different type, either a foreign LAN or a long-haul architecture such as SNA or x.25"* [Allan, 1989].

There are now many types of network configurations with various architectures that have been designed for various purposes. For the purposes of this thesis a network is defined as "a complex assemblage of computer hardware and software components interconnected by a series of communications linkages with a minimum level of global coordination implemented in the software such that information can be exchanged among users".

The technologies associated with data transfer and data processing have been changing rapidly over the past 2 decades. Several factors have contributed to these changes. Computing systems have become much faster. The introduction of such technologies as fibre optics and satellite communication systems have contributed to the ability of systems to transfer larger volumes of data at significantly increased speeds. However, hand-in-hand with the technological changes have come technological and organizational problems.

Many of the problems and issues associated with the transferring of data and the sharing of information among users with various network and database configurations have yet to be solved. This chapter identifies and discusses some of the issues and problems associated with distributed data processing and the networking of heterogeneous databases. The focus will be on: incompatibility of computer hardware and software, database management systems, data models, trends toward distributed processing and distributed database management systems, and network types and functions.

5.2 THE TREND IN DATA PROCESSING

Traditionally all data processing needs for an organization were done within a central facility and the results transferred via various means. Several reasons are cited for central processing such as: centralized control, data independence, reduction of redundancy, complex physical structures for efficient access, integrity, recovery, concurrency control, and security [Ceri and Pelagatti, 1984]. Earlier centralized data systems consisted of flat files, tapes, and manual handling of transactions by operators. These are gradually being replaced by databases, disks, and automatic handling of transactions by modern database management systems [DBMS]. Flat files are collections of related information in a computer that can be accessed by unique names, while databases consist of collections of interrelated information that can be accessed according to the relationships built into the database management system [Pollock, 1990]. A DBMS is defined by Burrough [1986] as *" a set of computer programs for organizing the information in a database".*

Over the last couple of decades three major types of centralized DBMSs have evolved. The first two, network DBMS and hierarchical DBMS, began in the late 1960s while the third, the relational DBMS, was pioneered in the early 1970s. Bourrough [1986] defines the structures of these DBMSs as follows:

Network Database Structure: *A method of arranging data in a database so that the explicit connections and relations are defined by links or pointers of a many-to-one type.*

Hierarchical Database Structure: *A method of arranging computer files or other information so that the units of data storage are connected by a hierarchically defined pathway. From above to below, relations are one-to-many.*

Relational Database Structure: *A method of structuring data in the form of sets of records or tuples so that the relations between different entities and attributes can be used for data access and transformation.*

For various reasons, mainly because of its flexibility, the relational DBMS has become the choice of many DBMS users.

The development and maturity of centralized DBMSs along with the development of computer networks have made it possible to implement distributed data processing supported by distributed database management systems (DDBMS). Since relational tables can be segmented very easily, the relational model is being most widely adopted as the foundation for DDBMS. "*Most of the research and development work in the distributed area has been with network or 'semi-relational' DBMSs, i.e. DBMSs that have some relational facilities built into them, but do not conform rigidly to the 13 rules for a relational database.*" [Gretton-Watson, 1988].

A distributed database is defined by Ceri and Pelagatti [1984] as "*a collection of data which are distributed over different components of a computer network. Each site of the network has autonomous processing capability and can perform local applications. Each site also participates in the execution of at least one global application, which requires accessing data at several sites using a communication subsystem*". Distributed databases are not just centralized databases distributed over several locations with remote access. They allow for the design of systems which present different features than centralized databases. The reader is referred to Gretton-Watson [1988] for a specific set of rules for determining whether a given DBMS should be regarded as distributed. Stonebraker [1989] says that "*at the very least distributed databases should provide a seamless interface to data that is stored on multiple locations*".

5.3 DISTRIBUTED DATABASE MANAGEMENT SYSTEMS

Distributed database management systems have the potential to disperse needed data out to the users much more quickly than the traditional centralized database management system's [Mase, 1989]. However, DDBMS are still of limited use to many organizations for various reasons. Between homogeneous databases some distributed data processing capabilities exist, but data processing between heterogeneous databases still pose significant problems if it can be done at all. Stonebraker [1989] warns that a user should very carefully check the technique being used by any vendor who claims to sell a distributed database system. Many vendors claim to have DDBMS but instead what they have is a network file system-based (NFS) distributed data manager. These systems may work but will generally offer bad performance. However, given the application a NFS distributed data manager may be adequate. It is up to the user to determine whether the increase in performance justifies the added costs associated with acquiring a DDBMS over a NFS distributed data manager. Date [1987] presents twelve rules for determining whether a given DBMS should be regarded as distributed. Gretton-Watson [1988] states that there are 3 categories of distributed databases (DDB) systems as shown in Table 5.1.

Table 5.1 Categories of distributed databases.

1. *Those that were developed for a specific application which requires distributed facilities. DDBs developed in this way have tended to be difficult to market as general purpose databases, because the techniques used are rather specialized.*
2. *DDBs which are designed primarily as research and development testing beds.These have involved universities and/or industrial research laboratories, and in some cases have been undertaken as national projects.*
3. *DDBs which are aimed at the commercial marketplace. In the majority of cases, these have developed by the gradual addition of distributed facilities to DBMSs which were originally designed with only centralized facilities.*

Nevertheless many authors [Stonebraker, 1989; Hsiao and Kamel, 1989; Gretton-Watson, 1988] suggest that DDBMS will find universal acceptance in the next few years.

5.3.1 Why Distributed Databases?

Distributed databases are of particular interest to the marine information community for several reasons. Some of the main motivations are presented below.

Decentralization of Organizations: As previously stated most of the marine-related data in Canada is held by the federal government departments responsible for the management of the various marine resources. Many of these departments are decentralized and have databases at several locations. It may be more practical, based on benefit/costs analysis results, to have a database administrator at each site and then construct a distributed database to allow users to access the whole of the organization's data. This approach would seem to fit better with the structure of the organization. Also, from an economics point of view the economy-of-scale of maintaining large centralized computer centres is being questioned.

Addition of Personal Workstations: More and more employees are replacing standard terminals with personal workstations. These workstations usually come equipped with hard drives for maximum performance. These stations can be used for electronic mail, job scheduling, mailing lists, phone directories,etc., and consequently require a DDBMS to perform related tasks between offices.

Incremental Growth: As new branches are added to an organization the distributed database approach allows for a smooth, incremental growth with a minimum degree of interference with existing units.

Reduced Communication Overhead: Distributed database systems allow many applications to be local therefore reducing communication costs relative to using centralized databases.

High Transaction Rates: In an environment where large data transactions take place it is more cost effective to assemble a network of smaller machines and use DDBMS technology than to purchase large mainframe computers [Stonebraker, 1989]. Also from a reliability and availability perspective DDBMSs are more effective. According to Mace [1989] *"PC database server technology is providing corporate America with its first full-blown model of distributed database management"*. An example of such server technology is SQL Server by Microsoft.

While these reasons for implementing DDBMS are not new the capability is new. The capability can be attributed to two main reasons: (1) the recent developments in personal computer technology, including lower cost and increased computing power previously available only in large mainframes, and (2) the recent advances in the technologies associated with networking and database management systems.

5.3.2 Distributed Data Systems in the Marine Community

Data can be distributed and used in a number of different formats and configurations both as file systems and as database systems. An assortment of distributed data system configurations which are likely to be encountered within a network linking marine databases are shown in Figure 5.1 and Figure 5.2. Figure 5.1 (A) is a typical centralized system with a single computer accessing a local database. Figure 5.1 (B) shows a similar arrangement except that multiple workstations can access the database either through a LAN or remotely through a wide area network.

Figure 5.1 (C) and (D) are examples of hierarchical data systems. In the configuration shown in (C), labeled *hierarchical file system*, the data schema in the lower level computers is closely related to that in the higher level system. Data stored at the lower level are often a subset of the master copy stored in the higher level. Any change made to the data at the lower level must be passed to higher level machines interactively or at some scheduled updating arrangement. In order to perform certain functions the upper level machine will require access to data stored at lower level, whereas the reverse is not true. For example, hydrographic field data used to create a navigation chart may be stored and processed on a lower level machine while the symbols for the chart are stored on the upper level system. The finished product (the navigation chart) is drawn and filed on the higher level computer. Any new field data which would require updating of the chart must be transferred to the upper level system to make the changes. However, if certain symbols were changed and the chart was updated the change would not be transferred to the lower level system.

Figure 5.1 (D) shows a *distributed file system* consisting of machines capable of operating independent of the level at which the data exists. Each machine in the configuration is an

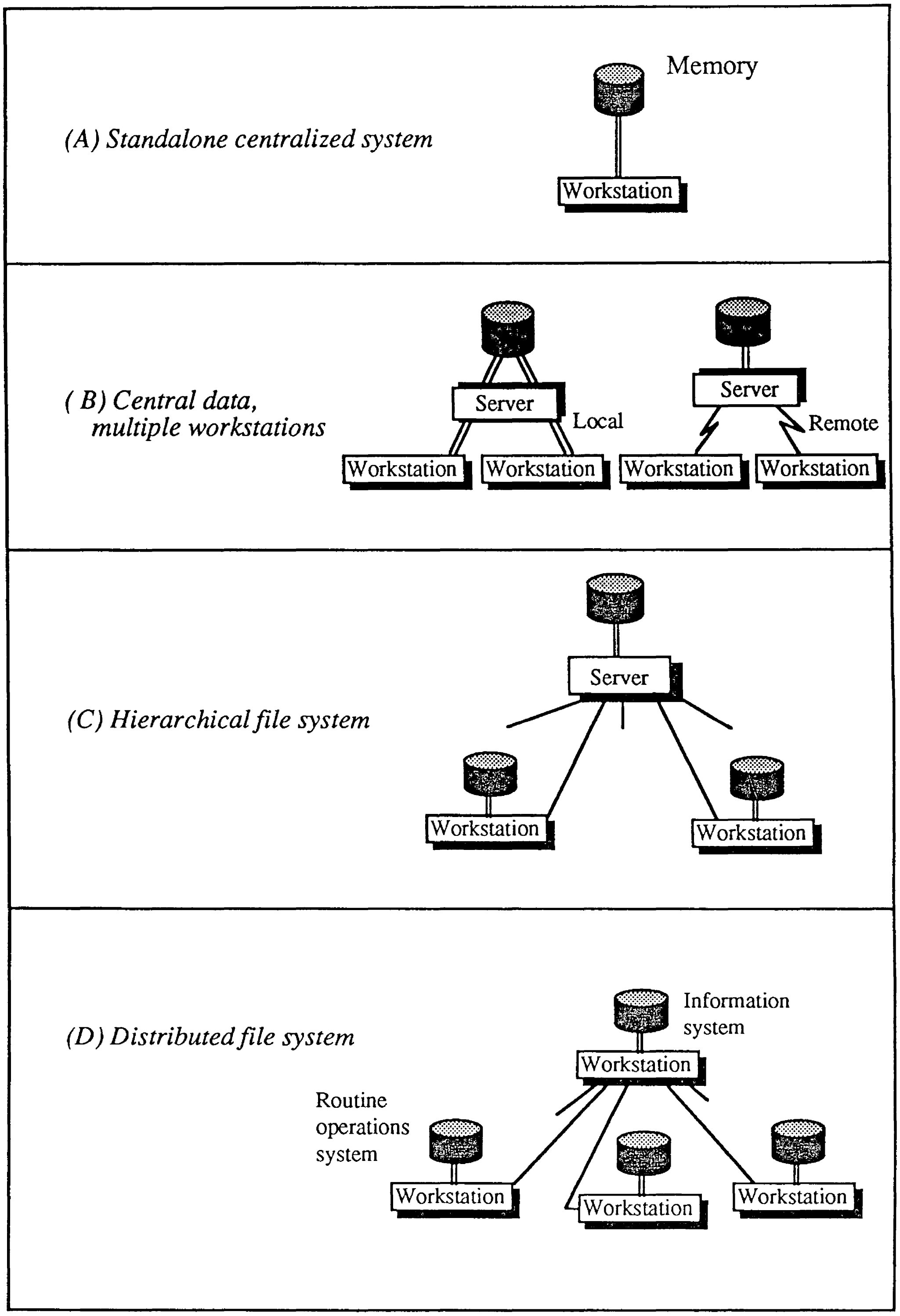

Figure 5.1 Categories of network file exchange systems.

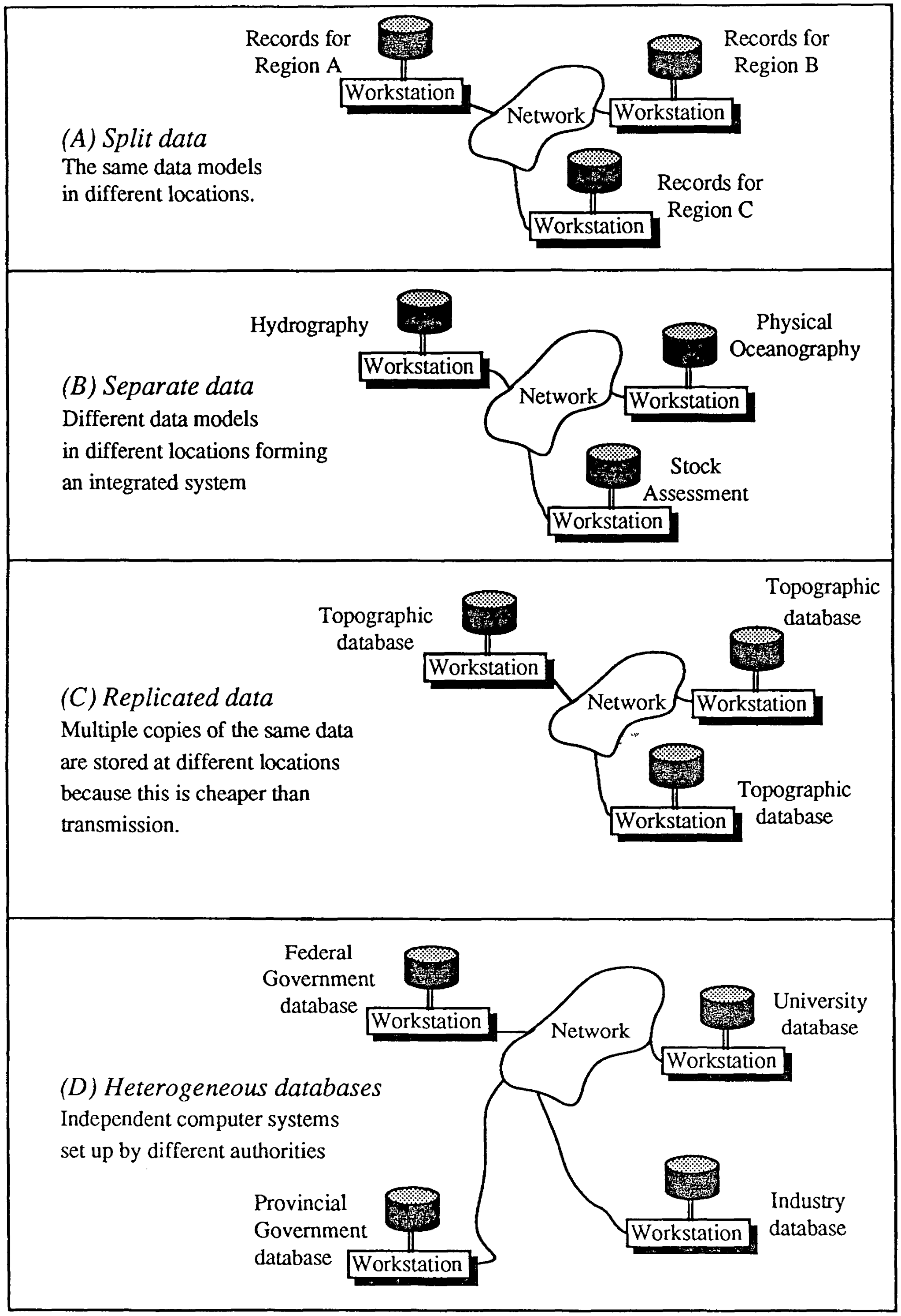

Figure 5.2 Categories of distributed data systems.

independent, self-contained processing unit and the data schema can be totally different. Nevertheless, in this arrangement data can be transferred between systems at both levels for processing provided the data schema of each system is compatible or mechanisms are in place to restructure the data. It should be noted that in order for the lower level machines to access each other they must go through the upper level system. Typically the upper level system would be an information system used by administration for policy and planning and would consist of data culled from the lower level machines which would be used mainly for operations. An application of such a system might be for fishery management. For example, the lower level system could contain records of permits, catch records, violations, etc.. The upper level could then draw on specific sets of that data to establish fish stock management policies.

In the *split data* system shown in Figure 5.2 (A) the same data organization with different content exists at several different locations. For example, DFO requires the same type of information for all Regions in order to maintain consistency throughout the organization. Occasionally data from one Region may be required in another Region. Provided the data organization is the same in all regions the raw data or the processed data can be transferred through the network. This is in contrast to the arrangement shown in Figure 5.2 (B) where separate data sets with separate data organization are stored in separate locations but serve the same organization. In the example shown in Figure 5.2 (B) data related to hydrography, physical oceanography, and stock assessment are stored in different locations. A user may wish to acquire data from either or all of the locations and may do so through the network.

Figure 5.2 (C) shows a configuration consisting of systems containing identical copies of the same data sets in geographically different locations. This configuration is usually referred to as *replicated data*. Usually this case would apply when there is a need to access a relatively large data set and it would be more feasible to store redundant copies of the data than to transfer it between systems frequently. Sometimes only fragments of the data are replicated. This would be especially true for data sets that require infrequent updates. An example of this could be a topographic data set which is relatively static but is required for several applications in several locations within an organization.

Figure 5.2 (D) shows a *heterogeneous data* system configuration. Here independent computer systems are set up by different authorities for different applications. The data sets contained within the various authorities may be related to the same application but are established for entirely different purposes. In the example shown in (D) the university database could have been created for research purposes in marine biology; the government databases created for administration and regulation of the offshore mineral resources; the industry database may have been created to assist in the management of an aquaculture business. Each organization may wish to access some, if not all, of the data of another in order to effectively execute its mandate.

5.3.3 Centralization Versus Decentralization

The data processing industry has been using mainly centralized databases since the late 1960s. Traditionally, data processing was done on the mainframe computer located at the head office or main centre of operations of a particular agency. Since the early 1980s there has been an infiltration of cheaper and more versatile mini and microcomputers into the data processing field. As a result organizations are decentralizing their data processing and are distributing the data over several geographic locations. Most of the existing distributed databases consist of replicated databases (i.e. everyone gets a copy) as opposed to distribution of individual databases [Gretton-Watson, 1988]. One of the problems with this approach is the difficulty in ensuring consistency when there are updates to the data. Improved communications and data transfer systems will allow further decentralization of individual databases in the future and allow data processing to be placed at the operations site most directly impacted by the use of the data.

The introduction of distributed databases offers the data processing manager several new data processing options. The choices of which processing functions should be centralized or which should be decentralized; what data should be kept where; what sort of network configuration should be adopted; what standards in hardware and software should be established; what qualities should personnel possess at various locations?

5.3.4 Horizontal and Vertical Distribution

Horizontal and vertical distribution [Martin, 1981] refers to the order in which a distributed processing system performs the various processing functions. Horizontal distribution implies that all processors within a network are of equal status (Figure 5.2). Vertical distribution implies that there is a hierarchy of processors in the network (Figure 5.1). There will be occasions when it will be necessary to transfer the data contained in the database of one computer in the network to a second computer for processing. Table 5.2 shows some of the reasons for horizontal distribution.

Table 5.2 Some reasons for horizontal distribution.

1) Users wish to analyse the data themselves rather than (for various reasons) rely on the analysis performed by the data owner or custodian. 2) Users perform specialized processing operations on the data. 3) The owner or custodian is unwilling to analyse the data for other users. 4) Many users access one database.

Vertical distribution takes place when certain processing functions are carried out by machines at different levels in the hierarchy. An example of vertical distribution related to the marine user community might be that the results of data processed from the fish catch database and from the fish habitat database would be passed up to a management level machine for further processing to create information on which to establish harvesting quotas.

5.4 DATA TRANSFER NETWORKS

Data can be transferred from one point to another by various methods depending on its format and the transportation networks available. Data stored in conventional paper format such as charts and log sheets can be physically transported from one location to another. Data in electronic format can similarly be transported in tape or disk format. However, the communications networks may provide a faster and more convenient means of transporting electronic data. Many different combinations and configurations of computer hardware and software are available to network the multitude of existing marine databases scattered throughout the marine user community. The abundance of these different combinations and configurations, however, often makes it more difficult to exchange data rather than easier. Problems occur because of incompatibility of hardware, software, and data formats as discussed in Chapter 4.

5.4.1 Basic Network Functions

The basic function of a computer network is to allow machines having access to the network to communicate efficiently and reliably between the nodes comprising the network. There are several reasons for moving data between computer systems in a network. First, one machine in the network may not have the processing capabilities required to perform certain operations on the data, therefore it has to be passed to another machine. Second, data stored in one location is needed to support the operational functions of the same or another organization in different physical locations. The need for networking in the marine information environment is more closely aligned with the second reason.

5.4.2 Types of Networks

There are many different types of networks for transferring data depending on the needs of the user, the type of organization for which the network was designed, and the physical area over which the network operates. Computers are networked locally by LANs and are networked regionally and nationally/internationally by wide area networks (WANs). WANs often consist of a combination of two or more LANs linked by a bridging process. LANs are generally established to serve one organization using compatible hardware and software systems while wide area networks may consist of multiple organizations using incompatible equipment. For example, interconnected LANs each of which uses a different set of protocols.

LANs may have external connections but for practical purposes they are generally confined to use within a small geographic area (usually within a 1 km radius). The speed at which the data can be transmitted is a limiting factor for use of LANs over long distances. With the introduction of technology such as fibre optics speeds are increasing significantly. As speed increases so will distance [Allan, 1989]. The majority of applications associated with marine information networking will involve wide area, horizontal and vertical, private, and public networks since the databases are spread over a very large geographic area and throughout multiple organizations.

5.4.3 Network Speeds

The speed at which the data can be transmitted over the communications networks will be a factor in determining the usefulness of the network particularly when large data sets are to be transferred. Data is commonly transmitted across Canada at 9600 bits/s and 19 kilobits/s (kbits/s) via DATAPAC using X.25 packet switching architecture. In certain areas of the country network speeds of 56 kbits/s exist. At the same time there are still many online text retrieval services operating in Canada and other countries at only 1200 bits/s. However, recent and planned developments in the telecommunications field will have a significant impact on future network speeds as is shown in Table 5.3.

Table 5.3 Comparison of network speed versus telecommunication service type.
(After [Cavill et al., 1989])

SERVICE TYPE	TRANSMISSION SPEED		EXAMPLES OF DATA TYPES, FILE SIZE, AND TRANSMISSION TIME (Full screen, uncompressed encoding)			
	Speed Range	Example Speed	TEXT 8.5 x 11 page 240 Kbits	IMAGE low resolution 256 Kbits	IMAGE high resolution 1.2 Mbits	IMAGE satellite 34 Mbits
Public Service Telephone Nets	300 - 4800 bits/s	300 bits/s 4800 bits/s	13.3 min 50.0 sec	14.2 min 53.3 sec	1.1 hr 4.2 min	31.5 hr 2.0 hr
Dedicated Dial-up Net.	2400 bits/s - 48 Kbits/s	9600 bits/s	25.0 sec	26.7 sec	2.1 min	59 min
DATAPAC Dial-up x.25	300-2400 bits/s 2400 bits/s - 48 Kbits/s	1200 bits/s 48 Kbits/s	3.3 min 5.0 sec	3.6 min 5.3 sec	16.7 min 25.0 sec	7.9 hr 11.8 min
Integrated Services Digital Network	64 Kbits/s	64 Kbits/s	3.8 sec	4.0 sec	18.8 sec	8.9 min
Broadband Integrated Services Digital Network	1 - 155 Mbits/s	50 Mbits/s	< 0.1 sec	< 0.1 sec	< 0.1 sec	0.7 sec

5.5 THE FUTURE OF NETWORK ARCHITECTURE

There are basically two options available to users wishing to transfer data via networks from one location to another. They may use the existing public or private communications networks and pay a prescribed user fee, or they may build their own private networks. Since Canada already has an expansive array of telecommunications networks in place most users will no doubt use them. As Baser [1989] points out, the telecommunications industry in Canada is in a position to meet the network requirements of ICOIN. ICOIN is a concept that proposes the networking of geographically referenced databases relating to inland waters, the coastal zone, and the oceans. The existing telecommunications array consists of two national telecommunications microwave transmission networks, a domestic satellite system, and two public data networks. The rapid developments in microelectronics have made it possible to embed computers throughout these networks. Consequently, all parts of the networks can interact intelligently and the various networks can now *handle traffic that was previously the monopoly preserve of others* [Communications Canada, 1987].

5.5.1 Standards and Protocols in Telecommunications

The fact that Canada is moving to full digitization of the national communications networks is significant to the concept of networking marine information systems and databases. With the introduction of Integrated Services Digital Network (ISDN) full digital capabilities will exist. *"ISDN is a set of agreed-upon international standards for allowing public telephone networks to accommodate a wide range of voice, data, and, video services."* The first phase of ISDN is based on copper technology but it is the second phase, based on fibre optics technology, that will have the greatest impact on marine information networking. Optical fibre technology allows for broadband services making it possible to include text, graphics, and video transmission simultaneously [White, 1986]. Broadband ISDN (BISDN) will offer fast, highly reliable packet-switching capabilities thereby increasing data transmission speeds. This means that it will be possible to integrate traditional data processing, communications and exchange of graphics through different channels of the same network at the same time.

The existing data transfer networks are based on the Open Systems Interconnect (OSI) seven protocol layers [Communications Canada, 1987]. These protocol layers are shown in Table 5.4.

Table 5.4 Protocol layers of OSI.

1. Physical control.
2. Link control.
3. Network control.
4. Transport end-to-end.
5. Session control.
6. Presentation control.
7. Process control.

Each layer contains different functions and, when data transfer is taking place, communicates with its peer in another machine. Layers 1 to 3 provide the interface to a shared network. Layers 4 to 7 provide the end-to-end between the session software. At the session level the logical sequence of events conducted to communicate between two networked computers is analogous to that of two people communicating by telephone. A circuit is opened by dialing a number, a conversation is conducted if someone answers, and eventually the circuit is closed by hanging up the telephone. When computers communicate various levels of network protocols are engaged to make the contact (open the circuit), conduct the session (the conversation), and terminate the session (hang up the phone). This is where the similarities end. The processes that take place to conduct these phases of communication are vastly different. Therefore it would be erroneous to think that because an extensive telecommunications network is in place, the transfer of data between computers is trivial. Irven et al. [1988] suggests that even though information services are readily available and are very powerful, they still have limitations.

ISDN is designed according to Open System Interconnect (OSI) principles. OSI was developed in 1984 by the International Standards Organization (ISO) as a model for a computer architecture for defining standards for the networking of heterogeneous computer systems [Bown, 1989]. OSI is a collection of protocols consisting of seven layers, as mentioned earlier, for data communication. Davis [1986] gives a good description of OSI and its functions.

Map and Chart Data Interchange Format (MACDIF) is an example of a standard interchange format being developed cooperatively between the Ontario Ministry of Natural Resources, several Canadian Federal Government departments and the US National Oceans Services. The objective of the MACDIF project is to provide a comprehensive telecommunications oriented standard for the transfer of digital map and chart data. *"MACDIF was designed according to the principles of OSI and conforms to established practices and standards in the telecommunications, mapping, and charting industries" [Baser, 1989].* Although MACDIF has undergone successful "proof of concept" testing it has not yet been accepted by the ISO nor the general user community. Its acceptance or rejection by either group may rely as much on political considerations as on its technical merits.

5.6 COMPUTER SYSTEMS

An important component to consider is the computer systems that do the processing and the data manipulation within the distributed nodes of the networks. The end-to-end response time for transmitting data between nodes in a network will also be a function of the computing power operating the databases. There are many options available to the user when it comes to computers and peripheral equipment. The marine information user community will contain the whole range of computers including mainframes, minicomputers, and microcomputers and possibly even the super series in each model. Table 5.5 shows how the mainframe computer environment has evolved over the last few decades. To add to these developments, in the mid sixties the minicomputer was introduced and in the early eighties the microcomputer was introduced and has since expanded rapidly both in computing power and in use. With the exception of the first generation, the whole range of systems are likely to be encountered when attempting to network the various users. The processing speed, the disk access speed, and the input/output rate will vary significantly depending on the CPU and the hardware and software subsystem engaged.

The design of a network to respond to user request for information must consider the time the user is willing to wait for the information to appear on the monitor of the workstation. Irven et al. [1988] claims that *"...to browse electronic information effectively... it is essential that the end-to-end system, comprising the network, terminals, and applications software provide a total response time of about one-second or better during the interactive part of the session..."*. The introduction of truly distributed data processing capabilities will contribute to reducing the browse time. The user will be able to transfer only the portion of the file required for the particular application rather than transferring the entire file as is done in a network file system. Of course not all users will require the information in a "browse" mode. However, the network design must consider the "browser" since many users will enter the network in search of data with poorly defined information needs and will wish to scan the databases to see what they contain.

Table 5.5 Evolution of the mainframe computer environment.

Generation of Computer	Main Memory size	Predominant Software Innovations	Typical CPU Speeds	Era
First Generation	2 KB	•Machine language •Subroutines •Assemblers	10 KIPS*	1946-56
Second Generation	32 KB	•FORTRAN •ALGOL •COLBOL	200 KIPS	1957-63
Third Generation	2 MB	•Multiprogramming operating systems •Data management systems •Symbol manipulating languages	5 MIPS**	1964-81
Fourth Generation	8 MB	•Expert systems •ADA	30 MIPS	1982-90
Fifth Generation	??	•Knowledge base management systems	Expected to exceed 1 GIPS***	1991-??

* Kiloinstructions per second
** Megainstructions per second
*** Gigainstructions per second

In the case of WANs it should be pointed out that the time required by the computer to access and load the data onto the network is minimal compared to the speed at which the data can be currently transferred. Network speed becomes less of a concern with LANs since many types are extremely fast. Nevertheless, for large data sets and particularly for data sets containing graphics, end-to-end response times as stated previously could not be achieved with certain computer systems regardless of the network speed.

5.7 CONCLUSION

The technology associated with distributed data processing, distributed database management systems, and communications networking is improving at a rapid pace. The developments in computer hardware and software is making a major contribution toward increasing network speeds and functionality. Currently one of the greatest drawbacks to networking is the incompatibility of the various systems due mainly to the lack of standards in the industry. The standards issue is now being addressed across the communications and data processing fields. The approach being taken to the problem of lack of standards is to develop transfer and data conversion formats as opposed to attempting to standardize hardware, software or data formats. Examples of some of the data exchange formats currently being developed are ISDN, OSI, and MACDIF.

As a result of these developments the future of data transfer networks and distributed data processing looks very promising from the technological perspective. As was pointed out in Chapter 4 the impediments to networking caused by the institutional issues are also being recognized and are being addressed at high levels in the various organizations responsible for the management of marine information. For example, DFO hosted a Client Consultation workshop entitled "Managing for the Future of Canada's Oceans" in Ottawa, in June, 1989. At that workshop senior government officials were, among other management issues, briefed on the information management requirements for the department. The combination and coordination of the efforts of the various organizations working on the technological and the institutional issues will facilitate the design of a marine information system to serve the future needs of the marine community.

Chapter 6

INFRASTRUCTURE DESIGN FOR A MARINE INFORMATION NETWORK

The justification for computers and communications is ***end user service.*** *Processing, database, and datacomm must move closer to the end user. The systems which we design are for the end user. They must be simple and easy to use in the distributed environment, and they must be friendly.*

[Dimitris N. Chorafas, 1983]

6.1 INTRODUCTION

The participants of the ICOIN Forum held in Fredericton, N.B., in June 1989, unanimously agreed that it is important to the social and economic well being of Canada to build a marine information network [ICOIN Proceedings, 1989]. The benefits and challenges of building the network were discussed but no attempt was made to provide direction as to how to proceed with the development of the network. And with the exception of a couple of speakers presenting their view of what the ICOIN infrastructure should look like, there was little input into how the infrastructure should be designed to achieve such a task.

Before a marine information network can be implemented the infrastructure on which to build the network must be in place. The underlying structures, or the foundation on which a marine information network is built consist of both technology and process components. The technology components provide the access to the data in the network while the process components provide the means of access. The previous chapters have demonstrated examples of existing systems, identified the need for data sharing, and reviewed some of the technological and institutional issues associated with networking marine information systems. In this chapter the design of an infrastructure on which to build a marine information network will be presented.

6.2 THE NEED FOR THE INFRASTRUCTURE

As pointed out in Chapter 2 there are many diverse databases which contain marine information. The databases are diverse in terms of size, content, data models, hardware, software, and purpose. Most of the data processing currently being done uses traditional files, tapes and manual handling of transactions. These are gradually being replaced by modern database management systems using databases, disks, and automatic handling of transactions. Such a mixture of technology and philosophy poses a significant challenge to building a network that will not only allow ready access but also allow the user to obtain the information required in a directly usable format with the minimum interaction and delay.

The Chambers English Dictionary [1988] defines infrastructure as the *inner structure, or the structure of the components parts*. An ocean information infrastructure should consist of the collection systems, databases and networks necessary to provide an effective information service to the whole spectrum of users including governments, industries, educational institutions and other interests who make use of the ocean's resources. In order to build the infrastructure many topics must be considered. The key topics are *policy, finance, technology, organizational structure, education, and research and* *development* [RIM Group, 1988]

The development of an ocean information infrastructure will involve two distinctly different sets of components. There will be the physical or the technology components such as databases, networks, data collection systems, and data manipulation systems. Then there will be process components such as user needs definition, policy development, organization of systems, financing, and applications. No doubt there will be a strong correlation between these components and to change one may impact on one or several of the others simultaneously. For example, a policy decision to change data collection technology could impact in financing, education, the organizational structure, and maybe eliminate certain applications or add others. It may be necessary to purchase new equipment, hence, financing is required. It may be necessary to retrain existing personnel or reorganize the existing operational structure. New applications may arise because different or better data is collected. Similarly, technology may have an influence over policy. The available technology for data collection may dictate the policy on what data is collected and the format in which it is collected. Since there is no choice of technology and the data is required for a particular application then the policy is to use that technology.

An ocean information infrastructure would provide the means of accessing the information required to plan and manage the development of Canada's ocean resources. Users would have access to online, up-to-date data sets on which to base management decisions which require relatively quick response time. The information requirements of different users may be quite different . For example, industry and government have very different goals. The basic goal of industry is to increase productivity (profits) while the goals of government are to ensure sustainable development of the nations resources and to establish and maintain sovereignty. In order to design an appropriate information infrastructure the requirements of the users should first be determined. A decision must be made on what type of data should be collected and at what scale, methods, standards, intervals (spatial and temporal), etc. One way to analyze these needs is to view them within a framework.

The framework proposed in this thesis categorizes the users in the three major ocean sectors previously identified as fisheries, energy/mineral resources, and transportation. The major objectives of each sector are then identified and broken down into the information needs associated with obtaining each objective.

Table 6.1 forms a matrix which identifies the three main users of ocean information and their reasons for needing information. This table establishes a framework within which to view the common information needs of each user and identify the problems associated with satisfying those needs. Many of the cells in the matrix contain common elements. Bathymetry appears to be common to almost all applications of ocean information. However, not all applications will require bathymetric measurements to the same accuracy, standard, density, etc. In developing an ocean information infrastructure to meet universal needs this can cause a multiplicity of problems. For example, accurate bathymetry is not required by the aquaculture site operator whereas it is critical to the ship's navigator operating in the same general vicinity. If the bathymetric data are collected to meet the minimum requirements for aquaculture then it cannot meet the minimum requirements for the shipping industry. On the other hand, to meet the shipping requirements incurs extra expenses which contributes toward an extra cost to the aquaculture operator wishing to acquire the data. In order to fully develop the infrastructure these problems need to be solved.

Table 6.1 Three main ocean economic sectors and sample information requirements.

	FISHERY	ENERGY/MINERALS	TRANSPORTATION
PRODUCTIVITY	1 •location of stocks •improved technology (harvesting and processing) •ocean engineering	2 •sea state •extraction technology •ice forecasting •resource location •ocean engineering	3 •sea state •weather forecasting •ocean engineering
SAFETY	4 •weather forecasting •bathymetry •hazards •vessel traffic management •sea state •ice forecasting	5 •weather forecasting •bathymetry •hazards •vessel traffic management •sea state •ice forecasting	6 •weather forecasting •bathymetry •hazards •vessel traffic management •sea state •ice forecasting
ENVIRONMENTAL QUALITY	7 •oil spill monitoring •pollution detection	8 •oil spill monitoring •environmental impact	9 •oil spill monitoring
SOVEREIGNTY	10 •delineation of 200 mile limit •defence •policy	11 •delineation of 200 mile limit •defence •policy	12 •delineation of 200 mile limit •defence •policy

To look at the entire marine environment with a broad brush approach may be unwise. For example, the information requirements for the coastal zone may be different from those for the deep oceans. A higher frequency of bathymetric measurements may be needed for an offshore oil development site than would be needed for a fishing application on the same site. Maybe it is necessary to look at the ocean in several segments. These are issues to be addressed before the infrastructure can be built.

6.2.1 Technological Considerations

Technology plays a major role in the networking of marine information databases. There is technology associated with almost all aspects of the network from the data collection systems through to the product provided by the end user. Some of the necessary technology is already well developed and operational in other fields such as the telecommunications industry and the electronic data processing business. Much of the technology that has been developed for these industries will be needed to create the infrastructure and operate the marine information network.

6.2.2 Institutional Considerations

The term *institutional,* in the context of this writing, refers to the non-technical processes such as policy development and other organizational behaviour patterns that influence the management and use of marine information. Because of the large number of users and the extremely large volume of data involved the institutional issues associated with networking the data become very complex. Some of the decisions that have to be considered and made are: What will it cost? Who pays ? Who controls the databases? Who owns the data? What kind of networks are needed? What technology exists to meet the needs and what technology still needs to be developed? Who sets the standards and what standards should be adopted? Who will be responsible for updating and maintenance and at what frequency will the data be updated? Who decides what to collect, what scale, where, and when have to be considered and made.

Since the databases containing marine data are held by different levels of government as well as in the private sector, agreements on data sharing to allow ready access are likely to be even more difficult to achieve. In order to build the infrastructure on which to create a marine information network these issues must be first addressed and a method of resolution defined.

6.3 ZONES OF MARINE INFORMATION MANAGEMENT

To address the problem identified earlier of different users requiring data at different scales, resolution, and accuracy, it is proposed to divide the marine environment into three zones for information management purposes. Specific standards with respect to scale, temporal and spatial resolution, accuracy, etc. can then be applied to each zone independently. The following three zones, as shown in Figure 6.1 are proposed.

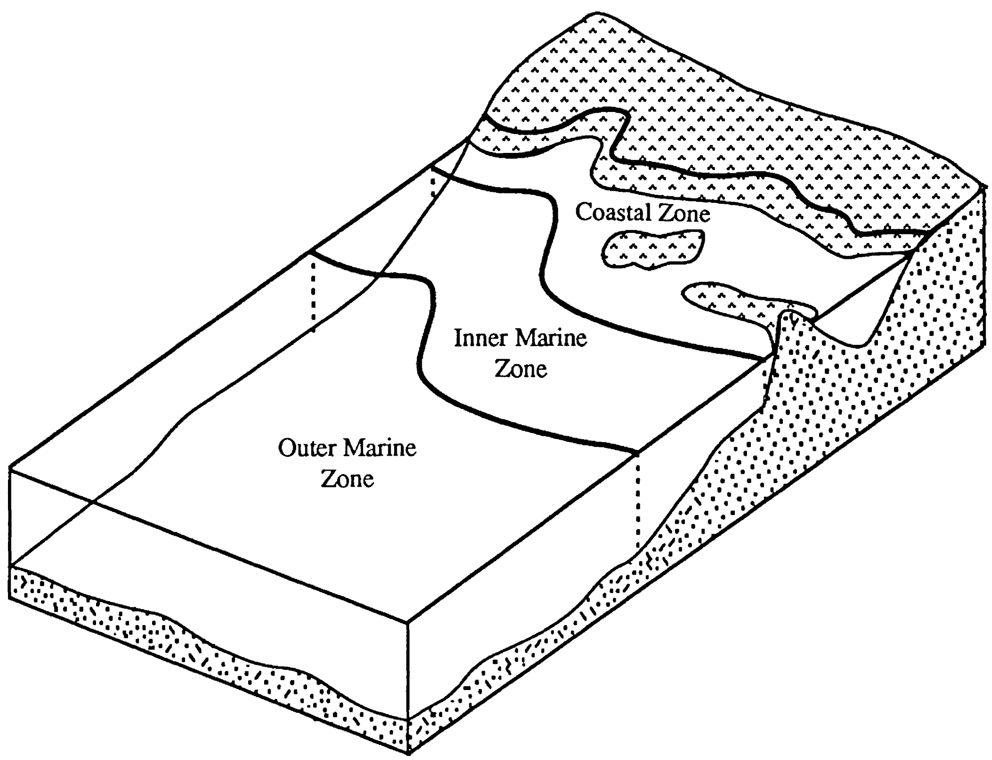

Figure 6.1
Recommended zones of marine information management.

6.3.1 The Coastal Zone

The proposed Coastal Zone is a zone which consists of a strip of the shore area extending 1 km inland from a line defined by the ordinary high water mark and extending seaward 3 nautical miles from the same line. Much of the activity taking place in this zone will be controlled by one of three levels of government. The land based activities such as residential and commercial site development, recreational development, building of access roads to waterfront facilities, provision of utility services, development of coastal land tenure policies, waste discharge, etc. will most likely be controlled by local or regional governments. Activities such as port and harbour development, aquaculture site development, recreational yachting, inshore fishing, etc, would be controlled by the federal or provincial governments. Up-to-date, reliable, and accurate information is important for the coordinated use of both the land and the water resources in this zone.

Since this zone is usually an area of intense use and changes are frequently occurring data collection will be required frequently to keep the databases up-to-date. Data resolution and accuracy will also need to be high in this zone. For example, bathymetric measurements should be relatively dense and accurate for areas where vessels are operating at the limits of safety with respect to water depth to vessel draft. The accuracy of positional data for navigational aids and hazards is also more critical when vessels are operating within restricted areas such as around docking facilities.

6.3.2 The Inner Marine Zone

The proposed Inner Marine Zone defines an area extending from the outer limits of the Coastal Zone to a line 12 nautical miles seaward which defines the outer limits of the territonal sea. This zone comes under the jurisdiction of the federal government. The main activities which occur in this zone include: shipping, inshore fishing, recreational boating, sand and gravel extraction, etc. Virtually no construction takes place in this zone.

A great deal of shipping activity takes place in the Inner Marine Zone and as a result it is a high risk area for environmental pollution from marine accidents. For example, many oil spills take place in this zone. Therefore, it is important to understand the currents and the effects of wind conditions in this zone. Since inshore fishing is a prominent activity in this zone a knowledge of the bottom type is important to the fishermen in order to minimize gear damage.

6.3.3 The Outer Marine Zone

The proposed Outer Marine Zone extends from the outer limits of the Inner Marine Zone to the outer limits of the Exclusive Economic Zone or to the edge of the Continental Shelf. Deep sea fishing, shipping, and offshore oil and gas exploration currently dominates this marine area. The major information requirements for this zone is related to deep sea fishing. Information about the physical, chemical, and biological oceanography is important to the management of the living resources in this zone. The information most critical to shipping in this zone would be sea state and ocean currents. Offshore oil and gas related interest would be in sea state and the geological and geophysical characteristics of the ocean floor.

6.4 INFRASTRUCTURE DESIGN

The proposed infrastructure to be put in place to support the development of a marine information network is designed to service the needs of the general marine information user community. The infrastructure must be built with the technological and institutional issues addressed earlier foremost in mind. The proposed infrastructure will consist of several components with each component consisting of technological and institutional elements as suggested in Section 6.2 and shown in Figure 6.2. Since the vast majority of marine data in Canada is collected and stored by the public sector the design of the infrastructure will be strongly influenced by the information requirements of government departments, particularly the federal government departments. Since the government provides the data to the private sector it is implicit that government requirements reflect private sector requirements.

6.4.1 Infrastructure Components

The main components of the marine information infrastructure are identified and described in the following section. According to Baser [1989] the infrastructure required to be the foundation for ICOIN consists of information providers, database producers, system operators, communication systems and networks, standards, and hardware and software products. Anderson [1989] states that "*... there are three principal characteristics common to all infrastructure - a common set of standards, an integrated network, and a design that*

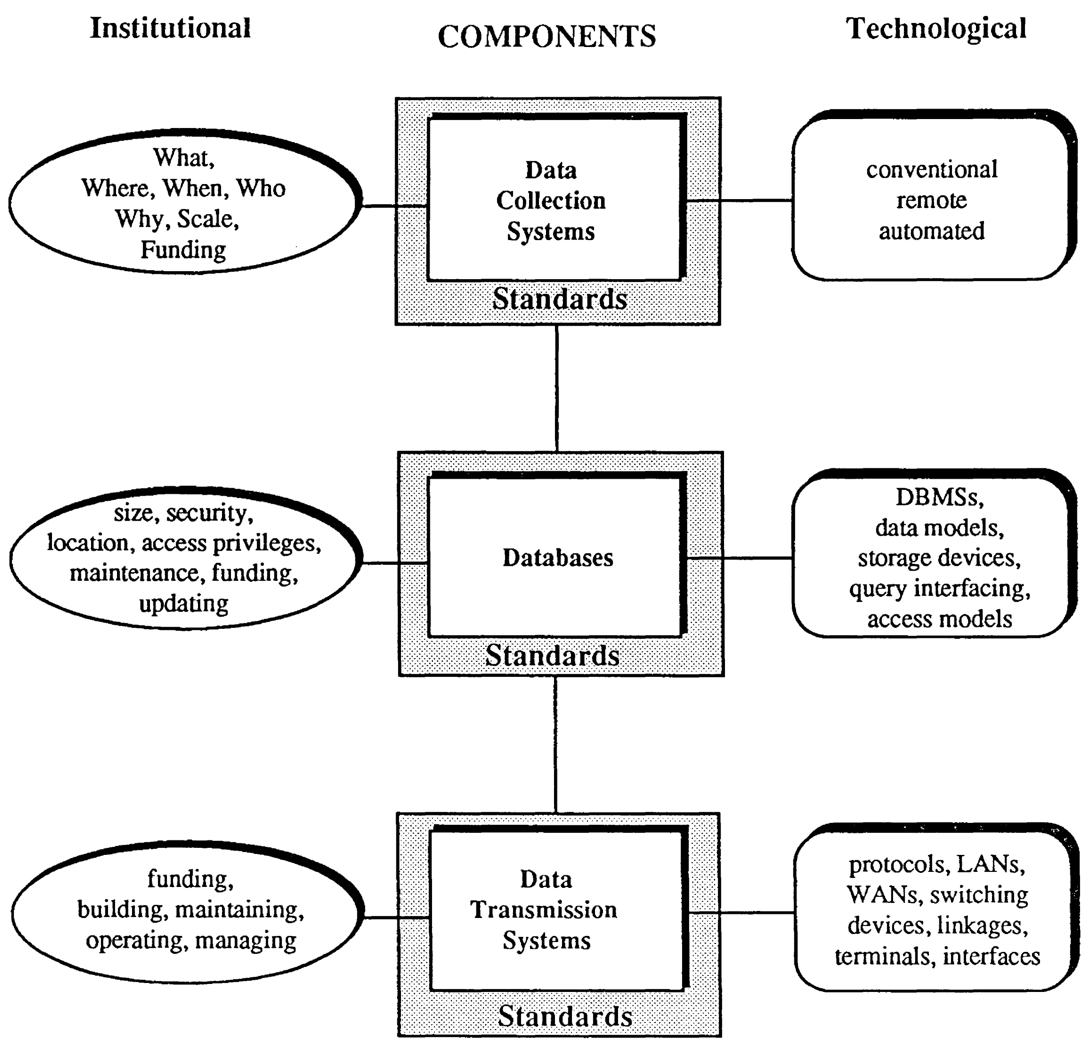

Figure 6.2
Infrastructure components for a marine information network.

facilitates simple third-party access". Baker [1989] suggests that *"the infrastructure consists of databases, networks, and user systems"*. All three authors identify certain common components as being essential to the infrastructure. The approach taken in this thesis is to consolidate all of these components and create an infrastructure to meet the marine information network requirements identified throughout this research. Subsequently the role of each component in the network, along with its technological and institutional elements, will be defined.

6.4.2 Data Collection Systems

The most basic ingredient for the provision of information is data. The data that is currently being collected is usually application specific. As a result other users requiring the same data for the same area may not, even if they are aware it is available, be able to use the data for various reasons such as scale, accuracy, incompatible format, etc. Consequently, it is important to consider the information needs of the user community in general when data collection missions are planned.

From the technological point of view there are several options available such as: (1) remote sensing tools, (2) conventional devices, and (3) automated systems. From the institutional point of view some of the questions to be answered are: (1) what technology will be used, (2) who will collect the data, (3) who will pay, (4) why the data is being collected, (5) where the data is to be collected, (6) when the data will be collected and when it should be updated, and (7) what data collection priorities are established.

6.4.3 Databases

Most of the existing databases have been built for specific users. The issue of data sharing was not a concern when the databases were designed. As a result the databases are not committed to any particular data structure. The question then arises whether data from one system can efficiently and accurately be transferred to another. The existing databases need to be examined as to their degree of compatibility, usefulness for other applications, and the ease of which the data can be transferred between systems.

Some of the institutional issues to be resolved with respect to databases include: (1) what data structure to use, (2) where the databases will reside, and (3) who provides funding. Some of the technological issues of main concern include: (1) database management systems, (2) storage devices, and data models.

6.4.4 Data Transmission Systems

In order to share data a means of transferring the data from one location to another must be established. The data may be physically transported in hard copy, tapes, or magnetic disks via conventional modes of transport such as air or surface transportation systems. However, the preferred means of data transfer by the marine information user community is electronically via telecommunications systems. The rationale for that preference need not be expounded upon here.

Some of the institutional issues to solve with respect to data transmission systems include:

(1) funding, (2) maintenance, (3) network speed, (4) network architecture, and (5) physical area of coverage. Some of the technological issues to be dealt with include: (1) Software and hardware for data transmission, (2) telecommunications technology, and (3) communications satellite technology.

6.4.5 System Operation and Maintenance

In order to ensure any system fulfils the functions for which it was created there must be an operating and maintenance component. This component consists of the personnel who perform the servicing of the equipment, install upgrades, plan improvements to the system, perform trouble shooting, etc.

Examples of the institutional issues to be dealt with include: (1) the qualifications of personnel, (2) education and training, (3) number of staff required to operate and maintain the system, and (4) funding. An example of a technological issue to be dealt with could be appropriate technology to provide, at least, a minimally acceptable level of performance.

6.4.6 Distribution and Presentation

Up to this point the data is collected, stored in databases, and transferred over the data transfer networks. However, the data must now be taken out off the transmission devices and displayed to the users. The design of the system must take into consideration the variety of presentation systems currently and plan to move toward an acceptable standard as soon as is feasible.

6.4.7 Standards

One of the major problems currently existing in the sharing of data is the lack of standards. To date little effort has been made to standardize databases, data collection systems and methods, data display devices, and data analysis methods. Fortunately, more success has been achieved in this area in the telecommunications industry. For example, digital data transfer models such as ISDN are being accepted as the standard throughout the industry. However, some authors suggest that even ISDN may never be fully standardized. As ISDN constantly expands and improves and new versions hit the market certain functions differ in minor ways with the previous versions [Lassers, 1989]. Stonebraker [1989] makes similar comments about such products as SQL and UNIX, where "*versions offered by various vendors also differ in minor ways*".

When introducing standards for the networking of marine information systems it would be prudent not to adopt a standard that would jeopardize future improvements to the system. The ideal standard to adopt would be one which would allow improved versions of the system to be introduced and still perform the same functions as the old version as well as adding new features. While standards are important one must be cautious not to restrict growth and improvements in a system by adopting standards based on technology alone. Another concern expressed about standards is that "waiting for the ultimate standard to be developed and implemented can lead to long periods of inactivity and delays in establishing a marine information network" [MacDonald, 1989].

From the technological point of view standards will be difficult to adopt and indeed may not be absolutely necessary. It appears that the best approach to solving the standards problem is to develop exchange formats to handle the transfer data with different structures and models between different data management systems. From the institutional point of view the problem of getting an agreement between the various players on how to resolve the standards issues is the major challenge.

6.5 FUNDING THE INFRASTRUCTURE

The question of central importance to the promoters of the marine information networking concept is: who will fund the development of the infrastructure on which to build the network? The telecommunications industry will be a major player since much of the data transmission requirements can be met by the existing telecommunications networks. Some specialized hardware and software, along with some extra physical linkages will need to be installed to meet the extra demand. However, compared to the cost of building telecommunications networks, these costs are quite small. As well, a significant portion of the system operations and maintenance facilities currently exist to support the telecommunications networks.

If, as predicted by many writers who write about the "Information Age", *the information networks is to the 21st century what the interstate highway network was to the 20th century and the rail system was to the 19th century* [Anderson, 1989], then government funding should be available. Governments funded the highway and the rail systems on the premise of the job creation opportunities and the advantages and economic benefits associated with the opening up of broader markets for manufactured goods. If information is viewed as a consumer good, as it is verified to be by the demand for information in all sectors of society, then arguments can be made that its distribution can produce similar benefits.

The various levels of government are currently creating the majority of the marine databases in-house and there is no indication that this trend will change in the immediate future. Therefore the cost of building the database component of the infrastructure is already being absorbed by government. Improved database management systems would be of benefit to the government departments holding the data, maybe even to the extent that any investment made in improving the DBMS could be offset by savings through improved operating efficiency.

The major effort required with respect to the database component is associated with the issues of standards for data collection and DBMS. Decisions will have to be made regarding the issues identified in these components of the infrastructure. That is a matter of the government appointing a body and giving it the authority to make these decisions. The cost associated with establishing a standard data collection process will add very little to funding of the infrastructure.

6.6 NETWORK DEVELOPMENT AND IMPLEMENTATION

It is proposed that a marine information network be implemented in three phases. The first phase in the implementation process would be to create a **Directory of Marine Data** (DMD) that would be accessible by all marine information users. The responsibility for creating, maintaining, and updating of the DMD could be placed with DFO. DFO would appoint a manager responsible for the DMD. Another alternative would be to turn the responsibility over to a private sector organization.

The DMD would consist of an inventory of the marine data existing in the various organizations involved in marine data acquisition across Canada. Government agencies and departments acquiring marine data would be required, through legislation if need be, to provide the necessary information about their data to the DMD manager. While the private sector would be strongly encouraged to participate it may not be practical to attempt to force them to do so. However, maybe certain incentives, such as low subscription rates, could be introduced to draw the private sector into the network.

Access to the DMD would be the first Level (Quick-look Stage) in searching through the network for marine data for a particular application. The data information shown in Table 6.2 would be contained in the DMD.

Table 6.2 **LEVEL I (Quick-look Stage)**

1. List of organizations holding marine data.
2. Categories of data held by each organization.
3. General geographic area of the data coverage
4. Location of the databases.
5. Policy on data sharing for respective databases.
   - who has access,
   - how much of the data is publicly available,
   - the cost to purchase the data,
6. How to access the data.

Updating of the DMD would be the responsibility of the DMD manager. The organizations acquiring the database would be charged with the responsibility of ensuring the DMD manager is aware of all changes to the databases such as corrections and updates.

It is necessary to implement a quick-look level since many users commence a data search with poorly defined data requirements. They may not know what they are looking for until they see something that looks interesting and looks relevant to their needs. The quick-look level would provide the user with information as to whether data exist for a specific geographic location, whether the user qualifies to access the data, whether it is feasible to purchase the data, and if so how the data can be acquired. Managers or professionals needing information on a specific application could also directly access the DMD and get a report on what data sources are available without going through an intermediary . They could then give specific direction to their staff as to what information they require thereby decreasing response time and improving performance.

The second phase of the network development would be to connect the various databases into a wide area network such that users can gain access to them. The Quick-look Stage provides the user with information on where to find marine data and how to access it. If any potential data sources are found during the query of the DMD the user could find out more about the data by entering Level II (Browsing Stage). At this level the user is in contact with the organization responsible for the database. Information about the specific data and the databases contained within that particular organization is available in this stage. The user would find such information as that shown in Table 6.3.

Table 6.3 **LEVEL II (Browsing Stage)**

1. Purpose of the data.
2. When the data was collected.
3. Precise (as precise as possible) geographic area of coverage.
4. Method of collection (including instrumentation used).
5. Scale(s) of the data.
6. Resolution (spatial and temporal).
7. Accuracy of the data.
8. Size of the database.
9. Storage medium (magnetic tape, disk drives, etc).
10. Type of data models used to create the databases.
11. Access keys.

The third phase of the network development is to introduce fully distributed processing capabilities. From Levels I and II the user has enough information to decide whether or not there is any data suitable for the application for which the search is being conducted. If so, the user can then proceed on to Level III (Detailed Follow-up Stage). At this stage the user can actually perform certain operations, such as those shown in Table 6.4, on the data depending on the complexity of the data and the level of sophistication of the network.

Table 6.4 **LEVEL III (Detailed Follow-up Stage)**

1. View the data if on-line or arrange to have a copy delivered.
2. Perform analysis through distributed processing if capabilities exist.
3. Transfer a copy of the data, or extract a portion of the data and transfer it, to the user's workstation.

In this scenario the data remains with the organization responsible for creating the databases. These organizations still maintain the databases and hold complete control as they have traditionally done. The only change in the role of the organizations is making information about their data available to the DMD. The phased approach to building the network allows for the creation and introduction of the DMD independent of overcoming the institutional issues associated with data sharing agreements between the various organizations. The marine user community could at least find out what data is existing and where it is located. Users could then make their own arrangements to get access to the data until the issues are resolved.

When the institutional issues are resolved the second phase can be implemented. Phase Two could then operate until the technological issues associated with the transfer of data between different databases, file systems, and information systems are resolved. At such time Phase Three could be implemented. Coincident with the implementation of Phase Three new tools, such as expert systems and artificial intelligence for interactive hierarchical searches and data manipulation capabilities, can be developed and introduced into the network. The ultimate situation is to have all marine databases on-line and accessible to the whole user community.

6.7 CONCLUSION

Development of the infrastructure to support a marine information network goes beyond the physical linkages such as the hardware and software, the telephone lines or satellite systems, and the terminals over which the data is transmitted. The standards by which these components must be designed and operated is also an important part of the infrastructure. But first of all the data must be collected and databases created to support the network.

When the infrastructure is being designed it is important to understand the purpose of the network that it will support. Table 6.5 shows the objectives of a marine information network.

Table 6.5 Objectives of a marine information network.

1. Reducing duplication of data collection and storage.
2. Providing the capability of sharing information within the marine community.
3. Encouraging the sharing of ideas with respect to marine resource management.
4. Creating opportunities to develop a Value Added industry.
5. Providing faster distribution and processing of marine data.

As the infrastructure is developed and the network is in place new benefits and opportunities not currently envisioned will arise.

Chapter 7

CONCLUSIONS AND RECOMMENDATIONS

If a Nation expects to be ignorant and free in a state of civilization, it expects what never was and never will be ... if we are to guard against ignorance and remain free, it is the responsibility of every ... [citizen]... to be informed.

[Thomas Jefferson, 1816]

7.1 CONCLUSIONS

Until the recent years little effort has been made by the marine data user community towards data sharing. Traditionally, each time data were required in support of a marine project the individual user undertook to collect the data specifically for that particular application. For various reasons outlined throughout this thesis that attitude has changed. In the last couple of years it has been recognized that a great deal of valuable marine data are existing in various formats and in various locations throughout Canada and that these data, if accessible, can meet many of the user's requirements. As a result some efforts are currently being made towards developing marine information management systems that would make it possible for users to access and share data needed to make informed decisions in support of the management of the marine environment.

In Chapter 2 it was shown that the trend has been toward individual, application specific data systems. Although the data contained in these systems can generally be made available to other users it is often difficult to access. If users other than those who collected the data are aware that it exists, it is often difficult to determine whether the data can meet their requirements. The data are often at varying scales, resolution, formats, etc. and are often subject to varying security regulations and ownership policies. These pieces of information about the data are seldom included hence leaving the user uncertain whether to rely on the data for a particular application or to collect a new set. The decision is generally to do the later, again independent of other user's requirements, thus further compounding the problem. The basic problem is that there is a lack of standards and policies in place, with respect to marine information management, to make data sharing possible.

An assessment of user requirements based on two selected applications determined that a method must be developed to place marine data where it is needed at the right time and in a format that is usable for a given application. The logical solution to this problem is to network the various databases and information systems. However, when the state-of-readiness for networking of the existing data is assessed it is evident that considerable effort in terms of financial resources and human resources will be required to prepare the data for input into a marine information network. Since most of the existing electronic data is in index sequential file systems instead of databases and a large volume of the data is in the form of hard copy, such as maps and log sheets, a significant amount of data conversion will be required [Richards, 1990].

The problems and issues associated with preparing the data and the users for data sharing through networking have been identified and discussed in this thesis. The main focus has been on defining the infrastructure requirements that are necessary and sufficient to build the network. A system design has been proposed and the following recommendations for implementation of a marine information network are presented.

7.2 RECOMMENDATIONS

Since the implementation of the recommendations impact on various sectors of the marine information user community in different ways they are broken down and presented in three categories: Organizational, Operational, and Research and Development.

7.2.1 Organizational Recommendations

1. A Steering Committee consisting of senior federal and provincial government officials and industry representatives, chaired by industry, should be appointed by the Minister of Fisheries and Oceans to:

   a. Identify and establish funding.
   b. Approve and direct the planning, design, and phased implementation of a marine information network.
   c. Establish project priorities.

2. Establish a Project Office with staff dedicated to the development of the network as a sole responsibility.

3. At a minimum the federal government's participation on the Steering Committee should consist of representatives from the departments of Fisheries and Oceans, Environment, Communications, National Defence, and Transport.

4. The Department of Fisheries and Oceans be assigned the responsibility of creating a Directory of Marine Data and keeping it updated since it is currently responsible for the coordination of ocean information activities.

7.2.2 Operational Recommendations

1. The implementation of the network should commence by building a Directory of Marine Data as defined in Chapter Six.

2. A data conversion program should be undertaken to convert the existing hardcopy data into electronic format in preparation for input into the proposed network as per priorities established by the Steering Committee.

3. Priority should be assigned to the networking of the databases which provide the data most frequently requested by the marine users.

4. The Canadian Hydrographic Service should be the source of data for electronic charts and provide the corrections and updates (patches), Notices to Mariners, and Notices to Shipping available on-line, via the existing satellite communications systems.

7.2.3 Research and Development Recommendations

1. Research projects should be undertaken to determine the capabilities of distributed database managements systems and distributed data processing for marine applications involving the processing of large graphical data sets.

2. Research should be undertaken towards determining and implementing standards in data models, database management systems, and data networking systems applicable to the marine environment.

3. Research should be carried out to develop tools such as expert systems and artificial intelligence for modelling and analysis for the extraction of information from marine data.

4. Research and Development identified in the previous three recommendations should be conducted in coordination with other R & D efforts currently ongoing in related fields.

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